Monetary and Macroprudential Policy in an Estimated DSGE Model of the Euro Area*

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Abstract

In this paper, we study the optimal mix of monetary and macroprudential policies in an estimated two-country model of the euro area. The model includes real, nominal and financial frictions, and hence both monetary and macroprudential policies can play a role. We find that the introduction of a macroprudential rule would help in reducing macroeconomic volatility, improve welfare, and partially substitute for the lack of national monetary policies. Macroprudential policies always increase the welfare of savers, but their effects on borrowers depend on the shock that hits the economy. In particular, macroprudential policies may entail welfare costs for borrowers under technology shocks, by increasing the countercyclical behavior of lending spreads.

Key words: Monetary Policy, EMU, Basel III, Financial Frictions.

JEL Codes: C51, E44, E52.

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1 Introduction

The recent financial crisis, that started in the summer of 2007, lead to the worst recession since World War II. Excessive leverage has complicated the recovery and the return to pre-crisis growth rates in several advanced countries. Before the crisis, a combination of loose monetary and regulatory policies encouraged excessive credit growth and a housing boom in many countries. This turned out to be a problem when the world economy slowed down: as Claessens et al. (2008), Crowe et al. (2011) and IMF (2012) show, the combination of credit and housing boom episodes amplifies the business cycle and in particular, the bust side of the cycle, measured as the amplitude and duration of recessions. There is wide recognition that the best way to avoid a large recession in the future is precisely to reduce the volatility of credit cycles and their effects on the broader macroeconomy.

However, the search for the appropriate toolkit to deal with financial and housing cycles is still in its infancy. There is high uncertainty on which measures can be more effective at delivering results. Conventional monetary policy is too blunt of an instrument to address imbalances within the financial sector or overheating in one sector of the economy (such as housing). There is a need to further strengthen other instruments of economic policy in dealing with sector-specific fluctuations.[1] In particular, a key question to be addressed is what should be the role of macro-prudential regulation. Should it be used as a countercyclical policy tool, leaning against the wind of large credit and asset and house price fluctuations, or should it take a more passive role and just aim at increasing the buffers of the banking system (provisions and capital requirements), thereby minimizing financial sector risk, as currently envisioned in Basel III?

Early contributions to this debate include several quantitative studies conducted by the BIS on the costs and benefits of adopting the new regulatory standards of Basel III (see Angelini et al., 2011a; and MAG, 2010a and 2010b), and in other policy institutions (see Bean et al., 2010; Roger and Vlcek, 2011; and Angelini et al., 2011b). This paper contributes to this debate by studying the optimal policy mix needed within a currency union, where country- and sector-specific boom and bust cycles cannot be directly addressed with monetary policy. Specifically, we focus on the European Economic and Monetary Union (EMU), whose central bank has mandate of price stability at the union-wide level. We provide a quantitative study

[1] See Blanchard et al. (2010).

on how monetary and macroprudential measures could interact in the euro area, and pay special attention to coordination issues between the European Central Bank (ECB), national supervision authorities and the newly created European Systemic Risk Board (ESRB) that will be responsible of macroprudential oversight at the euro area level.

The recent developments in Southern Europe share many characteristics with other crises. Real exchange rate appreciation (which in the EMU took the form of persistence inflation differentials), large capital inflows mirrored by large current account deficits, and above-potential GDP growth fuelled by cheap credit and asset price bubbles are the traditional symptoms of ensuing financial, banking and balance of payments crises in many emerging and developed economies.[2] The story of the euro-zone debt crisis is now well know, and in addition to all these over-heating symptoms, many Southern European economies faced prolonged negative real interest rates, which magnified the business cycle. When the crisis hit, all problems came at once: a sudden stop of capital flows, concerns about debt sustainability, low or negative real GDP growth, and credit spreads that helped amplify the business cycle.

The four Southern European economies (and also Ireland) could not use monetary policy to cool down their economies and financial systems, address asset and house price bubbles and abnormal credit growth. Therefore, the use of other policy instruments in a currency union can potentially help in stabilizing the business and financial cycle. Recently, several authors have suggested that the use of macroprudential tools could improve welfare by providing instruments that target large fluctuations in credit markets. In an international real business cycle model with financial frictions, Gruss and Sgherri (2009) study the role of loan-to-value (LTV) limits in reducing credit cycle volatility in a small open economy, while Lambertini et al. (2011) also look at the role of using LTV ratios and their effect on welfare. Bianchi and Mendoza (2011) study the role of macroprudential taxes to avoid the externalities associated to "overborrowing". Borio and Shim (2008) point out the prerequisite of a sound financial system for an effective monetary policy and, thus, the need to strengthen the interaction of prudential and monetary policy. IMF (2009) suggests that macroeconomic volatility can be reduced if monetary policy does not only react to signs of an overheating financial sector but if it is also com-

[2] See Kaminsky and Reinhart (1999) and IMF (2009).

bined with macroprudential tools reacting to these developments.[3] Angelini et al. (2011b) study the interaction between optimal monetary and macroprudential policies in a set-up where the central bank determines the nominal interest rate and the supervisory authority can choose countercyclical capital requirements and LTV ratios. Unsal (2011) studies the role of macroprudential policy when a small open economy receives large capital inflows.[4]

In this paper we study the role of monetary and macroprudential policies in stabilizing the business cycle in the euro area. The model includes: (i) two countries (a core and a periphery) who share the same currency and monetary policy; (ii) two sectors (non-durables and durables, which can be thought of as housing); and (iii) two types of agents (savers and borrowers) such that there is a credit market in each country and across countries in the monetary union. The model also includes a financial accelerator mechanism on the household side, such that changes in the balance sheet of borrowers due to house price fluctuations affect the spread between lending and deposit rates. In addition, risk shocks affect conditions in the credit markets and in the broader macroeconomy. The model is estimated using Bayesian methods and includes several nominal and real rigidities to fit the data.

Having obtained estimates for the parameters of the model and for the exogenous shock processes, we proceed to study different policy regimes. In all cases, we assume that the optimal policy aims at maximizing the welfare of all households in the EMU, by maximizing their utility function taking into account the population weights of each type of household in each country. First, we derive the optimal monetary policy when the ECB optimizes over the coefficients of the Taylor rule that reacts to EMU-wide consumer price index (CPI) inflation and output growth. We find that the optimal Taylor rule reacts strongly to deviations of CPI inflation and output growth from their steady-state values, as is typical in the literature. Next, we extend the monetary policy rule to react to either credit aggregates or house prices. We find that the extended Taylor rule improves welfare with respect to the original one, but the welfare improvements are smaller than from moving from the estimated to the optimized rule, with borrowers being worse off.

[3]Bank of England (2009) lists several reasons, why the short-term interest rate may be ill-suited and should be supported by other measures to combat financial imbalances.

[4]Beau, Clerc and Mojon (2012) study the role of macro-prudential policies in an estimated DSGE model of the euro area but do not distinguish between different countries. Brzoza-Brzezina et al. (2012) distinguish between a core and a periphery in a model with optimal monetary and macroprudential policies in the euro area, but do not estimate the model. In both cases, the credit friction consists in a borrowing constraint a la Iacoviello (2005).

Next, we introduce a macroprudential instrument that influences credit market conditions by affecting the fraction of liabilities (deposits and loans) that banks can lend. This instrument can be thought of as additional capital requirements, liquidity ratios, reserve requirements or loan-loss provisions that reduce the amount of loanable funds by financial intermediaries and increase credit spreads. We find that the welfare gains of introducing macroprudential policies are comparable to those of moving from an estimated to an optimal rule, but that there are winners and losers of including macroprudential measures. This is a common theme for most optimization results: we find that while savers benefit from the ECB or a macroprudential authority reacting to financial variables, borrowers do not. As we discuss in Section 4, under housing demand or risk shocks, optimal monetary and macroprudential policies improve everyone's welfare by reducing the volatility of real variables by reducing accelerator effects triggered by these shocks. However, when technology shocks hit the economy, macroprudential policies increase the countercyclical behavior of the spreads, thereby magnifying fluctuations for borrowers and reducing their welfare. Therefore, identifying the source of the credit and house price boom is crucial. Finally, we find that when macroprudential policies are left to national regulators instead of being conducted at the EMU-level, the optimal response of the macroprudential instrument is very similar.

It is important to note from the start that while the model includes financial frictions on the household side, financial intermediaries are very simple entities that take deposits, engage in bond trading across countries and give mortgage loans. Because of this simplicity, the model does not allow us to measure other potentially large benefits from improving banking regulation at the macro and the micro level such as reducing the frequency and cost of financial and banking crisis. The rest of the paper is organized as follows: Section 2 presents the model, and Section 3 discusses the data and the econometric methodology to estimate the parameters of the model. In Section 4, we discuss the different exercises of optimal monetary and macroprudential policies, while we leave Section 5 for concluding remarks.

2 The Model

The theoretical framework consists of a two-country, two-sector, two-agent general equilibrium model of a single currency area. The two countries, home and foreign, are of size n and $1-n$. There are two types of goods, durables and non-durables, that are produced under monopolistic competition and nominal rigidities. While non-durables are traded across countries, durable goods are non-tradable and used to increase the housing stock. In each country, there are two types of agents, savers and borrowers, who differ in their discount factors and habit formation parameters. Both agents consume non-durable goods and purchase durable goods to increase their housing stock. Borrowers are more impatient than savers and have preference for early consumption, which creates the condition for credit to occur in equilibrium. In addition, borrowers are hit by an idiosyncratic quality shock to their housing stock, which affects the value of collateral that they can use to borrow against.[5] Hence, we adapt the mechanism of Bernanke, Gertler and Gilchrist (1999), henceforth BGG, to the household side and to residential investment: shocks to the valuation of housing affect the balance sheet of borrowers, which in turn affect the default rate on mortgages and the lending-deposit spread.

Domestic financial intermediaries take deposits from savers, give loans to borrowers, and issue bonds that are traded across countries by international intermediaries. Savings and (residential) investment need not to be balanced at the country level period by period, since excess credit demand in one region can be met by funding coming from elsewhere in the monetary union. International financial intermediaries channel funds from one country to the other, and also charge a risk premium which depends on the net foreign asset position of the country.

In what follows, we present the home country block of the model, by describing the domestic and international credit markets, households, and firms. Monetary policy is conducted by a central bank that targets the union-wide CPI inflation rate, and also reacts to fluctuations in the union-wide real GDP growth. The foreign country block has a similar structure for credit markets, households and firms, and to save space is not presented. Unless specified, all shocks follow zero-mean AR(1) processes in logs.

[5] We could also assume that savers are hit by a housing quality shock. Since they do not borrow and use their housing stock as collateral, this quality shock does not have any macroeconomic impact.

2.1 Credit Markets

We adapt the Bernanke, Gertler and Gilchrist (1999) financial accelerator idea to the housing market, by introducing default risk in the mortgage market, and a lending-deposit spread that depends on housing market conditions. There are two main differences with respect to the BGG mechanism. First, there are no agency problems or asymmetric information in the model, and borrowers will only default if they find themselves underwater: that is, when the value of their outstanding debt is higher than the value of the house they own. Second, unlike the BGG setup, we assume that the one-period lending rate is predetermined and does not depend on the state of the economy, which seems to be a more realistic assumption.[6]

2.1.1 Domestic Intermediaries

Domestic financial intermediaries collect deposits from savers (S_t), for which they pay a deposit rate that equals the risk-free rate of the central bank (R_t), and extend loans to borrowers (S_t^B) for which they charge the lending rate (R_t^L) in the home country. Credit given to borrowers is backed by the value of the housing stock that they own. We introduce risk in the credit and housing markets by assuming that each borrower (indexed by j) is subject to an idiosyncratic quality shock to the value of their housing stock, ω_t^j, that is log-normally distributed with CDF $F(\omega)$ and parameters $\mu_{\omega,t}$ and $\sigma_{\omega,t}$, and with $E\omega_t = 1$. Hence, there is idiosyncratic risk but not aggregate risk in the housing market. This assumption implies that $\log(\omega_t^j) \sim N(-\frac{\sigma_{\omega,t}^2}{2}, \sigma_{\omega,t}^2)$. We assume that the variance of the quality shock is time-varying, and follows an AR(1) process in logs:

$$\log(\sigma_{\omega,t}) = (1 - \rho_{\sigma_\omega}) \log(\bar{\sigma}_\omega) + \rho_{\sigma_\omega} \log(\sigma_{\omega,t-1}) + u_{\omega,t}$$

and $u_{\omega,t} \sim N(0, \sigma_{u_\omega})$.

The presence of this quality shock leads to mortgage defaults and affects the spread between lending and deposit rates. The realization of the shock is known at the end of the period. High realizations of ω_{t-1}^j allow households to repay their loans in full, and hence they repay the full amount of the outstanding loan ($R_{t-1}^L S_{t-1}^B$) back. Realizations of ω_{t-1}^j that are low enough force the household to default on its loans

[6] A similar approach is taken by Suh (2012).

in period t, and it can only repay the value of its housing stock after the shock has realized, $\omega_{t-1}^{j} P_t^D D_t^{B,j}$. The value of the idiosyncratic shock is common knowledge, so households will only default when they are underwater. After defaulting, banks pay a fraction μ of the value of the house to real estate agents that put the house back into the market and resell it. The profits of these real estate agents are transferred to savers, who own them.[7]

When granting credit, financial intermediaries do not know the threshold $\bar{\omega}_t$ which defines the cut-off value of those households that default and those who do not. The ex-ante threshold value expected by banks is thus given by:

$$\bar{\omega}_t^a E_t \left[P_{t+1}^D D_{t+1}^B \right] = R_t^L S_t^B. \tag{1}$$

Intermediaries require the expected return from granting one euro of credit to be equal to the funding rate of banks, which equals the deposit rate (R_t):

$$\begin{aligned} R_t &= (1-\mu) \int_0^{\bar{\omega}_t^a} \omega dF(\omega, \sigma_{\omega,t}) \frac{E_t \left[P_{t+1}^D D_{t+1}^B \right]}{S_t^B} + \left[1 - F\left(\bar{\omega}_t^a, \sigma_{\omega,t} \right) \right] R_t^L \\ &= (1-\mu) G\left(\bar{\omega}_t^a, \sigma_{\omega,t} \right) \frac{E_t \left[P_{t+1}^D D_{t+1}^B \right]}{S_t^B} + \left[1 - F\left(\bar{\omega}_t^a, \sigma_{\omega,t} \right) \right] R_t^L, \end{aligned} \tag{2}$$

The participation constraint ensures that the opportunity costs R_t are equal to the expected returns, which are given by the expected foreclosure settlement as percent of outstanding credit (the first term in the right hand side of 2) and the expected repayment of households with higher housing values (the second term). Due to the fees paid to real estate agents to put the house back in the market, financial intermediaries only receive a fraction $(1 - \mu)$ of the mortgage settlement. When we examine macroprudential policies in Section 4.2, we assume that they work by affecting the supply and demand of credit by borrowers, and hence affect the lending-deposit spread implied by equation (2).

We assume that, for a given demand of credit from borrowers, observed values of risk ($\sigma_{\omega,t}$) and expected values of the housing stock, intermediaries passively set the lending rate R_t^L and the expected (ex-ante) threshold $\bar{\omega}_t^a$ so that (1) and the participation constraint (2) are fulfilled. Unlike the original BGG set-up, the one-period lending rate R_t^L is determined at time t, and does not depend on the state

[7] Under this assumption, no fraction of the housing stock is destroyed during the foreclosure process. If as in BGG a fraction of the collateral was lost during foreclosure, risk shocks would have unrealistic expansionary effects on housing.

of the economy at $t+1$. This means that the participation constraint delivers ex-ante zero profits. However, it is possible that, ex-post, financial intermediaries can make profits or losses. We assume that savers collect profits or recapitalize financial intermediaries as needed.

It is very important to note that the participation constraint delivers a positive relationship between LTV ratios and the spread between the funding and the lending rate, due to the probability of default. To see the intuition more clearly, we set $\mu = 1$ (so, in case of default, the financial intermediary recovers nothing from the defaulted loan). The participation constraint becomes:

$$\frac{R_t^L}{R_t} = \frac{1}{\left[1 - F\left(\bar{\omega}_t^a, \sigma_{\omega,t}\right)\right]}.$$

Hence, the higher is the LTV ratio, the higher is the threshold $\bar{\omega}_t^a$ that leads to default. This shrinks the area of no-default $\left[1 - F\left(\bar{\omega}_t^a, \sigma_{\omega,t}\right)\right]$, and therefore increases the spread between R_t^L and R_t. Similarly, an increase in $\sigma_{\omega,t}$ increases the spread between the lending and the deposit rates. When $\sigma_{\omega,t}$ rises, it leads to a mean-preserving spread for the distribution of ω_t^j: the tails of the distribution become fatter but the mean is unchanged. As a result, because lower realizations of ω_t^j are more likely, more borrowers will default on their loans. Clearly, in an economy where aggregate LTV ratios are high, and the range of possible realizations is large, higher rates of defaults are more likely.

When the financial intermediary is able to recover a fraction $(1-\mu)$ of the collateral value, the participation constraint can be written as:

$$\frac{R_t^L}{R_t} = \frac{1}{\frac{(1-\mu)G(\bar{\omega}_t^a, \sigma_{\omega,t})}{\bar{\omega}_t^a} + \left[1 - F\left(\bar{\omega}_t^a, \sigma_{\omega,t}\right)\right]} \tag{3}$$

It can be shown (using the properties of the lognormal distribution when $E\omega_t = 1$) that the denominator in the spread equation is always declining in $\bar{\omega}_t^a$, and hence the spread is always an increasing function of the LTV. Evidence for the euro area suggests that mortgage spreads are an increasing function of the LTV ratio, as discussed in Sorensen and Lichtenberger (2007) and ECB (2009).

Finally, we assume that the deposit rate in the home country equals the risk-free rate set by the central bank. In the foreign country, domestic financial intermediaries behave the same way. In their case, they face a deposit rate R_t^* and a lending rate

$R_t^{L^*}$, and the spread is determined in an analogous way to equation (2). We explain how the deposit rate in the foreign country R_t^* is determined.

2.1.2 International Intermediaries

International financial intermediaries buy and sell bonds issued by domestic intermediaries in both countries. For instance, if the home country domestic intermediaries have an excess B_t of loanable funds, they will sell them to the international intermediaries, who will lend an amount B_t^* to foreign country domestic intermediaries. International intermediaries apply the following formula to the spread they charge between bonds in the home country (interest rate R_t) and the foreign country (R_t^*):

$$R_t^* = R_t + \left\{ \vartheta_t \exp\left[\kappa_B \left(\frac{B_t}{P_t^C Y^C} \right) \right] - 1 \right\}. \tag{4}$$

The spread depends on the ratio of real net foreign assets to steady-state non-durable GDP in the home country (to be defined below). When home-country domestic intermediaries have an excess of funds that they wish to lend to the foreign country domestic intermediaries, then $B_t > 0$. Hence, the foreign-country intermediaries will pay a higher interest rate R_t^*, which is also the deposit rate in the foreign country. In that case, international financial intermediaries make a profit equal to $(R_t^* - R_t)B_t$. Conversely, if the foreign country becomes a net creditor, then its deposit rate becomes smaller than in the home country. In that case, profits also equal $(R_t^* - R_t)B_t$ which is a positive quantity because both $(R_t^* - R_t) < 0$ and $B_t < 0$. These profits of international intermediaries are split equally across savers of both countries.

The parameter κ_B denotes the risk premium elasticity and ϑ_t is a risk premium shock, which increases the wedge between the domestic and the foreign interest deposit rates. This functional form is also chosen for modeling convenience: international intermediaries are owned by savers in each country, and optimality conditions will ensure that the net foreign asset position of both countries is stationary.[8]

[8] Hence, the assumption that international intermediaries trade uncontingent bonds amounts to the same case as allowing savers to trade these bonds. Under market incompleteness, a risk premium function of the type assumed in equation (4) is required for the existence of a well-defined steady-state and stationarity of the net foreign asset position. See Schmitt-Grohé and Uribe (2003).

2.2 Households

In each country a fraction λ of agents are savers, while the rest $1-\lambda$ are borrowers.

2.2.1 Savers

Savers indexed by $j \in [0, \lambda]$ in the home country maximize the following utility function:

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[\gamma \xi_t^C \log(C_t^j - \varepsilon C_{t-1}) + (1-\gamma) \xi_t^D \log(D_t^j) - \frac{\left(L_t^j\right)^{1+\varphi}}{1+\varphi} \right] \right\}, \tag{5}$$

where C_t^j, D_t^j, and L_t^j represent the consumption of the flow of non-durable goods, the stock of durable goods (i.e. housing) and the index of labor disutility of agent j.

Following Smets and Wouters (2003) and Iacoviello and Neri (2010) we assume external habit persistence in non-durable consumption, with ε measuring the influence of past aggregate non-durable consumption C_{t-1}. The utility function is hit by two preference shocks, each one affecting the marginal utility of non-durable consumption (ξ_t^C) and housing (ξ_t^D). The parameter β stands for the discount factor of savers, γ measures the share of non-durable consumption in the utility function, and φ is the inverse elasticity of labor supply. Furthermore, non-durable consumption is an index composed of home ($C_{H,t}^j$) and foreign ($C_{F,t}^j$) non-durable consumption goods:

$$C_t^j = \left[\tau^{\frac{1}{\iota_C}} \left(C_{H,t}^j\right)^{\frac{\iota_C - 1}{\iota_C}} + (1-\tau)^{\frac{1}{\iota_C}} \left(C_{F,t}^j\right)^{\frac{\iota_C - 1}{\iota_C}} \right]^{\frac{\iota_C}{\iota_C - 1}}, \tag{6}$$

with $\tau \in [0,1]$ denoting the fraction of domestically produced non-durables at home and ι_C governing the substitutability between domestic and foreign goods. In order to be able to explain comovement at the sector level, it is useful to introduce, as in Iacoviello and Neri (2010), imperfect substitutability of labor supply between the durable and non-durable sectors:

$$L_t^j = \left[\alpha^{-\iota_L} \left(L_t^{C,j}\right)^{1+\iota_L} + (1-\alpha)^{-\iota_L} \left(L_t^{D,j}\right)^{1+\iota_L} \right]^{\frac{1}{1+\iota_L}}. \tag{7}$$

The labor disutility index consists of hours worked in the non-durable sector $L_t^{C,j}$ and durable sector $L_t^{D,j}$, with α denoting the share of employment in the non-durable sector. Reallocating labor across sectors is costly, and is governed by parameter ι_L.[9] Wages are flexible and set to equal the marginal rate of substitution between consumption and labor in each sector.

The budget constraint in nominal terms reads:

$$P_t^C C_t^j + P_t^D I_t^j + S_t^j \leq R_{t-1} S_{t-1}^j + W_t^C L_t^{C,j} + W_t^D L_t^{D,j} + \Pi_t^j, \tag{8}$$

where P_t^C and P_t^D are the price indices of non-durable and durable goods, respectively, which are defined below. Nominal wages paid in the two sectors are denoted by W_t^C and W_t^D. Savers have access to deposits in the domestic financial system (S_t^j), that pay the deposit interest rate (R_t). In addition, savers also receive profits (Π_t^j) from intermediate goods producers in the durable and the non-durable sectors, from domestic and international financial intermediaries, and from housing agents that charge fees to domestic financial intermediaries to put repossessed houses back in the market.

Purchases of durable goods, or residential investment (I_t^j) are used to increase the housing stock D_t^j, according to the following law of motion:

$$D_t^j = (1-\delta) D_{t-1}^j + \left[1 - \digamma\left(\frac{I_t^j}{I_{t-1}^j}\right)\right] I_t^j \tag{9}$$

where δ denotes the depreciation rate and $\digamma(\cdot)$ an adjustment cost function. Following Christiano, Eichenbaum, and Evans (2005), $\digamma(\cdot)$ is a convex function, which in steady state meets the following criteria: $\bar{\digamma} = \bar{\digamma}' = 0$ and $\bar{\digamma}'' > 0$.[10]

2.2.2 Borrowers

Borrowers differ from savers along three main dimensions. First, their preferences are different. The discount factor of borrowers is smaller than the factor of savers ($\beta^B < \beta$), and we allow for different habit formation coefficients (ε^B). Second, borrowers do not earn profits from owning intermediate goods producers and finan-

[9] Note that when $\iota_L = 0$ the aggregator is linear in hours worked in each sector and there are no costs of switching between sectors.

[10] This cost function can help the model to replicate hump-shaped responses of residential investment to shocks, and reduce residential investment volatility.

cial intermediaries. For this reason, in equilibrium, savers are willing to accumulate assets as deposits, and borrowers are willing to pledge their housing wealth as collateral to gain access to loans. Finally, as discussed above, borrowers are subject to an quality shock to the value of their housing stock, ω_t^j, that is log-normally distributed with $E\omega_t = 1$.

Their utility function for each borrower $j \in [\lambda, 1]$ reads:

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^{B,t} \left[\gamma \xi_t^C \log(C_t^{B,j} - \varepsilon^B C_{t-1}^B) + (1-\gamma)\xi_t^D \log(D_t^{B,j}) - \frac{\left(L_t^{B,j}\right)^{1+\varphi}}{1+\varphi} \right] \right\}, \tag{10}$$

where all variables and parameters with the superscript B denote that they are specific to borrowers. The indices of consumption and hours worked, and the law of motion of the housing stock have the same functional form as in the case of savers.

The budget constraint for borrowers differs between those who default and those who repay their loans in full. Hence, aggregating borrower's budget constraints and dropping the j superscripts, we obtain the following:

$$\begin{aligned} & P_t^C C_t^B + P_t^D \left[I_t^B + G\left(\bar{\omega}_{t-1}^p, \sigma_{\omega,t-1}\right) D_t^B \right] + \left[1 - F\left(\bar{\omega}_{t-1}^p, \sigma_{\omega,t-1}\right)\right] R_{t-1}^L S_{t-1}^B \\ \leq \ & S_t^B + W_t^C L_t^{C,B} + W_t^D L_t^{D,B}. \end{aligned} \tag{11}$$

Borrowers consume non-durables and invest in the housing stock, and supply labor to both sectors. Savers and borrowers are paid the same wages W_t^C and W_t^D in both sectors. That is, hiring firms are not able to discriminate types of labor depending on whether a household is a saver or a borrower.

Borrowers obtain loans S_t^B from financial intermediaries at a lending rate R_t^L. After aggregate and idiosyncratic shocks hit the economy, borrowers will default if the realization of the idiosyncratic shock falls below the ex-post threshold:

$$\bar{\omega}_{t-1}^p = \frac{R_{t-1}^L S_{t-1}^B}{P_t^D D_t^B}. \tag{12}$$

Because the lending rate is predetermined and is not a function of the state of the economy, it is possible that $\bar{\omega}_t^a$ and $\bar{\omega}_t^p$ differ. Note, however, that when the loan is signed, $\bar{\omega}_t^a = E_t \bar{\omega}_t^p$. The term $\left[1 - F\left(\bar{\omega}_{t-1}^p, \sigma_{\omega,t-1}\right)\right] = \int_{\bar{\omega}_{t-1}^p}^{\infty} dF(\omega; \sigma_{\omega,t-1}) d\omega$ defines the fraction of loans which are repaid by the borrowers, because they were hit by a realization of the shock above the threshold $\bar{\omega}^p_{t-1}$. Similarly, $G\left(\bar{\omega}^p_{t-1}, \sigma_{\omega,t-1}\right) = \int_0^{\bar{\omega}^p_{t-1}} \omega dF(\omega; \sigma_{\omega,t-1}) d\omega$ is the value of the housing stock on which borrowers have defaulted on and which is put back into the market by real estate agents.

2.3 Firms, Technology, and Nominal Rigidities

In each country, homogeneous final non-durable and durable goods are produced using a continuum of intermediate goods in each sector (indexed by $h \in [0, n]$ in the home, and by $f \in [n, 1]$ in the foreign country). Intermediate goods in each sector are imperfect substitutes of each other, and there is monopolistic competition and staggered price setting a la Calvo (1983). Intermediate goods are not traded across countries and are bought by domestic final good producers. In the final good sector, non-durables are sold to domestic and foreign households.[11] Durable goods are solely sold to domestic households, who use them to increase the housing stock. Both final goods sectors are perfectly competitive, operating under flexible prices.

2.3.1 Final Good Producers

Final good producers in both sectors aggregate the intermediate goods they purchase according to the following production function:

$$Y_t^k \equiv \left[\left(\frac{1}{n}\right)^{\frac{1}{\sigma_k}} \int_0^n Y_t^k(h)^{\frac{\sigma_k - 1}{\sigma_k}} dh \right]^{\frac{\sigma_k}{\sigma_k - 1}}, \text{ for } k = C, D \tag{13}$$

where σ_C (σ_D) represents the price elasticity of non-durable (durable) intermediate goods. Profit maximization leads to the following demand function for individual intermediate goods:

$$Y_t^C(h) = \left(\frac{P_t^H(h)}{P_t^H}\right)^{-\sigma_C} Y_t^H, \text{ and } Y_t^D(h) = \left(\frac{P_t^D(h)}{P_t^D}\right)^{-\sigma_D} Y_t^D \tag{14}$$

Price levels for domestically produced non-durables (P_t^H) and durable final goods

[11] Thus, for non-durable consumption we need to distinguish between the price level of domestically produced non-durable goods $P_{H,t}$, of non-durable goods produced abroad $P_{F,t}$, and the consumer price index P_t^C, which will be a combination of these two price levels.

(P_t^D) are obtained through the usual zero-profit condition:

$$P_t^H \equiv \left\{ \frac{1}{n} \int_0^n \left[P_t^H(h) \right]^{1-\sigma_C} dh \right\}^{\frac{1}{1-\sigma_C}}, \text{ and } P_t^D \equiv \left\{ \frac{1}{n} \int_0^n \left[P_t^D(h) \right]^{1-\sigma_D} dh \right\}^{\frac{1}{1-\sigma_D}}.$$

The price level for non-durables consumed in the home country (i.e. the CPI for the home country) includes the price of domestically produced non-durables (P_t^H), and of imported non-durables (P_t^F):

$$P_t^C = \left[\tau \left(P_t^H \right)^{1-\iota_C} + (1-\tau) \left(P_t^F \right)^{1-\iota_C} \right]^{\frac{1}{1-\iota_C}}. \tag{15}$$

2.3.2 Intermediate Good Producers

Intermediate goods are produced under monopolistic competition with producers facing staggered price setting in the spirit of Calvo (1983), which implies that in each period only a fraction $1-\theta_C$ $(1-\theta_D)$ of intermediate good producers in the non-durable (durable) sector receive a signal to re-optimize their price. For the remaining fraction θ_C (θ_D) we assume that their prices are partially indexed to lagged sector-specific inflation (with a coefficient ϕ_C, ϕ_D in each sector).

In both sectors, intermediate goods are produced solely with labor:

$$Y_t^C(h) = Z_t Z_t^C L_t^C(h), \quad Y_t^D(h) = Z_t Z_t^D L_t^D(h) \text{ for all } h \in [0,n] \tag{16}$$

The production functions include country- and sector-specific stationary technology shocks Z_t^C and Z_t^D, each of which follows a zero mean AR(1)-process in logs. In addition, we introduce a non-stationary union-wide technology shock, which follows a unit root process:

$$\log(Z_t) = \log(Z_{t-1}) + \varepsilon_t^Z.$$

This shock introduces non-stationarity to the model and gives a model-consistent way of detrending the data by taking logs and first differences to the real variables that inherit the random walk behavior. In addition, it adds some correlation of technology shocks across sectors and countries, which is helpful from the empirical point of view because it allows to explain comovement of main real variables.

Since labor is the only production input, cost minimization implies that real marginal costs in both sectors are given by:

$$MC_t^C = \frac{W_t^C / P_{H,t}}{Z_t Z_t^C}, \quad MC_t^D = \frac{W_t^D / P_t^D}{Z_t Z_t^D}. \tag{17}$$

Intermediate goods producers in the durable sector face the following maximization problem:

$$Max_{P_t^D(h)} E_t \sum_{s=0}^{\infty} \theta_D^s \Lambda_{t,t+s} \left\{ \left[\frac{P_t^D(h) \left(\frac{P_{t+s-1}^D}{P_{t-1}^D} \right)^{\phi_D}}{P_{t+s}^D} - MC_{t+s}^D \right] Y_{t+s}^D(h) \right\}$$

subject to future demand

$$Y_{t+s}^D(h) = \left[\frac{P_t^D(h)}{P_{t+s}^D} \left(\frac{P_{t+s-1}^D}{P_{t-1}^D} \right)^{\phi_D} \right]^{-\sigma_D} Y_{t+s}^D,$$

where $\Lambda_{t,t+k} = \beta^k \frac{\lambda_{t+k}}{\lambda_t}$ is the stochastic discount factor, with λ_t being the marginal utility of non-durable consumption by savers (since they are the owner of these firms). The evolution of the durable sector price level is given by:

$$P_t^D = \left[\theta_D \left(\widehat{P_t^D} \right)^{1-\sigma_D} + (1-\theta_D)[P_{t-1}^D (P_{t-1}^D / P_{t-2}^D)^{\phi_D}]^{1-\sigma_D} \right]^{\frac{1}{1-\sigma_D}}. \tag{18}$$

where $\widehat{P_t^D}$ is the optimal price of durables chosen at time t. Producers in the non-durable sector face a similar maximization problem with the appropriate change of notation, which delivers a Phillips curve for domestically produced non-durables P_t^H.

2.4 Closing the Model

2.4.1 Market Clearing Conditions

For intermediate goods, supply equals demand. We write the market clearing conditions in terms of aggregate quantities and, thus, multiply per-capita quantities by population size of each country. In the non-durable sector, production is equal to domestic demand by savers $C_{H,t}$ and borrowers $C_{H,t}^B$ and exports (consisting of demand by savers $C^*_{H,t}$ and borrowers $C^{B*}_{H,t}$ from the foreign country):

$$nY_t^C = n\left[\lambda C_{H,t} + (1-\lambda)\, C^B_{H,t}\right] + (1-n)\left[\lambda^* C^*_{H,t} + (1-\lambda^*)\, C^{B*}_{H,t}\right]. \tag{19}$$

Durable goods are only consumed by domestic households and production in this sector is equal to residential investment for savers and borrowers:

$$nY_t^D = n\left[\lambda I_t + (1-\lambda)\, I_t^B\right]. \tag{20}$$

In the labor market total hours worked has to be equal to the aggregate supply of labor in each sector:

$$\int_0^n L_t^k(h)dh = \lambda \int_0^n L_t^{k,j}dj + (1-\lambda)\int_0^n L_t^{k,B,j}dj, \text{ for } k = C, D. \tag{21}$$

Credit market clearing implies that for domestic credit and international bond markets, the balance sheets of financial intermediaries are satisfied:

$$\begin{aligned} n\lambda(S_t + B_t)/\eta_t &= n\,(1-\lambda)\, S_t^B, \qquad (22)\\ n\lambda B_t + (1-n)\lambda^* B_t^* &= 0. \end{aligned}$$

The macro-prudential instrument, η_t, is assumed to be constant and equal to one in the estimation exercise. When we discuss optimal macroprudential policies, we allow η_t to be set countercyclically in order to maximize household's welfare. Finally, aggregating the resource constraints of borrowers and savers, and the market clearing conditions for goods and financial intermediaries, we obtain the law of motion of bonds issued by the home-country international financial intermediaries. This can also be viewed as the evolution of net foreign assets (NFA) of the home country:

$$n\lambda B_t = n\lambda R_{t-1}B_{t-1} + \left\{(1-n)\, P_{H,t}\left[\lambda^* C^*_{H,t} + (1-\lambda^*)\, C^{B*}_{H,t}\right] - nP_{F,t}\left[\lambda C_{F,t} + (1-\lambda)\, C^B_{F,t}\right]\right\}, \tag{23}$$

which is determined by the aggregate stock of last period's NFA times the interest rate, plus net exports.

2.4.2 Monetary Policy and Interest Rates

Monetary policy is conducted at the currency union level by the central bank with an interest rate rule that targets union-wide CPI inflation and real output growth. We assume that the central bank sets the deposit rate in the home-country. Let $\bar{\Pi}^{EMU}$ be the steady state level of union-wide CPI inflation, $\bar{R}$ the steady state level of the interest rate and ε_t^m an *iid* monetary policy shock, the interest rate rule is given by:

$$R_t = \left[\bar{R}\left(\frac{P_t^{EMU}/P_{t-1}^{EMU}}{\bar{\Pi}^{EMU}}\right)^{\gamma_\Pi}\left(Y_t^{EMU}/Y_{t-1}^{EMU}\right)^{\gamma_y}\right]^{1-\gamma_R} R_{t-1}^{\gamma_R}\exp(\varepsilon_t^m). \tag{24}$$

The euro area CPI P_t^{EMU} is given by a geometric average of the home and foreign country CPIs, using the country size as a weight:

$$P_t^{EMU} = \left(P_t^C\right)^n \left(P_t^{C*}\right)^{1-n}.$$

Real GDP in the euro area is given by:

$$Y_t^{EMU} = \left(Y_t\right)^n \left(Y_t^*\right)^{1-n},$$

where the national GDPs are expressed in terms of non-durables, using the employment weights to aggregate both sectors:

$$Y_t = \left(Y_t^C\right)^\alpha \left(Y_t^D \frac{P_t^D}{P_t^C}\right)^{1-\alpha}, \text{ and } Y_t^* = \left(Y_t^{C*}\right)^{\alpha^*} \left(Y_t^{D*} \frac{P_t^{D*}}{P_t^{C*}}\right)^{1-\alpha^*}.$$

3 Parameter Estimates

We apply standard Bayesian methods to estimate the parameters of the model (see An and Schorfheide, 2007). First, the equilibrium conditions of the model are normalized such that all real variables become stationary. This is achieved by dividing real variables in both countries by the level of non-stationary technology, Z_t. Second, the dynamics of the model are obtained by taking a log-linear approximation of equilibrium conditions around the steady state with zero inflation and net foreign asset positions.[12] Third, the solution of the model is expressed in state-space form

[12] Appendix A details the full set of normalized, linearized equilibrium conditions of the model.

and using a Kalman filter recursion the likelihood function of the model is computed. Then, we combine the prior distribution over the model's parameters with the likelihood function and apply the Metropolis-Hastings algorithm to obtain the posterior distribution to the model's parameters.[13]

3.1 Data

We distinguish between a core (home country) and a periphery (foreign country) region of the euro area. Data for the core is obtained by aggregating data for France and Germany, whereas the periphery is represented by Ireland, Italy, Greece, Portugal, and Spain. We use quarterly data ranging from 1995q4-2011q4.[14] For both regions we use five observables: real private consumption spending, real residential investment, the harmonized index of consumer prices (HICP), housing prices, and outstanding debt for households. We also include the 3-month Euribor rate, which we use as counterpart of the deposit rate in the core.[15] The data is aggregated taking the economic size of the countries into account (measured by GDP). All data is seasonally adjusted in case this has not been done by the original source. We use quarterly growth rates of all price and quantity data and we divide the interest rates by 4 to obtain a quarterly equivalent. All data is finally demeaned.

3.2 Calibrated Parameters

Some parameters are calibrated because the set of observable variables that we use does not provide information to estimate them (Table 1). We assume that the discount factors are the same in both countries ($\beta = \beta^*$ and $\beta^B = \beta^{B^*}$) We set the discount factor of savers to $\beta = 0.99$. The steady state LTV ratio, which also determines the cut-off point for defaulting on a loan, is set to $\bar{\omega} = 0.7$ and equally across countries, according to euro area data such as Gerali et al. (2010). We set the default rate on loans, $\bar{F}(.)$ to 2.5 percent.[16] As a result, the steady-state

[13]The estimation is done using Dynare 4.3.1. The posterior distributions are based on 250,000 draws of the Metropolis-Hastings algorithm.

[14]Due to the rather short history of the EMU we include the years 1995-1998 although during this time span European countries were still responsible for their own monetary policy, but were conducting it in a coordinated way.

[15]See Appendix B for further details on the data set.

[16]It is difficult to find non-perfoming loans for household mortgages only. Therefore, we use non-performing loans as percent of total loans for the euro area between 2000-2011, from the World Bank World Development Indicators database (http://data.worldbank.org/topic/financial-sector).

value of the risk shock is $\bar{\sigma}_\omega = 0.1742$. We set the housing agent fee to $\mu = 0.2$, which is a value higher than that calibrated by Forlati and Lambertini (2010), but lower than recovery rates for loans estimated for the United States.[17] Using these values, the zero-profit condition for financial intermediaries, and the consumption Euler equation for borrowers, we calibrate the discount factor of borrowers to $\beta^B = 0.985$. The depreciation rate is assumed to be 10 percent annually and equal across countries ($\delta = \delta^* = 0.025$). The degree of monopolistic competition in the goods markets is the same across sectors and countries, implying mark-ups of 10 percent. We set the size of the core countries in the euro area to $n = 0.6$, based on GDP data. The bilateral trade parameter $1 - \tau$ is calibrated based on the weighted average of total imports to private consumption from periphery to core economies. The analogous parameter for the periphery $1 - \tau^*$ is calculated in a similar way, but is rounded to ensure that the trade balance and the net foreign asset position are zero in the steady state. Finally, we assume that the size of the durable and non-durable sectors is about the same for the core and the periphery of the euro area ($\alpha = \alpha^*$). The assumption of symmetry makes it easier to compute a steady-state where all relative prices in all sectors equal to one, and where all per capita quantities are the same.

Table 1: Calibrated Parameters

β	Discount factor savers	0.99
$\bar{\omega}$	Loan-to-Value ratio	0.7
$\bar{F}$	Default rate on loans	0.025
$\bar{\sigma}_\omega$	Steady-state risk	0.1742
μ	Proportion of housing value paid to real estate agents	0.2
β^B	Discount factor borrowers	0.985
δ	Depreciation rate	0.025
σ	Elasticity of substitution between intermediate goods	10
n	Size core economies	0.6
$1 - \tau$	Fraction of imported goods from periphery to core economies	0.06
$1 - \tau^*$	Fraction of imported goods from core to periphery economies	0.09
α	Size of non-durable sector in GDP	0.94

[17] See Mortgage Bankers Association (2010).

3.3 Prior and Posterior Distributions

In Table 2 we present the prior distributions and the posterior mean and 90 percent credible set of the estimated parameters.[18] We face the problem of a short sample, so, in addition to calibrating some parameters, we restrict others to be the same across countries. More specifically, we only let the parameters related to nominal rigidities across sectors and countries to differ across countries, to allow for quantitatively different transmission channels of monetary policy. On the other hand, the parameters relating to preferences, adjustment costs, and fraction of savers are assumed to be the same in both countries. Also, in order to reduce the number of parameters to be estimated, we assume that the AR(1) coefficients of the shocks are the same across countries. In order to capture different volatilities in the data, we let the standard deviation of the shocks differ across countries. Also, in order to better capture the correlation of key macro variables across countries, we assume that the housing demand shock and the TFP shock in non-durables has a common component across countries. For instance, the housing demand shock follows:

$$\begin{aligned} \log(\xi_t^D) &= \rho_{\xi,D}\log(\xi_{t-1}^D) + \varepsilon_t^{\xi,D} + \varepsilon_t^{\xi,D,COM} \\ \log(\xi_t^{D^*}) &= \rho_{\xi,D}\log(\xi_{t-1}^{D^*}) + \varepsilon_t^{\xi,D^*} + \varepsilon_t^{\xi,D,COM} \end{aligned} \tag{25}$$

where the country-specific $(\varepsilon_t^{\xi,D}, \varepsilon_t^{\xi,D^*})$ and common $(\varepsilon_t^{\xi,D,COM})$ innovations are Normal iid, and with zero mean.

First, we comment on the parameters that relate to preferences of borrowers and savers. We opt for a prior distribution centered at 0.5 for the fraction of savers in the economy. We set a highly informative prior by setting a small standard deviation of 0.1. The posterior mean suggests a larger fraction (0.7) to fit the macro data.[19] Interestingly, we find that the habit formation coefficient for borrowers is smaller than that of savers even though we set the same prior for both coefficients. These estimates suggest that above and beyond the effect of the financial accelerator, consumption of savers is less volatile than consumption of borrowers, who will react more to changes in their relevant (lending) interest rates. We center the priors

[18] For each step of the Metropolis-Hastings algorithm, given a draw of the parameters that we wish to estimate, we must solve for the steady-state levels of consumption of durables and non-durables, hours worked in each sector by each type of agent, and for each country. Then, these steady-state values are needed to obtain the log-linear dynamics to the system. Also, for every draw, we solve for the weight of non-durables in the utility function in each country (γ and γ^*), which is not a free parameter but rather a function of α, δ, λ, β, β^B, ε, ε^B, and φ.

[19] Gerali et al. (2010) calibrate this fraction to be 0.8 for the euro area.

related to the elasticity of substitution between home and foreign non-durables, the elasticity of labor supply and the coefficient measuring costly labor reallocation to parameters available in the literature (Smets and Wouters, 2003; Iacoviello and Neri, 2010; and Adolfson et al., 2007). We find a large elasticity of substitution between home and foreign goods (the posterior mean of 1.94 is much higher than the prior mean of 1.5). Regarding the coefficients that determine labor supply, we find that the posterior mean of the labor disutility coefficient φ and the degree of costly labor reallocation is about one half, which is similar to Iacoviello and Neri (2010).

Table 2: Prior and Posterior Distributions

			Prior		Posterior	
	Parameters		Mean	SD	Mean	90% C.S.
λ	Fraction of savers	Beta	0.5	0.1	0.70	[0.60,0.81]
ε	Habit formation	Beta	0.5	0.15	0.71	[0.63,0.79]
ε^B	Habit formation borrowers	Beta	0.5	0.15	0.41	[0.22,0.61]
φ	Labor disutility	Gamma	1	0.5	0.59	[0.36,0.82]
ι_C	Elasticity of subst. between goods	Gamma	1.5	0.5	1.94	[1.06,2.73]
ι_L	Labor reallocation cost	Gamma	1	0.5	0.59	[0.37,0.81]
ψ	Investment adjustment costs	Gamma	2	1	1.82	[1.11,2.47]
γ_π	Taylor rule reaction to inflation	Normal	1.5	0.1	1.56	[1.41,1.71]
γ_y	Taylor rule reaction to real growth	Gamma	0.2	0.05	0.21	[0.13,0.29]
γ_r	Interest rate smoothing	Beta	0.66	0.15	0.79	[0.76,0.83]
κ_B	International risk premium	Gamma	0.01	0.005	0.0045	[0.002,0.007]
θ_C	Calvo lottery, non-durables	Beta	0.75	0.15	0.58	[0.50,0.67]
θ_C^*	Calvo lottery, non-durables	Beta	0.75	0.15	0.70	[0.64,0.77]
θ_D	Calvo lottery, durables	Beta	0.75	0.15	0.60	[0.51,0.70]
θ_D^*	Calvo lottery, durables	Beta	0.75	0.15	0.60	[0.52,0.67]
ϕ_C	Indexation, non-durables	Beta	0.33	0.15	0.17	[0.03,0.32]
ϕ_C^*	Indexation, non-durables	Beta	0.33	0.15	0.14	[0.02,0.26]
ϕ_D	Indexation, durables	Beta	0.33	0.15	0.22	[0.03,0.39]
ϕ_D^*	Indexation, durables	Beta	0.33	0.15	0.40	[0.16,0.64]

The coefficients on the Taylor rule suggest a strong response to inflation fluctuations in the euro area (coefficient of 1.56, close to the prior mean), a moderate response to real GDP growth (posterior mean of 0.21) and a high degree of interest rate inertia (0.79). We opt for a gamma priors for the risk premia elasticity (κ_B) between countries with a mean of 0.01. We find that the risk premium elasticity between countries moves about 0.45 basis points.

Next, we comment on the coefficients regarding nominal rigidities. We opt for Beta prior distributions for Calvo probabilities with a mean of 0.75 (average duration of price contracts of three quarters) and standard deviation of 0.15. We set the mean of the prior distributions for all indexation parameters to 0.33. This set of priors is consistent with the survey evidence on price-setting presented in Fabiani et al. (2006). The posterior means for the Calvo lotteries are lower than the prior means, and in all cases prices are reset roughly every three quarters. Overall, these probabilities are lower than other studies of the euro area like Smets and Wouters (2003). We also find that price indexation is low in all prices and sectors. One possible explanation is that we are using a shorter and more recent data set where inflation rates are less sticky than in the 1970s and 1980s.

In Table 3 we present the prior and posterior distributions for the shock processes. While it is difficult to extract too much information from just discussing the shock processes, the posterior means for the AR(1) coefficients suggest highly correlated shocks, in particular for both technology shocks and for the preference shock to durables. Table 3 also shows that for both technology and preference shocks, the standard deviations tend to be larger for shocks affecting durables, which reflect that housing variables (prices and quantities) are more volatile than consumption and the CPI. The common innovation to non-durable technology shocks and durable preference shocks is important, and as we discuss in the next subsection it is key to obtain cross-country correlations of some key macro variables.

The scaling of the housing risk shocks deserve some explanation. As we showed in Table 1, the mean of the (log) risk shock is $\log(0.1742) = -1.74$. Therefore, we set a prior standard deviation for the innovation to the housing risk shock of 0.25 (that is, 25 percent), such that, roughly, the two-standard deviation interval is between -1.25 and -2.25. Given the properties of the log-normal distribution discussed above, this means that the default rate for mortgages ranges between 0.04 and 13.6 percent with 95 percent probability. This seems to be an acceptable range in the euro area.[20] The estimates for the quality shock in the periphery are similar to the prior, while in the core there seems to be much less risk volatility, and the posterior of the standard deviation of the innovation to risk is about a half of the prior mean.

3.4 Model Fit and Variance Decomposition

In order to better understand the model fit, we present the standard deviation and first five autocorrelations of the observable variables, and their counterpart in the

[20] See the World Development Indicators database from the World Bank.

Table 3: Prior and Posterior Distributions, Shock Processes

	Parameters		Prior		Posterior	
	AR(1) coefficients		Mean	S.D.	Mean	90% C.S.
$\rho_{Z,C}$	Technology, non-durables	Beta	0.7	0.1	0.84	[0.76,0.94]
$\rho_{Z,D}$	Technology, durables	Beta	0.7	0.1	0.89	[0.84,0.95]
$\rho_{\xi,C}$	Preference, non-durables	Beta	0.7	0.1	0.71	[0.58,0.83]
$\rho_{\xi,D}$	Preference, durables	Beta	0.7	0.1	0.98	[0.96,0.99]
ρ_{ω}	Risk shock, durables	Beta	0.7	0.1	0.84	[0.79,0.89]
ρ_{ϑ}	Risk premium, core-periphery	Beta	0.7	0.1	0.72	[0.57,0.87]
	Std. Dev. Shocks (in percent)					
σ_Z	Technology, EMU-wide	Gamma	0.7	0.2	0.50	[0.41,0.69]
σ_Z^C	Tech., non-durables, core	Gamma	0.7	0.2	0.58	[0.37,0.79]
σ_Z^{C*}	Tech., non-durables, periphery	Gamma	0.7	0.2	0.94	[0.64,1.22]
$\sigma_Z^{C,COM}$	Tech., non-durables, common	Gamma	0.7	0.2	0.60	[0.42,0.78]
σ_Z^D	Tech., durables, core	Gamma	0.7	0.2	1.43	[1.07,1.76]
σ_Z^{D*}	Tech., durables, periphery	Gamma	0.7	0.2	1.50	[1.17,1.83]
σ_ξ^C	Preference, non-durables, core	Gamma	1	0.5	1.99	[1.42,2.54]
σ_ξ^{C*}	Pref., non-durables, periphery	Gamma	1	0.5	1.61	[1.05,2.18]
σ_ξ^D	Pref., durables, core	Gamma	1	0.5	3.15	[2.25,4.02]
σ_ξ^{D*}	Pref., durables, periphery	Gamma	1	0.5	3.65	[2.76,4.55]
$\sigma_\xi^{D,COM}$	Pref., durables, common	Gamma	1	0.5	1.83	[0.92,2.74]
σ_m	Monetary	Gamma	0.4	0.2	0.12	[0.1,0.14]
σ_ϑ	Risk premium, international	Gamma	0.4	0.2	0.2	[0.09,0.31]
$\sigma_{u_{\omega,t}}$	Risk shock, durables, core	Gamma	25	12.5	11.89	[8.55,15.04]
$\sigma_{u^*_{\omega,t}}$	Risk shock, durables, periphery	Gamma	25	12.5	22.91	[17.07, 28.67]

model implied by the posterior distribution of the parameters. In Table 4, the first row in each case is the data, the second row is the 90 percent confident set implied by the model estimates. The model does reasonably well in explaining the standard deviation of all variables in the periphery. However, the model overpredicts the volatility of prices and quantities in both sectors in the core of the euro area, despite having allowed for different degrees of nominal rigidities, indexation, and different standard deviations of shocks. It appears that business cycles are less pronounced in the core, at least for the time period we study. Finally, the model correctly implies that credit growth in the periphery is more volatile than in the core, but at the same time it overpredicts the volatility of credit growth in the core.

The model does also a better job in explaining the persistence of variables in the periphery than in the core, and does a good job in predicting the persistence of interest rates. It slightly overpredicts the persistence of CPI inflation in the periphery, and slight underpredicts the persistence of residential investment, consumption growth, and house prices. In the core, the model has a harder time fitting the lack of persistence in CPI inflation, residential investment and consumption growth.

Table 4: Posterior Second Moments in the Data and in the Model

	Std. Dev.	Autocorrelation				
		1	2	3	4	5
R	0.35	0.89	0.76	0.62	0.47	0.32
	[0.22,0.29]	[0.84,0,91]	[0.65,0.80]	[0.48,0.68]	[0.34,0.59]	[0.24,0.50]
Δp^C	0.30	0.21	0.08	0.21	-0.15	-0.19
	[0.35,0.45]	[0.46,0.60]	[0.12,0.30]	[-0.02,0.15]	[-0.07,0.07]	[-0.08,0.04]
$\Delta \log C$	0.46	-0.13	0.12	0.11	-0.05	0.26
	[0.60,0.76]	[0.44,0.54]	[0.13,0.26]	[-0.01,0.08]	[-0.08,-0.01]	[-0.11,-0.06]
$\Delta \log Y^D$	1.67	0.05	0.06	0.06	0.12	-0.01
	[1.95,2.59]	[0.47,0.65]	[0.15,0.39]	[-0.01,0.20]	[-0.09,0.08]	[-0.11,0.00]
Δp^D	0.72	0.56	0.53	0.40	0.30	0.18
	[0.88,1.13]	[0.57,0.68]	[0.20,0.37]	[-0.01,0.17]	[-0.09,0.05]	[-0.11,-0.02]
$\Delta \log S$	0.45	0.25	0.32	0.17	0.52	-0.01
	[0.92,1.14]	[0.60,0.74]	[0.20,0.37]	[-0.01,0.17]	[-0.09,0.05]	[-0.11,-0.02]
Δp^{C^*}	0.31	0.42	0.22	0.02	-0.27	-0.22
	[0.34,0.43]	[0.54, 0.67]	[0.22,0.40]	[0.05,0.23]	[-0.03,0.13]	[-0.06,0.06]
$\Delta \log C^*$	0.59	0.59	0.52	0.44	0.31	0.23
	[0.53,0.68]	[0.45, 0.57]	[0.15,0.29]	[0.00,0.12]	[-0.07,0.02]	[-0.10,-0.03]
$\Delta \log Y^{D^*}$	2.24	0.59	0.55	0.58	0.47	0.46
	[2.19,2.88]	[0.44, 0.65]	[0.11,0.40]	[-0.04,0.20]	[-0.09,0.07]	[-0.11,0.00]
Δp^{D^*}	1.44	0.87	0.84	0.77	0.72	0.65
	[0.97,1.27]	[0.61, 0.73]	[0.24,0.40]	[0.00,0.16]	[-0.11,0.02]	[-0.14,-0.05]
$\Delta \log S^*$	1.38	0.46	0.62	0.46	0.61	0.27
	[1.42,1.80]	[0.51, 0.67]	[0.39,0.54]	[0.27,0.42]	[0.17,0.31]	[0.09,0.21]

Notes: For each variable, the top row denotes second moments in the data, and the bottom row denotes posterior second moments in the estimated model (90 percent credible set). Standard deviations for all variables are in percent terms.

The model captures most of the comovement between main aggregates within and across countries of the euro area, which is especially important for the design of optimal monetary and macroprudential policies. In Table 5 we present the contemporaneous correlation of the observable variables in the data and in the model (90 percent confidence set). Among the successes, we note that the model explains the correlation between house prices and residential investment within each area well. The model also fits well the correlation of CPI inflation, house price inflation, consumption growth and residential investment growth across countries. The model can explain the comovement between consumption and residential investment in the core, but fails at explaining the comovement in the periphery. Finally, the model does a good job in explaining the correlation of credit with main macroeconomic variables in the core. However, while it gets the sign of the correlation right, the model does a worse job in explaining the correlation of credit with other macro aggregates in the periphery, because it implies a correlation that is smaller than in the data.

Table 5: Correlation Matrix

	R	Δp^C	$\Delta \log C$	$\Delta \log Y^D$	Δp^D	$\Delta \log S$	Δp^{C^*}	$\Delta \log C^*$	$\Delta \log Y^{D^*}$	Δp^{D^*}
Δp^C	0.01	1								
	[0.28,0.44]	1								
$\Delta \log C$	0.05	-0.17	1							
	[-0.24, -0.13]	[-0.16,0.05]	1							
$\Delta \log Y^D$	-0.21	-0.04	0.10	1						
	[-0.05,0.01]	[-0.03,0.06]	[-0.04,0.11]	1						
Δp^D	-0.53	0.03	0.31	0.35	1					
	[-0.10,-0.01]	[-0.35,0.17]	[-0.12,0.05]	[0.27,0.50]	1					
$\Delta \log S$	0.15	-0.03	0.18	0.20	0.29	1				
	[0.09,0.26]	[-0.11,0.09]	[0.06,0.22]	[0.28,0.39]	[0.43,0.55]	1				
Δp^{C^*}	0.23	0.74	-0.13	0.12	0.09	0.08	1			
	[0.32,0.47]	[0.5,0.72]	[-0.22,-0.10]	[-0.05,0.01]	[-0.21,-0.11]	[-0.07,0.05]	1			
$\Delta \log C^*$	0.17	-0.03	0.31	0.16	0.29	0.61	0.13	1		
	[-0.28,-0.17]	[-0.25,-0.12]	[0.09,0.31]	[0.03,0.16]	[0.06,0.15]	[0.02,0.12]	[-0.13,0.07]	1		
$\Delta \log Y^{D^*}$	0.23	0.12	0.35	0.26	0.32	0.50	0.34	0.63	1	
	[-0.05,0.00]	[-0.05,0.01]	[0.02,0.11]	[0.06,0.34]	[0.04,0.25]	[0.03,0.16]	[0.02,0.12]	[0.01, 0.18]	1	
Δp^{D^*}	0.09	-0.09	0.18	0.03	0.38	0.24	0.09	0.54	0.59	1
	[-0.07,0.01]	[-0.18,-0.07]	[0.01,0.10]	[0.04,0.25]	[0.33,0.38]	[0.06,0.21]	[-0.17,0.12]	[-0.04,0.17]	[0.22,0.50]	1
$\Delta \log S^*$	0.22	0.04	0.16	0.07	0.30	0.37	0.21	0.61	0.53	0.73
	[0.07,0.22]	[-0.06,0.03]	[0.01,0.08]	[0.03,0.13]	[0.06,0.17]	[0.08,0.21]	[-0.02,0.15]	[0.01,0.11]	[0.23,0.33]	[0.33,0.43]

Notes: For each variable, the top row denotes the correlation in the data, and the bottom row denotes the posterior correlation in the estimated model (90 percent credible set).

Next, we proceed to ask which shocks explain the volatility of each variable, always through the lens of the estimated model. The results are presented in Table 6, where we show the 90 percent confidence set for the share of the variance of each variable explained by the two most important shocks. For all variables, two shocks are enough to explain at least half of their variance, while the remaining shocks explain a small fraction of the variance one at a time. Perhaps a bit surprisingly, each variable in each country and sector is mostly explained by technology and preference shocks in that country and sector. For instance, residential investment and housing prices are mostly explained by a combination of supply and demand shocks in both the core and the periphery. There are no important spillovers from shocks originating in one country or sector to another. There are two exceptions to this pattern. CPI inflation in both areas is explained by the common innovation component to nondurable technology, and monetary shocks. The unit root shock to aggregate technology explains an important fraction of volatility of consumption growth in both areas. Finally, it is worth noting that in each country, the volatility of credit is mostly explained by risk shocks and by housing demand (durable preference) shocks. However, both monetary and risk shocks do not have an important impact on the volatility of real macroeconomic variables.

3.5 Model Comparison: A Brief Discussion

The model we have just discussed is the one that appears to explain the observable data best. In this subsection, we briefly discuss other model specifications that we have estimated. The full results including model comparison statistics such as the marginal likelihood for each model, and posterior distributions for the model's parameters and second moments implied by each model are available upon request.

First, we discuss the main findings of estimating a model with only savers by setting $\lambda = 1$. In this case, the model does not have financial frictions and credit growth does not enter the set of observable variables for both areas in the EMU, which complicates using the marginal likelihood as a model comparison statistic. Also, we dropped the risk shocks in the housing market, because without financial frictions they play no role. In the only savers case, we found that most parameter estimates are very similar to what we reported in Table 2, and the posterior second moments are also very similar to the model with borrowers and savers. Hence, we find that in order to fit macroeconomic variables such as CPI inflation, house prices, consump-

Table 6: Posterior Variance Decomposition (90 percent confidence set)

	Shocks	
R	Common Nondurable Technology [24.2,51.0]	Core Nondurable Preference [9.7, 32.9]
Δp^C	Common Nondurable Technology [22.2,46.8]	Monetary [16.7,31.8]
$\Delta \log C$	Core Nondurable Preference [60.5,82.5]	EMU-wide Technology [7.6,23.6]
$\Delta \log Y^D$	Core Durable Preference [36.3,66.2]	Core Durable Technology [16.5,32.1]
Δp^D	Core Durable Preference [29.0,53.1]	Core Durable Technology [19.4,34.3]
$\Delta \log S$	Risk Core [38.7,58.7]	Core Durable Preference [17.9,38.1]
Δp^{C^*}	Common Nondurable Technology [16.5,37.2]	Monetary [12.9,27.8]
$\Delta \log C^*$	Periphery Nondurable Preference [41.6,75.4]	EMU-wide Technology [9.5,28.0]
$\Delta \log Y^{D^*}$	Periphery Durable Preference [40.8,67.9]	Periphery Durable Technology [19.2,31.5]
Δp^{D^*}	Periphery Durable Preference [29.0,53.1]	Periphery Durable Technology [19.4,34.3]
$\Delta \log S^*$	Risk Periphery [63.2, 79.7]	Periphery Durable Preference [9.6,20.2]

tion and residential investment, it is not necessary to introduce financial frictions in the model. However, the model we presented in this paper allows us to model the interaction between credit aggregates and other macroeconomic variables.

Second, we also estimated the model without common innovations in nondurable technology shocks and durable preference shocks across countries. In this case, the model fit to the data was worse when trying to explain the correlation of consumption growth, residential investment growth and house prices across countries. This result holds in the model with borrowers and savers, and in a model with savers only. We also experimented with introducing common innovations to other shocks in the model but we found that the estimates of the standard deviations were quite small, and hence did not change the implications of the model for posterior second moments.

Finally, following the results in Christiano, Motto and Rostagno (2013), we also introduced news shocks in the housing quality shocks as follows:

$$\log(\sigma_{\omega,t}) = (1-\rho_{\sigma_\omega})\log(\bar{\sigma}_\omega) + \rho_{\sigma_\omega}\log(\sigma_{\omega,t-1}) + \sum_{p=0}^{s} u_{\omega,t-p}$$

for $s = 1$ to 4. We found that the marginal likelihood favored the model without news shocks, and this is why we excluded them from the analysis. When we performed a posterior variance decomposition exercises as in Table 6, we found that each news shocks explained a fraction of the variance of credit, but they only explained a very minor fraction (less than 1 percent) of real macroeconomic variables.

4 Policy Experiments

This section discusses the optimal monetary and macroprudential policy mix for the euro area. For this purpose, we analyze the performance of different policy rules using the estimated parameter values and shock processes of the previous section. We evaluate aggregate welfare by taking a second order approximation to the utility function of each household and country, and to the equilibrium conditions of the model, at the posterior mode of the model's parameters. When policy is conducted at the EMU-wide level, we assume that policy makers maximize the welfare function of all citizens of the euro area (borrowers and savers in the core and periphery) using their population weights. That is, we define the welfare function as:

$$\begin{aligned} \mathcal{W}^{EMU} &= n\mathcal{W} + (1-n)\mathcal{W}^* \qquad (26) \\ \text{with } \mathcal{W} &= \lambda\mathcal{W}^S + (1-\lambda)\mathcal{W}^B \text{ and } \mathcal{W}^* = \lambda^*\mathcal{W}^{S^*} + (1-\lambda^*)\mathcal{W}^{B^*}, \end{aligned}$$

where $\mathcal{W}^S$ is the welfare of core savers, which is evaluated by taking a second order approximation to the utility function (5) and subtracting the value of the utility function at the non-stochastic steady-state.[21] $\mathcal{W}^B$ is the welfare of core borrowers, which is evaluated similarly using their utility function (10). $\mathcal{W}^{S^*}$ and $\mathcal{W}^{B^*}$ are defined analogously for the periphery households.

First, we study optimal monetary policy rules by optimizing over the coefficients of the estimated Taylor rule. Second, we extend the Taylor rule to react to house price

[21] That is, $\mathcal{W}^S = E\left[U(C_t, D_t, N_t)\right] - U(\bar{C}, \bar{D}, \bar{N})$, where E[.] is the expectations operator, U is a second order approximation to the utility function and $\bar{C}, \bar{D}$ and $\bar{N}$ are the non-stochastic steady-state values.

inflation and different measures involving credit (such as credit growth, the credit-to-GDP ratio, and the LTV ratio), and optimize over the additional coefficients. Third, we include a macroprudential rule that "leans against the wind" of credit cycles. We assume that macroprudential policies affect the credit market clearing condition (22) by using the η_t instrument directly. Different measures could be used to that effect, such as increasing loan provisions, capital requirements, and reserve requirements, or changing maximum LTV ratios.[22] As in the case of extended optimal monetary policy, the macroprudential instrument reacts whenever house price inflation or different measures involving credit (such as credit growth, the credit-to-GDP ratio, and the LTV ratio) deviate from steady-state values. To obtain the optimal policy response of the central bank, we shut off the monetary policy shock ε_t^m in all of these simulations.[23]

4.1 Optimal Monetary Policy

4.1.1 Estimated Taylor Rule

We start by optimizing over the coefficients of the estimated Taylor rule to maximize the EMU-wide welfare function (26). In particular, we optimize over the coefficients of the reaction to area-wide inflation, area-wide growth, and interest rate smoothing. Also, we truncate the coefficients of the response to inflation and output growth in the Taylor rule. As in Schmitt-Grohe and Uribe (2007), we found that the welfare improvements were numerically very small (in the range of 10^{-6}) when the coefficients of the Taylor rule were left unbounded. In order to speed up the maximization routines, it was helpful to truncate the coefficients γ_π and γ_y to 5. The coefficient on interest rate smoothing is restricted to be between $[0, 1]$.

In the first row of Table 7, we show the optimized coefficients of the estimated Taylor rule. We also compute the improvement in welfare with respect to the estimated Taylor rule in percentage terms.[24] The optimal monetary policy suggests stronger responses to euro-area CPI inflation and output growth than the estimated coeffi-

[22] See Crowe et al. (2011) and Vandenbussche et al. (2012) for a discussion on the effects of different macroprudential measures.

[23] Including the monetary policy shock in our policy experiments would primarily affect the results for the inertia coefficient. In this case, the optimal degree of inertia would tend towards zero for most simulations.

[24] In optimal monetary policy analysis, it is customary to report changes in welfare in terms of consumption goods (see Schmitt-Grohe and Uribe, 2007). However, this is a two-country, two-agent, two-good economy, so this calculation is not straightforward.

Table 7: Optimal Taylor Rule Coefficients

	γ_π	γ_y	γ_r	γ_s	$\mathcal{W}^S$	$\mathcal{W}^B$	$\mathcal{W}^{S^*}$	$\mathcal{W}^{B^*}$	$\mathcal{W}^{EMU}$
Original	5.00	0.47	0.54	-	3.71	1.41	3.45	0.56	2.72
with Nom. Credit Growth	5.00	0.00	0.71	0.80	5.17	-0.39	6.26	-1.46	3.40
	1.57	*0.21*	*0.80*	0.31	2.62	-1.79	3.84	-2.09	1.41
with Credit/GDP	5.00	0.47	0.54	0.00	3.71	1.41	3.45	0.56	2.72
	1.57	*0.21*	*0.80*	0.00	0.00	0.00	0.00	0.00	0.00
with House Price Infl.	5.00	0.06	0.15	1.34	7.11	-1.29	5.78	-1.17	3.94
	1.57	*0.21*	*0.80*	0.60	3.99	-2.17	3.15	-1.51	1.80
with Loan to Value	5.00	0.47	0.54	0.00	3.71	1.41	3.45	0.56	2.72
	1.57	*0.21*	*0.80*	0.00	0.00	0.00	0.00	0.00	0.00

Note: Parameter values in italics are not optimized over but calibrated at their estimated posterior mean.

cients, and less interest-rate smoothing. In this case, the welfare of all households in the euro area improves by about 2.7 percent, but more so for savers (about 3.5 percent) in both countries.

4.1.2 Extending the Taylor Rule with Financial Variables

Next, we examine by how much would welfare improve if the ECB were to react to additional euro-area wide indicators. We either optimize over: (i) all the coefficients of the Taylor rule, including the coefficient of the financial variable, or (ii) only over the coefficient on the additional indicator only, leaving the others at their estimated values. There is no welfare improvement in reacting to the credit-to-GDP ratio and the LTV ratio. Among the four policies we study, the rule that optimizes welfare at the EMU level consists in extending the original rule with house price inflation. The optimal coefficient on the reaction to nominal house price inflation is 1.34. This result is somewhat expected since the model features nominal house price rigidity, so having monetary policy react to house prices is desirable. Also, while the policy improves on EMU welfare, it actually declines for borrowers both in the periphery and in the core. However, in the aggregate, welfare improves by an additional 1 percent with respect to the optimized Taylor rule without house prices. The same qualitative result is obtained when the ECB reacts to nominal credit growth. In this case, the optimal coefficient is positive, and the welfare of savers increases between 5 and 6 percent compared to the estimated Taylor rule. Yet, welfare of borrowers declines, especially in the periphery, implying that overall, welfare in the EMU only improves slightly with respect to the case where the ECB optimizes over the original coefficients of the Taylor rule only. We will examine this result below in the context of impulse-response functions.

The same qualitative results hold when we keep the coefficients of the Taylor rule at their estimated values and only optimize over the additional parameter. Reacting to nominal credit growth or house price inflation improves welfare in the aggregate, but not for everyone. Responding to these two indicators is thus, not Pareto improving, while reacting to the credit-to-GDP or LTV ratios does not improve welfare at all. What is most interesting for our results is that the heterogeneity in the model allows us to identify the winners and losers of different monetary policy regimes in the EMU.

4.2 Macroprudential Regulation

Monetary policy in a currency union has a mandate to stabilize union-wide variables such as inflation and output. However, risk build-ups due to excessive credit growth or leverage can be limited to a few countries, potentially amplifying the business cycles in those countries. Therefore, macroprudential regulation could be a toolkit applicable on the national level aiming at preventing financial vulnerabilities in a particular member state. In addition, regulation reacting to national developments can make up for the lack of national monetary policy among euro area members. In this subsection, we analyze macroprudential policies that are set countercyclically either at the EMU or at the national level. As in Kannan, Rabanal, and Scott (2012) we introduce a macroprudential tool that aims at affecting the credit market conditions countercyclically. We assume that the macroprudential rule affects credit supply and spreads imposing higher capital requirements, liquidity ratios or loan-loss provisions that either restrict the amount of available credit or increase the cost for banks to provide loans. A similar approach is followed by several models studied by the BIS to quantify the costs and benefits of higher capital requirements (see MAG, 2010a and 2010b; Angelini et al., 2011a).

We assume that financial intermediaries are only allowed to lend a fraction η_t of loanable funds that they are able to collect. This fraction could be thought of a liquidity ratio, a reserve requirement, or a capital requirement. Hence, financial intermediaries will pass the costs of not being able to lend a given amount of funds to their customers. For instance, in the home country the macroprudential policy affects the domestic credit market equilibrium as follows:

$$\lambda(S_t + B_t)/\eta_t = (1-\lambda)\, S_t^B,$$

It is useful to rewrite the participation constraint of financial intermediaries, using aggregate quantities and the macroprudential instrument as:

$$\frac{R_t^L}{R_t} = \frac{\eta_t}{\left[(1-\mu)\int_0^{\bar{\omega}_t^a} \omega dF(\omega, \sigma_{\omega,t})\bar{\omega}_t^a + \left[1 - F\left(\bar{\omega}_t^a, \sigma_{\omega,t}\right)\right]\right]}$$

A tightening of credit conditions, reflected in a higher η_t, will increase the lending rate faced by borrowers. We specify the macroprudential instrument as reacting to an indicator variable (Υ_t):

$$\eta_t = (\Upsilon_t)^{\gamma_\eta}, \quad \eta_t^* = (\Upsilon_t^*)^{\gamma_\eta^*} \tag{27}$$

We study four cases, where in each country the macroprudential instrument reacts to following domestic variables: (i) nominal credit growth, (ii) credit-to-GDP ratio, (iii) nominal house price growth, and (iv) the LTV ratio. In all cases the indicator reacts to deviations from steady-state values.[25]

4.2.1 Regulation at the EMU-Level

We analyze the optimal policy regime consisting of the estimated Taylor rule together with a national macroprudential rule and optimize over the parameters of both rules in order to maximize the welfare criterion (26). In this first scenario, monetary policy reacts to union-wide developments, while macroprudential policy responds to domestic developments in each country. The coefficients of both policy rules are jointly decided to maximize welfare at the European level. Since we allow the macroprudential rule to affect credit spreads directly, we no longer include the reaction to credit or housing aggregates in the Taylor rule. Therefore, the macroprudential instrument can be viewed as an alternative to having monetary policy react to indicators beyond CPI inflation and output growth. We present the results in Table 8, where rules are ranked according to percent changes in welfare from the case of using the estimated Taylor rule and no countercyclical macroprudential

[25]Note that while the regulator sets the target for the loan-to-value ratio and knows that value, she might have a more difficult time in calibrating the correct target for the credit-to-GDP ratio for the private sector.

Table 8: Optimal Monetary and Macroprudential Policy at the EMU Level

Using Optimized Taylor Rule										
	γ_π	γ_y	γ_r	γ_η	γ_η^*	$\mathcal{W}^S$	$\mathcal{W}^B$	$\mathcal{W}^{S^*}$	$\mathcal{W}^{B^*}$	$\mathcal{W}^{EMU}$
Nom.Credit Growth	5.00	0.29	0.71	0.47	0.70	3.19	5.76	3.12	8.82	4.58
Restricted	5.00	0.29	0.71	0.59	-	2.43	7.46	4.09	7.29	4.55
Credit/GDP	5.00	0.59	0.62	5.00	5.00	13.27	-9.00	41.82	-31.01	9.63
Restricted	5.00	0.59	0.63	5.00	-	13.27	-9.00	41.82	-31.01	9.63
House Price Infl.	5.00	0.42	0.62	0.39	0.41	4.95	0.35	5.44	-0.61	3.36
Restricted	5.00	0.42	0.62	0.40	-	4.95	0.35	5.43	-0.60	3.36
Loan to Value	5.00	0.44	0.42	0.19	0.84	10.81	-10.35	37.74	-32.26	7.12
Restricted	5.00	0.43	0.36	0.44	-	11.23	-12.18	36.06	-29.97	6.94
Using Estimated Taylor Rule										
	γ_π	γ_y	γ_r	γ_η	γ_η^*	$\mathcal{W}^S$	$\mathcal{W}^B$	$\mathcal{W}^{S^*}$	$\mathcal{W}^{B^*}$	$\mathcal{W}^{EMU}$
Nom. Credit Growth	*1.57*	*0.21*	*0.80*	0.55	0.76	0.52	3.71	1.08	7.57	2.43
Restricted	*1.57*	*0.21*	*0.80*	0.66	-	-0.03	4.92	1.79	6.43	2.40
Credit/GDP	*1.57*	*0.21*	*0.80*	0.75	1.71	6.68	-7.00	36.39	-30.76	5.94
Restricted	*1.57*	*0.21*	*0.80*	1.11	-	7.22	-8.36	35.25	-29.29	5.88
House Price Infl.	*1.57*	*0.21*	*0.80*	0.50	0.50	2.56	-2.64	3.54	-2.26	1.14
Restricted	*1.57*	*0.21*	*0.80*	0.51	-	2.56	-2.65	3.55	-2.27	1.14
Loan to Value	*1.57*	*0.21*	*0.80*	0.14	0.52	6.29	-10.76	32.89	-31.96	4.02
Restricted	*1.57*	*0.21*	*0.80*	0.30	-	6.79	-12.80	30.81	-29.19	3.82

policy. We consider the following combinations of cases: (i) when the coefficients of the Taylor rule are the estimated ones, or are optimized with the parameters of the macroprudential rule, and (ii) when the coefficients of the macroprudential policies are allowed to change across countries, and when they are restricted to be the same.

Several interesting results arise from this exercise. First of all, and as in the case of having monetary policy react to financial variables, there are winners and losers of introducing macroprudential policies in most cases. The only policy that improves welfare for all citizens of the EMU, yet it ranks third among the four possible options, is to have macroprudential policy react to nominal credit growth. In this regime, all household experience increases in welfare between 2.5 and 9 percent, and there are no numerical differences (in the coefficients of the Taylor rule) if we impose the restriction that the coefficients are the same across countries. For both cases, there is a further welfare improvement at the EMU level of about 2 percentage points with respect to the regime with optimized Taylor rule coefficients only. Second, the policy that delivers higher welfare (reacting to the credit-to-GDP ratio) is highly divisive, since savers benefit greatly from it, while borrowers witness an important decrease of welfare with respect to the estimated rule. The same outcome applies when macroprudential policies react countercyclically to LTV ratios. Finally, the worse policy in terms of welfare is to use macroprudential policies to lean against the wind of house prices. Similar qualitative results are obtained when we use the estimated Taylor rule but optimized coefficients over the macroprudential instrument.

Why is it the case that the welfare of borrowers declines under some optimal regimes of monetary and macroprudential policy? In Figures 1-2 we plot the impulse responses to a housing demand shock and a risk shock in the periphery. We choose these shocks since the periphery has been experiencing a larger boom-bust cycle in housing prices and credit than in the core, especially in Spain and Greece. After a housing demand shock (normalized such that nominal house prices increase by 1 percent), GDP, CPI inflation, house prices and credit-to-GDP increase in the periphery under the estimated rule (Figure 1). In the core, GDP increases slightly, while all other variables fall because the ECB tightens rates due to above-normal CPI inflation and growth in the periphery. But the spillover effects tend to be quantitatively small. In the periphery, both borrowers and savers increase residential investment demand, and consumption behaves very differently. Savers reduce their consumption expenditures because they want to tilt spending towards housing, but borrowers increase non-durable consumption because higher house prices and residential investment improve their ability to borrow. This is the accelerator mechanism at work. The optimal monetary policy response leads in general to a decline in the response of all real quantities and a smaller response of CPI inflation in the periphery, but to a recession in the core. In this sense, the core is forced to pay for excesses committed by the periphery. But even in this case, the stronger monetary policy stance on CPI inflation and growth does not affect credit-to-GDP ratio enough in the periphery, and does not contain accelerator effects in the periphery. In order to do that, the use of macroprudential measures is necessary. When macroprudential tools are used, credit-to-GDP in the periphery increases by less, there are less accelerator effects in the periphery, and hence the stance of monetary policy can be softened in the EMU as a whole. Overall, the regime of optimal monetary policy plus macroprudential delivers more stability on all real quantities in the periphery, and this improves welfare. Similar results would hold if the housing boom was in the core, but with core savers and borrowers benefitting more from stability using macroprudential policies.

A negative risk shock in the periphery has very similar effects on most variables in the periphery as the housing demand shock. When risk declines, lending-deposit spreads decline in the periphery (the shock is normalized such that spreads decline by 25 basis points on an annualized basis), triggering an increase in the credit-to-GDP ratio. Under the estimated rule, consumption and residential investment by borrowers increase in the periphery, but that of savers decline. In the aggregate, GDP increases in the periphery, and also in the core, mostly through the net exports channel, because spending falls for both borrowers and savers. The optimal monetary policy tries to stabilize spending by borrowers in the periphery (especially, residential investment), but at the expense of reductions of spending for all other households in the EMU. As in the case of the housing demand shock, optimal monetary policy cannot do much to offset the accelerator effects, but the use of macroprudential tools delivers overall stability and improves welfare for everyone. As was the case for the housing demand shock, if the risk shock affected the core, it would have a similar impact on core variables as the one described here for periphery variables, and vice versa.

When does the use of macroprudential tools lead to inferior welfare outcomes? In Figure 3 we plot the effect of an innovation to the EMU-wide (one standard deviation) permanent technology shock. In this case, macroprudential policies increase the countercyclicality of the lending-deposit premium, increasing the volatility of borrower-specific variables and reducing their welfare. When a permanent technology hits the economy, this increases the level of real variables permanently (however, growth rates and transformed variables remain stationary). Also, since this is a permanent shock and both economies are quite symmetric, the effects are similar in both areas of the EMU. In particular, consumption by savers smoothly moves to the new level, while residential investment by savers is a bit more volatile. CPI inflation falls in both areas due to the decline in real marginal costs, while nominal house prices first decrease and then increase. Note, however, that real house prices increase (nominal house price inflation is higher than CPI inflation), reflecting improved fundamentals. Interestingly, under the estimated rule, credit-to-GDP falls, even though both quantities increase, but the lending-deposit spread moves only slightly, reflecting minimal movements in the LTV ratios. Hence, the main variables for borrowers move similarly to that of savers. Optimal monetary policy aims at bringing CPI inflation back to target as soon as possible, hence the ECB cuts nominal interest rates and CPI inflation falls by less. Also, most real variables display less volatility and a faster transition to their new steady-state values. What is the problem of using macroprudential policies in this set-up? As we can see in Figure

3, the macroprudential policy aims at addressing the decline of the credit-to-GDP ratio by allowing banks to lend more in this case. As a result, the credit-to-GDP ratio falls by much less and the lending-deposit rate becomes more volatile. This generates a higher countercyclical response of the lending rate, which leads to too much volatility of consumption and residential investment by borrowers. Because they have access to cheap credit and spend more, borrowers supply less labor, making it more volatile and adding to their welfare cost. On the other hand, savers still face a smooth consumption and investment plan, and by picking up the labor slack left by borrowers their overall labor supply is less volatile, contributing to their welfare increase.

Hence, in a model with a micro-founded behavior of the lending-deposit spread, and the welfare function, we find a similar result to Kannan et al. (2012), who used ad-hoc lending-deposit spread and welfare functions. Macroprudential policies that "lean against the wind" improve welfare when it is optimal to reduce the countercyclical behavior of the spread, as is the case of housing demand or risk shocks. However, under technology shocks, mechanical responses to the credit-to-GDP ratio will actually increase the countercyclical behavior of the spread, leading to too much volatility of spending by borrowers, and hurting their welfare, even when the impact on aggregate variables such as real GDP or CPI inflation is quantitatively very small.

We conduct an additional robustness result by looking at the optimal response by monetary and macroprudential policies if the policy makers where able to identify the source of the shock. To that end, we simulate the model with either technology shocks only (including all sectors and countries and the unit root shock), preference shocks only (including all countries and sectors), and financial shocks only (including the housing quality risk shock and the risk premium shock across countries). The optimal responses can be quite different when the monetary and macroprudential authorities can identify the source of the shock (Table 9). In all cases, it is optimal to respond to house price shocks, just as was the unconditional case of Table 7. The reaction to nominal credit growth under preference shocks is similar to the unconditional cases of Tables 7 and 8.

A key difference, that we identified in the impulse response analysis, is that the optimal macro-prudential response to any credit aggregate becomes zero under the optimized Taylor rule and technology shocks. As we already saw from Figure 3, in-

Table 9: Optimal Monetary and Macroprudential Policy, Conditional on Shocks

Technology Shocks	γ_π	γ_y	γ_r	γ_s	γ_η	γ_η^*
Nominal Credit Growth						
Monetary Policy	5.00	0.00	0.86	0.00	-	-
Mon. Pol. and Macro-Pru	5.00	0.00	0.86	-	0.00	0.00
Credit/GDP Ratio						
Optimal Monetary Policy	5.00	0.00	0.86	0.10	-	-
Mon. Pol. and Macro-Pru	5.00	0.00	0.86	-	0.00	0.00
House Price Inflation						
Optimal Monetary Policy	5.00	0.00	0.48	1.49	-	-
Mon. Pol. and Macro-Pru	5.00	0.00	0.85	-	0.28	0.28
Loan to Value						
Optimal Monetary Policy	5.00	0.00	0.86	0.00	-	-
Mon. Pol. and Macro-Pru	5.00	0.00	0.86	-	0.00	0.00
Preference Shocks	γ_π	γ_y	γ_r	γ_s	γ_η	γ_η^*
Nominal Credit Growth						
Monetary Policy	4.54	5.00	0.98	0.55	-	-
Mon. Pol. and Macro-Pru	3.09	5.00	0.98	-	0.28	0.29
Credit/GDP Ratio						
Optimal Monetary Policy	3.03	5.00	0.98	0.01	-	-
Mon. Pol. and Macro-Pru	4.71	5.00	0.97	-	1.66	3.06
House Price Inflation						
Optimal Monetary Policy	5.00	2.91	0.97	1.12	-	-
Mon. Pol. and Macro-Pru	3.22	5.00	0.98	-	0.36	0.36
Loan to Value						
Optimal Monetary Policy	2.81	5.00	0.97	0.00	-	-
Mon. Pol. and Macro-Pru	2.82	5.00	0.97	-	0.00	0.00
Financial Shocks	γ_π	γ_y	γ_r	γ_s	γ_η	γ_η^*
Nominal Credit Growth						
Monetary Policy	5.00	5.00	0.00	0.53	-	-
Mon. Pol. and Macro-Pru	5.00	5.00	0.00	-	1.21	1.41
Credit/GDP Ratio						
Optimal Monetary Policy	5.00	5.00	0.00	0.00	-	-
Mon. Pol. and Macro-Pru	5.00	5.00	0.00	-	5.00	5.00
House Price Inflation						
Optimal Monetary Policy	2.69	5.00	0.00	5.00	-	-
Mon. Pol. and Macro-Pru	2.03	5.00	0.00	-	0.25	2.91
Loan to Value						
Optimal Monetary Policy	5.00	5.00	0.00	0.00	-	-
Mon. Pol. and Macro-Pru	5.00	5.00	0.00	-	5.00	5.00

cluding macroprudential policies when technology shocks are present reduced welfare of borrowers by inducing too much volatility in the lending-deposit spread. However, when financial shocks hit the economy, the optimal macroprudential responses calls for responding to all credit aggregates to offset their effects. Also, when preference and financial shocks hit the economy, monetary policy would want to respond to output growth, while the optimal monetary policy response to output growth is zero when technology shocks hit the economy.

4.2.2 Regulation at the National Level

Having studied how macroprudential policies should be conducted at the European level, we turn to analyze what is the role of conducting macroprudential policies at the national level, while keeping the behavior of the ECB at its historical estimated level. We still assume that the regulatory instrument reacts to domestic variables in each country, but in this subsection we assume that the macroprudential authority (which would be the national central banks) chooses the optimal response to maximize domestic welfare. That is, in the core, the national central bank chooses γ_η to maximize the domestic welfare function

$$\mathcal{W} = \lambda \mathcal{W}^S + (1 - \lambda)\mathcal{W}^B \tag{28}$$

taking as given all the equilibrium conditions of the model, the behavior of the ECB (given by the estimated Taylor rule 24) and crucially, the response of macroprudential policy in the periphery, given by γ_η^*. The same maximization problem is conducted by the national central bank in charge of macroprudential regulation in the periphery. To solve for the simultaneous decision between macroprudential authorities in the core and in the periphery, we compute the best response functions for each country as a function of the response in the other country. Then, the Nash equilibrium is given by the intersection of the two best responses.

Two results are worth emphasizing. First, the best response functions of the national macroprudential policies are flat: this means that the optimal response in choosing the coefficient γ_η in the core is independent of the choice of the macroprudential instrument in the periphery, and this is also true in the periphery. We show an example when both regulators react to nominal credit growth in Figure 4. Second, the optimal coefficients when macroprudential policy is set at the national level

Table 10: Optimal Macroprudential Policy at the National Level

	γ_η	γ_η^*
Nominal Credit Growth	0.53	0.75
Credit/GDP Ratio	0.83	1.81
House Price Inflation	0.48	0.50
Loan to Value	0.14	0.51

are numerically very similar to the case where macroprudential policies are set at the EMU-level maximizing joint welfare (see Table 8 when the ECB follows the estimated rule).

5 Conclusions

In this paper, we have studied the optimal mix of monetary and macroprudential policies in an estimated DSGE model of the euro area. We have found that in a variety of scenarios and calibrations, the introduction of a macroprudential rule would help in reducing macroeconomic volatility and hence in improving EMU-wide welfare. At the same time, we find that macroprudential policies "lend a hand" to monetary policy by reducing accelerator effects and thus, requiring smaller responses of the nominal interest. We have also shown that the effects of macroprudential regulations can affect savers and borrowers differently. The policy that improves welfare the most in the EMU, which would be to have macroprudential policies respond to the credit-to-GDP ratio, reduces the welfare of borrowers by inducing a too countercyclical response of the lending-deposit spread. Therefore, the policy that improves welfare for all citizens in the EMU would be one where macroprudential policies respond to deviations of nominal credit growth from steady-state values. Finally, we have also found that there are no negative spillover effects of regulation from one member state to another, and therefore having macroprudential policies set at the national or EMU wide levels does not change the outcome.

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A Appendix: Linearized Conditions

In this section we present all log-linear conditions of the model. Upper case variables denote steady state values, lower case variables denote log-linear deviations from steady state values, and foreign variables are indicated with asterisks. Additionally, we make use of the following definitions:

- Q_t denotes the relative price of durables in term of non-durables ($Q_t \equiv \frac{P_t^D}{P_t^C}$)
- $\tilde{w}_t^i$ denotes the deviation of the real wages (nominal wages W_t^i divided by the CPI index P_t^C, for $i = C, D$) from their steady state values.
- $\tilde{S}_t^B$ denotes real domestic debt expressed in terms of non-durable goods ($\tilde{S}_t^B \equiv \frac{S_t^B}{P_t^C}$).
- b_t denotes the deviations of foreign assets as percent of steady state non-durable output from its steady state value of zero ($b_t \equiv \frac{B_t}{P_t^C Y^C}$).
- $\hat{\bar{\omega}}_t^i$ and $\hat{\sigma}_{\omega,t}$ denote the deviations from their steady state values for the threshold $\bar{\omega}_t^i$ and the variance $\bar{\sigma}_{\omega,t}$, respectively (for $i = a, p$).
- The terms of trade is given by $T_t = \frac{P_{F,t}}{P_{H,t}}$.
- The average interest rate of those who default is defined as $R_t^D = G\left(\bar{\omega}_{t-1}^P, \sigma_{\omega,t-1}\right) P_t^D D_t^B / S_{t-1}^B$.
- Aggregate non-durable consumption is given by $C_t^{TOT} = \lambda C_t + (1 - \lambda) C_t^B$.

In addition, since the model includes a unit root shock in technology, then the following variables in both countries inherit the same unit root behavior:

- consumption of non-durables (by agent and aggregate, including domestically produced and imported): C_t, C_t^B, C_t^{TOT}, $C_{H,t}$, $C_{F,t}$,
- residential investment and the housing stock of both borrowers and savers: I_t, I_t^B, D_t, D_t^B,
- real wages in both sectors: W_t^C, and W_t^D,
- the production of durable and non-durable goods: Y_t^C and Y_t^D, and real GDP Y_t,

- and real credit $\tilde{S}_t^B$.

Hence, we normalize all these real variables by the level of technology Z_t. Hence, for these variables, lower case variables denote deviations from steady-state values of normalized variables. That is, $c_t = \log(C_t/Z_t) - \log(\overline{C/Z})$ and so on. Foreign country variables are normalized in the same way. For instance, $c_t^* = \log(C_t^*/Z_t) - \log(\overline{C^*/Z})$.

A.1 Home Country

From the optimal decision by savers we get the following:[26]

$$q_t + \xi_t^C - \frac{c_t - \varepsilon(c_{t-1} - \varepsilon_t^z)}{1-\varepsilon} + \psi(i_t - i_{t-1} + \varepsilon_t^z) = \varrho_t + \beta\psi(E_t i_{t+1} - i_t), \tag{29}$$

where $\psi = F''(.)$ and ϱ_t is the normalized Lagrange multiplier associated with the law of motion of the housing stock (9) for savers, and

$$[1 - \beta(1-\delta)]\,(\xi_t^D - d_t) = \varrho_t - \beta(1-\delta)E_t\varrho_{t+1}, \tag{30}$$

$$\varepsilon(\Delta c_t + \varepsilon_t^z) = E_t\Delta c_{t+1} - (1-\varepsilon)(r_t + E_t\Delta\xi_{t+1}^C - E_t\Delta p_{t+1}^C). \tag{31}$$

The labor supply schemes to the non-durable and durable sectors are:

$$[(\varphi - \iota_L)\alpha + \iota_L]\,l_t^C + (\varphi - \iota_L)(1-\alpha)l_t^D = \tilde{w}_t^C + \xi_t^C - \frac{c_t - \varepsilon(c_{t-1} - \varepsilon_t^z)}{1-\varepsilon} \tag{32}$$

$$[(\varphi - \iota_L)(1-\alpha) + \iota_L]\,l_t^D + (\varphi - \iota_L)\alpha l_t^C = \tilde{w}_t^D + \xi_t^C - \frac{c_t - \varepsilon(c_{t-1} - \varepsilon_t^z)}{1-\varepsilon}. \tag{33}$$

The same conditions for borrowers are:

$$q_t + \xi_t^C - \frac{c_t^B - \varepsilon^B(c_{t-1}^B - \varepsilon_t^z)}{1-\varepsilon^B} + \psi(i_t^B - i_{t-1}^B + \varepsilon_t^z) = \varrho_t^B + \beta^B\psi(E_t i_{t+1}^B - i_t^B), \tag{34}$$

with ϱ_t^B being the Lagrange multiplier associated with the law of motion of the housing stock (9) for borrowers, and

$$\left[1 - \beta^B(1-\delta)\right](\xi_t^D - d_t^B) = \varrho_t^B - \beta^B(1-\delta)E_t\varrho_{t+1}^B, \tag{35}$$

[26] Since all households behave the same way, we drop the j subscript in what follows.

$$
\begin{aligned}
& \varepsilon^B(\Delta c_t^B + \varepsilon_t^z) \\
= \; & E_t \Delta c_{t+1}^B - (1-\varepsilon^B)\left(\beta^B R^D E_t r_{t+1}^D + E_t \Delta \xi_{t+1}^C - E_t \Delta p_{t+1}^C\right) \qquad (36) \\
& -(1-\varepsilon^B)\beta^B R^L \left[1 - F(\bar{\omega}, \sigma_\omega)\right]\left(r_t^L - \frac{F_\omega(\bar{\omega}, \sigma_\omega)\bar{\omega}}{1 - F(\bar{\omega}, \sigma_\omega)}\hat{\bar{\omega}}_t^a - \frac{F_{\sigma_\omega}(\bar{\omega}, \sigma_\omega)\sigma_\omega}{1 - F(\bar{\omega}, \sigma_\omega)}\hat{\sigma}_{\omega,t}\right)
\end{aligned}
$$

with the interest rate for those who default is given by:

$$
r_t^D = d_t^B - \tilde{s}_{t-1}^B + \frac{G_\omega(\bar{\omega}, \sigma_\omega)\bar{\omega}}{G(\bar{\omega}, \sigma_\omega)}\hat{\bar{\omega}}_{t-1}^p + \frac{G_{\sigma_\omega}(\bar{\omega}, \sigma_\omega)\sigma_\omega}{G(\bar{\omega}, \sigma_\omega)}\hat{\sigma}_{\omega,t-1} + q_t + \Delta p_t^C + \varepsilon_t^z \qquad (37)
$$

The labor supply schemes to the non-durable and durable sectors are:

$$
\left[(\varphi - \iota_L)\alpha + \iota_L\right] l_t^{B,C} + (\varphi - \iota_L)(1-\alpha) l_t^{B,D} = \tilde{w}_t^C + \xi_t^C - \frac{c_t^B - \varepsilon^B\left(c_{t-1}^B - \varepsilon_t^z\right)}{1 - \varepsilon^B} \qquad (38)
$$

$$
\left[(\varphi - \iota_L)(1-\alpha) + \iota_L\right] l_t^{B,D} + (\varphi - \iota_L)\alpha l_t^{B,C} = \tilde{w}_t^D + \xi_t^C - \frac{c_t^B - \varepsilon^B\left(c_{t-1}^B - \varepsilon_t^z\right)}{1 - \varepsilon^B} \qquad (39)
$$

The budget constraint of borrowers is:

$$
\begin{aligned}
& C^B c_t^B + \delta D^B(q_t + i_t^B) + R^D \tilde{S}^B\left[r_t^D + \tilde{s}_{t-1}^B - \Delta p_t^C - \varepsilon_t^z\right] \\
& + \left[1 - F(\bar{\omega}, \sigma_\omega)\right] R^L \tilde{S}^B\left[r_{t-1}^L + \tilde{s}_{t-1}^B - \Delta p_t^C - \varepsilon_t^z - \frac{F_\omega(\bar{\omega}, \sigma_\omega)\bar{\omega}}{1 - F(\bar{\omega}, \sigma_\omega)}\hat{\bar{\omega}}_{t-1}^p - \frac{F_{\sigma_\omega}(\bar{\omega}, \sigma_\omega)\sigma_\omega}{1 - F(\bar{\omega}, \sigma_\omega)}\hat{\sigma}_{\omega,t-1}\right] \\
= \; & \tilde{S}^B \tilde{s}_t^B + \alpha W L^B(\tilde{w}_t^C + l_t^{B,C}) + (1-\alpha) W L^B(\tilde{w}_t^D + l_t^{B,D}) \qquad (40)
\end{aligned}
$$

The lending rate for borrowers is determined by the participation constraint of financial intermediaries:

$$
\begin{aligned}
& \frac{1}{\beta}\tilde{S}^B\left(r_t + \tilde{s}_t^B + \eta_t\right) \\
= \; & (1-\mu) D^B G(\bar{\omega}, \sigma_\omega)\left[\frac{G_\omega(\bar{\omega}, \sigma_\omega)\bar{\omega}}{G(\bar{\omega}, \sigma_\omega)}\hat{\bar{\omega}}_t^a + \frac{G_{\sigma_\omega}(\bar{\omega}, \sigma_\omega)\sigma_\omega}{G(\bar{\omega}, \sigma_\omega)}\hat{\sigma}_{\omega,t} + E_t q_{t+1} + E_t d_{t+1}^B + E_t \Delta p_{t+1}^C\right] \\
& + \left[1 - F(\bar{\omega}, \sigma_\omega)\right] R^L \tilde{S}^B\left[r_t^L + \tilde{s}_t^B - \frac{F_\omega(\bar{\omega}, \sigma_\omega)\bar{\omega}}{1 - F(\bar{\omega}, \sigma_\omega)}\hat{\bar{\omega}}_t^a - \frac{F_{\sigma_\omega}(\bar{\omega}, \sigma_\omega)\sigma_\omega}{1 - F(\bar{\omega}, \sigma_\omega)}\hat{\sigma}_{\omega,t}\right] \qquad (41)
\end{aligned}
$$

The ex-ante and ex-post default threshold is:

$$
\hat{\bar{\omega}}_t^a + E_t\left[q_{t+1} + d_{t+1}^B\right] = r_t^L + \tilde{s}_t^B - E_t \Delta p_{t+1}^C \qquad (42)
$$

$$
\hat{\bar{\omega}}_{t-1}^p + q_t + d_t^B = r_{t-1}^L + \tilde{s}_{t-1}^B - \Delta p_t^C - \varepsilon_t^z \qquad (43)
$$

The evolution of domestic and imported non-durable consumption is:

$$c_{H,t} = \iota_C(1-\tau)t_t + c_t^{TOT}, \tag{44}$$

$$c_{F,t} = -\iota_C \tau t_t + c_t^{TOT}. \tag{45}$$

where aggregate non-durable consumption is:

$$\left[\lambda C + (1-\lambda)C^B\right] c_t^{TOT} = \lambda C c_t + (1-\lambda)C^B c_t^B. \tag{46}$$

The production functions are given by:

$$y_t^C = z_t^C + l_t^{C,TOT}, \tag{47}$$

$$y_t^D = z_t^D + l_t^{D,TOT}, \tag{48}$$

where total hours in each sector are given by:

$$\left[\lambda L^C + (1-\lambda)L^{B,C}\right] l_t^{C,TOT} = \lambda L^C l_t^C + (1-\lambda)L^{B,C} l_t^{B,C}, \tag{49}$$

$$\left[\lambda L^D + (1-\lambda)L^{B,D}\right] l_t^{D,TOT} = \lambda L^D l_t^D + (1-\lambda)L^{B,D} l_t^{B,D}, \tag{50}$$

The CPI is given by:

$$\Delta p_t^C = \tau \Delta p_{H,t} + (1-\tau)\Delta p_{F,t}. \tag{51}$$

The relative price of housing is:

$$q_t = q_{t-1} + \Delta p_t^D - \Delta p_t^C. \tag{52}$$

And the pricing equations are given by:

$$\Delta p_t^H - \varphi_C \Delta p_{t-1}^H = \beta E_t(\Delta p_{t+1}^H - \varphi_C \Delta p_t^H) + \kappa^C \left[\tilde{w}_t^C + (1-\tau)t_t - z_t^C\right], \tag{53}$$

where $\kappa^C = \frac{(1-\theta_C)(1-\beta\theta_C)}{\theta_C}$, and

$$\Delta p_t^D - \varphi_D \Delta p_{t-1}^D = \beta E_t(\Delta p_{t+1}^D - \varphi_D \Delta p_t^D) + \kappa^D \left[\tilde{w}_t^D - q_t - z_t^D\right], \tag{54}$$

where $\kappa^D = \frac{(1-\theta_D)(1-\beta\theta_D)}{\theta_D}$.
The market clearing conditions for the non-durable good sector reads as follows:

$$y_t^C = \tau c_{H,t} + \frac{(1-n)(1-\tau^*)}{n} c_{H,t}^*. \tag{55}$$

Aggregate investment expenditures equal production of investment goods:

$$y_t^D = \frac{\lambda\delta D i_t + (1-\lambda)\delta D^B i_t^B}{\lambda\delta D + (1-\lambda)\delta D^B}. \tag{56}$$

And the law of motion of the two types of housing stocks are given by:

$$d_t = (1-\delta)(d_{t-1} - \varepsilon_t^z) + \delta i_t, \tag{57}$$

$$d_t^B = (1-\delta)(d_{t-1}^B - \varepsilon_t^z) + \delta i_t^B. \tag{58}$$

Aggregated output is given by:

$$y_t = \alpha y_t^C + (1-\alpha)\left(y_t^D + q_t\right). \tag{59}$$

A.2 Foreign Country

Here, we present the conditions of the model for the foreign country. From the optimal decision by savers we get the following:

$$q_t^* + \xi_t^{C^*} - \frac{c_t^* - \varepsilon(c_{t-1}^* - \varepsilon_t^z)}{1-\varepsilon} + \psi(i_t^* - i_{t-1}^* + \varepsilon_t^z) = \varrho_t^* + \beta\psi(E_t i_{t+1}^* - i_t^*), \tag{60}$$

$$[1-\beta(1-\delta)]\left(\xi_t^{D^*} - d_t^*\right) = \varrho_t^* - \beta(1-\delta)E_t\varrho_{t+1}^*, \tag{61}$$

$$\varepsilon(\Delta c_t^* + \varepsilon_t^z) = E_t\Delta c_{t+1}^* - (1-\varepsilon)(r_t^* + E_t\Delta\xi_{t+1}^{C^*} - E_t\Delta p_{t+1}^{C^*}). \tag{62}$$

$$[(\varphi-\iota_L)\alpha+\iota_L]\, l_t^{C^*}+(\varphi-\iota_L)(1-\alpha)l_t^{D^*} = \tilde{w}_t^{C^*}+\xi_t^{C^*}-\frac{c_t^*-\varepsilon(c_{t-1}^*-\varepsilon_t^z)}{1-\varepsilon} \quad (63)$$

$$[(\varphi-\iota_L)(1-\alpha)+\iota_L]\, l_t^{D^*}+(\varphi-\iota_L)\alpha l_t^{C^*} = \tilde{w}_t^{D^*}+\xi_t^{C^*}-\frac{c_t^*-\varepsilon(c_{t-1}^*-\varepsilon_t^z)}{1-\varepsilon} \quad (64)$$

The same conditions for borrowers are:

$$q_t^*+\xi_t^{C^*}-\frac{c_t^{B^*}-\varepsilon^B(c_{t-1}^{B^*}-\varepsilon_t^z)}{1-\varepsilon^{B^*}}+\psi(i_t^{B^*}-i_{t-1}^{B^*}+\varepsilon_t^z)=\varrho_t^{B^*}+\beta^B\psi(E_t i_{t+1}^{B^*}-i_t^{B^*}), \quad (65)$$

$$\left[1-\beta^B(1-\delta)\right](\xi_t^{D^*}-d_t^{B^*})=\varrho_t^{B^*}-\beta^B(1-\delta)E_t\varrho_{t+1}^{B^*}, \quad (66)$$

$$\begin{aligned} & \varepsilon^B(\Delta c_t^{B^*}+\varepsilon_t^z) \\ = \; & E_t\Delta c_{t+1}^{B^*}-(1-\varepsilon^B)\left(\beta^B R^{D^*}E_t r_{t+1}^{D^*}+E_t\Delta\xi_{t+1}^{C^*}-E_t\Delta p_{t+1}^{C^*}\right) \quad (67) \\ & -(1-\varepsilon^B)\beta^B R^{L*}\left[1-F(\bar{\omega},\sigma_\omega)\right]\left(r_t^{L*}-\frac{F_\omega(\bar{\omega},\sigma_\omega)\bar{\omega}}{1-F(\bar{\omega},\sigma_\omega)}\hat{\bar{\omega}}_t^{a*}-\frac{F_{\sigma_\omega}(\bar{\omega},\sigma_\omega)\sigma_\omega}{1-F(\bar{\omega},\sigma_\omega)}\hat{\sigma}_{\omega,t}^*\right) \end{aligned}$$

$$r_t^{D^*}=d_t^{B^*}-\tilde{s}_{t-1}^{B^*}+\frac{G_\omega(\bar{\omega},\sigma_\omega)\bar{\omega}}{G(\bar{\omega},\sigma_\omega)}\hat{\bar{\omega}}_{t-1}^{p*}+\frac{G_{\sigma_\omega}(\bar{\omega},\sigma_\omega)\sigma_\omega}{G(\bar{\omega},\sigma_\omega)}\hat{\sigma}_{\omega,t-1}^*+q_t^*+\Delta p_t^{C^*}+\varepsilon_t^z \quad (68)$$

$$[(\varphi-\iota_L)\alpha+\iota_L]\, l_t^{B,C^*}+(\varphi-\iota_L)(1-\alpha)\, l_t^{B,D^*}=\tilde{w}_t^{C^*}+\xi_t^{C^*}-\frac{c_t^{B^*}-\varepsilon^B\left(c_{t-1}^{B^*}-\varepsilon_t^z\right)}{1-\varepsilon^B} \quad (69)$$

$$[(\varphi-\iota_L)(1-\alpha)+\iota_L]\, l_t^{B,D^*}+(\varphi-\iota_L)\alpha l_t^{B,C^*}=\tilde{w}_t^{D^*}+\xi_t^{C^*}-\frac{c_t^{B^*}-\varepsilon^B\left(c_{t-1}^{B^*}-\varepsilon_t^z\right)}{1-\varepsilon^B} \quad (70)$$

The budget constraint of borrowers is:

$$\begin{aligned} & C^{B^*}c_t^{B^*}+\delta D^{B^*}(q_t^*+i_t^{B^*})+R^{D^*}\tilde{S}^{B^*}\left[r_t^{D^*}+\tilde{s}_{t-1}^{B^*}-\Delta p_t^{C^*}-\varepsilon_t^z\right] \\ & +\left[1-F(\bar{\omega},\sigma_\omega)\right]R^{L*}\tilde{S}^{B^*}\left[r_{t-1}^{L*}+\tilde{s}_{t-1}^{B^*}-\Delta p_t^{C^*}-\varepsilon_t^z-\frac{F_\omega(\bar{\omega},\sigma_\omega)\bar{\omega}}{1-F(\bar{\omega},\sigma_\omega)}\hat{\bar{\omega}}_{t-1}^{p*}-\frac{F_{\sigma_\omega}(\bar{\omega},\sigma_\omega)\sigma_\omega}{1-F(\bar{\omega},\sigma_\omega)}\hat{\sigma}_{\omega,t-1}^*\right] \\ = \; & \tilde{S}^{B^*}\tilde{s}_t^{B^*}+\alpha W^*L^{B^*}(\tilde{w}_t^{C^*}+l_t^{B,C^*})+(1-\alpha)W^*L^{B^*}(\tilde{w}_t^{D^*}+l_t^{B,D^*}) \quad (71 \end{aligned}$$

The participation constraint of financial intermediaries:

$$\begin{aligned}
& \frac{1}{\beta}\tilde{S}^{B^*}\left(r_t^* + \tilde{s}_t^{B^*} + \eta_t^*\right) \\
= \quad & (1-\mu)D^{B^*}G(\bar{\omega},\sigma_\omega)\left[\frac{G_\omega(\bar{\omega},\sigma_\omega)\bar{\omega}}{G(\bar{\omega},\sigma_\omega)}\hat{\bar{\omega}}_t^{a*} + \frac{G_{\sigma_\omega}(\bar{\omega},\sigma_\omega)\sigma_\omega}{G(\bar{\omega},\sigma_\omega)}\hat{\sigma}_{\omega,t}^* + E_t q_{t+1}^* + E_t d_{t+1}^{B^*} + E_t\Delta p_{t+1}^{C^*}\right] \\
& + [1-F(\bar{\omega},\sigma_\omega)]R^{L*}\tilde{S}^{B^*}\left[r_t^{L*} + \tilde{s}_t^{B^*} - \frac{F_\omega(\bar{\omega},\sigma_\omega)\bar{\omega}}{1-F(\bar{\omega},\sigma_\omega)}\hat{\bar{\omega}}_t^{a*} - \frac{F_{\sigma_\omega}(\bar{\omega},\sigma_\omega)\sigma_\omega}{1-F(\bar{\omega},\sigma_\omega)}\hat{\sigma}_{\omega,t}^*\right] \qquad (72)
\end{aligned}$$

The ex-ante and ex-post default threshold is:

$$\hat{\bar{\omega}}_t^{a*} + E_t\left[q_{t+1}^* + d_{t+1}^{B^*}\right] = r_t^{L*} + \tilde{s}_t^{B^*} - E_t\Delta p_{t+1}^{C^*} \qquad (73)$$

$$\hat{\bar{\omega}}_{t-1}^{p*} + q_t^* + d_t^{B^*} = r_{t-1}^{L*} + \tilde{s}_{t-1}^{B^*} - \Delta p_t^{C^*} - \varepsilon_t^z \qquad (74)$$

The evolution of domestic and imported non-durable consumption is:

$$c_{H,t}^* = \iota_C \tau^* t_t + c_t^{TOT^*}, \qquad (75)$$

$$c_{F,t}^* = -\iota_C(1-\tau^*)t_t + c_t^{TOT^*}, \qquad (76)$$

where aggregate non-durable consumption is:

$$\left[\lambda C^* + (1-\lambda)C^{B^*}\right]c_t^{TOT^*} = \lambda C^* c_t^* + (1-\lambda)C^{B^*}c_t^{B^*}. \qquad (77)$$

The production functions are given by:

$$y_t^{C^*} = z_t^{C^*} + l_t^{C,TOT^*}, \qquad (78)$$

$$y_t^{D^*} = z_t^{D^*} + l_t^{D,TOT^*}, \qquad (79)$$

where total hours in each sector are given by:

$$\left[\lambda L^{C^*} + (1-\lambda)L^{B,C^*}\right]l_t^{C,TOT^*} = \lambda L^{C^*}l_t^{C^*} + (1-\lambda)L^{B,C^*}l_t^{B,C^*}, \qquad (80)$$

$$\left[\lambda L^{D^*} + (1-\lambda)L^{B,D^*}\right]l_t^{D,TOT^*} = \lambda L^{D^*}l_t^{D^*} + (1-\lambda)L^{B,D^*}l_t^{B,D^*}. \qquad (81)$$

The CPI is:

$$\Delta p_t^{C^*} = (1-\tau^*)\Delta p_{H,t} + \tau^*\Delta p_{F,t}. \qquad (82)$$

The relative price of housing is:

$$q_t^* = q_{t-1}^* + \Delta p_t^{D^*} - \Delta p_t^{C^*}. \tag{83}$$

And the pricing equations are given by:

$$\Delta p_t^F - \varphi_C^* \Delta p_{t-1}^F = \beta E_t(\Delta p_{t+1}^F - \varphi_C^* \Delta p_t^F) + \kappa^{C^*} \left[\tilde{w}_t^{C^*} - (1-\tau^*) t_t - z_t^{C^*} \right], \tag{84}$$

where $\kappa^{C^*} = \frac{(1-\theta_C^*)(1-\beta\theta_C^*)}{\theta_C^*}$, and

$$\Delta p_t^{D^*} - \varphi_D^* \Delta p_{t-1}^{D^*} = \beta E_t(\Delta p_{t+1}^{D^*} - \varphi_D^* \Delta p_t^{D^*}) + \kappa^{D^*} \left[\tilde{w}_t^{D^*} - q_t^* - z_t^{D^*} \right], \tag{85}$$

where $\kappa^{D^*} = \frac{(1-\theta_D^*)(1-\beta\theta_D^*)}{\theta_D^*}$.

The market clearing conditions for the non-durable good sector reads as follows:

$$y_t^{C^*} = \tau^* c_{F,t}^* + \frac{n(1-\tau)}{1-n} c_{F,t}. \tag{86}$$

Aggregate investment expenditures equal production of investment goods:

$$y_t^{D^*} = \frac{\lambda \delta D^* i_t^* + (1-\lambda)\delta D^{B^*} i_t^{B^*}}{\lambda \delta D^* + (1-\lambda)\delta D^{B^*}}. \tag{87}$$

And the law of motion of the two types of housing stocks are given by:

$$d_t^* = (1-\delta)(d_{t-1}^* - \varepsilon_t^z) + \delta i_t^*, \tag{88}$$

$$d_t^{B^*} = (1-\delta)(d_{t-1}^{B^*} - \varepsilon_t^z) + \delta i_t^{B^*}. \tag{89}$$

Aggregated output is given by:

$$y_t^* = \alpha^* y_t^{C^*} + (1-\alpha^*)\left(y_t^{D^*} + q_t^*\right). \tag{90}$$

A.3 Euro Area Variables and Other Equations

The relationship between the two nominal interest rates in the home and foreign country is as follows:

$$r_t^* = r_t + \beta\left(\kappa_b b_t + \vartheta_t\right). \tag{91}$$

The evolution of net foreign assets is:

$$\lambda b_t = \lambda \frac{1}{\beta} b_{t-1} + \frac{(1-n)(1-\tau^*)}{n}\left(c_{H,t}^* - t_t\right) - (1-\tau)c_{F,t}, \tag{92}$$

where we have used the fact that $t_t = -t_t^*$, and the evolution of the terms of trade is given by:

$$t_t = t_{t-1} + \Delta p_t^F - \Delta p_t^H. \tag{93}$$

The monetary policy Taylor rule conducted by the ECB reads:

$$r_t = \gamma_R r_{t-1} + (1-\gamma_R)\left[\gamma_\pi \Delta p_t^{EMU} + \gamma_\pi\left(y_t^{EMU} - y_{t-1}^{EMU} + \varepsilon_t^z\right)\right] + \varepsilon_t^m, \tag{94}$$

where the euro area CPI and output is given by:

$$\Delta p_t^{EMU} = n\Delta p_t^C + (1-n)\Delta p_t^{C*} \tag{95}$$

$$y_t^{EMU} = n y_t + (1-n) y_t^*. \tag{96}$$

Finally, in Sections 4, when we include the macroprudential tools, we assume that they are linear functions of an indicator variable (Υ_t and Υ_t^*) with is either credit growth or credit to GDP in each country:

$$\eta_t = \gamma_\eta \Upsilon_t, \tag{97}$$

$$\eta_t^* = \gamma_\eta \Upsilon_t^*. \tag{98}$$

A.4 Shock Processes

All shocks included in the model evolve according to:

$$\begin{aligned}
\xi_t^C &= \rho_{\xi,H}\xi_{t-1}^C + \varepsilon_t^{\xi,C} && (99)\\
\xi_t^{C*} &= \rho_{\xi,H}\xi_{t-1}^{C*} + \varepsilon_t^{\xi,C*} && (100)\\
\xi_t^D &= \rho_{\xi,D}\xi_{t-1}^D + \varepsilon_t^{\xi,D} + \varepsilon_t^{\xi,D,COM} && (101)\\
\xi_t^{D*} &= \rho_{\xi,D}\xi_{t-1}^{D*} + \varepsilon_t^{\xi,D*} + \varepsilon_t^{\xi,D,COM} && (102)\\
z_t^C &= \rho_{Z,C}z_{t-1}^C + \varepsilon_t^{Z,C} + \varepsilon_t^{Z,C,COM} && (103)\\
z_t^{C*} &= \rho_{Z,C}z_{t-1}^{C*} + \varepsilon_t^{Z,C*} + \varepsilon_t^{Z,C,COM} && (104)\\
z_t^D &= \rho_{Z,D}z_{t-1}^D + \varepsilon_t^{Z,D} && (105)\\
z_t^{D*} &= \rho_{Z,D}z_{t-1}^{D*} + \varepsilon_t^{Z,D*} && (106)\\
\sigma_{\omega,t} &= (1-\rho_{\sigma\omega})\,\bar{\sigma}_\omega + \rho_{\sigma\omega}\sigma_{\omega,t-1} + u_{\omega,t} && (107)\\
\sigma_{\omega,t}^* &= (1-\rho_{\sigma\omega})\,\bar{\sigma}_\omega + \rho_{\sigma\omega}\sigma_{\omega,t-1}^* + u_{\omega,t}^* && (108)\\
\vartheta_t &= \rho_\vartheta\vartheta_{t-1} + \varepsilon_t^\vartheta, && (109)
\end{aligned}$$

while the non-stationary innovation to the union-wide technology shock and the monetary policy shock are iid: ε_t^Z and ε_t^m.

B Appendix: Data and Sources

Since we distinguish between two regions of the euro area, data for the core is obtained by aggregating data for France and Germany, while for the periphery data for Ireland, Italy, Greece, Portugal, and Spain are combined. The aggregation is done by computing weighted averages taking into account the relative economic size of the countries (measured by nominal GDP). Some of the series start later than 1995q4 or end earlier than 2011q4. If this is the case, aggregation for these quarters only takes into account available data, where as weights are adjusted accordingly. All data is seasonally adjusted in case this has not been done by the original source. Finally, all data is demeaned.

Inflation: Quarter on quarter log differences in the Harmonized Index of Consumer Prices (HICP), not seasonally adjusted by the source. Source: ECB.

Change in House Price Data: Quarter on quarter log differences in real housing prices. All data, except for Greece and Portugal, is provided by the OECD. Greek and Portuguese data is provided by the BIS. All OECD data is seasonally adjusted by the source, while BIS data is not. Portuguese data is only available on a monthly basis and is transformed to a quarterly frequency by taking averages. Data for Italy already ends in 2011q3.

Real Private Consumption: Final consumption of households and nonprofit institutions serving households (NPISH), seasonally adjusted by the source. Source: Eurostat.

Real Residential Investment: Gross fixed capital formation in construction work for housing, seasonally adjusted by the source. Data for Ireland is only available on an annual basis while data for Greece is only available from 2000 onwards on an annual basis. Both data is interpolated to obtain quarterly values. Source: Eurostat.

ECB Interest Rate: 3-month Euribor, Source: ECB.

Household Outstanding Debt: Data seasonally adjusted by the source. Data for Greece starts in 1997q4, for Ireland in 2002q1, and for Italy in 1997q1. Source: Eurostat.

Nominal GDP for computing the weights used in the aggregation is taken from the IMF International Financial Statistics (IFS). This data is also used to calculate the size of the core and periphery region. Furthermore, for the calibration we use import data (Source: IMF Direction of Trade Statistics) and data on nominal household consumption (Source: IFS) to compute the fraction of imported goods. The size of the non-durable sector is calculated as a ratio of gross value added by the construction sector to that of all branches (Source: Eurostat). The steady state ratio of defaults is calculated using non-performing loans as percent of total loans for the euro area between 2000-2011 (Source: World Bank World Development Indicators Database).

Figure 1a-Impulse Response to a Housing Demand Shock in the Periphery

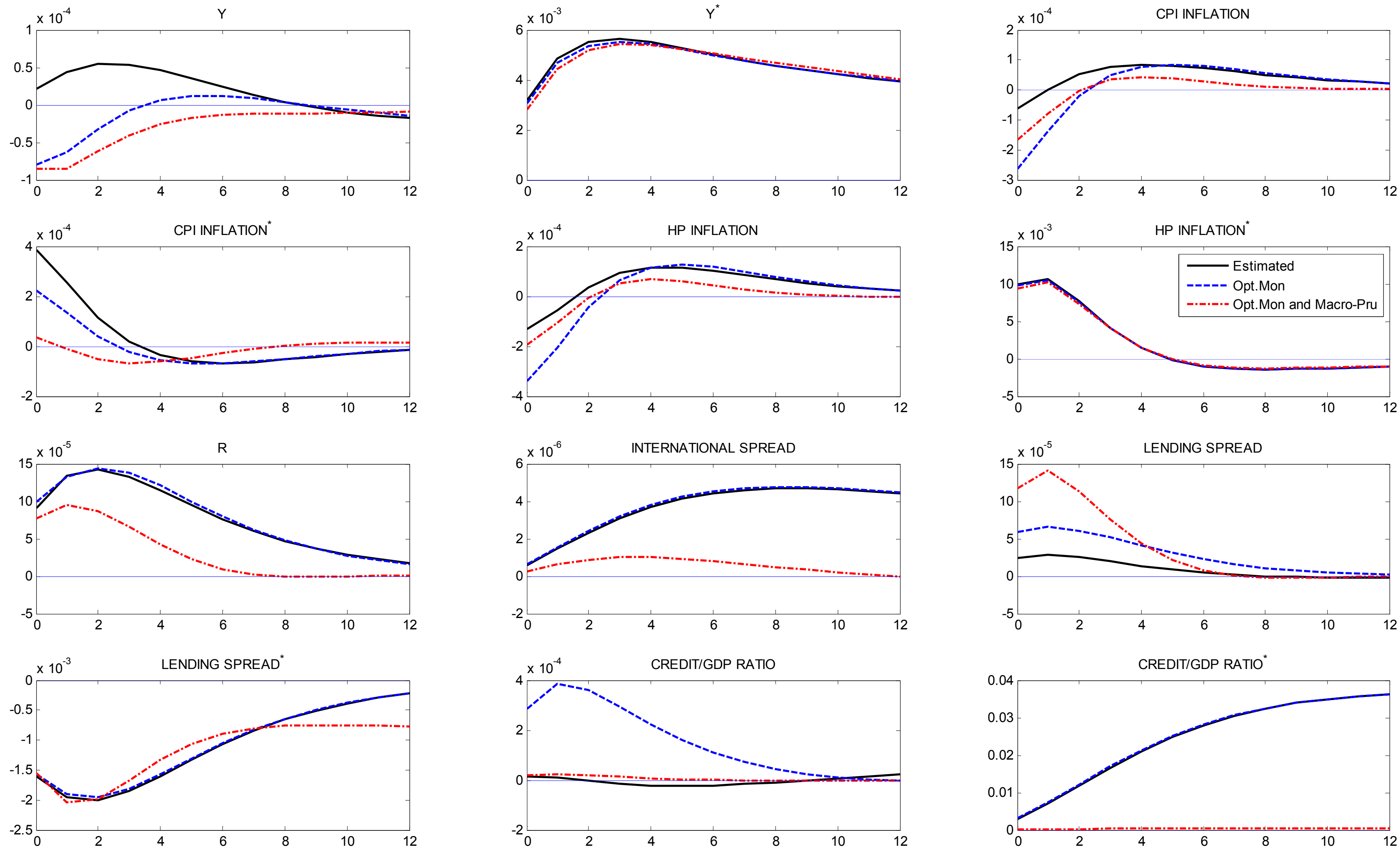

Figure 1b-Impulse Response to a Housing Demand Shock in the Periphery

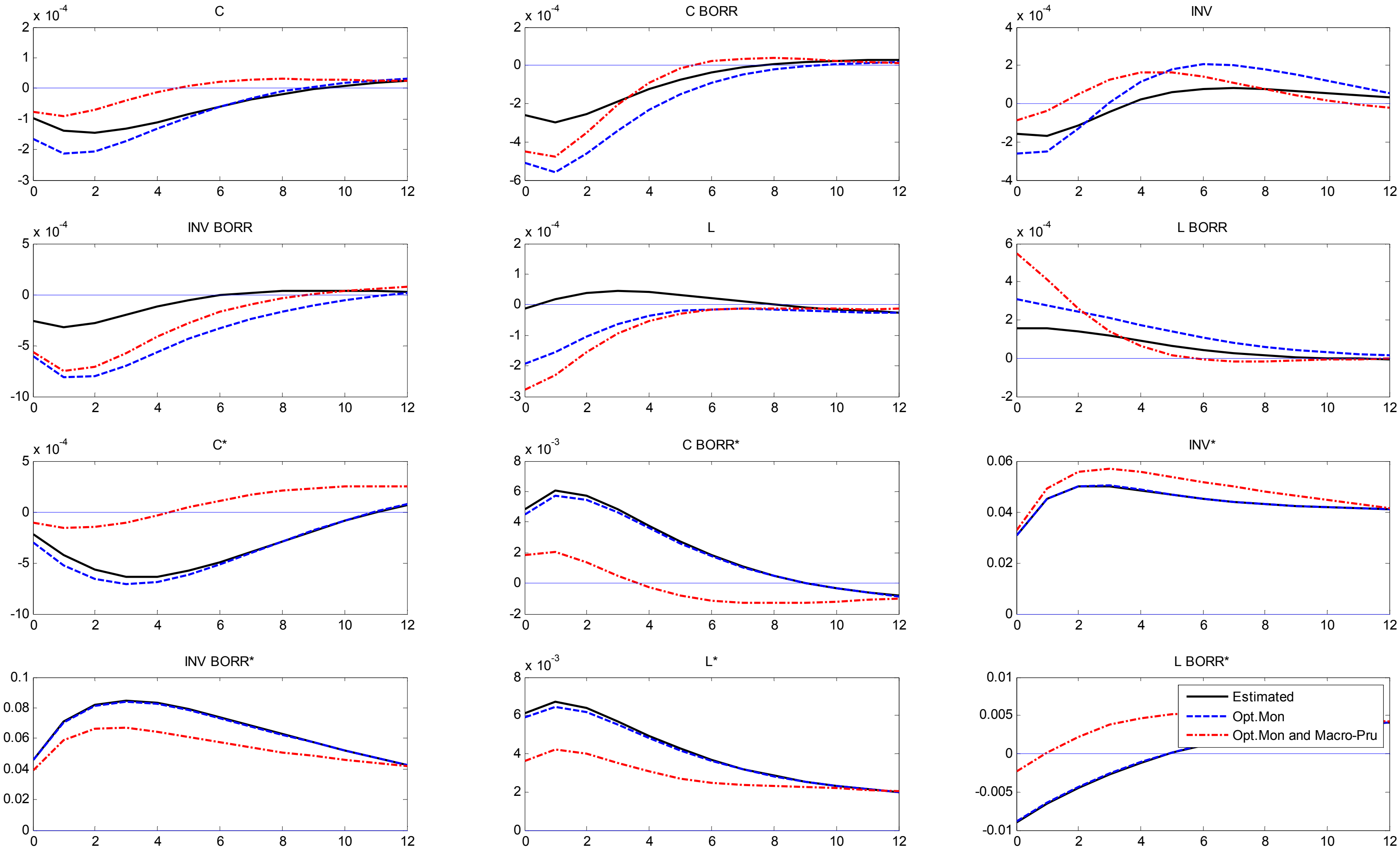

Figure 2a-Impulse Response to a Risk Shock in the Periphery

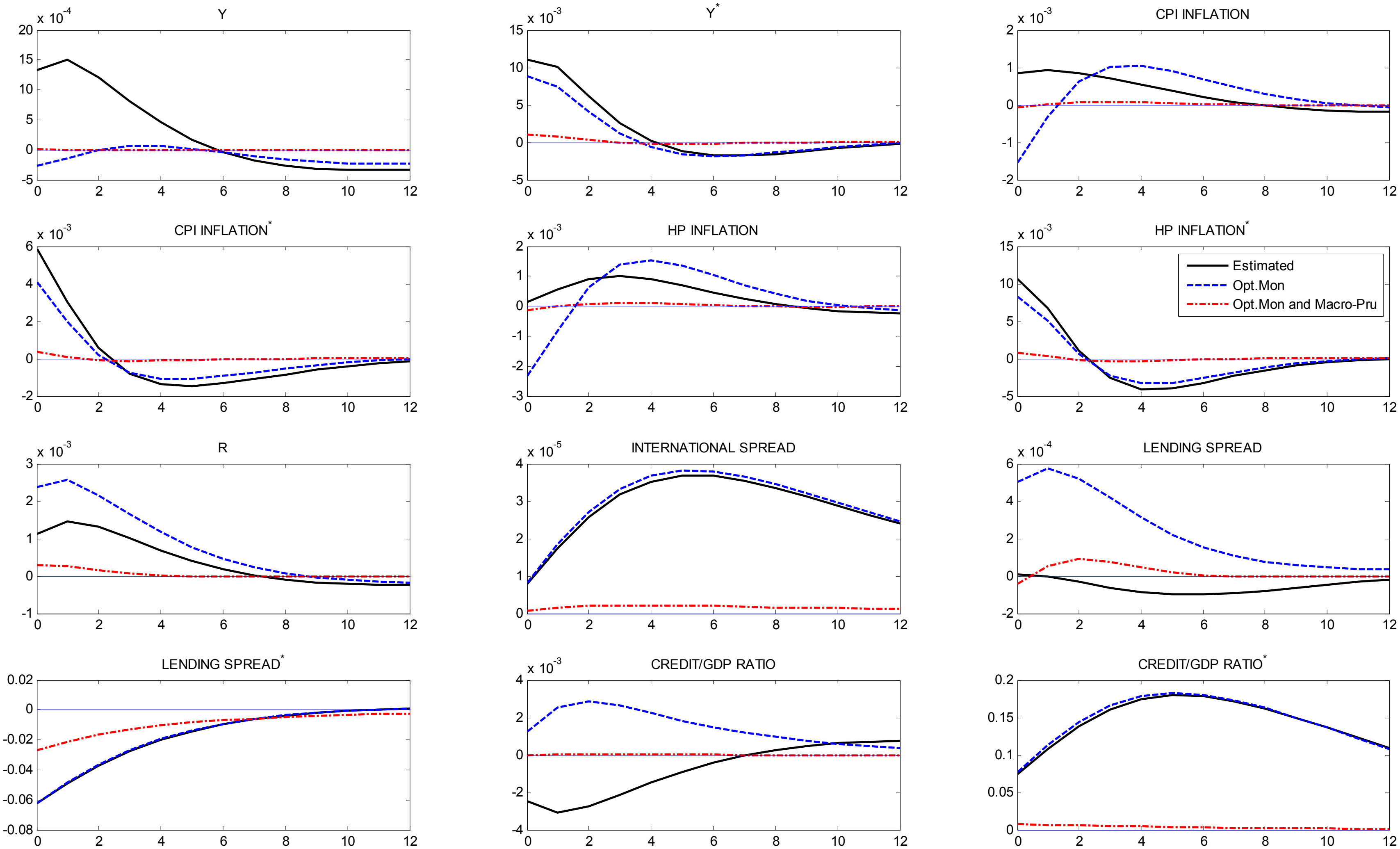

Figure 2b-Impulse Response to a Risk Shock in the Periphery

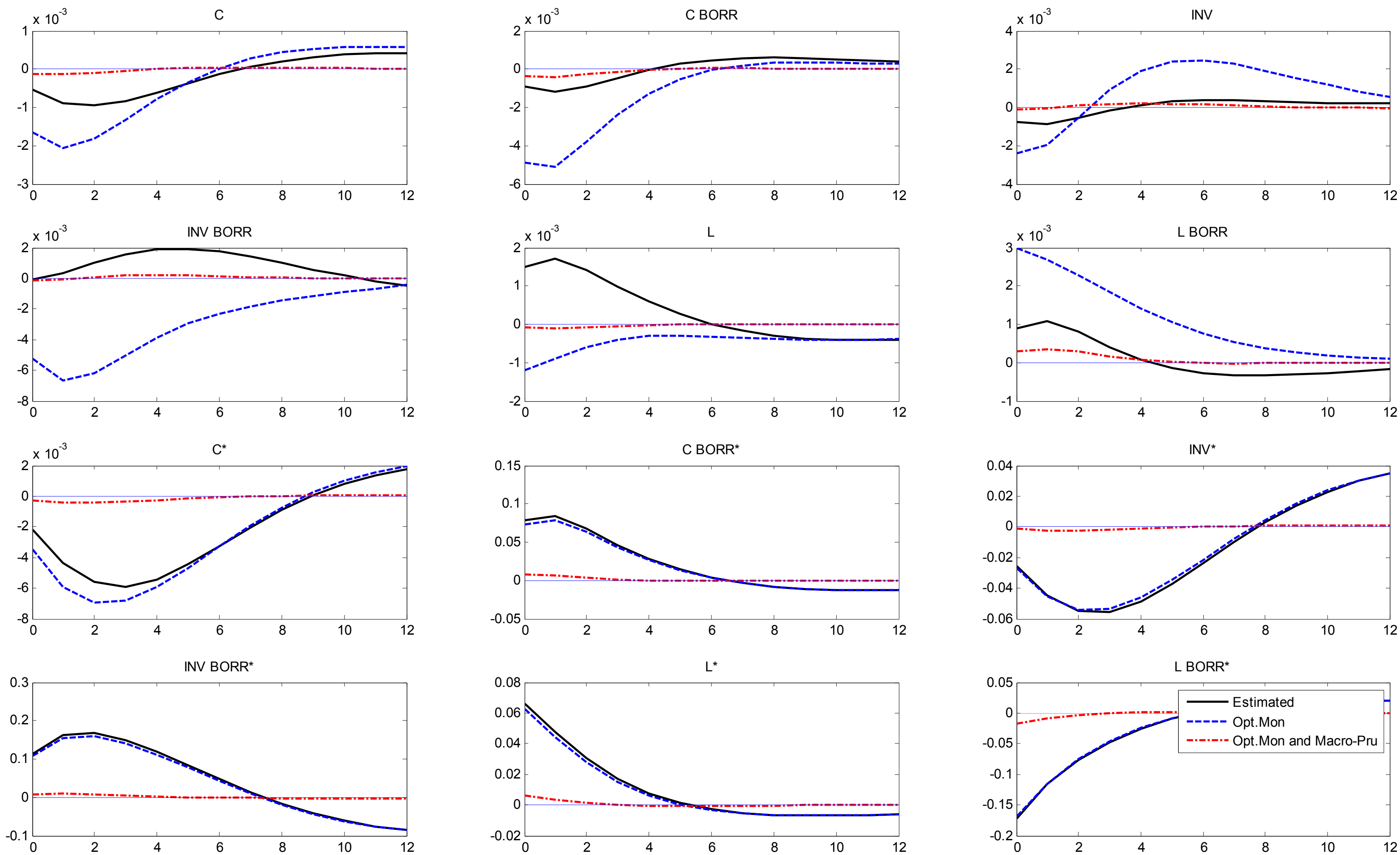

Figure 3a-Impulse Response to a Permanent Technology Shock in the EMU

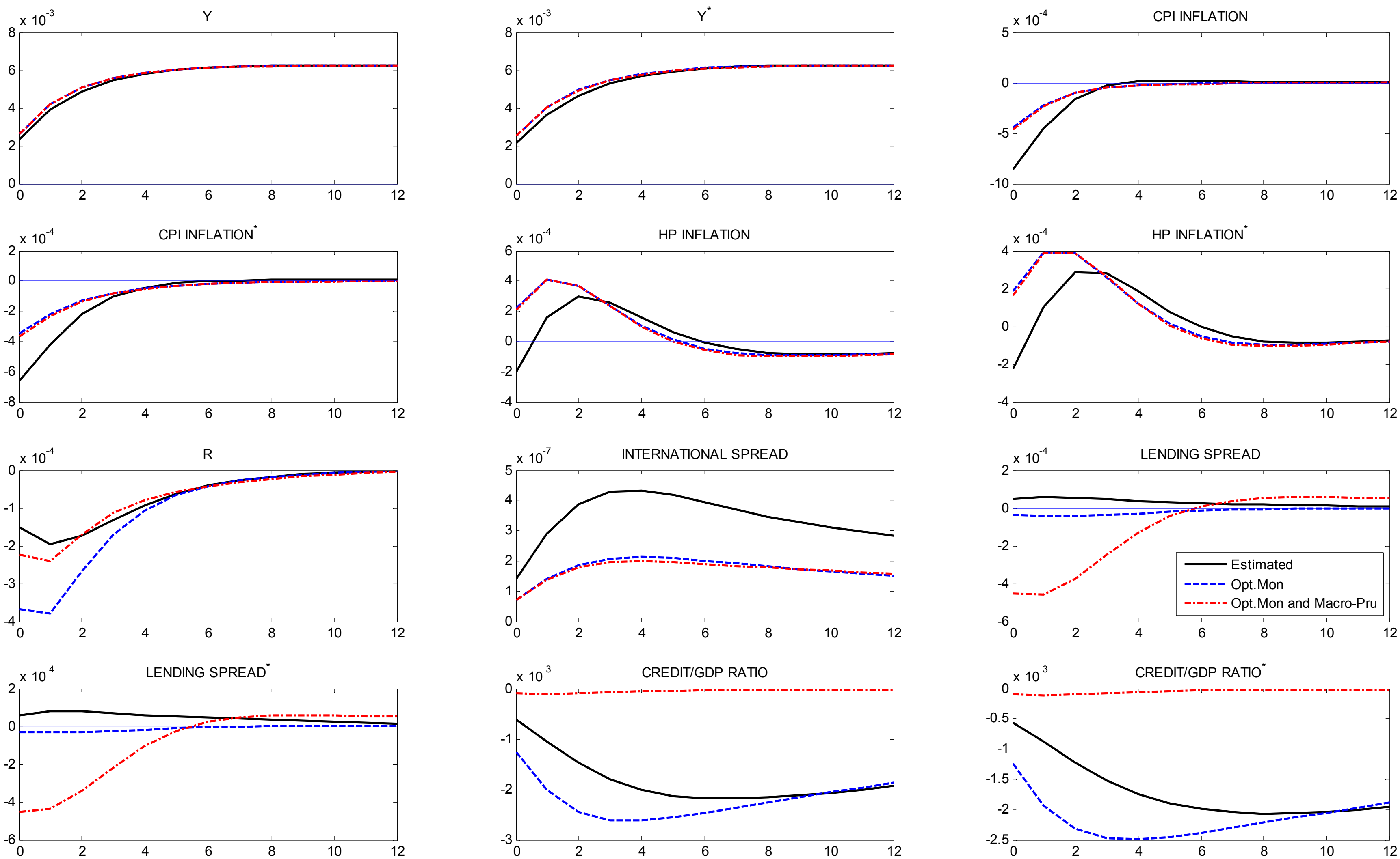

Figure 3b- Impulse Response to a Permanent Technology Shock in the EMU

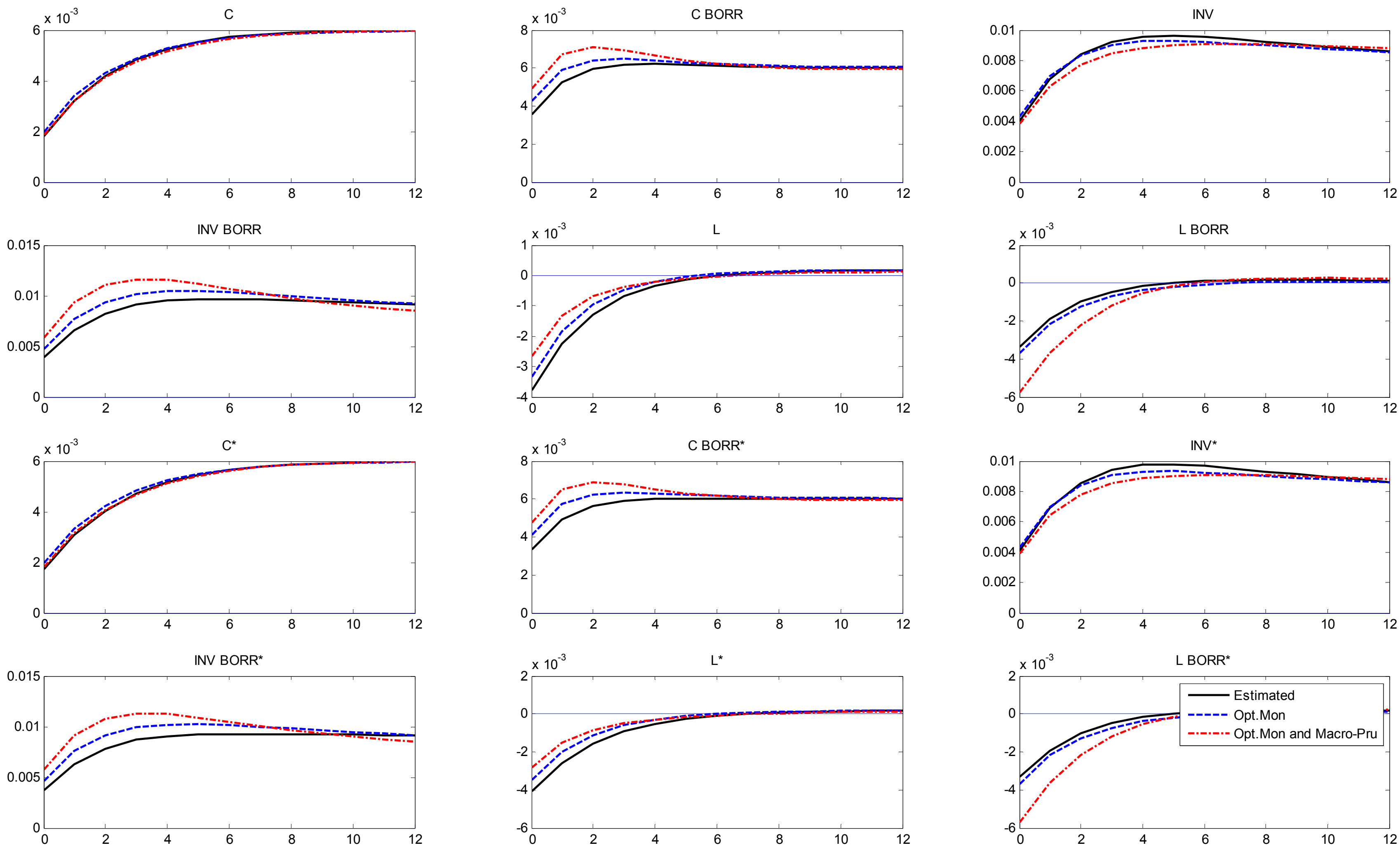

Figure 4- Best Responses when Macro-Prudential Policies Maximize Domestic Welfare