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PhD Registration Number	1287580

Thesis title:

News, Current Account Imbalances and International Business Cycles

PhD in	ECONOMICS
Cycle	XXIII
Candidate's tutor	TOMMASO MONACELLI
Year of discussion	2013

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News, Current Account Imbalances and International Business Cycles

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Dissertation in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Economics (XXIII Cycle)

Thesis Committee:
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Preface

This dissertation has been written as part of my effort to complete the PhD programme in Economics at Bocconi University in Milan, Italy. It is comprised of three chapters.

The first two chapters focus on the the imbalances experienced inside the European Monetary Union before the Great Recession. Significant flows of capital and diverging current account balances have characterized the European Monetary Union member countries since its formation. Ireland, Portugal and Spain, from 1996 to 2007, accumulated current account deficit, experienced real exchange rate appreciation and grew slightly above trend. Current events in the euro area have shown that international imbalances have contributed to exacerbate the vulnerability of European Monetary Union (EMU) periphery. In the first two chapters, first from a theoretical perspective and then relying on empirical findings, I uncover the sources of the current account imbalances experienced in the euro area before the Great Recession. I also assess the role of *unanticipated vs. anticipated* shocks on international variable fluctuations.

In the first chapter I build a comprehensive framework that allows me to investigate which, among different plausible shocks, is an important source of the experienced imbalances inside the euro area periphery. I construct a small open economy DSGE 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. As current account can be thought of as a measure of trade over time I focus on the role of anticipated shocks as important drivers of the flows of capital and goods across the European Monetary Union. By relying on three different specifications of the model and letting the calibration vary in different ways I conclude that theoretically, anticipated as well as unanticipated productivity shocks, whether in the traded or in the non-traded sector, cannot be the relevant sources of the current account deficits experienced inside the EMU. The reason is the inability of productivity shocks to generate the experienced co-movement between the current account, the real exchange rate and the output growth.

In the second chapter of my thesis I want to assess, with Bayesian estimation, the contribution of *anticipated vs. unanticipated* shocks in the accumulation of the current account imbalances experienced inside the euro area periphery before the Great Recession. I estimate two different specifications of the small open economy dynamic stochastic general equilibrium model presented in the previous chapter, using data for Ireland, Portugal and Spain (IPS). I determine the values of the crucial parameters: the trade elasticity, the elasticity between tradable and non tradable goods and the persistency of shocks. Three are the main results. First, anticipated productivity shocks, whether in the traded or in the non-traded sector, cannot be the relevant sources of the experienced imbalances. Second, anticipated international yield spread shocks are the main drivers of the euro area periphery imbalances: analyzing impulse-response functions and simulating the model, I show that anticipated yield spread shocks account for the majority of the experienced imbalances. Third, anticipated shocks are responsible for an important fraction of international variable fluctuations: more than four fifth of the current account movements are due to long-term anticipated shocks.

The third chapter looks at the role of anticipated shocks for international real business cycle co-movements. Starting from a two-country, two-good real business cycle model with complete financial markets, I study the role of anticipated shocks in the international real business cycles. The increased synchronization of the United States and the European Union business cycles with the rest of the world and the experienced increase in the international financial market integration motivates the search for a solution of the IRBC puzzles that does not rely on the incompleteness of financial markets. Anticipated productivity shocks, in a standard IRBC model, featuring weak short-run wealth effects on the labor supply and investment adjustment costs, match the observed cross-country correlation of output, consumption, investment and hours worked. I conclude that anticipated shocks are an important source of international synchronization in a world in which financial markets are becoming more and more integrated.

Acknowledgments

I would like to express my gratitude to my advisor Prof. Tommaso Monacelli and my thesis committee Prof. Luca Sala and Prof. Paolo Manasse.

In addition, I would like to thank Gerry Abdesaken, Alberto Alesina, Marco Arnone, Sebastian Barnes, Marianna Battaglia, Andrea Ciani, Simone Emiliozzi, Gianluca Flego, Gunes Gokmen, Marco Lossani, Annaig Morin, Alberto Osnago, Fabrizio Perri, Giorgio Primiceri, Artur Radziwill for their comments and support. Thanks are due to the Organization for Cooperation and Development for their hospitality.

Contents

Chapter 1

The European Monetary Union and Imbalances. The Theory

Current events in the Euro Area have shown that international imbalances have contributed to exacerbate the vulnerability of European Monetary Union (EMU) periphery. We want, within a theoretical framework, to uncover the sources of the current account imbalances experienced in the euro area periphery before the Great Recession. We construct a small open economy DSGE 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. This creates a comprehensive framework that allows us to investigate which, between different plausible shocks, is an important source of the experienced imbalances. Focusing only on the dynamics of the current account can be misleading: targeting the co-movement between current account, real exchange rate and output growth allows to avoid mis-interpretations of similar impulse-response generated by very different shocks. We compare the results within three different specifications of the model.

1.1 Introduction

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

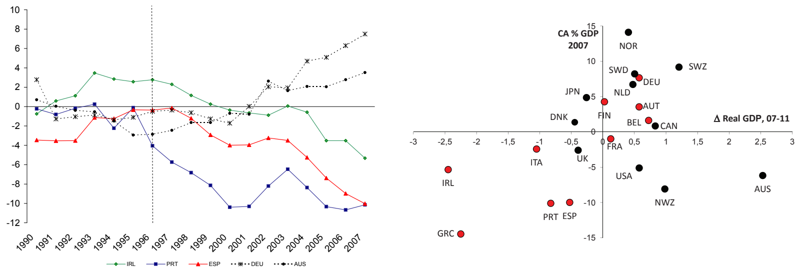
Current events in the euro area have shown that international imbalances have contributed to exacerbate the vulnerability of European Monetary Union (EMU) periphery. Therefore it would be important to understand and try to explain the causes of these current account imbalances in the euro area. The aim of this paper is to construct a comprehensive theoretical framework that allows to uncover the sources of the current account imbalances experienced in the euro area periphery before the Great Recession and permits to understand the role of unanticipated vs. anticipated shocks on international variable fluctuations.

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 and Austria, persistently increased the surpluses (figure 1.1(a)). The Great Recession revealed that the euro area countries that accumulated negative current account balances were those that suffered more from the crisis (figure 1.1(b)). Hence, it is important to understand the sources of those imbalances.

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

[2] From now on we will focus on Ireland, Portugal and Spain. We discard Greece from the analysis because the data for the period analyzed are unreliable.

Euro Area Current Account



(a) Current Account Dynamics (b) ΔGDP 2007-11 Vs. 2007 Current Account Position

Figure 1.1: (a) Euro Area current account from 1990 to 2007 for Austria, Germany, Ireland, Portugal and Spain; (b) Average real GDP growth between 2007 and 2011 against the current account position in 2007. Red dots are countries members of the European Monetary Union. Source: Eurostat

Focusing only on current account movements can be mis-leading. From 1996 to the Great Recession, in addition to persistent deficits in the current account, Ireland, Portugal and Spain (henceforth, IPS) experienced growth in output and real exchange rate appreciation. Figure 1.2 shows the co-movement of those three variables for the weighted average of Ireland, Portugal and Spain.[3] Understanding the sources of the experienced current account imbalances cannot be done without considering the movements of the real exchange rate and output growth. Therefore, among plausible drivers of current account imbalances, we search for those that can generate the experienced co-movement of current account, real exchange rate and output growth.

Current account can be thought of as a measure of trade over time and therefore expectations are crucial drivers of international flows of capitals and goods. Investigating plausible sources of current account imbalances cannot be abstracted from studying the role of

[3] Annual HICP relative household consumption expenditure shares in the euro area are used as weights.

Ireland, Portugal and Spain

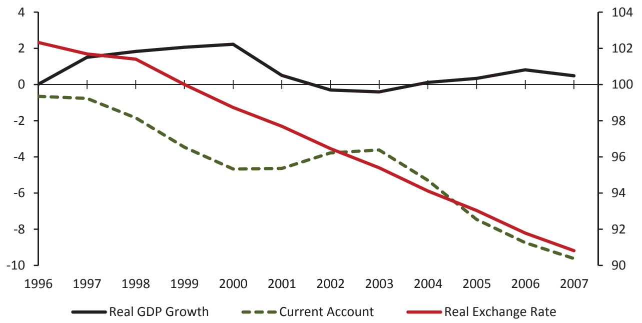


Figure 1.2: Real exchange rate, current account (percentage of GDP) and detrended output growth for the weighted average of Ireland, Portugal and Spain. Annual HICP (Harmonized Index of Consumption Prices) relative household consumption expenditure shares in the euro area are used as weights. Output growth is detrended in a model consistent way. Source: Eurostat.

anticipated shocks.

We lay out a two-sector, tradable and non tradable, New Keynesian DSGE small open economy model[4] in a monetary union. We combine different features of open economy general equilibrium models: 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. For the baseline model we present two different specifications characterized by two different choices of the utility of agents. We analyze both a separable and a non-separable preference specification.

Unanticipated, one-year anticipated and long term anticipated (10-quarters) components are introduced for each shock. The impor-

[4]Matheson (2010) shows that a small open economy model with a non tradable good sector fits the data better than the one-sector model. Our 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 (2010).

tance of productivity[5], preference, investment, labor supply, monetary policy and yield spread shocks as sources of uncertainty is analyzed using impulse-response functions, understanding which shock can reproduce the experienced co-movement of current account, real exchange rate and output growth.

To have a complete understanding of the role of anticipated shocks on international variable fluctuations and to make sure that the results are not a consequence of the choice of the informational structure, we study two different frameworks: first, we assume that shocks are anticipated with no uncertainty regarding the persistency and the timing of the shocks; second, we construct a model in which agents have imperfect information on the realized shocks. They use old and new information available to form the best possible estimation of the realization of the shock.

Differently from a growing literature, we focus on international imbalances within the European Monetary Union and not on global imbalances. Ireland, Portugal and Spain were not the only countries accumulating current account deficits starting in the mid nineties: the United States, New Zealand and Australia accumulated persistent inflows of capitals before the Great Recession. However, figure 1.1(b) shows that the fact that countries that had negative current account balances were those that suffered more from the crisis seems to be true only for the euro area periphery. Therefore we focus on the sources, and possibly the peculiarities, of the EMU current account imbalances.

The present paper is related to Hoffmann, Krause & Laubach (2011), henceforth HKL, who find that imperfectly observed changes in productivity can explain the build-up of the United States im-

[5]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.

balances started in the mid-1990s. However, unlike HKL, we claim that it is important to consider the co-movement of the current account with the real exchange rate and the output growth. Relative prices, as the terms of trade and the real exchange rate, are crucial variables for the dynamics of international flows. Focusing on the co-movement of the current account and the real exchange rate allows to avoid mis-interpretations of the responses of the current account to very different shocks.

The paper is organized as follows. Section 1.2 describes the baseline model with separable utility function while section 1.3 illustrates the set-up of the model when we introduce non-separable preferences. We then present, in section 1.4, the framework in which agents have imperfect information and cannot perfectly distinguish the shocks that hit the economy. Section 1.5 shows the impulse-response analysis for all the three specifications of the model analyzed focusing on the important role played by some parameters. Section 1.6 concludes.

1.2 The Baseline Model

We build a two-sector New Keynesian Dynamic Stochastic General Equilibrium (DSGE) small open economy model. Domestic economy is part of a monetary union with a foreign economy which, for analytical simplicity, represents all the rest of the union (henceforth RoEMU).

The domestic representative household consumes, saves or borrows through domestic and foreign internationally traded bonds, supplies labor and decides the level of the capital to be used in production. In the baseline model we allow for a standard utility function separable in consumption and hours worked. The capital depreciates and investments are costly. The model features variable capital utilization and adjustment cost to investment in order to generate aggregate and sectoral co-movement in presence of anticipated shocks.[6] 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.

Within each country there are two sectors: one producing tradable goods and the other producing non tradable goods. 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 the considered 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.[7] The nominal exchange rate is fixed, given the participation to a monetary union, and becomes a key

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

[7] Notice that there is no government in the model and the reason is simple. Between 1996 and 2007 government deficit and government debt over GDP of the weighted average of Ireland, Portugal and Spain were decreasing. Government debt to GDP went from 66.39% in 1996 to 39.49% at the end of 2007. Government deficit in 1996 was almost 5% but, with a constant decrease, it became a surplus in 2007 of 1.08%. The introduction of government spending in the model would decrease the accumulation of current account deficit. Therefore, to keep the model as tractable as possible, we do not include the government sector.

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 (X^*) will characterize foreign variables, an overscript tilde ($\widetilde{X}$) will indicate detrended variables, lower case letters (x) will characterize natural logarithm and overscript hat ($\widehat{X}$) will define deviations from the steady state.

1.2.1 Domestic Household

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

$$E_t \sum_{t=0}^{\infty} \chi_{t-1} \zeta_t U(C_t, L_t), \tag{1.1}$$

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:

$$\log \zeta_t = \rho_\zeta \log \zeta_{t-1} + u_t^\zeta, \qquad \text{where} \qquad u_t^\zeta \sim N(0,1). \tag{1.2}$$

χ_t denotes 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, $\widehat{C_t}$:[8]

$$\chi_t = \beta_t \chi_{t-1} \qquad \text{where} \qquad \beta_t \equiv \frac{1}{1+\psi^{\beta}(\log \widetilde{C}_t - \chi^{\beta})}. \tag{1.3}$$

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:[9]

$$U(C_t, L_t) = \left\{ log(C_t - hC_{t-1}) - \epsilon_t^L \psi^L \frac{L_t^{1+\nu}}{1+\nu} \right\}, \tag{1.4}$$

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

$$\log \epsilon_t^L = \rho_{\epsilon^L} \log \epsilon_{t-1}^L + u_t^L, \qquad \text{where} \quad u_t^L \sim N(0,1). \tag{1.5}$$

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 :

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

[8] 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.

[9] In section 1.3 we present 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.

$\eta > 0$ 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.[10] Following Faia & Monacelli (2008) we also allow for a symmetric home bias, with respect to the RoEMU, in the share of home produced tradable goods.

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

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

$$C_{h,t} \equiv \left[\left(\frac{1}{n} \right)^{\frac{1}{\phi}} \int_0^n C_{h,t}(i)^{\frac{\phi-1}{\phi}} di \right]^{\frac{\phi}{\phi-1}} \text{ and } C_{N,t} \equiv \left(\int_0^1 C_{N,t}(i)^{\frac{\theta-1}{\theta}} di \right)^{\frac{\theta}{\theta-1}}$$

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 goods (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 1.8.1 we present the optimal allocation bundles in details.

The representative household maximizes his/her utility function subject to the following budget constraint:

$$C_t + \frac{B_t}{P_t} - \frac{A_t}{P_t} + I_t \leq W_t L_t + R_{t-1}^B \frac{B_{t-1}}{P_t} - R_{t-1} \frac{A_{t-1}}{P_t} + \tag{1.6}$$
$$+ \left(R_t^k u_t - \Psi(u_t) \right) K_{t-1}^p + \int_0^1 \Gamma_{N,t}(i) + \int_0^1 \Gamma_{h,t}(i),$$

[10] 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 this framework.

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 firms in both the tradable and non tradable sectors.[11] 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^B_{t-1} and R_{t-1}.

The representative household owns physical capital k^p_t which accumulates according to

$$K^p_t = (1-\delta)K^p_{t-1} + \epsilon^I_t \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] I_t. \tag{1.7}$$

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^i_t is an investment specific shock that evolves according to $\log \epsilon^I_t = \rho_{\epsilon^I} \log \epsilon^I_{t-1} + u^{\epsilon^I}_t$.

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^k_t:

$$K_t = u_t K^p_{t-1}. \tag{1.8}$$

$\Psi(u_t)$ in equation (1.7) 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 $\{C_t, L_t, B_t, A_t, u_t, K^p_t, I_t\}^\infty_{t=0}$ taking as given the set of processes $\{P_t, W_t, R^k_t, R_t, R^B_t\}^\infty_{t=0}$ and the initial wealth B_0 and A_0, to maximize equation (1.1) subject to (1.4),(1.7),(1.7) and (1.3).

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

The first order necessary conditions of the maximization problem are:

$$\zeta_t \frac{1}{C_t - hC_{t-1}} - h\beta_t \zeta_{t+1} \frac{1}{C_{t+1} - hC_t} = \lambda_t \tag{1.9}$$

$$\lambda_t = \beta_t E_t \left\{ \lambda_{t+1} \frac{R_t^B}{\Pi_{N,t+1}} \frac{m_t}{m_{t+1}} \right\} \tag{1.10}$$

$$\lambda_t = \beta_t E_t \left\{ \lambda_{t+1} \frac{R_t}{\Pi_{N,t+1} \frac{m_t}{m_{t+1}}} \right\} \tag{1.11}$$

$$r_t^k = \Psi'(u_t) \tag{1.12}$$

$$\begin{aligned} 1 = q_t \epsilon_t i \left[1 - S\left(\frac{I_t}{I_{t-1}}\right) - S'\left(\frac{I_t}{I_{t-1}}\right) \frac{I_t}{I_{t-1}} \right] + \\ + \beta_t E_t \left\{ q_{t+1} \epsilon_{t+1}^i \frac{\lambda_{t+1}}{\lambda_t} S'\left(\frac{I_{t+1}}{I_t}\right) \frac{I_{t+1}^2}{I_t^2} \right\} \end{aligned} \tag{1.13}$$

$$q_t = \beta_t E_t \left[\frac{\lambda_{t+1}}{\lambda_t} [r_{t+1}^k u_{t+1} - \Psi(u_{t+1}) + q_{t+1}(1-\delta)] \right] \tag{1.14}$$

$$\zeta_t \epsilon_t^L L_t^\nu = \lambda_t W_t \tag{1.15}$$

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.

1.2.2 Firms

From this section onwards, to lighten the notation, we introduce an indicator $j = \{N, h\}$ to denote both the tradable and the non tradable sectors.

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 stochastic trend for the overall economy. Production is carried out with the use of both capital, K_t, and working hours L_t:

$$Y_{j,t} = A_{j,t} K_{j,t}^{\alpha} \left[X_t L_{j,t} \right]^{1-\alpha}, \tag{1.16}$$

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

$$A_{N,t} = (1+g^N)^t \widetilde{A}_{N,t}, \text{ where} \tag{1.17}$$

$$log(\widetilde{A}_{N,t}) = \rho_{A_N} log(\widetilde{A}_{N,t-1}) + u_t^{AN} + u_t^A; \tag{1.18}$$

$$A_{h,t} = (1+g^T)^t \widetilde{A}_{h,t}, \text{ where} \tag{1.19}$$

$$log(\widetilde{A}_{h,t}) = \rho_{A_h} log(\widetilde{A}_{h,t-1}) + u_t^{Ah} + u_t^A. \tag{1.20}$$

The labor-augmenting technology follows:

$$X_t = (1+x)^t \widetilde{X_t}, \qquad \text{where} \qquad \widetilde{X_t} = u_t^X. \tag{1.21}$$

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 a model consistent based method to detrend the data when we proceed with the estimation.

Firms can costly change prices and that implies a sluggish response of those 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:

$$\frac{\psi}{2}\left(\frac{P_{j,t}(i)}{\overline{\Pi}^j P_{j,t-1}(i)}-1\right)^2 P_{j,t}Y_{j,t}, \tag{1.22}$$

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.[12]

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 (1.16).

The optimality condition gives us

$$k_{j,t} = \frac{\alpha}{1-\alpha}\frac{W_t}{R_t^k}L_{j,t} \tag{1.23}$$

and the real marginal cost function

$$MC_{j,t} = \left(\frac{1}{1-\alpha}\right)^{1-\alpha}\left(\frac{1}{\alpha}\right)^{\alpha}\frac{W_t^{1-\alpha}R_t^{k\ \alpha}}{A_{j,t}X_t^{1-\alpha}}. \tag{1.24}$$

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

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

[12] The results do not change if we use instead Calvo style price stickiness. For simplicity we present here just the Rotemberg adjustment mechanism. We use a modified version of the general formulation, presented by Ireland (2007), that allows us to avoid steady state effects of positive inflation rate.

subject to (1.16) and the total demand for the i tradable and non tradable good:

$$Y_{j,t}(i) \leq \left(\frac{P_{j,t}(i)}{P_{j,t}}\right)^{-\theta} Y_{j,t}. \tag{1.25}$$

Assuming a symmetric equilibrium, in which each domestic producer sets equal prices optimally and produces the same level of output, the resulting equations are:

$$\frac{\Pi_{N,t}}{\Pi^N}\left(\frac{\Pi_{N,t}}{\Pi^N}-1\right) = E_t\left\{\beta_t \frac{\lambda_{t+1}}{\lambda_t}\frac{m(J_t)}{m(J_{t+1})}\frac{Y_{N,t+1}}{Y_{N,t}}\left(\frac{\Pi_{N,t+1}}{\Pi^N}-1\right)\frac{\Pi_{N,t+1}}{\Pi^N}\right\}+$$
$$+\frac{\theta}{\psi}MC_{N,t}m(J_t)-\frac{\theta-1}{\psi} \tag{1.26}$$
$$\frac{\Pi_{h,t}}{\overline{\Pi}^h}\left(\frac{\Pi_{h,t}}{\overline{\Pi}^h}-1\right) = E_t\left\{\beta_t \frac{\lambda_{t+1}Y_{h,t+1}}{\lambda_t Y_{h,t}}\frac{m(J_t)g(S_t)J_{t+1}}{m(J_{t+1})g(S_{t+1})J_t}\left(\frac{\Pi_{h,t+1}}{\overline{\Pi}^h}-1\right)\frac{\Pi_{h,t+1}}{\overline{\Pi}^N}\right\}+$$
$$+\frac{\phi}{\psi}\frac{MC_{h,t}m(J_t)g_t}{J_t}-\frac{\phi-1}{\psi} \tag{1.27}$$

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

1.2.3 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 two aims 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:

$$\frac{P_{T,t}}{P_{h,t}} = g(S_t) = [\gamma_{h,t} + \gamma_{f,t}S_t^{1-\epsilon}]^{\frac{1}{1-\epsilon}}, \qquad \text{with} \quad \frac{\delta g(S_t)}{\delta S_t} > 0. \tag{1.28}$$

$J_t \equiv \frac{P_{T,t}}{P_{N,t}}$ is the relative price of tradable over non tradable goods.

The ratio of the CPI index to the price of non tradables can then be written as:

$$\frac{P_t}{P_{N,t}} = m(J_t) = [\gamma_{T,t} J_t^{1-\eta} + \gamma_{N,t}]^{\frac{1}{1-\eta}}, \qquad \text{with} \quad \frac{\delta m(J_t)}{\delta J_t} > 0. \tag{1.29}$$

The nominal exchange rate NeR is defined as the price of foreign currency in terms of home currency.[13] Assuming that the small open economy is part of a Monetary Union, the nominal exchange rate with the rest of the monetary union is fixed. For simplicity we set $NeR = 1$. We assume that the law of one price holds $P_{f,t}(i) = NeR * P^*_{f,t}(i) = P^*_{f,t}(i)\ \forall i \in [0, 1]$. However notice that the Purchasing Power Parity (PPP) will not be satisfied given the presence of home bias in consumption.

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

$$Q_t = \frac{S_t}{g(S_t)} \frac{J_t}{m(J_t)} \frac{P_t^*}{P_{f,t}}, \qquad \text{with} \quad \frac{\delta Q_t}{\delta S_t} > 0 \ \ \frac{\delta Q_t}{\delta J_t} > 0. \tag{1.30}$$

It is important to notice that as a consequence the 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.[14]

[13] An increase of Ner 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.

[14] If we were in a model with perfect financial and insurance markets 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 show 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

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

$$E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \frac{R_t^B}{\pi_{t+1}} \right\} = E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \frac{R_t}{\pi_{t+1}} \right\}. \tag{1.31}$$

To solve the model we rely on a first order log-linear approximation around the steady state that implies that equation (1.31) becomes $\widehat{r_t^B} = \widehat{r_t}$. We are aware that by proceeding in this way we are not considering the nonlinearities of marginal utilities and prices. Therefore, following a standard practice in new open economy macroeconomics models, we insert an exogenous yield spread term to account for nonlinearities transforming the previous equation in the following equilibrium condition:

$$\widehat{r_t^B} = \widehat{r_t} + \widehat{Sp}_t, \tag{1.32}$$

where $\widehat{Sp}_t = \rho_{Sp}\widehat{Sp}_{t-1} + u_t^{Sp}$.

Using the budget constraint we can write the balance of payment condition (as share of mean level of output, Y) as:

$$NX_t + \frac{R_{t-1}^B B_{t-1}}{YP_t} - \frac{R_{t-1}A_{t-1}}{YP_t} - \frac{B_t - A_t}{YP_t} = 0, \tag{1.33}$$

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

$$NX_t = \frac{J_t}{g(S_t)m(J_t)} \frac{(Y_{h,t} - C_{h,t} - S_t C_{f,t})}{Y}. \tag{1.34}$$

complete overview of the literature, from the work of Cole & Obstfeld (1991) to most recent models.

We finally define the current account as the net change in real bond holding scaled by the mean level of output and the real GDP as the weighted sum, with relative prices as weights, of tradable and nontradable production:

$$CA_t = \frac{(B_t - A_t)}{P_t Y} - \frac{(B_{t-1} - A_{t-1})}{P_t Y} \quad \text{and} \tag{1.35}$$

$$Y_t = \frac{P_{h,t}}{P_t} Y_{h,t} + \frac{P_{N,t}}{P_t} Y_{N,t} + I_t + \Psi_{u_t} k^p_{t-1}. \tag{1.36}$$

1.2.4 Equilibrium in a Small Open Economy

In equilibrium we will have that firms meet the demand at selected prices clearing the good markets:

$$Y_{N,t} = C_{N,t} + \frac{\psi}{2}(\frac{\pi_{N,t}}{\overline{\pi}_N} - 1)^2 Y_{N,t}, \tag{1.37}$$

$$Y_{h,t} = C_{h,t} + C^*_{h,t} + \frac{\psi}{2}(\frac{\pi_{h,t}}{\overline{\pi}_h} - 1)^2 Y_{h,t}; \tag{1.38}$$

Also the labor and the capital markets clear, implying:

$$L_t = L_{N,t} + L_{h,t}, \tag{1.39}$$

$$K_t = K_{N,t} + K_{h,t}. \tag{1.40}$$

We finally introduce the monetary policy. Knowing that the small open economy is part of the European Monetary Union, we assume that the European Central Bank (ECB) is in charge of the monetary policy. We assume that the ECB, interested in maintaining the price stability, follows a simple Taylor rule targeting the union price index:

$$R_t = R^{\rho_r}_{t-1} \left(\frac{\Pi^{EMU}_t}{\Pi^{EMU}} \right)^{(1-\rho_r)\rho_\pi}, \tag{1.41}$$

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

1.2.5 Detrending Equilibrium Conditions

Due to the trends introduced in the model, the system of equilibrium conditions is non stationary. The deterministic trends in the sector specific productivities and the stochastic trend in the labor-augmenting technology generate variables that grow as time elapses. To be able to use standard solution techniques, we first need to detrend the model.

Focusing on those variables that grow in steady state we divide them by their specific growth rate generating a new stationary variable, denoted with a tilde, ex: $\widetilde{Y}$. For instance, the production in the two sectors, $Y_{N,t}$ and $Y_{H,t}$, can be made stationary as follows:

$$\widetilde{Y}_{N,t} = \frac{Y_{N,t}}{X_t(1+g^N)^t} = \widetilde{A}_{N,t} Z_t^{-\alpha} \widetilde{K}_{N,t}^{\alpha} L_{N,t}^{1-\alpha} \tag{1.42}$$

and

$$\widetilde{Y}_{h,t} = \frac{Y_{h,t}}{X_t(1+g^h)^t} = \widetilde{A}_{h,t} Z_t^{-\alpha} \widetilde{K}_{h,t}^{\alpha} L_{h,t}^{1-\alpha} \tag{1.43}$$

where $Z_t = \frac{X_t}{X_{t-1}}$ denotes the growth rate of the real aggregate variables, $\widetilde{K}_{j,t} = \frac{K_{j,t}}{X_{t-1}}$ denotes detrended capital and $\widetilde{A}_{j,t}$ are defined by equations 1.18 and 1.20. Notice that while real aggregate variables grow at rate Z_t, sector specific variables grow at rate $Z_t^j = \frac{X_t A_{j,t}}{X_{t-1} A_{j,t-1}}$. The full list of the detrended equilibrium conditions is presented in the appendix 1.8.2.

1.2.6 Anticipated shocks

Presenting the model, we showed that it is driven by nine sources of innovations: preference shocks; tradable, non tradable and common 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.[15] Medium term anticipated shocks, in fact, have been proved, by Schmitt-Grohe & Uribe (2012), to be extremely important. We want to introduce also a longer horizon of anticipation because we are interested in understanding the sources of current account imbalances, which are long intertemporal events. In particular, we select 10 quarters because it is the time that separates the start of the accumulating imbalances from the actual implementation of the European Monetary Union.

Following Schmitt-Grohe & Uribe (2012) closely, 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:

$$u_t^x = u_{0,t}^x + u_{4,t-4}^x + u_{10,t-10}^x \tag{1.44}$$

where, for example, $u_{4,t-4}^x$ is today's realization of a shock that was acknowledged a year before. For a full and detailed exposition of this method for introducing anticipated shocks we cross-refer to section 3 of Schmitt-Grohe & Uribe (2012).

1.3 Jaimovich and Rebelo preferences

Business cycle data feature aggregate co-movement between important macroeconomic variables, such as output, consumption, investment and hours worked. Barro & King (1984) showed that business cycle models often fail to generate this co-movement. This is often the case for models featuring anticipated shocks. For example, an expected permanent shock in technology leads to a negative correlation between consumption and hours worked. Agents, in fact, anticipate

[15] Here we exclude monetary policy shocks because it is hard to think that anticipated shocks to the policy rule are not already included in the anticipated borrowing risk premium shock.

the increase in wealth and demand more leisure and consumption. This generates a labor dynamics 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 present a second specification of the model in which we introduce a non separable formulation of the utility function introduced by Jaimovich & Rebelo (2009). This formulation allows to control the wealth elasticity of the labor supply through a parameter.

As in Hoffmann et al. (2011), we introduce two new features with respect to the standard Jaimovich & Rebelo (2009) formulation: habit persistence in consumption and the presence of a trend in the growth rate of our economy:

$$U(C_t, L_t) = \frac{\left\{(C_t - h\overline{C}_{t-1}) - \epsilon_t^L \psi^L L_t^{1+\nu}\Omega_t\right\}^{1-\sigma} - 1}{1-\sigma}, \qquad (1.45)$$

where

$$\Omega_t = (C_t - h\overline{C}_{t-1})^{\mu}\Omega_{t-1}^{1-\mu}\left(Z_t\right)^{1-\mu}. \qquad (1.46)$$

Utility depends on consumption at time t, C_t, a weighted fraction of average past consumption, $h\overline{C}_{t-1}$, and hours worked L_t.[16] Ω_t controls the wealth effect on labor supply through the parameter $\mu \in [0,1]$. By changing μ we can account for two important classes of utility functions 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

[16] The past average consumption is perceived as external by the maximizing household which does not take the effects of his/her decision on the accumulation of average consumption into account.

model to account for the possibility of having a trend growing labor augmenting productivity, X_t.[17]

All the rest of the model is equivalent to the baseline model presented in section 1.2. The representative agent will maximize his/her utility function subject to 1.3), (1.4), (1.7), (1.7) and to the new constraint (1.46).

The first order necessary conditions for this new maximization problem are:

$$\zeta_t \left[c_t - hC_{t-1} - \epsilon_t^L \psi^L L_t^{1+v} \Omega_t\right]^{-\sigma} + \lambda_t^{JR} \mu \left[c_t - h\bar{c}_{t-1}\right]^{\mu-1} \Omega_{t-1}^{1-\mu} Z_t^{1-\mu} = \lambda_t \tag{1.47}$$

$$\lambda_t = \beta_t E_t \left\{ \lambda_{t+1} \frac{R_t^B}{\Pi_{N,t+1}} \frac{m_t}{m_{t+1}} \right\} \tag{1.48}$$

$$\lambda_t = \beta_t E_t \left\{ \lambda_{t+1} \frac{R_t}{\Pi_{N,t+1} \frac{m_t}{m_{t+1}}} \right\} \tag{1.49}$$

$$r_t^k = \Psi'(u_t) \tag{1.50}$$

$$1 = q_t \epsilon_t i \left[1 - S\left(\frac{I_t}{I_{t-1}}\right) - S'\left(\frac{I_t}{I_{t-1}}\right) \frac{I_t}{I_{t-1}}\right] + + \beta_t E_t \left\{ q_{t+1} \epsilon_{t+1}^i \frac{\lambda_{t+1}}{\lambda_t} S'\left(\frac{I_{t+1}}{I_t}\right) \frac{I_{t+1}^2}{I_t^2} \right\} \tag{1.51}$$

$$q_t = \beta_t E_t \left[\frac{\lambda_{t+1}}{\lambda_t} [r_{t+1}^k u_{t+1} - \Psi(u_{t+1}) + q_{t+1}(1-\delta)] \right] \tag{1.52}$$

$$\zeta_t \left[c_t - hC_{t-1} - \epsilon_t^L \psi^L L_t^{1+v} \Omega_t\right]^{-\sigma} \epsilon_t^L \psi^L (1+v) L_t^v \Omega_t = \lambda_t W_t \tag{1.53}$$

$$\zeta_t \left[c_t - hC_{t-1} - \epsilon_t^L \psi^L L_t^{1+v} \Omega_t\right]^{-\sigma} \epsilon_t^L \psi^L L_t^{1+v} + \lambda_t^{JR} = \tag{1.54}$$

$$= \beta_t E_t \left\{ \lambda_{t+1}^{JR} (1-\mu) \left[c_{t+1} - h\bar{c}_t\right]^{\mu} \Omega_t^{-\mu} Z_{t+1}^{1-\mu} \right\} \tag{1.55}$$

where λ_t is the lagrangian multiplier associated with the budget constraint, Q_t the lagrangian multiplier associated with installed capital and λ_t^{JR} is the multiplier attached to the law of motion of Ω_t. As be-

[17] In Jaimovich & Rebelo (2009) 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.

fore, we denote $q_t = \frac{Q_t}{\lambda_t}$ the Tobin's Q, which is the value of installed capital in consumption units.

The supply side of the economy and the market clearing conditions remain equal to the ones presented in section 1.2.

1.4 Imperfect Information

From a setup where we allowed agents to have full and perfect information, we now move to a framework in which agents have imperfect information on the type of shock that hits the economy. 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. At each point in time they use the new information available, to form the best possible estimation of the driver of the experienced shock. Edge, Laubach & Williams (2007) show that this learning feature of the model can be though of as a plausible way of modeling expectations of long-run productivity growth. Therefore, we are interested in understanding if this way of modeling expectations will confirm the results of the previous models or if it will otherwise show that other shocks are important sources of the euro area periphery imbalances. Hoffmann et al. (2011) show, that in this type of framework, technology shocks can explain the accumulation of current account deficit experienced inside the United States.

To simplify the analysis, we modify the exogenous technology process. Instead of the two sector specific productivities, presented in section 1.2.2, we now introduce a single technology process common to both sectors. We define the stationary technology process $\widetilde{X}_t$ as

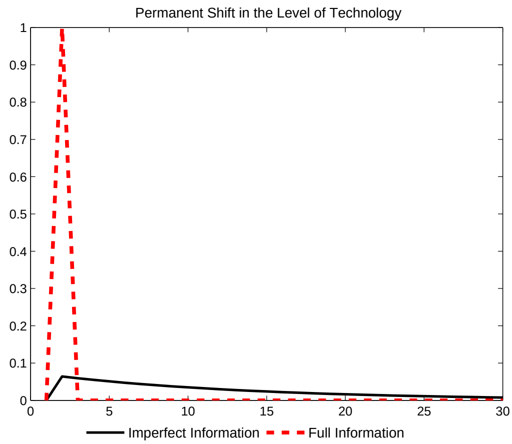


Figure 1.3: Beliefs attached to the technology process

the sum of two components:

$$X_t = (1+x)^t \widetilde{X}_t = (1+x)^t [\widetilde{A}_t + u_t^X], \tag{1.56}$$

$$\text{with} \tag{1.57}$$

$$log(\widetilde{A}_t) = \rho_A log(\widetilde{A}_{t-1}) + u_t^A. \tag{1.58}$$

Both $u_t^A \sim N(0, \sigma_A^2)$ and $u_t^X \sim N(0, \sigma_X^2)$ are independent and identically distributed random variables. As in the baseline model, a shock u_t^X leads to a one time permanent shift in the level of technology, while a shock u_t^A, generates a persistent effect on the growth rate of technology. The production in both sectors becomes $Y_{j,t} = K_{j,t}^{\alpha} [X_t L_{j,t}]^{1-\alpha}$.

Agents, at the beginning of time t, observe $Z_t = \frac{X_t}{X_{t-1}}$ but cannot perfectly distinguish if the underlying process generating the movement is the one time or the persistent shock.[18] They have the entire history of TFP shocks at time t at their disposal and they know the

[18]For the formulation of the learning process we follow Boz, Daude & Durdu (2011) and Hoffmann et al. (2011).

underlying distribution of both the trend and the cyclical component. 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 they behave accordingly. Given the linearity of our solution, the best estimate of the agents' forecast can be obtained with the Kalman Filter:

$$\widetilde{A}_{j,t|t} = (1-\kappa)\rho_{A_j}\widetilde{A}_{j,t-1|t-1} + \kappa z_t, \qquad \text{where} \quad z_t = ln(Z_t). \quad (1.59)$$

κ represent the Kalman gain which is given by the following equation:

$$\kappa = \frac{\sigma_1 - (1-\rho_{A_j}) + \sigma_1\sqrt{((1-\rho_{A_j})/\sigma_1)^2 + 1 + 2(1+\rho_{A_j})/\sigma_1}}{1 + \sigma_1 - (1-\rho_{A_j}) + \sigma_1\sqrt{((1-\rho_{A_j)}/\sigma_1)^2 + 1 + 2(1+\rho_{A_j})/\sigma_1}}, \quad (1.60)$$

where $\sigma_1 \equiv \frac{\sigma^2_{A_j}}{\sigma_X}$ is the signal-to-noise ratio. σ_1 measures the relative weight assigned to the persistent growth shock relative to the one time permanent change in the level of technology. For the signal-to-noise ratio we use the median unbiased estimator found by Garnier & Wilhelmsen (2009) for the euro area,[19] based on Stock & Watson (1998). This procedure works under the assumption of a unit root growth rate process. For stationarity reason we set $\rho_{A_j} = 0.99$ close but below one. Using $\kappa = 0.64$ and $\rho_{A_j} = 0.99$ we univocally pin down the value for σ_1. Figure 1.3 shows the difference between the true dynamics of the shock, a one standard deviation shock to the level of technology, and the dynamics perceived by the agents. As time goes by, the agents learn that the shock was not permanent and chose the right path.

[19] In Garnier & Wilhelmsen (2009), the euro area is considered as single entity over the entire period 1963-2004.

1.5 Dynamics: Impulse Responses

Ireland, Portugal and Spain, from 1996 to 2007, accumulated current account deficit, experienced real exchange rate appreciation and grew slightly above trend (figure 1.2). Keeping in mind that the aim of our research is to understand what shocks could explain the current account imbalances in the euro area, we study the equilibrium dynamics of all the three specifications of the model. We calibrate all the parameters but we conclude that, in order to make a choice among possible sources of the experienced euro area periphery imbalances, we need to estimate the model. In the next study we perform a Bayesian estimation of the subset of the parameters that are important for the dynamics of international variables.

For every perturbation 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. Sector specific technology, common productivity, permanent shift in the level of technology, investment cost, monetary policy, yield spread, preferences and labor supply are the shocks we consider in our specification. Our goal is to identify those shocks that could generate the experienced co-movement between current account, real exchange rate and output growth.

Calibrating the model leaves the freedom to check the robustness of some dynamics to the choices of parameters. In each subsection we present the calibration used first and then we introduce the impulse-responses. We start by looking at the baseline model with separable utility functions and complete information in which agents can perfectly forecast the future. Then we relax these two assumptions: in subsection 1.5.2 we show how the results change when we use the Jaimovich and Rebelo type of preferences and in subsection 1.5.3 we introduce imperfect information and the learning process introduced

Table 1.1: Calibrated Parameteres

Par	Value	Description	Source
v	1	Inverse elasticity of labor supply	Smets & Wouters (2003)
χ	-100	Discount factor, arbitrary parameter	Ferrero et al. (2008)
ψ^{β}	$1.017 \cdot 10^{-4}$	Spillover effect of average detrended consumption on discount factor	Steady-state of $\beta = 0.99$
ψ^{L}	13.3554	Labor supply preference parameter	$L^{ss} = 0.236$, Eurostat 96/07
θ	7.5	Elasticity between non tradables	Faia & Monacelli (2008)
α	0.3	Capital Share	Smets & Wouters (2003)
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
h	0.827	Habit in consumption	Burriel et al. (2010)
$\overline{\eta}_v$	0.394	Utilization rate elast	Burriel et al. (2010)
η_k	6.048	Capital adjustment cost elast	Smets & Wouters (2003)
$\rho_{A_h} = \rho_{A_N} = \rho_{\zeta} = \rho_{\epsilon_r b} = \rho_{\epsilon_I} = \rho_{\epsilon_L} = 0.7$			
ρ_r	0.94	AR interest rate	Smets & Wouters (2003)
ρ_{π}^{EMU}	1.658	Taylor rule inflation	Smets & Wouters (2003)
ϵ	1.5	Elasticity of subs	[0.36, 6]
η	0.75	Elasticity of subs T Vs NT	[0.1, 1.5]

in section 1.4.

1.5.1 Baseline Model

Calibration

The majority of the calibrated parameters of the baseline model are borrowed from previous studies, as shown in table 1.1 that summarizes their values and references. Please note that for two parameters, the trade elasticity ϵ and the elasticity between tradables and non tradables η, we assign a precise number but we also present the interval of plausible values recorded in the literature.

The work elasticity, the depreciation rate and the monetary policy rule are taken from Smets & Wouters (2003) estimation. 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, $\rho_\pi^{EMU} = 1.658$. Using Eurostat HCPI country weights, we set the parameter γ_{ips}, the weight of Ireland Portugal and Spain on the average EMU inflation, to 13.4 per cent.

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. Consumption habit, capital adjustment cost elasticity and capital utilization rate elasticity are set respectively equal to 0.9, 4 and 0.5. The autoregressive component of all the shocks is set equal to 0.7.

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 $p = 0.75$ 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 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 two remaining structural parameters are central for shaping the responses of the model to shocks. For those, a wide range of values, provided by empirical and theoretical studies, fail to give us a precise and reliable calibration. Therefore we try to understand what happens when we change these values in between a range of plausible values found by previous studies. Table 1.1 summarizes the starting value of these parameters and also the upper and lower bound that we impose when we let them vary.

The elasticity of substitution between home and foreign produced tradable goods (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) who claim that the elasticity decreases over time, ranging 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 and Smith puzzle[20] (Corsetti, Dedola & Leduc (2008) and Benigno & Thoenissen (2008)) and the volatility of the real exchange rate (Thoenissen (2011)).[21] We use both field findings for the two cutoff values: 0.36 as the lower bound and 6.8 as the upper bound.

The other central parameter is the elasticity of substitution between tradable and non tradable goods, η. Mendoza (1991), focusing on a set of industrialized countries, finds a value of 0.74 while Stock-

[20] Backus et al. (1993)

[21] The list of cited studies is far from being complete. Its only purpose is to give some important reference and an idea of the extremes of the estimates.

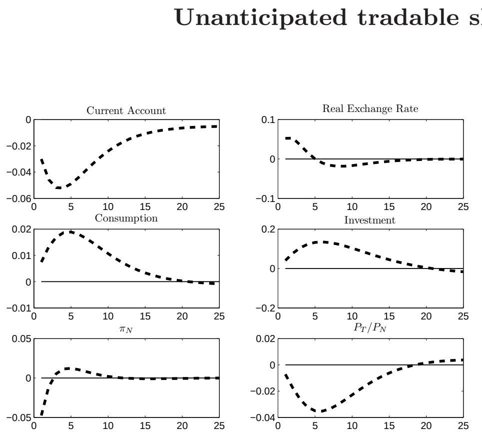


Figure 1.4: Impulse response to a positive unanticipated technology shock in the tradable sector.

man & 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 lower bound of 0.1 and an upper bound of 1.5.

Impulse Responses

To highlight some important mechanism behind productivity related shocks, we start by presenting the impulse-responses to a one standard deviation positive unanticipated technology shock in the tradable sector (figure 1.4). As the tradable technology jumps up, consumption and investment both increase pushing up also the total output. At the firm side, marginal costs of production in the tradable sector decrease and due to the stickiness of prices and the imperfect substitutability of goods, firms in that sector have excessive production. Prices in the tradable sector are forced down and so the demand

Trade elasticity of international substitution

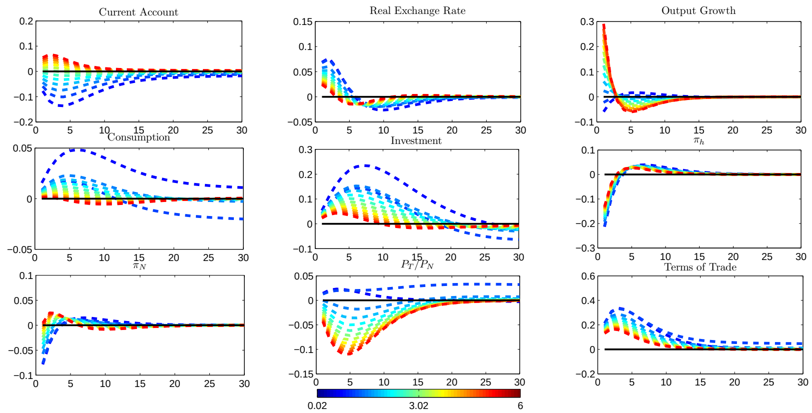


Figure 1.5: Impulse response to a positive unanticipated technology shock allowing ϵ to vary in between the boundaries found by previous studies.

for labor and capital. Therefore, wages and the rental rate of capital decrease resulting in a reduction of the marginal costs also in the non tradable sector. As prices go down in both sectors, the real exchange rate depreciates. However, notice that a sectoral Balassa-Samuelson effect is still active: non tradable goods become relatively more expensive than tradable goods. Home produced tradable goods become internationally more competitive through a term of trade depreciation. Despite this, 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 advantage.

Almost the same results are obtained when the shocks are 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

Changing ϵ vs. η

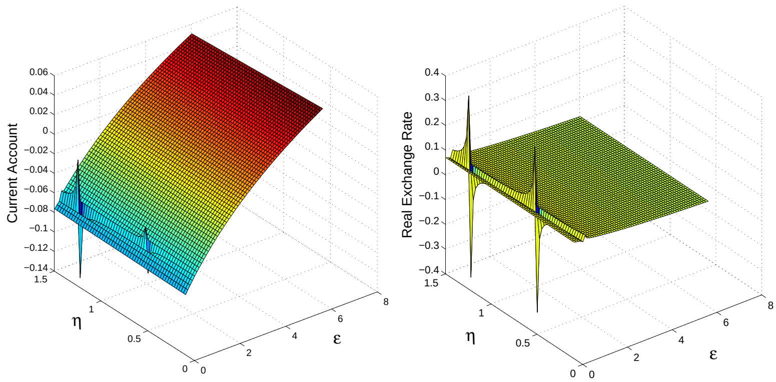


Figure 1.6: Impact of current account and real exchange rate to a positive unanticipated technology shock in the tradable sector when both ϵ, the international trade elasticity, and η, the elasticity between tradable and non tradable goods, vary between the boundaries found by previous studies.

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.

We now let the elasticity of substitution between domestic and foreign tradable goods vary keeping fixed the other parameters. Figure 1.5 shows again the impulse responses to an unanticipated technology shock in the tradable sector. Keeping fixed $\eta = 0.75$, the elasticity of substitution between tradable and non tradable goods, the model cannot generate a real exchange rate appreciation as a response to just a positive unanticipated technology shock.[22] To generate a real exchange rate appreciation in response to a positive technology shock we will need, as shown by Corsetti et al. (2008), a stronger wealth

[22]The graph would be the same for an unanticipated technology shock either in the non tradable sector or in both sectors and the results would not change.

effect that pushes the increase in demand for domestically produced goods above the increase in supply. The most important parameters governing the wealth effect are the combination of ϵ, the elasticity of substitution between domestic and foreign tradable goods, and η, the elasticity of substitution between non tradable and tradable goods.

On the contrary, a positive technology shock can generate a current account deterioration for every value of ϵ below 2.77. Current account reacts positively when goods are more substitutable and it reacts negatively if they are more complementary. As shown by Corsetti et al. (2008), in the presence of a marginal cost advantage with highly substitutable tradable goods, 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.

We now focus on the current account and the real exchange rate. We let both ϵ and η change value. With the help of a 3-D plot, figure 1.6, we find the combinations of the two elasticities so that the model can generate a real exchange rate appreciation and a current account deficit. While current account goes on deficit for a wide range of parameters the same cannot be said for the real exchange rate. The combination of ϵ and η, for which the demand for domestically produced goods goes above the supply, are really few.

The persistency of the technology shocks is the other key parameter that, by changing its value, it is able to generate different reactions of the international variables here considered. Corsetti et al. (2008) show in fact that with high trade elasticity it is possible to generate a real exchange rate appreciation as a response to a positive productivity shock if the shock is strongly persistent. Figure 1.7 shows in fact that, as we increase both the international elasticity between tradables and the persistency of the shock, the model generates a real exchange rate appreciation. However, notice that the model needs a

Changing the persistency vs ϵ

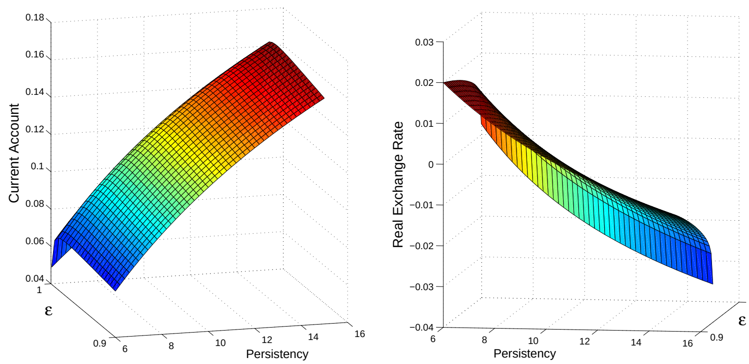


Figure 1.7: Impact of current account and real exchange rate to a positive unanticipated technology shock in the tradable sector when the trade elasticity, ϵ, and the persistency of the shock, $\rho_A N$, vary.

really high persistency in order to generate a relative increase of domestic consumer prices when trade elasticity is below 7. The aspect that it is worth noting for our purpose of investigating the possible sources of the experienced current account imbalances in the euro area periphery is that the reaction to the current account is always positive for all the considered combinations of the parametrization.

So far the results are twofold. First, the choice of some key parameters are crucial for the responses of international variables such as the current account and the real exchange rate: the trade elasticity, the elasticity between tradable and non tradables and the persistency of the technology shocks. Second, it is really hard for the model to contemporaneously generate a current account deficit and a real exchange rate appreciation in response to positive technology shocks, excluding few combinations of previously listed parameters. These two results explain why in the next study, in order to assess which shock played an important role for the euro area current ac-

Anticipated tradable shock

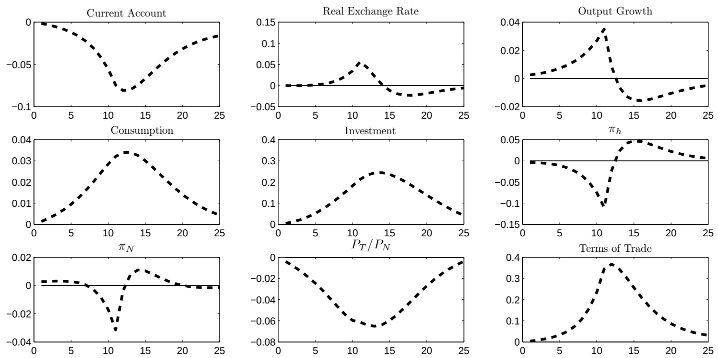


Figure 1.8: Impulse response to a positive anticipated technology shock in the tradable sector.

count imbalances, we bring the model to the data estimating these parameters.

We now try to understand the role of anticipated shocks. The Current account is a measure of trade over time and expectations are crucial drivers of capitals and goods through countries. Therefore, we want to test if the model can generate a current account deficit, a real exchange rate appreciation and a real output growth as a reaction to anticipated productivity shocks. From now on we will focus on 10-quarter anticipated shocks in the tradable sector.[23] We use the benchmark calibration of the parameters, used also for figure 1.4 and presented in table 1.1.

The representative agent anticipates that in 10 periods, from the moment in which he/she receives the news, productivity will increase. Given the perfect information set-up, he/she knows exactly the type of shock that will hit the economy and he/she internalizes that if the

[23]The results for the 4-quarter anticipated shocks would be similar.

shock is unanticipated the economy would react as shown in figure 1.4. The positive wealth effect and the increase in the future marginal productivity of capital start to be accounted in time t, pushing up both consumption and investment. The current account goes negative as domestic households demand more foreign goods. Notice that, with respect to figure 1.4, the transition is now smoother. In fact, given the formation of habits in consumption, smoother transitions are welfare improving for the agents in the economy. Looking at the supply side, firms in both sectors anticipate that they will have to decrease their prices in order to sell all the units produced. In the tradable sector the firms start to adjust prices right away. In the non tradable sector the same dynamics would apply except that the increase in demand is not now supported by an expected increase in the marginal productivity of both capital and labor. This forces prices in the non tradable sector up: the Balassa-Samuelson effect kicks in during the first part of the transition period, between the moment in which the news is reported and the the shock is actually realized. Depending on the weight of the non tradable sector in the economy we have a temporary, but small, real exchange rate appreciation.

If the shock had been either in the non tradable sector or in both sectors we would not have seen the real exchange appreciation in the first transition period. Our reasoning so far leads us to say that had the shock been in both sectors, the cause would have been self-explanatory. Otherwise, had the shock been in the non tradable sector, the result would have depended again on the trade elasticity. The higher is the trade elasticity, the smaller the increase in the price needed to compensate the jump in demand. For our benchmark calibration, the small increase in the tradable price is not able to offset the decrease in the price of the non tradable goods, forcing consumer prices down.

The conclusion of this impulse-response analysis is that it is hard for productivity shocks, even when they are anticipated and in the non tradable sector, to generate the experienced co-movement of the current account, real exchange rate and output growth (figure 1.2). Probably there are other important sources of the experienced current account imbalances. We learned from this section that, despite the fact that it seems hard for productivity shock to be the source of euro area imbalances, we cannot come to any conclusion before we have performed a proper estimation of those parameters on the data for the euro area periphery countries considered. In the next study, after having estimated the model, we investigate what other shocks are important for the current account imbalances.

1.5.2 Jaimovich and Rebelo Preferences

Anticipated persistent productivity shocks often fail to generate the business cycle regularities found in empirical studies. Output, consumption, investment and hours worked should move in the same direction in response to technology shocks. As shown in figure 1.9, a simplified version of our model[24] would also fail to generate the correct movement of hours worked. Jaimovich and Rebelo type of preferences, presented in section 1.3, help generating the increase in hours worked by controlling the wealth elasticity of the labor supply.

We are now interested in understanding if and how the results generated using the baseline model are influenced by the mis-behavior of the labor supply in the economy.

Calibration

We take the majority of the parameters from the baseline model calibration. Two are the new parameters and we follow Jaimovich & Rebelo (2009): σ, the intertemporal elasticity of substitution, is

[24] In 1.5.2 we present the details of the simplified model.

Anticipated persistent productivity shock

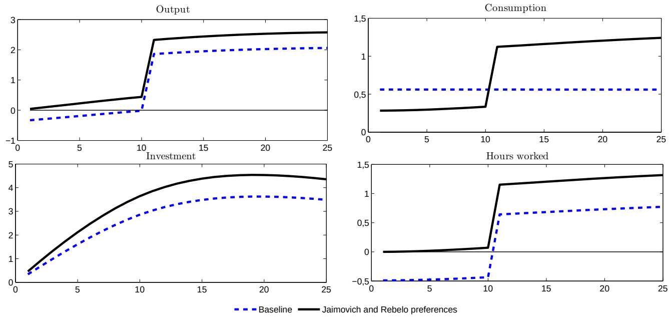


Figure 1.9: Impulse response to a positive strongly persistent ($\rho_{TFP} = 0.999$) 10-period anticipated technology shock for the baseline and the Jaimovich and Rebelo specification. The impulse responses come from a simplified version of the model: one sector economy with highly substitutable tradable goods and zero habit persistence, h=0.

set equal to 1 and μ, the degree of the wealth elasticity of the labor supply, is set to 0.001, The choice of mu close to zero makes the preferences close to GHH specification and ensures a small wealth elasticity of the labor supply.

Impulse Responses

To understand the implications of this type of preferences for the responses of the current account and the real exchange rate to different types of shocks, we first present the results we achieve by using a simplified version of the model with the following modifications: there is only one sector of production, the tradable sector; tradable goods are highly substitutable; prices are flexible; there is no consumption habit; preferences are of the Jaimovich and Rebelo type with $\mu = 0.0001$.[25]

[25] We start with this set of assumptions because it allows to compare our results with the ones shown by Jaimovich & Rebelo (2008).

In response to a 10-quarter anticipated positive persistent productivity shock, the model generates the positive co-movement of output, investment, consumption and hours worked. The really low wealth elasticity of the labor supply (controlled by $\mu = 0.0001$) ensures that agents will want to decrease the amount of work only by a small amount. We do not see this small reduction in hours because the presence of investment adjustment costs make it convenient for the agent to start investing immediately, creating a positive complementarity between labor and capital. Therefore, when we take out investment adjustment cost, hours worked slightly decrease. In figure 1.10 we show that this is the case also when we set the parameter μ equal to 1, reproducing King et al. (1988) preference specification. Now the wealth effect of the labor supply is strong, generating a strong decrease in the hours worked. In the same picture we show also what happens when we introduce habits in consumption. This introduction has strong effects on the dynamics of consumption which decreases before the realization of the shock but afterwards increases more and in a smoother way with respect to the dynamics implied by the previous specification. Even if not depicted in figure 1.10, we also prove that for the simplified specification of the model capital utilization rate and the stickiness of prices are not crucial components to generate the business cycle properties of the data[26].

Focusing on the current account and the real exchange rate we see in the last two panels of figure 1.10 that, apart from when we introduce habit in consumption, we are able to replicate a current account deficit and a real exchange rate appreciation, but only for the quarters preceding the realization of the shock. As soon as the shock hits, the real exchange rate depreciates and the current account goes on surplus.

[26]The small importance of capital utilization rate in open economy models is confirmed also in the analysis by Jaimovich & Rebelo (2008)

Anticipated persistent productivity shock, four model specifications

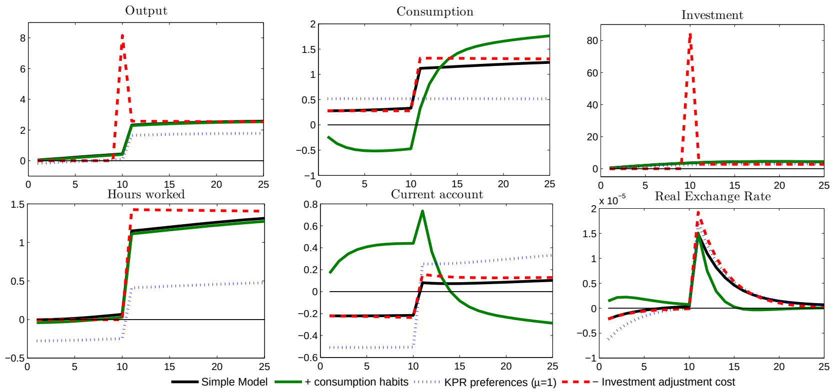


Figure 1.10: Impulse responses to a positive strongly persistent ($\rho_{TFP} = 0.999$) 10-period anticipated technology shock for four different specification of the model.

To understand the role of the Jaimovich and Rebelo preference specification we go back to the complete specification of the model and we study the effects of anticipated shocks. Following the calibration introduced in section 1.5.2, we show the responses to an anticipated productivity shock in both production sectors of the current account, the real exchange rate and the four business cycle variables we have been analysing in this section. Figure 1.11 compares the results between the baseline model of section 1.2 and the Jaimovich and Rebelo specification with both sticky and flexible prices. With sticky prices both models fail to generate an increase in hours worked at the moment in which the shock realizes. The decrease in the hours worked is not due to the decrease in labor supply but it is a consequence of the inability of firms to fully adjust their prices when the shock occurs generating excess supply of goods. As shown in figure 1.11, when we allow fully flexible prices and shut down the wealth

Anticipated productivity shock common to both production sectors

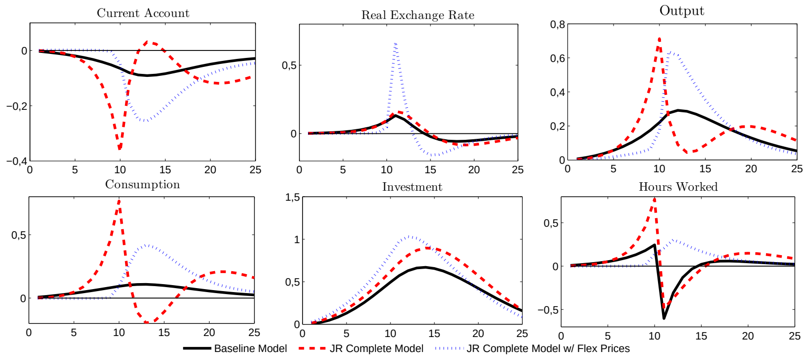


Figure 1.11: Impulse responses to a positive 10-period anticipated technology shock in both production sectors; the graphs refer to the baseline model and to the Jaimovich and Rebelo preference specification with both sticky and flexible prices.

effect on the labor supply we are able to generate an increase in the hours worked.

A persistent current account deficit can be the result of an anticipated productivity shock also with Jaimovich and Rebelo specification. Allowing for flexible prices the deficit becomes less persistent. The inability to match the experienced co-movement experienced by Ireland, Portugal and Spain (figure 1.2) comes from the real exchange rate. In the periods preceding the realization of the shock, but also afterwards, the real exchange rate depreciates.

Even controlling for the wealth effect of the labor supply, it is hard for anticipated productivity shocks to generate a persistent current account deficit and a real exchange rate appreciation. In the next study, giving the sensibility of the model to different parametrization, we will estimate the key parameters of the model and we will do an exhaustive investigation of the responses to all other shocks.

Imperfect Information

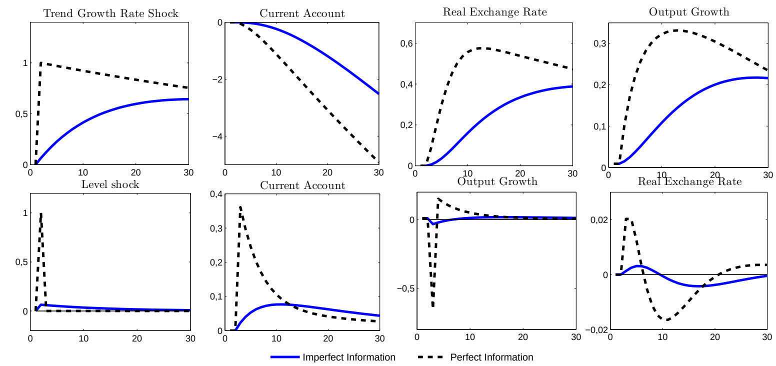


Figure 1.12: Impulse responses to a positive anticipated technology shock in the tradable sector. The figure compares responses of the baseline specification with the framework in which agents have imperfect information on the shocks. The first row shows the responses to a trend growth rate shock, u_t^A, while the second row depicts the responses to a permanent level shock, u_t^X

1.5.3 Imperfect Information

In section 1.4 we have described the framework in which agents have imperfect information and there are two types of shocks: a permanent shock to the level of the productivity, u_t^X, and a shock to the trend growth rate of productivity, u_t^A. In every period agents observe the total technology but they can only infer the exact decomposition. The best possible estimation, in the linear framework, is provided by the Kalman filter. Kalman filter estimations of productivity using real time data are found[27] to closely resemble the real time published expectations of productivity movements. In this section we want to understand if the results found in the previous sections is confirmed also for this informational way of modeling anticipated shocks. In

[27]Edge et al. (2007)

order to generate the impulse responses of the model to different shocks we use the same set of calibrated parameters presented in section 1.5.1.

Figure 1.12 shows the impulse responses of the current account, output growth and the real exchange rate to both types of productivity shocks in the economy. For both shocks we present the reactions for the perfect and imperfect information model. Qualitatively the results are almost equivalent. The main difference is that the shocks in the imperfect information setup are less pronounced and more persistent than the baseline counterpart. However, notice that, even for the incomplete information specification, which is a different way of modeling expected shocks, productivity shocks fail to reproduce the experienced co-movement of the current account, the real exchange rate and the output growth.

1.6 Conclusions

Ireland, Portugal and Spain, from 1996 to 2007, accumulated current account deficit, experienced real exchange rate appreciation and grew slightly above trend. Current events in the euro area have shown that international imbalances have contributed to exacerbate the vulnerability of European Monetary Union (EMU) periphery. In this study we uncover the sources of the current account imbalances experienced in the euro area before the Great Recession. We also assess the role of *unanticipated vs. anticipated* shocks on international variable fluctuations.

To that end, we have constructed a small open economy DSGE model featuring incomplete international financial market, price and investment adjustment cost, variable capital utilization, habit persistence, home bias and both tradable and non tradable sectors that has allowed to investigate among different plausible shocks, the sources of the experienced imbalances.

The idea that capitals were flowing towards "catching-up" euro area countries with high current or expected productivity growth has lost empirical support. This paper shows that also theoretically, anticipated as well as unanticipated productivity shocks, whether in the traded or in the non-traded sector, cannot be the relevant sources of the current account deficits experienced inside the EMU before the Great Recession. The reason is the inability of productivity shocks to generate the experienced co-movement between the current account, the real exchange rate and the output growth. The result holds for a wide range of parameters, but we have also shown that, for some parameter combinations, the model can generate a current account deficit with a contemporaneous real exchange rate appreciation and a positive output growth. Therefore in the next study we will provide an estimation of the model to understand the correct values of some important parameters.

We have shown that the result does not depend on the misbehavior of the labor market and that it is robust to modeling expected shocks as a signal extraction in an imperfect information framework. We have presented a specification of the model in which we have introduced the Jaimovich and Rebelo type of preference that allows to control the wealth elasticity of the labor supply through a parameter. We have shown that the inability of the model to generate the business cycle co-movement between hours worked and output, consumption and investment is not only caused by labor supply but mainly by the stickiness of prices. Anticipated shocks can also be modeled as an imperfectly estimated productivity shocks. In an imperfect setup we have show that agents, relying on their updated estimation, react to shocks less on impact but more persistently. In both specifications we have shown that it is hard for the model to generate a contemporaneous current account deficit and a real exchange rate appreciation.

To conclude, we think that it is a mistake to focus only on the dynamics of the current account if we are interested in understanding the sources of current account imbalances: the investigation cannot be carried out without focusing also on the real exchange rate and on the output growth at the same time. Focusing on the co-movement between these variables allows to avoid mis-interpretations of current account responses to very different shocks.

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1.8 Appendix

1.8.1 Full model

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

Household

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

$$C_{N,t} = \gamma_{N,t} \left(m(J_t)\right)^{\eta} C_t \tag{1.8.1.1}$$

$$C_{h,t} = \gamma_{T,t}\gamma_{h,t} \left(\frac{m(J_t)}{J_t}\right)^{\eta} g(S_t)^{\epsilon} C_t, \tag{1.8.1.2}$$

$$C_{f,t} = \gamma_{T,t}\gamma_{f,t} \left(\frac{m(J_t)}{J_t}\right)^{\eta} \left(\frac{g(S_t)}{S_t}\right)^{\epsilon} C_t \tag{1.8.1.3}$$

where

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

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

$$C^*_{h,t} = \gamma^*_{T,t}\gamma^*_{h,t} Q^{\eta} \left(\frac{m(J_t)}{J_t}\right)^{\eta} g(S_t)^{\eta} S_t^{\epsilon-\eta} C^*_t \tag{1.8.1.4}$$

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

$$\zeta_t \frac{1}{C_t - hC_{t-1}} - h\beta_t\zeta_{t+1}\frac{1}{C_{t+1} - hC_t} = \lambda_t \tag{1.8.1.5}$$

$$\lambda_t = \beta_t E_t\left\{\lambda_{t+1}\frac{R_t^B}{\Pi_{N,t+1}}\frac{m_t}{m_{t+1}}\right\} \tag{1.8.1.6}$$

$$\lambda_t = \beta_t E_t\left\{\lambda_{t+1}\frac{R_t}{\Pi_{N,t+1}\frac{m_t}{m_{t+1}}}\right\} \tag{1.8.1.7}$$

$$r_t^k = \Psi'(u_t) \tag{1.8.1.8}$$

$$1 = q_t\epsilon_t i\left[1 - S\left(\frac{I_t}{I_{t-1}}\right) - S'\left(\frac{I_t}{I_{t-1}}\right)\frac{I_t}{I_{t-1}}\right] + \tag{1.8.1.9}$$

$$+ \beta_t E_t\left\{q_{t+1}\epsilon_{t+1}^i\frac{\lambda_{t+1}}{\lambda_t}S'\left(\frac{I_{t+1}}{I_t}\right)\frac{I_{t+1}^2}{I_t^2}\right\}$$

$$q_t = \beta_t E_t\left[\frac{\lambda_{t+1}}{\lambda_t}[r_{t+1}^k u_{t+1} - \Psi(u_{t+1}) + q_{t+1}(1-\delta)]\right] \tag{1.8.1.10}$$

$$\zeta_t\epsilon_t^L L_t^\nu = \lambda_t W_t \tag{1.8.1.11}$$

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

$$K_t = u_t k_{t-1}^p \tag{1.8.1.12}$$

$$k_t^p = (1-\delta)k_{t-1}^p + I_t\left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right]\epsilon_t^I \tag{1.8.1.13}$$

$$\beta_t = \frac{1}{1 + \psi^\beta log\overline{C}_t - \psi^\beta\chi} \tag{1.8.1.14}$$

Firms

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

$$Y_{j,t} = A_{j,t} X_t^{1-\alpha} K_{j,t}^{\alpha} L_{j,t}^{1-\alpha} \tag{1.8.1.15}$$

The optimality conditions of the cost minimization problem are:

$$K_{j,t} = \frac{\alpha}{1-\alpha} \frac{W_t}{r_t^k} L_{j,t} \tag{1.8.1.16}$$

and

$$MC_{j,t} = \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \left(\frac{1}{\alpha}\right)^{\alpha} \frac{W_t^{1-\alpha} r_t^{k\,\alpha}}{A_{j,t} X_t^{1-\alpha}} \tag{1.8.1.17}$$

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 equations are:

$$\frac{\Pi_{N,t}}{\Pi^N}\left(\frac{\Pi_{N,t}}{\Pi^N} - 1\right) = E_t\left\{\beta_t \frac{\lambda_{t+1}}{\lambda_t} \frac{m(J_t)}{m(J_{t+1})} \frac{Y_{N,t+1}}{Y_{N,t}} \left(\frac{\Pi_{N,t+1}}{\Pi^N} - 1\right) \frac{\Pi_{N,t+1}}{\Pi^N}\right\} + $$
$$+ \frac{\theta}{\psi} MC_{N,t} m(J_t) - \frac{\theta - 1}{\psi} \tag{1.8.1.18}$$
$$\frac{\Pi_{h,t}}{\overline{\Pi}^h}\left(\frac{\Pi_{h,t}}{\overline{\Pi}^h} - 1\right) = E_t\left\{\beta_t \frac{\lambda_{t+1} Y_{h,t+1}}{\lambda_t Y_{h,t}} \frac{m(J_t) g(S_t) J_{t+1}}{m(J_{t+1}) g(S_{t+1}) J_t} \left(\frac{\Pi_{h,t+1}}{\overline{\Pi}^h} - 1\right) \frac{\Pi_{h,t+1}}{\overline{\Pi}^N}\right\} + $$
$$+ \frac{\phi}{\psi} \frac{MC_{h,t} m(J_t) g_t}{J_t} - \frac{\phi - 1}{\psi} \tag{1.8.1.19}$$

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

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 prices of tradable over non tradable goods and the CPI over the price of non tradable goods:

$$S_t \equiv \frac{P_{f,t}}{P_{h,t}} \tag{1.8.1.20}$$

$$g(S_t) = \frac{P_{T,t}}{P_{h,t}} = [\gamma_{h,t} + \gamma_{f,t} S_t^{1-\epsilon}]^{\frac{1}{1-\epsilon}} \text{ with } \frac{\delta g(S_t)}{\delta S_t} > 0 \tag{1.8.1.21}$$

$$J_t \equiv \frac{P_{T,t}}{P_{N,t}} \tag{1.8.1.22}$$

$$m(J_t) = \frac{P_t}{P_{N,t}} = [\gamma_{T,t} J_t^{1-\eta} + \gamma_{N,t}]^{\frac{1}{1-\eta}} \text{ with } \frac{\delta m(J_t)}{\delta J_t} > 0 \tag{1.8.1.23}$$

$$\tag{1.8.1.24}$$

We define the real exchange rate in the monetary union as

$$Q_t = \frac{P_t^*}{P_t} \tag{1.8.1.25}$$

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

$$NX_t + \frac{R_{t-1}^B B_{t-1}}{YP_t} - \frac{R_{t-1} A_{t-1}}{YP_t} - \frac{B_t - A_t}{YP_t} = 0 \tag{1.8.1.26}$$

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

$$NX_t = \frac{J_t}{g(S_t)m(J_t)} \frac{(Y_{h,t} - C_{h,t} - S_t C_{f,t})}{Y} \tag{1.8.1.27}$$

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

$$CA_t = \frac{(B_t - A_t)}{P_t Y} - \frac{(B_{t-1} - A_{t-1})}{P_t Y} \tag{1.8.1.28}$$

Market Clearing and Monetary Policy Rule

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

$$K_t = K_{N,t} + K_{h,t} \tag{1.8.1.29}$$

$$L_t = L_{N,t} + L_{h,t} \tag{1.8.1.30}$$

In the non tradable and in the tradable sectors markets clear:

$$Y_{N,t} = C_{N,t} + \frac{\psi}{2}\left(\frac{\pi_{N,t}}{\overline{\pi}_N} - 1\right)^2 Y_{N,t} \tag{1.8.1.31}$$

$$Y_{h,t} = C_{h,t} + C^*_{h,t} + \frac{\psi}{2}\left(\frac{\pi_{h,t}}{\overline{\pi}_h} - 1\right)^2 Y_{h,t} \tag{1.8.1.32}$$

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

$$Y_t = \frac{J_t}{m(J_t)g(S_t)} Y_{h,t} + \frac{1}{m(J_t)} Y_{N,t} + I_t \tag{1.8.1.33}$$

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

$$R_t = R_{t-1}^{\rho_r}\left(\frac{\Pi_t^{EMU}}{\Pi^{EMU}}\right)^{(1-\rho_r)\rho_\pi} \tag{1.8.1.34}$$

1.8.2 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 transformations of each variable, indicated with a overwritten tilde.

Technologies and Prices

Before going into the details of each equation notice that given the technology processes specified in equations (1.16) and (1.21), 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 variables $\frac{X_t}{X_{t-1}} = Z_t$. Assuming that CPI prices grow at Π^t, then the two sector specific prices grow at $\frac{\Pi^t}{(1-g^j)^t}$.

Household

The demand functions for each type of good become:

$$\widetilde{C}_{N,t} = \widetilde{\gamma}_{N,t}\left(\widetilde{m}(\widetilde{J}_t)\right)^{\eta}\widetilde{C}_t \tag{1.8.2.1}$$

$$\widetilde{C}_{h,t} = \widetilde{\gamma}_{T,t}\widetilde{\gamma}_{h,t}\left(\frac{\widetilde{m}(J_t)}{\widetilde{J}_t}\right)^{\eta}\widetilde{g}(S_t)^{\epsilon}\widetilde{C}_t, \tag{1.8.2.2}$$

$$\widetilde{C}_{f,t} = \widetilde{\gamma}_{T,t}\widetilde{\gamma}_{f,t}\left(\frac{\widetilde{m}(J_t)}{\widetilde{J}_t}\right)^{\eta}\left(\frac{\widetilde{g}(S_t)}{\widetilde{S}_t}\right)^{\epsilon}\widetilde{C}_t \tag{1.8.2.3}$$

$$\widetilde{C}^*_{h,t} = \widetilde{\gamma}^*_{T,t}\widetilde{\gamma}^*_{h,t}\widetilde{Q}^{\eta}\left(\frac{\widetilde{m}(J_t)}{\widetilde{J}_t}\right)^{\eta}\widetilde{g}(S_t)^{\eta}\widetilde{S}_t^{\epsilon-\eta}\widetilde{C}^*_t \tag{1.8.2.4}$$

where

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

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

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

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

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

and

$$\widetilde{S}_t = S_t\left(\frac{1+g^{T\,*}}{1+g^T}\right)^t\left(\frac{\Pi}{\Pi^*}\right)^t \qquad \widetilde{g}(S_t) = g(S_t)$$

$$\widetilde{J}_t = \left(\frac{1+g^T}{1+g^N}\right)^t \qquad \widetilde{m}(J_t) = \frac{m_t}{(1+g^N)^t}$$

$$\widetilde{Q}_t = Q_t\left(\frac{\Pi}{\Pi^*}\right)^t$$

Notice that

$$\widetilde{\Pi_t} = \frac{\Pi_t}{\Pi} \qquad \text{because} \quad \widetilde{P}_t = \frac{P_t}{(\Pi)^t}$$

$$\widetilde{\Pi_{N,t}} = \Pi_{N,t}\frac{(1+g^N)}{\Pi} \qquad \text{because} \quad \widetilde{P}_{N,t} = \Pi_{N,t}\frac{(1+g^N)^{t\,t}}{\Pi}$$

$$\widetilde{\Pi_{h,t}} = \Pi_{h,t}\frac{(1+g^T)}{\Pi} \qquad \text{because} \quad \widetilde{P}_{h,t} = \Pi_{h,t}\frac{(1+g^T)^{t\,t}}{\Pi}$$

The first order conditions of the household are:

$$\zeta_t \frac{1}{\widetilde{C}_t - \frac{h}{Z_t}\widetilde{\widetilde{C}}_{t-1}} - h\beta_t\zeta_{t+1}\frac{1}{\widetilde{C}_{t+1} - hZ_{t+1}\widetilde{C}_t} = \widetilde{\lambda}_t \tag{1.8.2.5}$$

$$\widetilde{\lambda}_t = \beta_t E_t \left\{ \widetilde{\lambda}_{t+1}\frac{\Pi}{Z_{t+1}}\frac{R_t^B}{\widetilde{\Pi_{N,t}}_{t+1}\frac{\widetilde{m}_t}{\widetilde{m}_{t+1}}} \right\} \tag{1.8.2.6}$$

$$R_t^B = R_t \tag{1.8.2.7}$$

$$r_t^k = \Psi'(u_t) \tag{1.8.2.8}$$

$$1 = q_t\epsilon_t i \left[1 - S\left(\frac{\widetilde{I}_t}{\widetilde{I_{t-1}}}Z_t\right) - S'\left(\frac{\widetilde{I}_t}{\widetilde{I_{t-1}}}Z_t\right)\frac{\widetilde{I}_t}{\widetilde{I_{t-1}}}Z_t \right] + \tag{1.8.2.9}$$

$$+ \beta_t E_t \left\{ q_{t+1}\epsilon_{t+1}^i \frac{\widetilde{\lambda}_{t+1}}{\widetilde{\lambda}_t}\frac{1}{Z_{t+1}} S'\left(\frac{\widetilde{I_{t+1}}}{\widetilde{I}_t}Z_{t+1}\right)\frac{\widetilde{I}_{t+1}^2}{\widetilde{I}_t^2}Z_{t+1}^2 \right\}$$

$$q_t = \beta_t E_t \left[\frac{\widetilde{\lambda}_{t+1}}{\widetilde{\lambda}_t}\frac{1}{Z_{t+1}}[r_{t+1}^k u_{t+1} - \Psi(u_{t+1}) + q_{t+1}(1-\delta)] \right] \tag{1.8.2.10}$$

$$\zeta_t\epsilon_t^L L_t^\nu = \widetilde{\lambda}_t\widetilde{W}_t \tag{1.8.2.11}$$

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:

$$\widetilde{K}_t = u_t \widetilde{k}^p_{t-1} \quad (1.8.2.12)$$

$$\widetilde{k}^p_t = (1-\delta)\widetilde{k}^p_{t-1} + \widetilde{I}_t \left[1 - S\left(\frac{\widetilde{I}_t}{\widetilde{I}_{t-1}}\right)\right] \epsilon^I_t \quad (1.8.2.13)$$

$$\beta_t = \frac{1}{1 + \psi^\beta log\widetilde{C}_t - \psi^\beta \chi} \quad (1.8.2.14)$$

where

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

Firms

Firms production functions in the two sectors are:

$$\widetilde{Y}_{N,t} = \widetilde{A}_{N,t} Z_t^{-\alpha} \widetilde{K}^\alpha_{N,t} L^{1-\alpha}_{N,t} \quad (1.8.2.15)$$

$$\widetilde{Y}_{h,t} = \widetilde{A}_{h,t} Z_t^{-\alpha} \widetilde{K}^\alpha_{h,t} L^{1-\alpha}_{h,t} \quad (1.8.2.16)$$

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:

$$\widetilde{K}_{N,t} = \frac{\alpha}{1-\alpha}\frac{\widetilde{W}_t}{r_t^k}L_{N,t}\widetilde{Z}_t \tag{1.8.2.17}$$

$$\widetilde{K}_{h,t} = \frac{\alpha}{1-\alpha}\frac{\widetilde{W}_t}{r_t^k}L_{h,t}\widetilde{Z}_t \tag{1.8.2.18}$$

$$\widetilde{MC}_{N,t} = \left(\frac{1}{1-\alpha}\right)^{1-\alpha}\left(\frac{1}{\alpha}\right)^{\alpha}\frac{\widetilde{W}_t^{1-\alpha} r_t^{k\ \alpha}}{\widetilde{A}_{N,t}} \tag{1.8.2.19}$$

$$\widetilde{MC}_{h,t} = \left(\frac{1}{1-\alpha}\right)^{1-\alpha}\left(\frac{1}{\alpha}\right)^{\alpha}\frac{\widetilde{W}_t^{1-\alpha} r_t^{k\ \alpha}}{\widetilde{A}_{h,t}} \tag{1.8.2.20}$$

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:

$$\frac{\widetilde{\Pi}_{N,t}}{\widetilde{\Pi}^N}\left(\frac{\widetilde{\Pi}_{N,t}}{\widetilde{\Pi}^N}-1\right) = E_t\left\{\beta_t\frac{\lambda_{t+1}}{\lambda_t}\frac{m(J_t)}{m(J_{t+1})}\frac{Y_{N,t+1}}{Y_{N,t}}\left(\frac{\Pi_{N,t+1}}{\overline{\pi}^N}-1\right)\frac{\Pi_{N,t+1}}{\overline{\pi}^N}\right\}+$$
$$+\frac{\theta}{\psi}MC_{N,t}m(J_t)-\frac{\theta-1}{\psi} \tag{1.8.2.21}$$

$$\frac{\Pi_{h,t}}{\overline{\Pi}^h}\left(\frac{\Pi_{h,t}}{\overline{\Pi}^h}-1\right) = E_t\left\{\beta_t\frac{\lambda_{t+1}Y_{h,t+1}}{\lambda_t Y_{h,t}}\frac{m(J_t)g(S_t)J_{t+1}}{m(J_{t+1})g(S_{t+1})J_t}\left(\frac{\Pi_{h,t+1}}{\overline{\Pi}^h}-1\right)\frac{\Pi_{h,t+1}}{\overline{\Pi}^N}\right\}+$$
$$+\frac{\phi}{\psi}\frac{MC_{h,t}m(J_t)g_t}{J_t}-\frac{\phi-1}{\psi} \tag{1.8.2.22}$$

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

$$\widetilde{NX}_t + \frac{R^B_{t-1}\widetilde{B}_{t-1}}{Z_t\widetilde{Y}\widetilde{P}_t} - \frac{R_{t-1}\widetilde{A}_{t-1}}{Z_t\widetilde{Y}\widetilde{P}_t} - \frac{\widetilde{B}_t - \widetilde{A}_t}{\widetilde{Y}\widetilde{P}_t} = 0 \tag{1.8.2.23}$$

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

$$\widetilde{NX}_t = \frac{\widetilde{J}_t}{\widetilde{g}(\widetilde{S}_t)\widetilde{m}(J_t)} \frac{\left(\widetilde{Y}_{h,t} - \widetilde{C}_{h,t} - \widetilde{S}_t\widetilde{C}_{f,t}\right)}{\widetilde{Y}} \tag{1.8.2.24}$$

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

$$\widetilde{CA}_t = \frac{(\widetilde{B}_t - \widetilde{A}_t)}{\widetilde{Y}\widetilde{P}_t} - \frac{(\widetilde{B}_{t-1} - \widetilde{A}_{t-1})}{Z_t\widetilde{P}_t\widetilde{Y}} \tag{1.8.2.25}$$

where

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

Labor supply and capital supply equalize labor demand and supply:

$$\widetilde{K}_t = \widetilde{K}_{N,t} + \widetilde{K}_{h,t} \tag{1.8.2.26}$$

$$L_t = L_{N,t} + L_{h,t} \tag{1.8.2.27}$$

The same occurs for demand and supply of non tradable and home tradable goods:

$$\widetilde{Y}_{N,t} = \widetilde{C}_{N,t} + \frac{\psi}{2}\left(\frac{\pi_{N,t}}{\overline{\pi}_N} - 1\right)^2 \widetilde{Y}_{N,t} \tag{1.8.2.28}$$

$$\widetilde{Y}_{h,t} = \widetilde{C}_{h,t} + \widetilde{C}^*_{h,t} + \frac{\psi}{2}\left(\frac{\pi_{h,t}}{\overline{\pi}_h} - 1\right)^2 \widetilde{Y}_{h,t} \tag{1.8.2.29}$$

Real GDP:

$$\widetilde{Y}_t = \frac{\widetilde{J}_t}{\widetilde{m}(J_t)\widetilde{g}(\widetilde{S}_t)}\widetilde{Y}_{h,t} + \frac{1}{\widetilde{m}(\widetilde{J}_t)}\widetilde{Y}_{N,t} + \widetilde{I}_t + \Psi_{u_t}\frac{\widetilde{k}^p_{t-1}}{Z_t} \tag{1.8.2.30}$$

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:

$$R_t = R_{t-1}^{\rho_r} \left(\frac{\widetilde{\Pi}_t^{EMU}}{\widetilde{\Pi}^{EMU}} \right)^{(1-\rho_r)\rho_\pi} \tag{1.8.2.31}$$

1.8.3 Log Linearizated Model

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

$$\widehat{c}_{N,t} = \eta \widehat{m}(J_t) + \widehat{c}_t \tag{1.8.3.1}$$

$$\widehat{c}_{h,t} = \eta \widehat{m}(j_t) - \eta \widehat{j}_t + \epsilon \widehat{g}(s_t) + \widehat{c}_t \tag{1.8.3.2}$$

$$\widehat{c}_{f,t} = \eta \widehat{m}(j_t) - \eta \widehat{j}_t + \epsilon \widehat{g}(s_t) - \epsilon \widehat{s}_t + \widehat{c}_t \tag{1.8.3.3}$$

$$\widehat{c}^*_{h,t} = \eta \widehat{q} + \eta \widehat{m}(j_t) - \eta \widehat{j}_t + \eta \widehat{g}(s_t) + (\epsilon - \eta)\widehat{s}_t + \widehat{c}^*_t \tag{1.8.3.4}$$

The first order conditions of the household are:

$$(1 - h\beta z)\widehat{\lambda}_t = \widehat{\zeta}_t - h\beta z E_t[\widehat{\beta} + \widehat{\zeta}_{t+1}] + \frac{h}{z-h}\widehat{c}_{t-1} + \tag{1.8.3.5}$$

$$+ \left[\frac{1+h^2\beta}{1-\frac{h}{z}}\right]\widehat{c}_t + \left[\frac{h\beta z}{1-\frac{h}{z}}\right]E_t\widehat{c}_{t+1} - \frac{h}{z-h}\widehat{z}_t \tag{1.8.3.6}$$

$$\widehat{\lambda}_t = \widehat{\beta}_t + E_t\left\{\widehat{\lambda}_{t+1} + \widehat{r}_t^B - \widehat{\Pi}_{N,t+1} + \widehat{m}_t - \widehat{m}_{t+1}\right\} \tag{1.8.3.7}$$

$$\widehat{r}_t^k = \frac{\Psi''(1)u}{\Psi'(1)}\widehat{u}_t \tag{1.8.3.8}$$

$$\widehat{q}_t = (1-\delta)\frac{\beta}{z}E_t\widehat{q}_{t+1} + \left[1 - \frac{\beta(1-\delta)}{z}\right]E_t\widehat{r}_{t+1}^k + \widehat{\beta}_t + E_t\widehat{\lambda}_{t+1} - \widehat{\lambda}_t \tag{1.8.3.9}$$

$$\widehat{q} = \eta_K z^2\widehat{z}_t - \widehat{\epsilon}_t^I - \eta_K z^2\widehat{i}_{t-1} + (1-\beta)\eta_K z^2\widehat{i}_t - \beta z^2\eta_K E_t\widehat{i}_{t+1} \tag{1.8.3.10}$$

$$\widehat{\zeta}_t + \widehat{\epsilon}_t + \nu\widehat{l}_t = \widehat{\lambda}_t + \widehat{w}_t \tag{1.8.3.11}$$

The other equilibrium conditions are:

$$\widehat{k}_t = \widehat{u}_t + \widehat{k}_{t-1}^p \tag{1.8.3.12}$$

$$\widehat{k}_t^p = \frac{(1-\delta)}{z}\left[\widehat{k}_{t-1}^p - \widehat{z}_t\right] + \frac{z-(1-\delta)}{z}\left[\widehat{i}_t + \widehat{\epsilon}_t^I\right] \tag{1.8.3.13}$$

$$\widehat{\beta}_t = -\beta\psi^\beta\widehat{c}_t \tag{1.8.3.14}$$

Firms

Firms production functions in the two sectors are:

$$\widehat{y}_{N,t} = \widehat{a}_{N,t} - \alpha\widehat{z}_t + \alpha\widehat{k}_{N,t} + (1-\alpha)\widehat{l}_{N,t} \tag{1.8.3.15}$$

$$\widehat{y}_{h,t} = \widehat{a}_{h,t} - \alpha\widehat{z}_t + \alpha\widehat{k}_{h,t} + (1-\alpha)\widehat{l}_{h,t} \tag{1.8.3.16}$$

Cost minimization and marginal cost:

$$\widehat{k}_{N,t} - \widehat{l}_t = \widehat{w}_t - \widehat{r}_t^k + \widehat{z}_t \tag{1.8.3.17}$$

$$\widehat{k}_{h,t} - \widehat{l}_t = \widehat{w}_t - \widehat{r}_t^k + \widehat{z}_t \tag{1.8.3.18}$$

$$\widehat{mc}_{N,t} = (1-\alpha)\widehat{w}_t + \alpha\widehat{r}_t^K - \widehat{a}_{N,t} \tag{1.8.3.19}$$

$$\widehat{mc}_{h,t} = (1-\alpha)\widehat{w}_t + \alpha\widehat{r}_t^K - \widehat{a}_{h,t} \tag{1.8.3.20}$$

Pricing equation:

$$\widehat{\pi}_{h,t} = E_t\left\{\beta\widehat{\pi}_{h,t+1}\right\} + \frac{\phi-1}{\psi}\left[\widehat{mc}_{h,t} + \widehat{m}_t + \widehat{g}(s_t) - \widehat{j}_t\right] \tag{1.8.3.21}$$

$$\widehat{\pi}_{N,t} = E_t\left\{\beta\widehat{\pi}_{N,t+1}\right\} + \frac{\theta-1}{\psi}\left[\widehat{mc}_{N,t} + \widehat{m}_t\right] \tag{1.8.3.22}$$

Relative prices and International variables

Relative prices:

$$\widehat{s}_t = \widehat{s}_{t-1} + \widehat{\pi}_{f,t} - \widehat{\pi}_{h,t} \tag{1.8.3.23}$$

$$\widehat{g}_t = \widehat{g}_{t-1} + \widehat{\pi}_{T,t} - \widehat{\pi}_{h,t} \tag{1.8.3.24}$$

$$\widehat{j}_t = \widehat{j}_{t-1} + \widehat{g}_t - \widehat{g}_{t-1} + \widehat{\pi}_{h,t} - \widehat{\pi}_{N,t} \tag{1.8.3.25}$$

$$\widehat{q}_t = \widehat{q}_{t-1} + \widehat{s}_t - \widehat{s}_{t-1} + \widehat{j}_t - \widehat{j}_{t-1} + \widehat{g}_t - \widehat{g}_{t-1} - \widehat{m}(j_t) + \widehat{m}(j_{t-1}) + \widehat{\pi}^*_t - \widehat{\pi}_{f,t} \tag{1.8.3.26}$$

$$\widehat{m}(j_t) = \gamma_T \widehat{j}_t \tag{1.8.3.27}$$

$$\widehat{\pi}_{T,t} = \gamma_h \widehat{\pi}_{h,t} + \gamma_f \widehat{\pi}_{f,t} \tag{1.8.3.28}$$

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

International variables become:

$$\widehat{b}_t = \frac{1}{\beta z}\widehat{b_{t-1}} + \widehat{nx}_t \tag{1.8.3.29}$$

$$\widehat{nx}_t = share_n x[\widehat{y}_{h,t} - \widehat{c}_{h,t} - \widehat{s}_t - \widehat{c}_{f,t}] \tag{1.8.3.30}$$

$$\widehat{ca}_t = \widehat{b}_t - \widehat{b}_{t-1}\frac{1}{z} \tag{1.8.3.31}$$

Market Clearing and Monetary Policy Rule

Market clearing conditions

$$\widehat{K}_t = \gamma_N \widehat{K}_{N,t} + \gamma_T \widehat{K}_{h,t} \tag{1.8.3.32}$$

$$\widehat{L}_t = \gamma_N \widehat{L}_{N,t} + \gamma_T \widehat{L}_{h,t} \tag{1.8.3.33}$$

$$\widehat{Y}_{N,t} = \widehat{C}_{N,t} \tag{1.8.3.34}$$

$$\widehat{Y}_{h,t} = \frac{c_h}{y_h}\widehat{C}_{h,t} + \frac{c^*_h}{y_h}\widehat{C}^*_{h,t} \tag{1.8.3.35}$$

Real GDP:

$$\widehat{y}_t = \tag{1.8.3.36}$$
$$\frac{P_h}{P}\frac{y_h}{y}[j_t - g_t - m(j_t) + y_{h,t}] + \frac{P_N}{P}\frac{y_N}{y}[m(j_t) + y_{N,t}] + \frac{I}{y}\widehat{I}_t + \frac{r^k k}{y}\widehat{u}_t$$

Monetary policy rule (ECB):

$$\widehat{r_t} = \rho_r \widehat{r_{t-1}} + (1-\rho_r)\rho_\pi \frac{\pi_{IPS}}{\pi_{EMU}}[\widehat{m}(j_t) - \widehat{m}(j_{t-1}) + \widehat{\Pi}_{N,t}] \tag{1.8.3.37}$$

1.8.4 Jaimovich and Rebelo Preferences

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 1.45. We just specifiy those equations that are different with respect to the baseline model.

$$\zeta_t \left[c_t - hC_{t-1} - \epsilon_t^L \psi^L L_t^{1+v}\Omega_t\right]^{-\sigma} + \tag{1.8.4.1}$$
$$\lambda_t^{JR}\mu\left[c_t - h\bar{c}_{t-1}\right]^{\mu-1}\Omega_{t-1}^{1-\mu}Z_t^{1-\mu} = \lambda_t$$
$$\zeta_t \left[c_t - hC_{t-1} - \epsilon_t^L \psi^L L_t^{1+v}\Omega_t\right]^{-\sigma}\epsilon_t^L\psi^L(1+v)L_t^v\Omega_t = \lambda_t W_t \tag{1.8.4.2}$$
$$\zeta_t \left[c_t - hC_{t-1} - \epsilon_t^L \psi^L L_t^{1+v}\Omega_t\right]^{-\sigma}\epsilon_t^L\psi^L L_t^{1+v} + \lambda_t^{JR} = \tag{1.8.4.3}$$
$$= \beta_t E_t\left\{\lambda_{t+1}^{JR}(1-\mu)\left[c_{t+1} - h\bar{c}_t\right]^\mu \Omega_t^{-\mu} Z_{t+1}^{1-\mu}\right\} \tag{1.8.4.4}$$

and finally the law of motion of Ω_t

$$\Omega_t = (C_t - h\overline{C}_{t-1})^\mu \Omega_{t-1}^{1-\mu}(Z_t)^{1-\mu} \tag{1.8.4.5}$$

where λ_t is the lagrangian multiplier associated with the budget constraint, and λ_t^{JR} is the multiplier attached to law 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:

$$\zeta_t \left[\widetilde{C}_t - \frac{h}{Z_t}\widetilde{C}_{t-1} - \epsilon_t^L \psi^L L_t^{1+v} \widetilde{\Omega}_t \right]^{-\sigma} + \tag{1.8.4.6}$$

$$\widetilde{\lambda}_t^{JR} \mu \left[\widetilde{C}_t - \frac{h}{Z_t}\widetilde{C}_{t-1} \right]^{\mu-1} \widetilde{\Omega}_{t-1}^{1-\mu} = \widetilde{\lambda}_t$$

$$-\zeta_t \left[\widetilde{C}_t - \frac{h}{Z_t}\widetilde{C}_{t-1} - \epsilon_t^L \psi^L L_t^{1+v} \widetilde{\Omega}_t \right]^{-\sigma} \epsilon_t^L \psi^L (1+v) L_t^v \widetilde{\Omega}_t = \widetilde{\lambda}_t \widetilde{W}_t \tag{1.8.4.7}$$

$$\zeta_t \left[\widetilde{C}_t - \frac{h}{Z_t}\widetilde{C}_{t-1} - \epsilon_t^L \psi^L L_t^{1+v} \widetilde{\Omega}_t \right]^{-\sigma} \epsilon_t^L \psi^L L_t^{1+v} - \widetilde{\lambda}_t^{JR} + \tag{1.8.4.8}$$

$$+ \beta_t E_t \left\{ \widetilde{\lambda}_{t+1}^{JR} (1-\mu) \left[\widetilde{C}_{t+1} - h\widetilde{C}_t \right]^{\mu} \widetilde{\Omega}_t^{-\mu} \right\} = 0 \tag{1.8.4.9}$$

$$\widetilde{\Omega}_t = (\widetilde{C}_t - h\widetilde{C}_{t-1})^{\mu} \widetilde{\Omega}_{t-1}^{1-\mu} \tag{1.8.4.10}$$

where

$$\widetilde{\lambda}_t^{JR} = \lambda_t^{JR} X^{\sigma} \qquad \widetilde{\lambda}_t = \lambda_t X^{\sigma} \qquad \widetilde{C}_t = \frac{C_t}{X_t} \qquad \text{and} \quad \widetilde{\Omega}_t = \frac{\Omega_t}{X_t} \tag{1.8.4.11}$$

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

$$\zeta M1^{-\sigma}[\widehat{\zeta}_t - \sigma \widehat{M1}_t] + \lambda^{JR} \mu [\widehat{\lambda}_t^{JR} + (\mu-1)\widehat{M2}_t + (1-\gamma)\widehat{\omega}_{t-1}] = \lambda \widehat{\lambda}_t \tag{1.8.4.12}$$

$$M1\widehat{M1}_t = c\widehat{c}_t - \frac{hc}{z}[\widehat{c}_{t-1} - \widehat{z}_t] - \epsilon^L \psi^L L^{1+v} \omega [\widehat{\epsilon}_t + (1+v)\widehat{L}_t + \widehat{\omega}_t] \tag{1.8.4.13}$$

$$M2\widehat{M2}_t = c\widehat{c}_t - \frac{hc}{z}[\widehat{c}_{t-1} - \widehat{z}_t] \tag{1.8.4.14}$$

$$\widehat{\zeta}_t - \sigma \widehat{M1}_t + \widehat{\epsilon}_t^L + v\widehat{L}_t + \widehat{\omega}_t = \widehat{\lambda}_t + \widehat{w}_t \tag{1.8.4.15}$$

$$\zeta M1^{-\sigma} psi^L L^{1+v} [\widehat{\zeta}_t - \sigma \widehat{M1}_t + \widehat{\epsilon}_t^L + (1+v)\widehat{L}_t] + \lambda^{JR} \widehat{\lambda}_t^{JR} = \tag{1.8.4.16}$$

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

Chapter 2

The EMU and Imbalances. Is it an Anticipation Story?

We assess, with Bayesian estimation, the contribution of *anticipated vs unanticipated* shocks in the accumulation of the current account imbalances experienced inside the euro area periphery before the Great Recession. We estimate two specifications of the small open economy DSGE model presented in a previous study, using data for Ireland, Portugal and Spain (IPS). We determine the values of the crucial parameters: the trade elasticity, the elasticity between tradable and non tradable goods and the persistency of shocks. We obtain three main results. First, anticipated productivity shocks, whether in the traded or in the non-traded sector, cannot be the relevant sources of the experienced imbalances. Second, anticipated international yield spread shocks are the main drivers of the euro area periphery imbalances: analysing impulse-response functions and simulating the model, we show that anticipated yield spread shocks account for the majority of the experienced imbalances. Third, anticipated shocks are responsible for an important fraction of international variable fluctuations: more than four fifth of the current account movements are due to long-term anticipated shocks.

2.1 Introduction

In this paper we assess, with Bayesian estimation, the contribution of *anticipated vs unanticipated* shocks in the accumulation of the current account imbalances experienced inside the euro area periphery before the Great Recession. We estimate two specifications of the small open economy dynamic stochastic general equilibrium model presented in a previous study, using data for Ireland, Portugal and Spain. The objectives of the paper are twofold: first to exploit the estimated theoretical framework to uncover the sources of the experienced imbalances; second, to understand the role of *anticipated* shocks for international variable fluctuations.

Ireland, Portugal and Spain (henceforth IPS), from 1996 to the Great Recession, accumulated current account deficits, experienced real exchange rate appreciation and grew above trend. Figure 2.1 shows the path of those three variables for the weighted average of Ireland, Portugal and Spain.[1] The Great Recession revealed that the euro area countries that accumulated negative current account balances were those that suffered more from the crisis. Hence, it is important to understand the sources of those imbalances.

In the theoretical framework of the previous study we showed that the choice of some key parameters is crucial for the responses to shocks of international variables such as the current account and the real exchange rate. The most important parameters are the trade elasticity, the elasticity between tradable and non tradable goods and the persistency of the technology shocks. In order to use the model to derive implications regarding the sources of the experienced current account imbalances inside the euro area periphery, we need to estimate these parameters in a robust way.

[1] Annual HICP relative household consumption expenditure shares in the euro area are used as weights. Notice that we discard Greece from the analysis because the data for the period analyzed are unreliable.

We rely on Bayesian techniques to estimate the parameters mentioned aboe and all the other parameters for which, a wide range of values provided by empirical and theoretical studies, fail to give a precise and reliable calibration. The main advantage of using Bayesian methods, with respect to classical ones, is that a meaningful set of priors allows to reduce the short sample data problem we face, given the youth of the European Monetary Union.[2] In order to assign priors we refer to recent research projects to set a range of meaningful values. As done previously in the literature, we calibrate the remaining parameters.

After having estimated the model, we perform a variance decomposition of the model to identify what fraction of the international variable fluctuations can be accounted for by anticipated shocks. In particular, unanticipated, one-year anticipated and long term anticipated (10-quarters) components are introduced for each shock. The importance of productivity, preference, investment, labor supply, monetary policy and yield spread shocks as a source of uncertainty is analyzed using both the impulse-response functions and the variance decomposition of the estimated model.

To complete the analysis we simulate the model with a constructed series of anticipated shocks, taken from real data, to show how well we can track the actual evolution of the current account, the real exchange rate and the output growth for the weighted average of Ireland Portugal and Spain.

To check the robustness of the results we estimate a second specification of the model featuring Jaimovich and Rebelo type of preferences.[3] We then check if the fraction of international variable fluc-

[2]In section 2.3.1 we explain the choice of January 1, 1996, as the starting point for our analysis.

[3]Jaimovich & Rebelo (2009) constructed a specification of preferences that enables, through the introduction of a parameter, to control the wealth elasticity of labor supply. This type of preferences is often used in the anticipated shock literature because, minimizing the wealth elasticity of the labor supply, as in

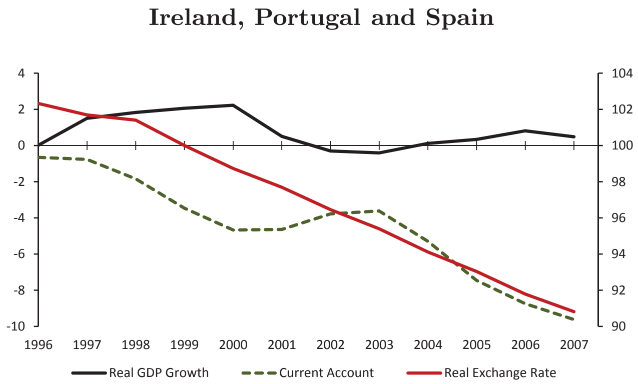

Figure 2.1: Real exchange rate, current account (percentage of GDP) and detrended output growth for the weighted average of Ireland, Portugal and Spain. Annual HICP (Harmonized Index of Consumption Prices) relative household consumption expenditure shares in the euro area are used as weights. Output growth is detrended in a model consistent way. Source: Eurostat.

tuations described by anticipated shock is in line with the results of the baseline specification. We show that the estimated values confirm the previous estimation results.

The main results of this study can be summarized as follows. First, anticipated as well as unanticipated productivity shocks, whether in the traded or in the non-traded sector, cannot be the relevant sources of the current account deficits experienced inside the EMU before the Great Recession. Second, anticipated international yield spread shocks are the main drivers of the euro area periphery imbalances. Third, the sum of all anticipated shocks are responsible 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 international yield spread shocks account for most of it.

Greenwood et al. (1988), it is possible to produce positive co-movement of output, hours worked, consumption and investment in response to permanent expected future changes in TFP.

The paper is organized as follows. After a brief summary of the main characteristics of the model in section2.2, section 2.3 illustrates the Bayesian estimation of the model. Section 2.4 analyzes which structural shock could explain the current account imbalance and investigates the importance of anticipated shocks for international variable fluctuations. Section 2.5 checks the robustness of the results presenting the estimation results of a different specification of the model. Section 2.6 concludes.

2.2 Summary of the Model

In this paper we perform the empirical assessment of the model presented in the previous study. Here we do not present the entire model but we just highlight the main characteristics, which could be relevant for understanding the empirical results.

We consider a two-sector New Keynesian Dynamic Stochastic General Equilibrium (DSGE) small open economy model. Domestic economy is part of a monetary union with a foreign economy which, for analytical simplicity, represents all the rest of the union (henceforth RoEMU). The domestic economy is small and does not affect the rest of the world, which is considered exogenous.

The domestic representative household consumes, saves or borrows through domestic and foreign internationally traded bonds, supplies labor and decides the level of the capital to be used in the production. In the baseline model we allow for a standard utility function separable in consumption and hours worked. The capital depreciates and investments are costly. The model features variable capital utilization and adjustment cost to investment in order to generate aggregate and sectoral co-movements in presence of anticipated shocks.[4] The consumption bundle is a collection of non tradables and

[4] See Jaimovich & Rebelo (2008), Jaimovich & Rebelo (2009) and Schmitt-

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.

Within each country there are two sectors: one producing tradable goods and the other producing non tradable goods. 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 labor augmenting permanent shift in the level of technology, we assume that each sector is characterized by persistent specific technology shocks with a trend. 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 the considered small open economy contributes for little above 13 percent. 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 (X^*) will characterize foreign variables, an overscript tilde ($\widetilde{X}$) will indicate detrended variables, lower case letters (x) will characterize natural logarithm and overscript hat ($\widehat{X}$) will define deviations from the steady state.

Grohe & Uribe (2012).

2.3 Estimation

We rely on Bayesian techniques to estimate the subset of key parameters of the model for which there is both theoretical and empirical controversy. Two are the main purposes of the estimation procedure: finding the values of the parameters which are crucial for the responses to shocks of international variables such as the current account and the real exchange rate and understanding the role of anticipated shocks in the EMU business cycle. For the remaining parameters we use standard calibration methods, which is the same as assigning infinitely tight priors. This allows to better compare our results with previous studies. We start by describing the data used to estimate the model and then we present the set of calibrated parameters. Following, we present the choice of the priors and compare them with the estimated posterior.

2.3.1 Data

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

We choose the last quarter of 2007, that is 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. Understanding the link between the sources of the accumulating imbalances and the crisis is an interesting future question which will not be addressed in this paper. So we focus on the period 1996:1-2007:4.

Ireland, Portugal and Spain experienced a similar dynamics of the current account during the period under investigation. We are aware that, to be coherent with the assumptions of our model, we should present the current account position only vis-a-vis the rest of the monetary union. However, even if these data are not readily available, we claim that the analysis for Spain and Portugal would not change. Using intra EU-12 trade balances as a proxy for the intra euro area current account, as suggested by Ahearne, Schmitz & von Hagen (2008), the results do not 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 also experienced similar dynamics of the real exchange rate (with respect to EMU countries) and the 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 observations 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.

Table 2.1: Observable Variables and Model counterparts

Observable variable	Model counterpart	Adjusting factor
Real GDP growth IPS	$\widetilde{y}_t$	z
Non tradable real GDP growth IPS	$\widetilde{y}_{N,t}$	z + g^{NT}
Real consumption growth IPS	$\widetilde{c}_t$	z
Real Investment growth IPS	$\widetilde{I}$	z
Current account ($\%GDP$)	$\widetilde{ca}_t$	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	$\widetilde{q}_t$	$\pi_{EMU} - \pi_{IPS} + g^{NT}$
Change avg weekly hours worked	L_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^*

Following Beltran & Draper (2008) we also include 3 time series from the exogenous foreign economy block in the estimation. We can do this because, in the previous study, we assumed that our open economy is so small that it does not have any effect on the rest of the world: the foreign block is then exogenous. We include, as unrestricted autoregression, after having subtracted the IPS group from the data, these 3 variables: HICP EMU(-IPS) inflation, foreign tradable HICP EMU(-IPS) inflation and foreign growth rate of real consumption.

The foreign observables are assumed to be generated by the following processes:

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

where u^{Π^*}, $u^{\Pi^*_T}$ and u^{c^*} are independent and identically distributed random errors. Details on the data are available in appendix 2.8.1.

Table 2.1 lists the 12 observable variables and their model counterparts. 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:

$$\widetilde{y}_t = logy_t^{data} - x_0 - xt = u_t^X \tag{2.3.1.1}$$

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

$$y_t^{data} - \widetilde{y}_t = x \tag{2.3.1.2}$$

2.3.2 Calibrated parameters

Table (2.2) 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

Table 2.2: Calibrated Parameteres

Par	Value	Description	Source
v	1	Inverse elasticity of labor supply	Smets & Wouters (2003)
χ	-100	Discount factor, arbitrary parameter	Ferrero et al. (2008)
ψ^{β}	$1.017 \cdot 10^{-4}$	Spillover effect of avgerage detrended consumption on discount factor	Steady-state of $\beta = 0.99$
ψ^{L}	13.3554	Labor supply preference parameter	$L^{ss} = 0.236$, Eurostat 96/07
α	0.3	Capital Share	Smets & Wouters (2003)
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)

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 et al. (2006), that $p = 0.75$ 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.

2.3.3 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 2.3 summarizes the prior of the parameters that we use in the estimation.

The elasticity of substitution between home and foreign produced tradable goods, 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 claim 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 and Smith puzzle[5] (Corsetti et al. (2008) and Benigno & Thoenissen (2008)) and the volatility of the real exchange rate (Thoenissen (2011)).[6] 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

[5] Backus et al. (1993)

[6] The list of cited studies is far from being complete. Its only purpose is to give some important reference and an idea of the extremes of those estimates.

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 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 the productivity processes 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 2.3: 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

2.3.4 Posterior Distribution

Table 2.3 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 2.2 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 with our focus on peculiar area: the European Monetary Union. Not surprisingly, following the reasoning of Lubik & Schorfheide (2006), in a monetary union, where the law of one price is easier to be satisfied, 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 (2010) for Spain in a similar timespan.

The autoregressive parameters of the innovation processes imply that there is no much 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

Elasticities of Substitution

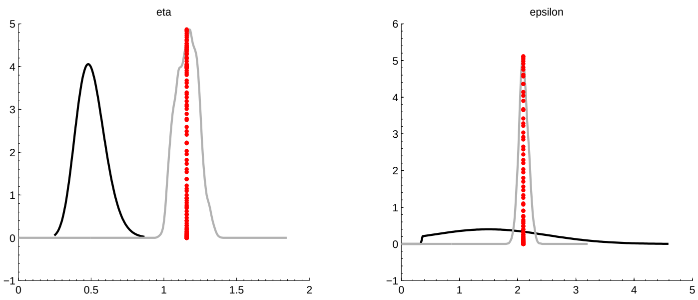

Figure 2.2: Prior and Posterior density

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-quarter 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-quarter anticipation, play an important role for almost all shocks.

2.4 What Explains Current Account Imbalances in the Euro Area?

Ireland, Portugal and Spain, from 1996 to 2007, accumulated current account deficit, experienced real exchange rate appreciation and grew slightly above trend (figure 2.1).[7] Current events in the euro area have shown that international imbalances have contributed to exacerbate the vulnerability of European Monetary Union (EMU) periphery. Therefore, we are interested in understanding the reasons that explains the current account imbalances in the euro area. In particular we want to uncover the sources of the current account imbalances experienced in the euro area periphery before the Great Recession and we want to understand the role of unanticipated vs. anticipated shocks on international variable fluctuations.

We start by exploiting the impulse-response functions of the estimated model to learn which shock can generate the experienced path of the current account, the real exchange rate and the output growth. Following, we understand, through a variance decomposition of the estimated model, what fraction of international variable fluctuations can be ascribed to anticipated shocks and which ones are the most relevant.

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 the ones resulting from a deeper financial integration that allows countries with

[7] Periods of increasing current account deficits coincide with output growing above trend. During 2002 and 2003, when the output was growing below trend, Ireland, Portugal and Spain experienced a reduction in the deficit.

better growth prospect to borrow capitals from abroad 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.

The idea that capitals, inside the EMU, were flowing towards catching up countries with higher current or expected productivity growth has partially lost empirical support.[8] In this section we exploit the estimated theoretical model to test which unanticipated and anticipated shocks are in fact important sources of the experienced current account imbalances inside the euro area.

2.4.1 Impulse-Responses

With respect to the previous study, we can now study the dynamics of the model in response to a wide range of possible shocks, using estimated parameters. 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 take place 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 the first assumption: in section 2.5 we show how the results change when we use the estimated model in which the preference specification allows to control the wealth elasticity of the labor supply.

Sector specific technology, common productivity, permanent shift in the level of technology, investment cost, monetary policy, yield spread, preferences and labor supply are the shocks we consider in

[8] 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. See also Schmitz & von Hagen (2009), Sodsriwiboon & Jaumotte (2010), Barnes, Lawson & Radziwill (2010), Barnes (2010) and Belke & Dreger (2011) for the dynamics and consequences of large current account deficits in the euro area from a policy perspective.

Unanticipated Tradable Shock

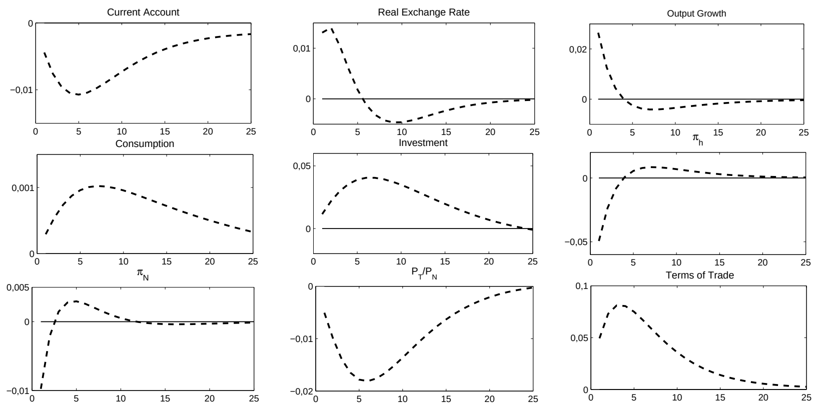

Figure 2.3: Impulse-response to an unanticipated technology shock in tradable sector.

our specification. For each shock we try to understand if it is an important source of the euro area periphery current account imbalance. We focus on the reaction of output growth, current account and real exchange rate to disclose which shock can generate the experienced co-movement of those three variables (figure 2.1).

To highlight some important mechanisms underneath productivity related shocks, we start by presenting the impulse-responses to a one standard deviation positive unanticipated technology shock in the tradable sector (figure 2.3). As the tradable technology jumps up, consumption and investment both increase pushing up also the total output. At the firm side, marginal costs of production in the tradable sector decrease and due to the stickiness of prices and the imperfect substitutability of goods, firms in that sector have excessive production. Prices in the tradable sector are forced down and so the demand for labor and capital. Therefore, wages and the rental rate of capital decrease resulting in a reduction of the marginal costs

TFP shocks

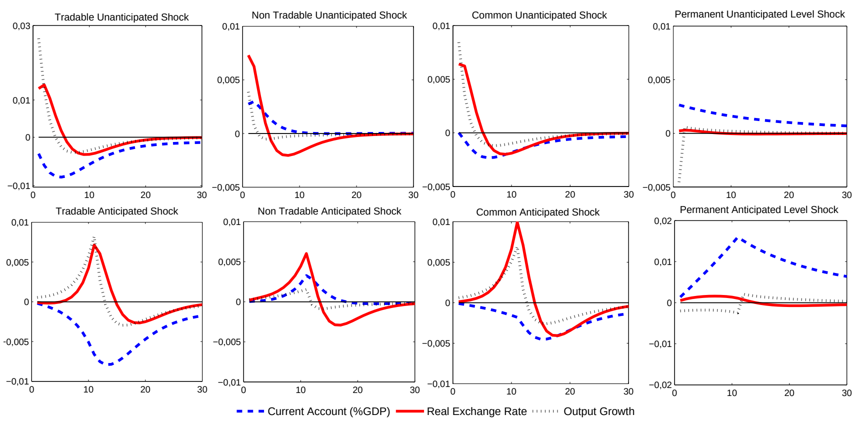

Figure 2.4: Impulse-response of current account(% of GDP), real output growth and real exchange rate to all types of technology shocks included in the model.

also in the non tradable sector. As prices go down in both sectors, the real exchange rate depreciates. However, notice that a sectoral Balassa-Samuelson effect is still active: non tradable goods become relatively more expensive than tradable goods. Home produced tradable goods become internationally more competitive through a term of trade depreciation.[9] Despite this, 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 advantage.

Everything works almost equally 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

[9] As we will see later the high elasticity of substitution 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.

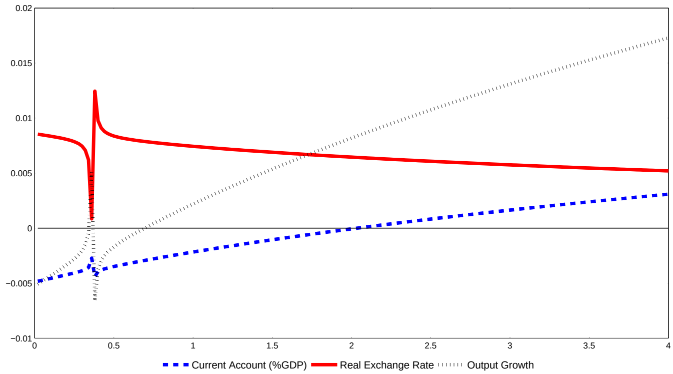

Figure 2.5: Impact of a technology shock, common to both sectors, on current account(% of GDP), real exchange rate and real output growth when we allow the international elasticity of substitution between tradable goods, ϵ, to vary.

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.

With the explained mechanism in mind, we now focus just on output growth, current account and real exchange rate. Figure 2.4 summarizes the responses of those three variables to a positive one standard deviation shock in all productivity processes included in the model. The upper row of the figure shows the responses to unanticipated shocks while the second row displays the ten-quarter anticipated shocks. Going from the left to the right we look at a sector specific shock in the tradable and non tradable sectors, a common shock in both sectors and a permanent shift in the level of technology. As we can see, none of the productivity shocks considered can

Non TFP shocks

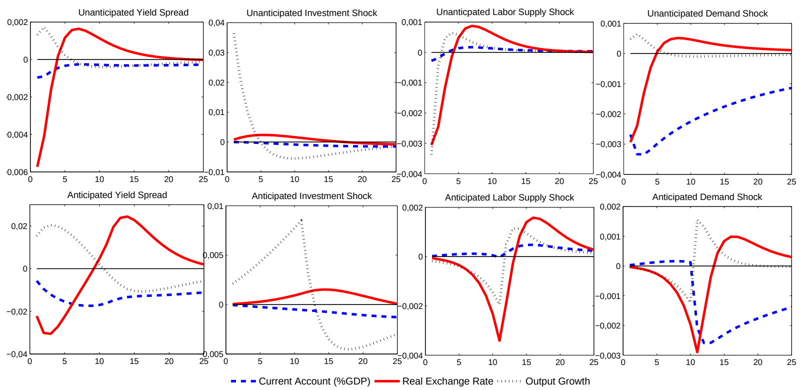

Figure 2.6: Impulse-response of current account(% of GDP), real output growth and real exchange rate to a drop in the yield spread, to an improvement in the investment technology, to a positive labor supply shock and to a positive demand shock.

reproduce the experienced co-movement of current account, real exchange rate and output growth, shown in figure 2.1.

The important result is 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 2.5, 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

Bond Yield Spread

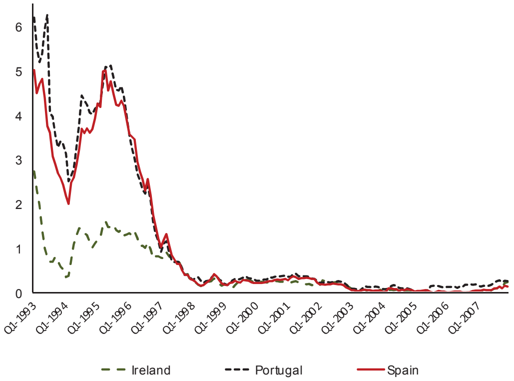

Figure 2.7: Spread of the interest rates for long-term government bonds between Germany and Ireland, Portugal and Spain. The data are based on central government bond yields on the secondary market, gross of tax, with a residual maturity of around 10 years. Source: Eurostat.

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 quite wide. Current account reacts positively when goods are more substitutable and it reacts negatively if they are more complementary. As shown by Corsetti et al. (2008), in the presence of a marginal cost advantage with highly substitutable tradable goods, 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.

Having shown that none of the productivity shocks included in the model can generate the experienced co-movement, we study the reaction of the model to other shocks. Figure 2.6 shows the responses to a drop in the yield spread, Sp_t, to an improvement in the investment technology, ϵ^I, to a positive labor supply shock, ϵ_t^L, and finally to a positive demand shock, ϵ^{ζ_t}.

Three are the shocks that can generate a contemporaneous deterioration of the current account, appreciation of the real exchange rate and increase in the output growth: unanticipated and anticipated yield spread drop and unanticipated positive demand shocks. Indeed, from figure 2.6, we see that investment shocks do not generate a real exchange rate appreciation and labor supply shocks move current account and real exchange in the right direction but push output growth below trend.

The dynamics generated by an unanticipated drop in the yield spread and an unanticipated increase in demand are somehow similar, if not for one variable. Both shocks lead to an increase in consumption that generates an increase in the demand for both tradable and non tradable goods. This pushes prices up in both sectors (but less than optimal, doing the stickiness of prices) and firms respond with an increase in the demand for labor and capital. Wages and rental rate of capital goes up, leading to an increase in the marginal costs. The result is an appreciation of the terms of trade and of the real exchange rate. The current account deteriorates both because of the increase in demand but also because of the lower price competitiveness of exportable goods. So far the dynamics implied by a decrease in the cost of borrowing and a pure increase in preferences are similar. However the two shocks imply opposite reactions of the real investment: a decrease in the cost of borrowing leads to an increase in the amount of investment, while the pure demand shock pushes investment down. Ireland, Portugal and Spain, between 1996 and 2007,

Table 2.4: Share of Variance Explained by Anticipated Shocks

Shock	Output Growth	Current Account(% of GDP)	Real Exchange rate
Unanticipated	46.02	14.13	60.48
4-Quarters Anticipated	11.36	9.51	10.62
10-Quarters Anticipated	42.61	76.36	28.89

Note: Sum of all shocks grouped by the length of anticipation. The unconditional variance decomposition is computed at the mean of the posterior distribution of the estimated structural parameters.

experienced a persistent increase in real investment, permitting us to conclude that the demand shocks are not the main driver of the imbalances in the euro area periphery.

Unanticipated and anticipated drop in the yield spread are the major sources of the experienced current account imbalance inside the EMU. Figure 2.7 shows that, in fact, a drop in the yield spread is what characterized Ireland Portugal and Spain starting in 1996.[10] The analysis in the next section will reveal that the long term anticipated component accounts for the majority of the experienced movements. From figure 2.6 we can already see that the anticipated shock implies a persistent deterioration of the current account while the anticipated shock does not.

2.4.2 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 international variables. 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 2.4 displays the share of unconditional variances of output growth, current account and real exchange rate explained by the

[10] We use government bond as a proxy for the riskless assets.

Table 2.5: Unconditional Variance Decomposition

Shocks		Output Growth	Current Account(% GDP)	Real Exchange rate
Techn. in both sectors	$u_{0,t}^{A}$	0.0091	0.002	0.0152
	$u_{4,t}^{A}$	0.0135	0.0062	0.0149
	$u_{4,t}^{A}$	0.0153	0.0113	0.0169
	Σu^{AH}	0.0379	0.0195	0.0470
Tradable tech.	$u_{0,t}^{AH}$	0.0955	0.0397	0.0651
	$u_{4,t}^{AH}$	0.0131	0.0135	0.0052
	$u_{4,t}^{AH}$	0.0197	0.0291	0.0086
	Σu^{AH}	0.1283	0.0823	0.0789
Non tradable tech.	$u_{0,t}^{AN}$	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
Permanent prod. Level	$u_{0,t}^{X}$	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
Demand	$u_{0,t}^{\zeta}$	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
Labor supply	$u_{0,t}^{L}$	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
Investment specific	$u_{0,t}^{I}$	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
Monetary Policy	u_{t}^{r}	0.0976	0.0786	0.3967
Yield spread	$u_{0,t}^{Risk}$	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
Foreign Tradable price	$u_{t}^{\Pi_{T}*}$	0.0005	0.0002	0.0212
Foreign CPI	$u_{t}^{\Pi*}$	0.0007	0.0002	0.0666
Foreign consumption	u_{t}^{c*}	0.0426	0.003	0.0004
	Σu^{*}	0.0438	0.0034	0.0882

Note: The unconditional variance decomposition is computed at the mean of the posterior distribution of the estimated structural parameters.

unanticipated shocks and the short and long run anticipated innovations. The sum of all news shock account for 54 percent of output growth fluctuations, 40 percent of real exchange rate variability and 86 percent of current account movements.

Table 2.5 presents the contribution of all the shocks to the variance of those three variables. 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: yield spread 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 ten-quarter anticipated drop in the yield spread. 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.

The most striking result is that only two shocks can explain almost all the current account fluctuations: ten-quarter anticipated permanent shifts on the level of productivity and 10 quarters anticipated shocks on the yield spread. Permanent productivity jumps account for a little more than 10 percent, with almost the same contribution of unanticipated and anticipated innovations. Investment, labor and preference shocks, once we include the yield spread, 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 the most important sources of the current account imbalance experienced by Ireland, Portugal and Spain.

2.4.3 Simulation

We have learned that long term anticipated yield spread shocks have played an important role in the accumulation of imbalances in the euro area periphery. To check for the robustness of the result we simulate the model with the actual realization of the anticipated yield spread shocks and we see how well the model can track the actual evolution of the current account, the real exchange rate and the output growth. The hard task is to find a measure of the anticipated long term yield shock. Aware of possible weaknesses we propose the following procedure to get an estimate of the shocks. The intuition behind our choice is to assign to anticipated premium shocks all the movements in the long term yield that cannot be explained by movements in the short run interest rates and by current realization of the shock to the premium. We now explain the details of the procedure we follow.

Denote with $i_{1,t}$ the one-year nominal interest rate in year t and with $i^e_{1,t+1}$ the expected one-year interest rate in year $t+1$. The long term interest rate reflects current and future expected short term interest rates and can be written as:

$$i_{2,t} \approx \frac{1}{2}(i_{1,t} + i^e_{1,t+1}), \qquad (2.4.3.1)$$

Equation 2.4.3.1 tells that the two-years interest rate in year t is approximately the average between the current one-year interest rate and the one-year interest rate expected for the following year. If we include a stochastic risk premium, $N \sim (0,1)$, then equation 2.4.3.1

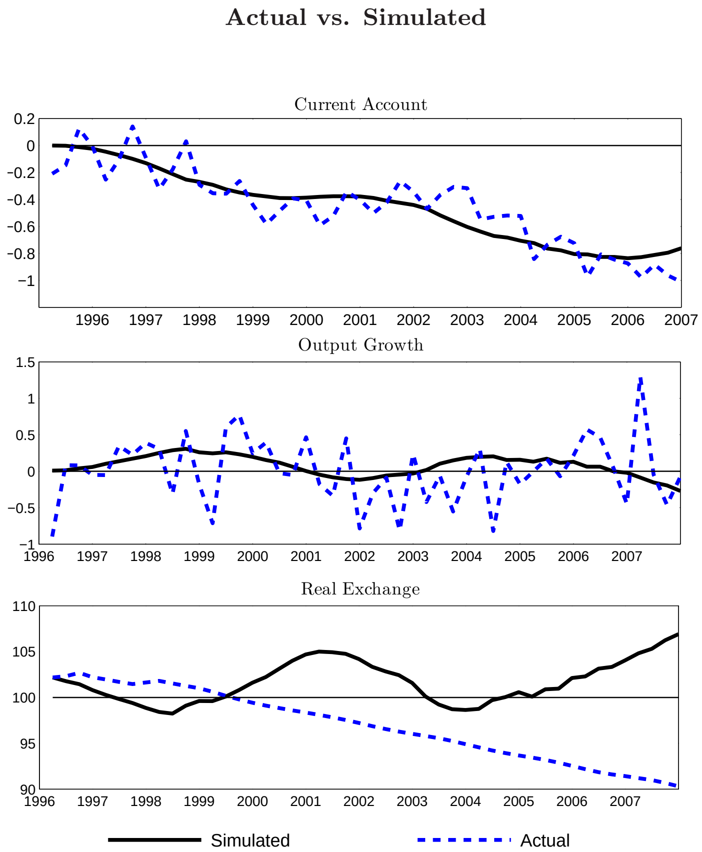

Figure 2.8: Actual and simulated evolution of the current account, the output growth and the real exchange rate of Ireland Portugal and Spain. Source: Eurostat.

can be written as:

$$i_{2,t} = i_{2,t}^{RF} + Risk_{2,t} \approx \frac{1}{2}\{[i_{1,t} + i_{1,t+1}^{e,RF} + Risk_{1,t} + Risk_{1,t+1}^{e}]\}, \quad (2.4.3.2)$$

where RF denotes the risk free rate, $Risk_{1,t}$ is the actual realization of the risk premium shock and $Risk_{1,t+1}^{e}$ is the one period anticipated risk premium shock. Therefore, it is easy to see that, as long as we have all the other components in the equation, we are able to find a value for the anticipated risk premium shock. In the data both $i_{2,t}$ and $i_{1,t}$ are available. Notice that today's interest rate includes already the risk free rate and the current risk premium shock and is equal to $i_{1,t}^{RF} + Risk_{1,t}$. In order to get the anticipated risk premium shock we just need to find an estimate for $i_{1,t+1}^{e,RF}$. We can get it from the model: it coincides with the expected future risk free rate, forecasted by the rational agent, if there are no shocks in the economy.

Therefore, combining the available data with the implications of the model we can find an estimate for the anticipated risk premium shock. In particular, in our framework, we look for the long term anticipated yield spread shock but the reasoning is equivalent. We focus on 10-years bond yield, assuming that the spread is between the IPS and Germany.[11]

Figure 2.8 shows the actual and simulated evolution of the current account, the real exchange rate and the output growth when we feed the model with the historical path of anticipated yield spread shock as the only source of uncertainty. The current account is by a large extent explained by the anticipated fluctuations of the yield spread. It is quite impressive how well the anticipated fluctuations in the yield can account for the underlying movement of the current account.

[11] It is important to notice that our technique to find anticipated yield spread shocks cannot distinguish between different length of anticipation. In the 10-quarters anticipated shocks we include all the shocks, from t+1 onwards, that generates a movement in the long term yield not explained by short run components. Data are taken from the Eurostat.

It fails to match the cyclical fluctuations, for which other factors will be important, but it matches the slower movements fairly well. Focusing on the output, we see that the dynamics can be partially explained by the anticipated drop in the yield spread. However notice that the importance of anticipated spread shocks for GDP seems to be decreasing throughout the sample. The real exchange rate, as also found in the variance decomposition of the shocks, cannot be explained with only anticipated shocks in the yield spread.

The results from the simulation confirm what we have found using the impulse-responses and the variance decomposition of the shocks and makes a strong point in attributing long current account movements to anticipated yield spread shocks.

2.5 Robustness - Jaimovich and Rebelo Preferences

Often, in theoretical models, an expected persistent shock in technology leads to a reduction in hours worked. In the previous study we understood how the wrong behavior of the labor dynamics can be driven by positive wealth effect. To make sure that our estimation results are not driven by the wrong behavior of the labor supply we substitute the baseline utility function specification with the non separable formulation introduced by Jaimovich & Rebelo (2009). This utility function allows to control the wealth elasticity of the labor supply through a parameter. For a full model specification we cross refer to section 3 of the previous study. Here we start by presenting the set of calibrated parameters and the priors used in the estimation.

Following section 2.3, before estimating the model with Bayesian techniques, we calibrate some parameters. The majority of the parameters overlap with the ones used for the baseline model. Therefore, we confirm the previous calibration and prior distribution. Three

Table 2.6: 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

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 Schmitt-Grohe & Uribe (2012).

Table 2.6 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 results are in line with the estimation of the parameter carried out by Schmitt-Grohe & Uribe (2012) with aggregated data. v is estimated to be high, close to 5.7 which implies, given the small value of μ, a low Frisch elasticity of labor supply. All other estimated parameters are really close to the value found in the estimation presented in section 2.3: the international elasticity between tradable goods is not statistically different; the elasticity of substitution between tradable and non tradable goods is slightly lower as the degree of habit persistence in consumption; instead capital adjustment cost elasticity is higher in this second estimation. The autoregressive components of productivity in the tradable sector and in the labor supply shocks are more persistent in this specification. For the standard deviation of the shocks the same analysis presented for the baseline model applies. The only major difference is the higher

Shocks - Jaimovich and Rebelo utility

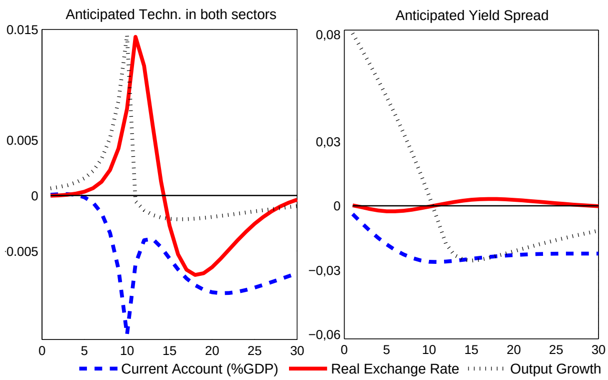

Figure 2.9: Impulse-response of current account(% of GDP), real output growth and real exchange rate to a drop in the yield spread for the model specification with the Jaimovich and Rebelo types of preferences.

standard deviation of preference shocks.

Anticipated shocks explain a big share of variables fluctuation. For instance 10-quarters anticipated fluctuation of the yield spread explain even a bigger share of the unconditional variance of output growth, current account and real exchange rate fluctuations.

Figure 2.9 plots the impulse-response of output growth, current account and real exchange rate to a 10-quarters positive one standard deviation anticipated drop in the yield spread. As for the baseline model, both shocks are able to generate a current account deficit but only the yield spread decrease generates a contemporaneous appreciation of the real exchange rate. A complete analysis confirms that all the results are robust under the model specification with the Jaimovich and Rebelo types of preferences.

2.6 Conclusions

Ireland, Portugal and Spain, from 1996 to 2007, accumulated current account deficit, experienced real exchange rate appreciation and grew slightly above trend. Current events in the euro area have shown that international imbalances have contributed to exacerbate the vulnerability of European Monetary Union (EMU) periphery.

In this paper we have focused on the sources of the current account imbalances experienced in the euro area before the Great Recession and we have investigated the role of *unanticipated vs. anticipated* shocks on international variable fluctuations. Using an estimated small open economy DSGE model, we have established the importance of *anticipated* shocks in the accumulation of the experienced current account imbalances.

The idea that capitals were flowing towards "catching-up" euro area countries with high current or expected productivity growth have lost empirical support. This paper shows that also theoretically, anticipated as well as unanticipated productivity shocks, whether in the traded or in the non-traded sector, cannot be the relevant sources of the current account deficits experienced inside the EMU before the Great Recession. The main driver of current account imbalances experienced by Ireland, Portugal and Spain are anticipated drops in the international yield spread.

Simulating the model with just data on the long term anticipated yield spread shock we have shown that we can match really well the experienced slow movements of the current account and, for the first part of the sample, also the dynamics of the output growth. Unanticipated interest rate shocks are, on the other hand, the most important source of the real exchange rate appreciation.

Anticipated shocks account for a large fraction of the fluctuations of international macroeconomic variables. The sum of all anticipated shocks are responsible 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 international yield spread shocks account for most of it.

The results are robust to different specification of the model. Estimation and impulse-response analysis for a specification of the model with Jaimovich and Rebelo type of preferences have confirmed all the results.

To conclude, whenever we are interested in understanding the sources of current account imbalances, we can't just look at the dynamics of the current account. Independently of the particular episode we are investigating, understanding the sources of the experienced current account imbalances cannot be done without considering the real exchange rate and the output growth. Focusing on the comovement between these variables allows to avoid mis-interpretations of current account responses to very different shocks.

A new distinction between types of current account imbalances is needed and this distinction is to be characterized by the sources of those imbalances. Therefore future studies should further analyze the implications of the sources of the imbalances and the conditions under which current account imbalance can be defined as "good" or "bad".

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2.8 Appendix

2.8.1 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

Chapter 3

News Shocks and International Business Cycles

Starting from a two-country, two-good real business cycle model with complete financial markets, we study the role of anticipated shocks in the international real business cycles (IRBC). The increased synchronization of the United States and the European Union business cycles with the rest of the world and the experienced increase in the international financial market integration motivates the search for a solution of the IRBC puzzles that does not rely on the incompleteness of financial markets. Anticipated productivity shocks, in a standard IRBC model, featuring weak short-run wealth effects on the labor supply and investment adjustment costs, match the observed cross-country correlation of output, consumption, investment and hours worked. We conclude that anticipated shocks are an important source of international synchronization in a world in which financial markets are becoming more integrated.

3.1 Introduction

The stochastic growth model developed by Backus, Kehoe & Kydland (1992), in particular the two good extension proposed by Backus, Kehoe and Kydland (1994 and 1995, henceforth BKK or standard IRBC model), has been used extensively in the literature to understand international business cycle properties. The original formulation with complete financial markets has been used successfully to explain the short run counter-cyclicality of the net export and the S-shaped cross-correlation of the trade balance and the terms of trade.[1] However, it is a well documented fact that the model fails to match the empirical positive cross-country correlations of output, employment and investment and that it cannot account for some important properties of the real exchange rate.[2]

Different studies have tried to understand what modifications of the model would help to solve those puzzles. Typically this literature assumes that financial markets are incomplete and the reason is straight forward: the existence of a full set of state-contingent assets implies perfect distribution of risks among domestic and foreign agents and determines the efficient allocation of resources; therefore, country specific shocks are spread internationally generating an almost perfect cross-country correlation of consumption and opposite cross-country reaction of investment and employment (wealth effect).

From the first quarter of 1961 to the first quarter of 2000 the United States and the European Union business cycles have become less synchronized with the cycle in the rest of the world. Heathcote & Perri (2003) explain that this fact can be seen as a transition from a less to a more financial integrated world. We are now interested in understanding how the business cycle correlations have evolved

[1]See Backus et al. (1994).

[2]Section 3.2.1 lists all the puzzles related to the standard IRBC model.

in the past decade, as the international financial integration process continued (Lane & Milesi-Ferretti (2007), Coordinated Investment Portfolio Survey, CIPS).

We update the sample of Heathcote & Perri (2003) up to the first quarter of 2012 for the United States (USA) and the European Union (EU, 15 countries). We use a broader and a narrower measure for the rest of the world to check how the USA and the EU business cycles co-move with respect to the rest of the world. Surprisingly, after the first documented decrease in the international business cycle synchronization (1960-2000), the past decade has been characterized by a strong increase in the cross-country correlation of business cycles. In the time span 1994:1-2012:1 the international correlation of output, consumption and employment reached levels well above the values registered in 1963:1-1979:4.

Therefore, we want to understand how the standard international business cycle model can account for a high international business cycle synchronization in a world in which the assumption of complete financial markets is less counterfactual. We propose anticipated shocks as the solution.

The existence of complete international financial markets implies full international risk sharing and efficient allocation of resources across-countries. Full insurance implies that shocks are spread among countries through the value of the financial assets while the efficient allocation implies that capitals are always invested in the more productive country. Understanding why these two implications restrain unanticipated but not anticipated shocks to generate cross-country co-movement is the main contribution of the paper.

We start by introducing anticipated shocks in the two-country, two-good real business cycle model with complete financial markets and we compare the results with the implications of the baseline model specification of Backus et al. (1994). We show that the model with anticipated shocks can generate the positive cross-country correlation of output, investment and hours worked that the baseline model fails to reproduce. The intuition for why unanticipated shocks in world with complete financial market cannot generate international co-movements is well known in the IRBC literature, and is as follows.

Consider an unanticipated positive productivity shock in the home country, which is for simplicity internationally uncorrelated. In the home country, the raise in productivity increases the present discounted value of future income and then the value of the domestic assets in the portfolio.[3] As the household wealth increase, where the wealth is given by the value of the portfolio, agents want to consume more and have more leisure (both normal goods), increasing consumption and decreasing the labor supply. On the other hand, as the increase in productivity makes capital and labor more productive, firms increase the demand of capital and labor pushing up their prices. In reaction, households increase investment and the amount hours worked.[4] In the home country, the reaction to a positive unanticipated productivity shock is an increase in output, consumption, hours worked and investment. What happens to the foreign economy? As the value of the domestic assets increases,[5] the value of the portfolio held by foreign agents raises, increasing the wealth of foreign households. The increase in wealth pushes up the demand for consumption and leisure, resulting in an increase in consumption

[3]Notice that through out the paper a positive/negative productivity shock, anticipated or unanticipated, will always increase/decrease the present value of future income resulting in an increase/decrease in the value of the financial assets. Henceforth we refer to these as changes in the wealth, implying that the lifetime wealth of agents is determined by the value of assets that they hold.

[4]Notice that the shift in the labor demand generates an increase in wages such that the new equilibrium in the labor market, where both the demand and supply curve shifted, is characterized by higher number of hours worked and higher wages.

[5]Notice that we didn't assume any bias in the portfolio holdings that implies that both domestic and foreign household have the same amount of domestic and foreign assets.

and a decrease in the labor supply. Differently from the home country, the firms demand of labor and capital remains unchanged, given the unchanged productivity. The result is a lower amount of hours worked, for a higher wages, that implies lower output. Given the contemporaneous increase in consumption and decrease in output, investment has to be reduced. Therefore, in the foreign economy, the reaction is an increase in consumption but a decrease in output, hours worked and investment. So far, we have shown the mechanism that ensures that unanticipated productivity shocks, in a model with complete financial markets, cannot generate positive international comovements of output, employment and investment but only generates positive cross-country correlation of consumption.

How is it possible that the same model can generate positive comovements when the shocks are the same but anticipated? The intuition is straight forward and is as follows. The only difference between unanticipated and anticipated shocks is the period which separates the announcement from the actual realization of the shock. During this periods, the values of the assets change but the real side of the economy is unaffected. But, as we already know from the unanticipated shocks mechanism, the change in the value of the assets affects the wealth of the domestic and foreign economy in the same way, due to full risk sharing assumption. Therefore, the two economies are affected by the same movement in wealth which will generate a positive co-movement. When the shock realizes we are back to the mechanism presented in the unanticipated shock case. To summarize, anticipated shocks are able to generate positive co-movement in the period between the announcement and the actual realization of the shock thanks to the symmetric reaction of the wealth effect. Another way of interpreting the role of the anticipated shock is that, in the lag between the announcement and the actual realization, it generates a symmetric cross-country demand shock. Longer is the period of the announcement, stronger will be the co-movement generated by the model.

Next, with the help of the impulse response functions, we learn that, although we are able to match the IRBC cycle properties, we fail to match the closed economy business cycle regularities: macroeconomics aggregate should increase in response to a positive anticipated productivity shock. In fact, while consumption goes up, output, investment and employment fall in both countries as a reaction to a positive anticipated shock.[6] The reason is the well known[7] failure of standard neoclassical models to generate the correct domestic business cycle dynamics in response to persistent anticipated shocks. The increase in the wealth, coming from the the positive anticipated shock, generates a decrease in the labor supply that pushes investment and output down: output, investment and hours worked fall in the country that is hit by the news shock. As a consequence of perfect risk sharing across countries, the positive wealth effect spreads to the foreign economy causing a decrease in the labor supply that generates a drop in investment and output also in the other economy. International business cycle properties are satisfied at the cost of failing to reproduce the domestic business cycle dynamics: output, employment and investment fall in both countries in response to positive anticipated shocks.

Therefore, we include in the model two features that have been proved to be important in order to match the business cycle dynamics in response to anticipated productivity shocks: preferences featuring weak short-run wealth effects and sluggishness in the adjustment of investments. Such a framework can now generate the correct inter-

[6]The inability of the standard BKK model to generate the correct domestic business cycle dynamics in response to a country specific anticipated shock has been proved also by Beaudry, Dupaigne & Portier (2011).

[7] se for example Jaimovich & Rebelo (2009), Schmitt-Grohe & Uribe (2012) and Lorenzoni (2011)

national and domestic business cycle dynamics. The contribution of these two new features of the model is straight forward. As before, anticipated positive productivity shocks increase the wealth in both countries. However, the reduced wealth elasticity of the labor supply guarantees now that labor does not fall in response to the increase in wealth: investment and output do not decrease. On the other hand, investment adjustment costs ensure that the reaction of investment, as soon as the shock realizes, is smoother in the two countries. Depending on the size of the cost, we will have that the adjustment of the amount of capital starts in both countries as soon as the news is received and this avoids the opposite instantaneous adjustment we would have in a world without frictions at the time in which the shock realizes.

Our conclusion is that in a world with complete financial markets, anticipated shocks could play a major role in international business cycle synchronization. From a theoretical experiment we see that anticipated productivity shock, in a world with low labor supply wealth elasticity and investment adjustment costs, can generate a positive cross-country correlation of output, consumption, investment and hours worked.

It is worth noting that an alternative explanation for the increase in the synchronization could be derived from the study by Davis (2012). He shows empirically that, depending on the type of the financial integration experienced, we could have both an increase and a decrease in international business cycle co-movements. If the wealth effect dominates, as predicted by the standard IRBC model with incomplete financial markets, we will have a decrease in the synchronization with respect to the baseline model. Otherwise we could have an increase in the cross-country correlations if the balance sheet effect dominates.[8]

[8]For a full descriptions of the empirical analysis and the theoretical mechanism

The paper is organized as follows. Section 3.2 introduces the major puzzles and the solutions proposed in the open-macroeconomic literature. In section 3.3 we look at the data in order to assess what the IRBC values are today, with a particular interest in understanding the evolution of the cross-country correlations. Section 3.4 illustrates the set-up of the baseline model and it introduces the structure of anticipated shocks. We present the results for the baseline and extended model in section 3.5. Section 3.6 concludes.

3.2 The Puzzles and the Solutions

The international real business cycle literature (IRBC) is a field in which a lot of puzzles are still open or only partially solved. Before analysing the role of anticipated shocks in international co-movements, we summarize the major miss-matches between the theoretical and the empirical findings which are relevant for our analysis.[9] We then briefly try to summarize the main contribution and mechanism behind some of the relevant studies that have been addressing those puzzles.

3.2.1 The Puzzles

With the help of Obstfeld & Rogoff (2001) we briefly list the major puzzles that are relevant for our analysis of the international real

behind the wealth and the balance effects we cross-refer to Davis (2012). The wealth effect mechanism was mentioned before and it will be explained later. The main idea is that shocks have an important wealth effect that spreads among countries. Instead, the intuition behind the balance sheet effect is the following: a shock to home country affects the balance sheet of firms/banks. The shock, through financial linkages, affects also the balance sheets of the foreign country in the same direction. If, due to some financial friction or borrowing constraint, the size of the bank balance sheet is important for the flow of credits in the economy, we have that the shocks will have the same impact in both countries, generating co-movements.

[9] In section 3.3 we will check if they are still valid in today's data

business cycles:

- Cross-country correlation of consumption is much higher in the model than in the data;
- Cross-country correlation of output is much higher in the data than in the model. Empirical international output correlation is higher than consumption;
- Cross country correlation of employment and investment is found to be negative in the model while it is positive in the data;
- The real exchange rate is negatively correlated with the ratio of domestic and foreign consumption while it is positive and almost equal to one in the model (Backus-Smith puzzle).

3.2.2 Literature Review - Possible Solutions

Many of the open economy puzzles come from a particular mechanism generated by the standard international real business cycle model. The assumptions of complete financial markets, equivalent to perfect international risk sharing, and constant relative risk aversion utility function imply that the real exchange rate is determined by the ratio between domestic and foreign consumptions. This generates a strong correlation between consumption across countries and a low volatility of the real exchange rate. The complete market assumption implies also that the two countries' output reacts in a different way when one of the two economies is hit by a shock. The reason, which we will see later in detail, is that the investment and the labor supply will increase in the most productive country but will decrease in the other country.

An important fraction of the open macroeconomic literature, after the construction of the standard IRBC model by Backus et al. (1992), explored different models aiming at reconciling the empirical findings with the results of the model. Most of those studies focus on relaxing the strong assumption of complete financial markets and can be clustered in two groups: models limiting the type/number of assets available and models limiting the functioning of the market.

We start by presenting the first group of models. Baxter & Crucini (1995) and later Kollmann (1996) and Arvanitis & Mikkola (1996) assume that there are only non-contingent bonds available in the economy. Whenever shocks are strongly persistent or do not get transmitted internationally through other mechanisms, the incompleteness of the financial market has important implications for the international transmission of business cycles: the cross-country output correlation becomes positive as in the data. In the same stream of literature Heathcote & Perri (2002) show that a model with financial autarky can explain, at the same time, the volatility of the terms of trade and the cross country correlation of output, consumption, investment and employment. Corsetti et al. (2008) and Benigno & Thoenissen (2008) focus more on the dynamics of the real exchange rate, but using incomplete financial market as an important mechansim, and show that the negative correlation between domestic and foreign consumption with the real exchange rate can be reconciled with standard open-economy models.

Behind this first block of models there is the idea that the increasing financial integration decreases the international cross-country correlation of the output, as a consequence of the wealth effect. The mechanism through which the wealth effect works, abstracting from the trade channel, is the following. Country 1 is hit by a negative productivity shock and will experience a decrease in investment due to the decrease in the marginal productivity of capital. With no financial market, country 2 would be completely unaffected: we would experience a decrease in output in country 1 and a constant output in country 2. Differently, remembering that a complete financial market is equivalent to having an asset for every possible realization of shocks, the effects change when there is perfect risk sharing across countries. Now, if a negative shock hits country 1, the wealth of country 2 will also be decreased. This decrease in wealth in country 2 would push savings and investments up increasing the output.[10]

The second group of models focuses on the functioning of the financial markets. Kehoe & Perri (2002) introduce the idea that international loans are imperfectly enforceable. This assumption can generate a positive correlation of cross-country output and succeeds in making employment and investment co-move positively. Using a similar market incompleteness, Bodenstein (2008) addresses the Backus-Smith puzzle through a two country model with complete asset markets but also with a limited enforcement of international financial contracts. At the cost of high real exchange rate volatility, this model performs better than the incomplete, single international bond, financial market used by Baxter & Crucini (1995).

3.3 Data - Business Cycle Synchronization

We are interested in measuring the levels and the evolutions of the international real business cycle correlations. We focus on the United States and the European Union with respect to the rest of the world in the quarters from 1960:1 to 2012:1. Heathcote & Perri (2003) showed that the United States business cycle, between the first quarter of 1960 and the second quarter of 2002, had become less synchronized with the cycle of the rest of the world. The international correlation of output, consumption, investment and employment decreased in the period from 1981:2 to 2000:1.

[10]For simplicity, in the exposition of the wealth effect, we excluded the mechanism that works through trade. When we consider also the trade effect, the results are even starker, as now trade flows are also affected by the decrease in wealth.

Table 3.1: Cross-country correlations (HP filtered)

Country	Period	GDP	Consumption	Investment	Employment
	Rest of the World = EU15 + Japan				
USA	1961:1-2012:2	0.72	0.55	0.65	0.42
	1961:1-1980:1	0.65	0.56	0.66	0.56
	1980:2-2002:2	0.32	0.17	0.26	0.15
	2002:3-2012:2	0.90	0.82	0.82	0.58
	Rest of the World = OECD (minus home country)				
USA	1961:1-2012:2	0.78	0.67	0.72	
	1961:1-1980:1	0.69	0.60	0.66	
	1980:2-2002:2	0.51	0.25	0.40	
	2002:3-2012:2	0.92	0.88	0.85	
European Union (15)	1961:1-2012:2	0.82	0.65	0.77	
	1961:1-1980:1	0.75	0.72	0.75	
	1980:2-2002:2	0.54	0.41	0.52	
	2002:3-2012:2	0.92	0.82	0.86	
USA	1961:1-2012:2	$Corr(\frac{\lambda_H}{\lambda_F}, RER)$	-0.09		
EU	1961:1-2012:2	$Corr(\frac{\lambda_H}{\lambda_F}, RER)$	0.05		

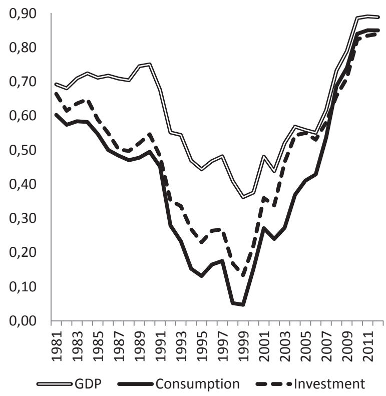
Home country: the USA or the European Union (15 member countries); Foreign country: Rest of the world measured both as the sum of the European Union plus Japan (see Heathcote & Perri (2003)) or as the sum of industrialized countries minus the home country (OECD - home). Data are taken from OECD Quarterly National Account fore the period Q1:1961-Q2:2012. Appendix 3.8.1 provides the details on the data used.

We consider data on GDP, consumption, gross fixed capital formation and employment.[11] We start by treating the USA as the home country and then we see if and how the level of the cross country correlation changes when we consider the European Union as the main country. For the foreign economy, the rest of the world, we provide two different measures: first, as in Heathcote & Perri (2003), we use the sum of the European Union (15 countries) and Japan; second, we propose the sum of all OECD countries, minus the home country. Results are sensitive to the set of countries we consider as the foreign economy but, qualitatively, the results are similar. Table 3.1 summarizes the results.

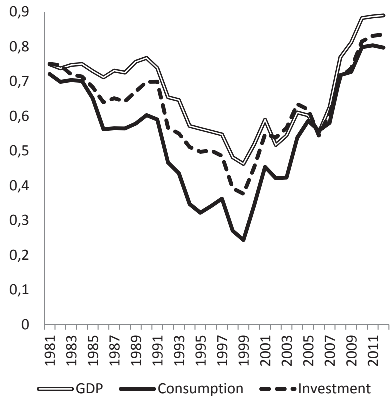
From 1960 to 2000, both the US and the EU business cycles have become less synchronized with the cycle in the rest of the world. This

[11] We subtract the government consumption from the GDP to avoid that episodes of wars could bias the results.

Correlations US and EU vs. ther OECD Countries (HP filtered)



(a) USA



(b) EU

Figure 3.1: Output, consumption and investment international correlations for a rolling window from 1963:1-1981:1 to 1994:1-2012 between US or EU and the rest of the industrialized countries. The x-axis identifies the the last year of the 17 years rolling window. For example, 1981 will be the reference for the value of the cross-country correlation of GDP, consumption and investment from 1963 to 1981.

result holds independently on the narrower or broader definition of the rest of the world. However, it is interesting to notice that starting in 2000 the international business cycle synchronization picked up again. This result is not just a consequence of the great Recession and it is not due to the particular choice of the sample. To prove it, in figure 3.1, we show the cross-country correlation of output, consumption and investment for the USA and the European Union in successive 17 year windows, from 1963:1-1979:4 to 1994:1-2012:1. It is clear that there was a decline of home and foreign cross country correlations up to 2000 but then, they have started to increase again reaching, at the beginning of 2012, values above the average between 1963 and 1974. The same cycle applies to all the series considered, not only for GDP or consumption.

Two more results from table 3.1 are worth to be noticed. First, when we take into consideration the IRBC correlations with the broader definition of the rest of world (including all OECD countries expect the USA), the synchronization, for all the series and all the time period considered, increases. This could be due to the fact that we are including countries, like for example Canada, which are strongly related to the USA. However this could be due also to other factors: stronger impact and transmission of shocks generated in the US to smaller OECD countries. The second fact is that, not surprisingly, also the European Union is strongly synchronized with the rest of the world cycle. What is not obvious is that the synchronization of the EU with respect to the other OECD countries is stronger than the one of the USA. Some more analysis is necessary to better understand these two points but it is interesting to keep in mind that the synchronization of the IRBC could be even stronger than what it is perceived and that the European Union co-movement is stronger than the one experienced in the USA.

The last line of table 3.1 shows that the Backus-Smith puzzle is still consistent with the data. The correlation between realtive cross-country consumption and the real exchange rate is negative in the United States and positive but small in the European Union.

We proved, using the most recent available data, that those empirical regularities that were in contrast with the standard IRBC model are still important: consumption is far from being perfectly correlated, even if we consider only the period of highest correlation. GDP is constantly more cross correlated than consumption; GDP, investment and employment are strongly correlated across industrialized countries and it is even more so in the last ten years.

3.4 The Model

The modeling framework has been proposed by Backus et al. (1994). The world is characterized by two countries inhabited by the same number of identical infinitely lived households. The two countries produce a differentiated tradable good respectively with domestic labor and capital. Factors of production are internationally immobile but international financial markets are complete.

Productivity shocks are the only source of fluctuations in the model. For those shocks we include an anticipated component: agents learn about the shock exactly a year before the actual realization of it. We follow the exposition of the model developed by Heathcote & Perri (2002).

3.4.1 Baseline Model

The two countries $i \in \{H, F\}$ produce respectively a differentiated good $j \in \{a, b\}$ which is traded internationally. We denote with S the set of all possible events and with $s_t \in S$ the particular event experienced in time t. s^t denotes the history of events up to and including date t. We attach a probability $\pi(s^t)$ to each history of events. A variable $X(s^t, s_{t+1})$ will depend on the history up to time t and will be related to the specific event s_{t+1}.

The infinitely lived representative household, in country i, enjoys consumption of a final good $C_i(s^t)$ and leisure $(1 - L_i(s^t))$:

$$U\left(C_i(s^t), 1 - L_i(s^t)\right) = \frac{1}{1-\sigma}\left[C_i^{\mu}(s^t)\left(1 - L_i(s^t)\right)^{1-\mu}\right]^{\sigma} \quad (3.4.1)$$

Households, in each country i, supply labor and rent the owned capital stocks, K_i, to perfectly competitive intermediate-good firms that produce good j for wage W_i and interest rate R_i^k. Labor and capital are internationally immobile but international asset markets are complete, providing a full set of Arrow securities. Let $B_i(s^t, s_{t+1})$ denote the quantity of bonds purchased by household, in country i, after history s^t, that pays one unit of j good in period $t+1$, if the state realized is s_{t+1}. $Q_i\left(s^t, s_{t+1}\right)$ denotes the price of the bond in units of the domestically produced good. The budget constraint of household in country i can be written as:

$$C_i(s^t) + I_i(s^t) + q_i^j(s^t) \sum_{s_{t+1}} Q_i\left(s^t, s_{t+1}\right) B_i(s^t, s_{t+1}) = q_i^j(s^t) B_i(s^{t-1}, s_t) +$$

$$+ q_i^j(s^t)\left[R_i^k(s^t) K_i(s^t) + W_i(s^t) L_i(s^t)\right] \tag{3.4.2}$$

$$\text{for} \quad \{i = H, j = a\} \text{ and } \{i = F, j = b\}$$

where q^j is the price of intermediate good a and b in terms of the final good F_i respectively in country H and F. Consumption, C_i and investment, I_i, are denoted in final good units. Investment augments the capital stock following the law of motion:

$$K_i(s^t) = (1-\delta) K_i(s^{t-1}) + I_i(s^t)^{12} \tag{3.4.3}$$

The major difference between our baseline specification and the original paper by Backus et al. (1993) is that we remove the assumption that capital needs time to accumulate. We will introduce an equivalent assumption later making clear why it is worth to investigate the role of friction in the accumulation of capital separately.

At period 0, the representative household, in country i, maximizes his/her expected lifetime utility subject to the budget con-

[12] In the original version of the model, proposed by Backus et al. (1994), the investment technology requires time to build new capital. We will introduce in section 3.5.1 an isomorphic way to model adjustment costs.

straint (3.4.2) combined with the law of motion of capital (3.4.3):

$$\max_{C_i(s^t),L_i(s^t),K_i(s^t)} E_0 \sum_{t=0}^{\infty} \sum_{s^t} \pi(s^t)\beta^t \frac{1}{1-\sigma} \left[C_i^{\mu}(s^t) \left(1 - L_i(s^t)\right)^{1-\mu} \right]^{\sigma}$$

$$\text{s.t. } C_i(s^t) + K_i(s^t) - (1-\delta)K_i(s^{t-1}) + q_i^j(s^t) \sum_{s_{t+1}} Q_i\left(s^t, s_{t+1}\right) B_i(s^t, s_{t+1}) =$$

$$= q_i^j(s^t) \left[R_i^k(s^t)K_i(s^t) + W_i(s^t)L_i(s^t) \right] + q_i^j(s^t)B_i(s^{t-1}, s_t)$$

where $\beta < 1$ is the discount factor which, for simplicity, is assumed to be constant.

Domestic intermediate firms produce only good a and foreign intermediate firms produce only good b. The output is carried with country specific technology using labor and capital combined in a Cobb-Douglas production function. Firms, in country i, maximize profits:

$$\max_{L_i(s^t),K_i(s^t)} Y_i(s^t) - W_i(s^t)L_i(s^t) - R_i^k(s^t)K_i(s^t)$$

$$\text{subject to } Y_i(s^t) = Z_i(s^t)K_i(s^t)^{\theta} L_i(s^t)^{1-\theta}, \;\; K_i(s^t), L_i(s^t) \geq 0 \qquad (3.4.4)$$

As in the budget constraint, $W_i(s^t)$ and $R_i^k(s^t)$ are the wage and the price of capital expressed in terms of the intermediate good produced.

The intermediate goods are used by the final good firms to produce F_i, which is formed by domestically and foreign produced goods. Those firms are perfectly competitive and have a constant return to scale technology available (Armington aggregator):

$$F_i(a_i(s^t), b_i(s^t)) = \begin{cases} \left[\gamma^{\frac{1}{\epsilon}} a_i(s^t)^{\frac{\epsilon-1}{\epsilon}} + (1-\gamma)^{\frac{1}{\epsilon}} b_i(s^t)^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}}, & \text{for } i = H \\ \left[(1-\gamma)^{\frac{1}{\epsilon}} a_i(s^t)^{\frac{\epsilon-1}{\epsilon}} + \gamma^{\frac{1}{\epsilon}} b_i(s^t)^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}}, & \text{for } i = F \end{cases} \qquad (3.4.5)$$

where γ sets the preferences for the home produced goods and ϵ is the elasticity of substitution between the domestic and foreign good. We set $\gamma \geq 0$ allowing for home bias in consumption. Final good firms maximize profits choosing the optimal demand for good a and b solving the following maximization:

$$\max_{a_i(s^t),b_i(s^t)} F_i(s^t) - q_i^a(s^t)a_i(s^t) - q_i^b(s^t)b_i(s^t)$$
$$\text{subject to } a_i(s^t), b_i(s^t) \geq 0 \text{ and equation (3.4.5).} \qquad (3.4.6)$$

Market clearing for intermediate and final goods requires that:

$$a_H(s^t) + a_F(s^t) = Y_H(s^t), \qquad (3.4.7)$$
$$C_H(s^t) + I_H(s^t) + G_H(s^t) = F_H(s^t); \qquad (3.4.8)$$
$$b_H(s^t) + b_F(s^t) = Y_F(s^t), \qquad (3.4.9)$$
$$C_F(s^t) + I_F(s^t) + G_F(s^t) = F_F(s^t). \qquad (3.4.10)$$

The law of one price holds throughout the world, for both goods, and asset market clears:

$$B_H(s^t, s_{t+1}) + B_F(s^t, s_{t+1}) = 0, \qquad \forall s_{t+1} \in S. \qquad (3.4.11)$$

Before defining the competitive equilibrium, we present the definition of three important international variables. The terms of trade, from a domestic perspective, is defined as the price of imports with respect to exports: $TOT_H(s^t) = \frac{q_H^a(s^t)}{q_H^b(s^t)}$. The real exchange rate, given the assumption of complete markets is given by the risk sharing condition and is defined as the price of the foreign final good with respect to the domestic final good: $RER_H(s^t) = \frac{q_H^a(s^t)}{q_F^a(s^t)}$. Finally we define the net export, $NX_H(s^t)$, as the ratio between the value of the exported goods minus the value of the imported goods to output:

$$NX_H(s^t) = \frac{a_F(s^t) - TOT_H(s^t)b_H(s^t)}{Y_H(s^t)} \qquad (3.4.12)$$

Table 3.2: Calibrated Parameteres - Baseline Model

Par	Value	Description
β	0.99	Discount Factor
μ	0.34	Consumption Share
σ	2	Risk Aversion
δ	0.025	Depreciation of capital
θ	0.36	Capital's share of output
γ	0.7208	Calibrated using import share = 0.15
ϵ	1.5	Trade elasticity
Technology process		
$\begin{bmatrix} \rho_z & \rho_{zz} \\ \rho_{zz} & \rho_z \end{bmatrix} = \begin{bmatrix} 0.906 & 0.088 \\ 0.088 & 0.906 \end{bmatrix}$		
$VAR\epsilon_H^Z = VAR\epsilon_F^Z = 0.00852^2$		
$Corr(\epsilon_H^Z, \epsilon_F^Z) = 0.258$		
$g_t = 0$		

As a source of fluctuations we include only productivity. The two exogenous sources of fluctuations, country i technologies (Z_H, Z_F), follow these processes:

$$\begin{bmatrix} \widehat{z}_H(s^t) \\ \widehat{z}_F(s^t) \end{bmatrix} = \begin{bmatrix} \rho_z & \rho_{zz} \\ \rho_{zz} & \rho_z \end{bmatrix} \begin{bmatrix} \widehat{z}_H(s^{t-1}) \\ \widehat{z}_F(s^{t-1}) \end{bmatrix} + \begin{bmatrix} \epsilon_H^Z(s^t) \\ \epsilon_F^Z(s^t) \end{bmatrix} \tag{3.4.13}$$

$$\text{with } \begin{bmatrix} \epsilon_H^Z(s^t) \\ \epsilon_F^Z(s^t) \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma^2_{\epsilon_H^Z} & \sigma_{\epsilon_H^Z \epsilon_F^Z} \\ \sigma_{\epsilon_H^Z \epsilon_F^Z} & \sigma^2_{\epsilon_F^Z} \end{bmatrix} \right) \tag{3.4.14}$$

where $\widehat{z}_H$ and $\widehat{z}_F$ represent the log deviation from steady state of those variables.

For each shock we introduce an unanticipated but also an anticipated component. Following Schmitt-Grohe & Uribe (2012) notation, if $x_t = \rho_x x_{t-1} + \epsilon_t^x$ identifies a general exogenous process, we assume that the error terms follows the structure:

$$\epsilon_t^x = \epsilon_{0,t}^x + \epsilon_{4,t-4}^x \tag{3.4.15}$$

where $\epsilon^x_{4,t-4}$ is today's realization of a shock that was acknowledged a year before. For a full and detailed exposition of this method of introducing anticipated shocks we cross-refer to section 3 of Schmitt-Grohe & Uribe (2012). We will follow this assumption, of having both an unanticipated and anticipated shock component in every specification of the model that we will see from now on.

Let $s_t = \{Z\}$, where $Z = \{Z_H, Z_F\}$. The competitive equilibrium is a set of home and foreign representative household decision rules $C_i(s_t)$, $L_i(s_t)$, $K_i(s_t)$ and $B_i(s_t)$; a set of domestic and foreign intermediate good firms decision rules $K_i(s_t)$ and $L_i(s_t)$; A set of domestic and foreign final good firms decision rules $a_i(s_t)$ and $b_i(s_t)$. A set of pricing functions $q^a_i(s_t)$, $q^b_i(s_t)$, $R^k_i(s_t)$, $W_i(s_t)$, $Q_i(s_t)$ such that they satisfy: 1. the household problem; 2. the intermediate and final firms problem; 3. the market clearing conditions.

Table 3.2 summarizes the values of the benchmark paramenters. We treat the United States as the domestic country and the rest of the world as the foreign country. We make this choice for two reasons: first, it allows us to better compare the results from the model with the empirical evidence presented in section 3.3; second, considering just a single country as a foreign economy will imply focusing on a really small fraction of the international flow of goods of the USA (see Heathcote & Perri (2002)). The benchmark parameters are taken from Backus et al. (1994). The discount factor is set equal to 0.99, the consumption share to 0.34 and the risk aversion to 2. Looking at the production side, capital share of output is 0.36, the depreciation rate of capital equal is 10 percent per year and the import share is set equal to 0.15. The most important parameter, ϵ, which determines the elasticity of substitution between domestic and foreign goods, is set equal to 1.5 (Heathcote & Perri (2002) and Backus et al. (1994)). For the technology process we follow exactly the specification proposed by Backus et al. (1994).

Unanticip vs. Anticip Productivity Shock - Baseline Model

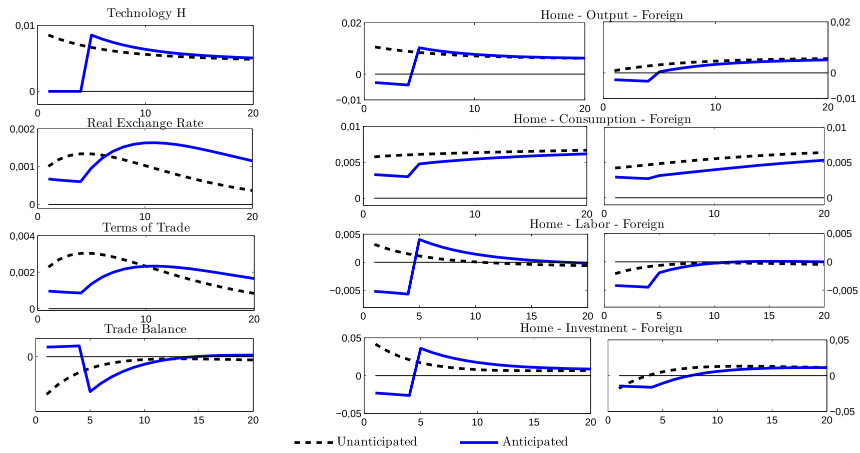


Figure 3.2: Impulse-responses to a positive unanticipated and anticipated technology shock (baseline model).

After having shown the implication of anticipated shocks in the IRBC baseline framework, section 3.5.1 assesses the importance of anticipated shocks in a model with little short run wealth effects on the labor supply and investment adjustment costs.

3.5 Results

Figure 3.2 depicts the impulse-responses of the baseline model to both an unanticipated and an anticipated positive productivity shock in the domestic economy. Focusing first on the more standard unanticipated shock, the dotted line, we see clearly how the model is unable to generate international co-movement of some variables.

In response to an unanticipated productivity shock consumption increases almost equally in both countries while output increases a lot more in the country hit by the shock. As explained in 3.2.2, this is a consequence of the full risk sharing assumption. Hours worked and investment have opposite reactions in the two countries. Marginal products of factors increase in the economy hit by the shock pushing up investment and labor, as the labor supply wealth effect is smaller than the substitution effect due to the increase in wages. Instead, in the foreign economy, the opposite happens as a result of the positive wealth effect, spread into the country through the value of the international assets. This leads to a reduction of hours worked and investment in the foreign economy: capitals will be invested more in the relative more productive country. Net export, therefore, decreases despite the gained international competitiveness of the terms of trade and the real exchange rate.

The mis-match between the model implications and the empirical findings is importantly reduced when we consider anticipated shocks. As can be seen in figure 3.2, the model can now generate positive international cross-correlation of output, employment and investment. Notice, in table 3.3, that the model is able to reduce some important IRBC puzzles: output has a positive cross correlation of 0.32; consumption international co-movement is reduced; investment and labor do not have opposite reactions.

The ability of anticipated productivity shock to synchronize the IRBC comes from the symmetric effect that news have on both economies in the periods preceding the realization of the shock. In fact, through the value of the internationally asset portfolio, the wealth effect of the anticipated shock is spread among the countries in a symmetric way. Another way of interpreting the role of the anticipated shock is that, in the periods preceding the actual change in productivity, it generates a symmetric cross-country demand shock.

However, notice that the ability of the BKK model with anticipated shocks to match the IRBC properties is illusory. It is a well documented fact that a persistent anticipated shock, in a frictionless neo-classical framework, generates the wrong behavior our output, consumption and employment. A positive persistent productivity shock is transmitted to both countries as an increase in wealth that leads agents to increase the demand for both normal goods: consumption and leisure. This generates a decrease in the labor supply. Productivity, until the shock realizes, is constant and capital is inherited from the previous period. Therefore output, and then investment, fall in both economies. This generates positive international co-movement but fails to match the domestic business cycle properties: output, consumption and employment response positively to an increase in expected productivity.

The results we have just presented were derived assuming the Backus et al. (1994) calibration. Changes in productivity were transmitted in-between countries through two channels. First, we allowed some degree of international spill-over, $\rho_{zz} = 0.088$, generated by the fact that the productivity of one country is partially influenced by the past productivity of the other country (equation 3.4.14); second, following Backus et al. (1994), we have assumed that shocks are correlated across countries $\sigma_{\epsilon_H^Z \epsilon_F^Z} = 0.258$.

We are now interested in understanding how the anticipated shocks would improve the cross-correlation of international business cycle variables when we assume that shocks are not correlated and there is no spill-over effect. We first assume a zero correlation between shocks leaving the spill-over effect and then we assume that there is no relationship in the productivity processes of the two economies. In table 3.3 we present the results. Anticipated shocks can still reduce the distance with the empirical evidence, even when we exclude possible spill-over effects, but, as we can see, the improvement is reduced. In fact, the model, without assuming any correlation between shocks, is unable to generate a positive co-movement of investment across countries just as a reaction to anticipated productivity shock.

Table 3.3: International Business Cycle Statistics (HP filtered)

		Correlation				
Economy		(y_H, y_F)	(c_H, c_F)	(I_H, I_F)	(L_H, L_F)	$(\frac{\lambda_H}{\lambda_F}, RER)$
Data		0.72	0.55	0.65	0.42	-0.09
Base Model	Non-Antic. TFP	-0.06	0.91	-0.81	-0.93	0.95
	Antic. TFP	0.32	0.80	0.10	0.49	0.83
Base Model	Non-Antic. TFP	-0.32	0.85	-0.96	-0.88	0.95
(no corr)	Antic. TFP	0.07	0.69	-0.17	0.26	0.83
Base Model	Non-Antic. TFP	-0.32	0.55	-0.46	0.03	0.97
(no corr/no spill-over)	Antic. TFP	0.01	0.26	-0.30	0.05	0.83
Invest. Adj Cost	Non-Antic. TFP	-0.17	0.85	-0.01	-0.37	1
(no corr)	Antic. TFP	-0.07	0.16	0.62	0.25	1
Jaimovich-Rebelo pref.	Non-Antic. TFP	0.13	0.98	-0.90	0.30	0.89
(no corr)	Antic. TFP	0.04	0.95	-0.47	0.12	0.72
JR + Inv Adj Cost	Non-Antic. TFP	0.34	0.97	-0.04	0.68	1
(no corr)	Antic. TFP	0.24	0.95	0.65	0.60	0.99
Incomplete Markets						
Base Model	Non-Antic. TFP	0.23	0.37	-0.76	-0.72	0.45
	Antic. TFP	0.42	0.53	-0.30	0.52	0.31
Base Model	Non-Antic. TFP	-0.03	0.13	-0.84	-0.83	0.45
(no corr)	Antic. TFP	0.18	0.32	-0.51	0.31	0.31

Output, consumption, investment and employment cross-country theoretical correlations compared with the data from 1960-2012 for the USA. The last column shows the correlation between the relative domestic and foreign consumption and the real exchange rate. All the variables, in the data and in the model, are hp-filtered. (no corr) stands for a parametrization in which shocks are not correlated across countries. (no spill-over) indicates $\rho_{zz} = 0$.

3.5.1 Jaimovich-Rebelo preferences and adjustment costs of investment

We have just shown how international business cycle features are better matched when anticipated shocks are introduced in the standard international business cycle model. However, while the model performs better in terms of international cross-correlation, it performs worse in terms of domestic business cycle regularities: output, consumption, investment and hours worked should move in the same direction of the anticipated technology shocks. The persistency of the shock in addition to the frictionless neo-classical framework generates an equilibrium in which the labor market dynamics doesn't allow to have an increase in all the variables in response to an anticipated shock (figure 3.2). The reason comes from the strong positive wealth effect caused by the future expected increase in productivity. Given that capital is inherited from the previous period and productivity will not change until the shock actually realizes, the only force that can generate an increase in output is labor. However, the demand of labor from the firm size does not change while the supply of labor, driven by the positive wealth effect, shifts down. The result is a decrease in hours worked and a decrease also of GDP and investment. A different specification of preferences, different information structures, nominal and real rigidities have been introduced in models featuring anticipated shocks to avoid this well known problem. Lorenzoni (2011) provides a comprehensive review of the different solutions proposed and their mechanism.

In order to exploit the ability of anticipated shocks to synchronize IRBC fluctuations, we need to introduce a new specification of the model that does not suffer from the wrong domestic business cycle behavior of the frictionless neo-classical model. From previous literature we learned that the combination of preferences that can control the degree of the labor wealth effect and frictions in the adjustment of capital is sufficient for anticipated productivity shocks to generate the proper co-movements. Therefore we introduce the preferences specification proposed by Jaimovich & Rebelo (2009) and investment adjustment cost in the model. Starting from the investment adjustment cost we introduce the two features in the model, one at the time, in order to properly understand the role played by each modification.

Lucca (2007) proved that adjustment costs associated with changes in the rate of investment are isomorphic to the time-to-build models used by Backus et al. (1994). In addition, Jaimovich & Rebelo (2009) showed how investment adjustment costs can be important for anticipated shocks: an increase in the cost makes it more convenient for agents to adjust sooner the stock of capital generating a smoother adjustment; capitals, if the cost is sufficiently large, will start to increase at the time of the news shock generating positive complementarities on the demand side of labor.

Capital accumulation, in equation 3.4.3, is substituted by this new formulation:

$$K_i(s^t) = (1-\delta)K_i(s^{t-1}) + I_i(s^t)\left[1 - \phi\left(\frac{I_t}{I_{t-1}}\right)\right], \qquad (3.5.1)$$

where the function ϕ represent the adjustment costs to be paid when the level of investment changes over time. We assume that $\phi(1) = \phi'(1) = 0$ and $\phi''(1) = \eta_k > 0$. As in Jaimovich & Rebelo (2008) we set $\eta_k = 1.3$.

Table 3.3 shows the results for the cross country correlation in response to both unanticipated and anticipated positive productivity shock in the domestic economy. Not surprisingly the model, for both shocks, works better in terms of the investment dynamics generating a positive cross-country correlation. Anticipated shocks improve in the matching of all the co-movements but, as before, the ability of generating a positive correlation between the domestic and the foreign labor market is driven by the decrease in the labor supply in the domestic economy hit by a positive anticipated shock.

To solve the problem of the miss-behavior of the labor market in response to anticipated shocks, we introduce a preference specification that allows us to control, through a parameter, the degree of the wealth elasticity of the labor supply. We follow Jaimovich & Rebelo (2009) formulation:

$$U(C_t, L_t) = \frac{\left\{C_t - \psi^L L_t^{1+\nu} X_t\right\}^{1-\sigma} - 1}{1-\sigma}, \tag{3.5.2}$$

where

$$X_t = C_t^{\mu} X_{t-1}^{1-\mu}. \tag{3.5.3}$$

Utility depends on consumption at time t, C_t, and hours worked L_t. X_t controls the wealth effect on labor supply through the parameter $\mu \in [0, 1]$. By changing μ we can account for two important classes of utility functions used in the business cycle literature: King et al. (1988) types of preferences (KPR henceforth) when $\mu = 1$ and Greenwood et al. (1988) when $\mu = 0$ (GHH henceforth). As in Jaimovich & Rebelo (2009), we impose $\mu > 0$, in order to put some weight on the KPR preferences which are growth consistent. We set the parameter $\mu = 0.0001$ in order to decrease the degree of the wealth effect on the labor supply consistently.

In order to isolate the results coming from the new utility specification, we first present the results assuming that the investment sector does not have any adjustment cost. Afterwards we combine the two new features in the baseline model to understand the role of anticipated shocks for the IRBC, when also the correct closed economy business cycle properties are satisfied.

Comparing the results between this new specification and the baseline framework, in table 3.3, we see how controlling the role of the wealth effect on the labor dynamics allows us to improve significantly in two aspects of the IRBC. Both for the unanticipated and anticipated shocks, the labor cross-country correlation becomes really close to the empirical findings and the output becomes positively correlated across country. We can conclude that the simple introduction of GHH preferences solves for both unanticipated and anticipated productivity shocks the puzzle related to the employment negative cross-country international dynamics of the standard IRBC model.

However, by just changing the preferences, we cannot match the proper dynamics of investment and by just using the investment adjustment costs we cannot match the correct labor dynamics (hours worked decrease in the country which experienced the anticipated productivity shock). We then add both features to the model contemporaneously and we check what happens. With the exception of the puzzles related to consumption (Backus-Smith and consumption correlation puzzle) the model matches the international business cycle regularities quite with anticipated shocks. Anticipated shocks, now consistent also with the proper closed business cycle economy properties, can really overturn some of the major puzzles in the international business cycle literature.

In order to understand how well anticipated shocks do in improving the ability of the standard BKK model to match the IRBC characteristics, we compare the results with the most used modification of the model in which financial markets are incomplete. Following Heathcote & Perri (2002) we assume that there is only one non contingent bond available in the economy.[13] All the other assumptions

[13]For a description of the framework we use, see Heathcote & Perri (2002), Enders & Mller (2009) and Opazo (2006). As in Enders & Mller (2009), we use endogenous discount factor to close the model and ensure stationarity and uniqueness of the steady state

are back to the baseline framework: separable utility function and no investment adjustment costs. As previously found in the literature, the model with incomplete risk sharing, is now able to reduce the cross-correlation of consumption and, in particular, performs much better in terms of the correlation between relative consumption and the real exchange rate (table 3.3). This should not come as a surprise given that we break the tight relation between consumption and the real exchange rate. However two things are worth noticing. First, the model performs poorly with respect to the cross-correlation between labor and investment in the two countries. In fact it generates a strong negative correlation as opposed to the positive correlation seen in the data. Second, the positive international co-movement of output holds only as long as we keep the two shocks being correlated. In the last line of table 3.5 we see how the model performs poorly when we assume zero correlation between the shocks. Anticipated shocks, even in the incomplete financial market setup, perform better in terms of IRBC properties.[14]

We conclude that just by adding anticipated shocks in the standard international real business cycle model and being careful in controlling both the positive wealth effect on the labor supply and the speed of capital adjustment, we can improve the performance of the model significantly, without the need of assuming incomplete markets. The reason why we are careful in assuming that markets are incomplete is the evidence shown in figure 3.1(b) by which we see that the cross-country correlation of consumption is increasing to levels similar to the ones implied by the models with complete financial markets.

[14]For a deeper analysis of anticipated socks in this framework we cross-refer to Opazo (2006)

3.6 Conclusion

We have examined the importance of anticipated shocks in a standard two-country, two-good real business cycle model with complete financial markets. The increased synchronization of the United States and the European Union business cycles with the rest of the world found in the data and the evidence that the international financial integration process is increasing (Lane & Milesi-Ferretti 2007) motivated us to find a source of international co-movements that works without the need of assuming imperfect risk sharing across countries.

From the empirical analysis we have found that international business cycle synchronization has been strongly increasing from the beginning of the year 2000. After the strong decrease in the synchronization, found by Heathcote & Perri (2003) and attributed to the wealth effect generated by the increasing financial integration, we now face a world in which the international-business cycle co-movements are particularly strong and the financial market is increasingly internationally integrated with respect to previous years. Explaining open-economy puzzles by just assuming financial market incompleteness could be puzzling in itself given that the data tell us that consumption cross-country correlation has almost reaching the values implied by models with complete financial markets.

We have found that anticipated shocks are an important source of international real business cycle movements in a world in which financial markets are complete. Once we have controlled for the positive wealth effect of the labor supply and we have introduced a mechanism by which capitals adjust smoothly, the otherwise standard IRBC model can account for the majority of the puzzles by just introducing some anticipated component in the productivity shocks. An anticipated technology shock generates a positive cross-country correlation of output, consumption, investment and hours worked. However, notice that the model cannot solve the Backus-Smith puzzle. That should not come as a surprise given that in the model we do not break the mechanism by which relative consumption is strongly correlated to the real exchange rate. A possible solution that we leave for future research is to understand if the model with complete financial market could solve the Backus-Smith puzzle by introducing anticipated shocks and limited international enforcement of contracts.

We conclude that anticipated shocks are an important source of international synchronization in a world in which financial markets are more and more integrated.

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3.8 Appendix

3.8.1 Data Sources

We list here the data used for the empirical analysis:

1. Gross Domestic Product - expenditure approach, OECD Quarterly National Account, Millions of US dollars, volume estimates, fixed PPPs, OECD reference year, annual levels, seasonally adjusted [for USA, EUROPEAN UNION 15, JAPAN, TOTAL OECD].

2. Private Final Consumption Expenditure , OECD Quarterly National Account, Millions of US dollars, volume estimates, fixed PPPs, OECD reference year, annual levels, seasonally adjusted [for USA, EUROPEAN UNION 15, JAPAN, TOTAL OECD].

3. Central Government Final Consumption Expenditure, OECD Quarterly National Account, Millions of US dollars, volume estimates, fixed PPPs, OECD reference year, annual levels, seasonally adjusted [for USA, EUROPEAN UNION 15, JAPAN, TOTAL OECD].

4. Gross Fixed Capital Formation, OECD Quarterly National Account, Millions of US dollars, volume estimates, fixed PPPs, OECD reference year, annual levels, seasonally adjusted [for USA, EUROPEAN UNION 15, JAPAN, TOTAL OECD].

5. Real Effective Exchange Rate - Price-adjusted Major Currencies Dollar Index, Foreign Exchange Rates - H.10, Board of the Governors of the Federal Reserve System [for USA]; Eurostat, Industrial countries' effective exchange rates including new Member States - quarterly data (ert_eff_ic_q) [for EUROPEAN UNION 15].

6. Weekly Hours, Establishment Survey, BLS [USA and EUROPEAN UNION 15] and ILO - montlhy data [JAPAN]

7. Real GDP, net of government consumption = (1) - (3)