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 DSGE 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 and improving welfare. However, the effects of macroprudential regulations tend to be modest and numerically much smaller than those achieved when the central bank implements monetary policy rules that are close to the optimal one. When the macroprudential regulator has an objective to minimize the volatility of credit/GDP to avoid the build up of excessive risks, macroprudential policies become quantitatively more important.

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

JEL Codes: C51, E44, E52.

1 Introduction

The recent financial crisis that started in the summer of 2007 lead to the worst recession since World War II, while excessive leverage complicates the recovery and the return to pre-crisis growth rates in several advanced countries. The sources of the crisis are several and complex, including country-specific factors, yet a combination of loose monetary and regulatory policies encouraged excessive credit growth, leverage and procyclicality in the financial sector, and a housing boom. This turns out to be a problem because, as Claessens et al. (2008) and Crowe et al. (2011) 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. Therefore, 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 appropiate toolkit to deal with financial and housing cycles has only recently begun, with high uncertainty on which measures can be more effective at producing 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), and hence 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 macroprudential regulation. Should it be used as a countercyclical policy tool, leaning against the wind of large credit and asset price fluctuations, or should it just aim at increasing the buffers of the banking system (provisions and capital requirements) should a crisis occur?

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, as it reacts to the aggregate, union-wide inflation rate and state of the economy. We provide a quantitative study on how monetary and macroprudential measures could interact in the euro area,

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

and pay special attention to the policy trade-offs and coordination issues between the European Central Bank (ECB), national supervision authorities and the newly created European Systemic Risk Board (ESRB) that would be in charge of enforcing such macroprudential regulation at the euro area level.

The recent developments in southern Europe shares many characteristics with other crises. Real exchange rate appreciation, 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] During the 1999-2007 period, Spain and Greece grew at a much higher rate than Germany (Figure 1). When the crisis hit, Germany's GDP collapsed by 6 percent, yet the rebound in 2010 and the first half of 2011 has been quite robust. On the contrary, Portugal and Spain exhibit an anemic recovery, while fiscal problems in Greece have led to a long recession. Since the creation of the euro. all three southern European countries displayed persistent inflation differentials with respect to Germany, which led to real exchange rate appreciation (Figure 2). With the ECB providing support to the euro area as a whole, southern European economies faced low and sometime negative interest rates and credit to the private sector as percent of GDP grew importantly during that period, while it declined in Germany (Figure 3). Monetary conditions and capital flows to the southern euro area economies fuelled a housing boom in Spain and Greece (Figure 4). Figure 5 plots the differential in real (ex-post) interest rate for consumer loans between the three southern European economies and Germany, using ECB data (that start in 2003). Real interest spreads with Germany were quite low, and even negative in the case of Spain before 2006. When the crisis hit, all problems came at once: low growth, high debt, and credit spreads that helped amplify the business cycle.

The three southern European economies (and also Ireland) could not use monetary policy to cool down their economies and financial systems. Therefore, the use of other policy instruments in a currency union can potentially help in stabilizing the 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 limits in reducing

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[2]See Kaminsky and Reinhart (1999), IMF (2009) and Gorodnichenko, Mendoza and Tesar (2011), among others.

credit cycle volatility in a small open economy. 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 interplay/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 a overheating financial sector but if it is also combined 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 decides the nominal interest rate and the supervisory authority can choose countercyclical capital requirements and loan-to-value ratios. Unsal (2011) studies the role of macroprudential policy when a small open economy receives large capital inflows.

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, financial 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. We derive the optimal monetary policy when the ECB minimizes a traditional central bank loss function including the variances of CPI inflation and the output gap. We find that the optimal Taylor rule reacts to fluctuations of inflation and output from their efficient levels, and leaves little room to react to credit aggregates in the euro area. Next, we introduce a macroprudential instrument that influences credit market conditions by affecting the wedge between the lending and the deposit rate. This instrument can be thought of as additional capital requirements, liquidity ratios, reserve require-

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[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.

ments 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 macro-prudential policies (in terms of reducing output gap and inflation volatility) are positive but small when the central bank follows an optimal Taylor rule. Macroprudential instruments helps reduce the volatility of macroeconomic aggregates but mostly, of credit aggregates.

It is important to note from the start that we are only computing how the variance of main macroeconomic aggregates (CPI inflation, output gap, and credit) changes when we introduce different monetary policies and macroprudential regimes. Hence, we are not measuring other potentially large benefits from improving banking regulation at the macro and the micro level such as: (i) reducing the frequency and cost of financial and banking crisis, (ii) reducing the probability of tail events materializing, and (iii) improved macroeconomic and financial environment due to a reduction in volatility and uncertainty. 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. In Section 5, we present impulse-responses for the different policy regimes, while we leave Section 6 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 $1-n$ and use the same currency to carry out transactions. Monetary policy is conducted by a central bank that targets the union-wide consumer price inflation rate. In each country two types of goods, durables and non-durables, 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 addition, there are two types of agents, savers and borrowers, who differ in their discount factors. Borrowers are more impatient than savers and have preference for early consumption.

There are two types of financial intermediaries in the model, domestic and international. Domestic financial intermediaries take deposits from savers and issue bonds

that are traded across countries by international intermediaries. Domestic financial intermediaries pay the deposit interest rate on these liabilities. On the asset side, they lend to borrowers at the lending rate. We assume that the lending-deposit spread depends on the loan-to-value ratio of borrowers, and on an exogenous mark-up. Thus, we generalize the literature that incorporates borrowing constraints using housing as collateral (as in Iacoviello, 2005, and Iacoviello and Neri, 2010) with a more flexible setup in the spirit of the financial accelerator literature (Bernanke, Gertler and Gilchrist, 1998).[4] This set-up is flexible in the sense that in the borrowing constraints literature impatient households always borrow up to the collateral constraint, while in our model they can choose how much to borrow depending on credit conditions. Borrowers can even go beyond the steady-state loan-to-value ratio if they choose to do so, at a higher interest rate.[5] Savings and (residential) investment at the country level need not to be balanced 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. The foreign country block has a similar structure for households and firms in all sectors, and to save space is not presented.

2.1 Households

2.1.1 Savers

In each country a fraction λ of agents are savers, while the rest $1 - \lambda$ are borrowers. Each saver household indexed by $j \in [0, \lambda]$ in the home country maximizes the following utility function:

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

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[4] Aoki et al. (2004) and Forlati and Lambertini (2011) derive a DSGE model with housing and risky mortgages where the external finance premium also depends on leverage and the value of the housing stock that can be used as collateral.

[5] This model has been used in a closed economy setup by Kannan, Rabanal and Scott (2009) to analyze the desirability to target credit growth targets by a central bank and/or a financial supervision authority.

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). Both shocks follow a zero-mean AR(1) process in logs. 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 and foreign non-durable consumption goods:

$$C_t^j = \left[\tau^{\frac{1}{\iota_C}} \left(C_{H,t}^j \right)^{\frac{\iota_C - 1}{\iota_C}} + (1 - \tau)^{\frac{1}{\iota_C}} \left(C_{F,t}^j \right)^{\frac{\iota_C - 1}{\iota_C}} \right]^{\frac{\iota_C}{\iota_C - 1}}, \text{ where } \iota_C > 0. \qquad (2)$$

Personal consumption expenditures on non-durables are spent on home goods ($C_{H,t}^j$) and foreign goods ($C_{F,t}^j$), 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:

$$L_t^j = \left[\alpha^{-\iota_L} \left(L_t^{C,j} \right)^{1 + \iota_L} + (1 - \alpha)^{-\iota_L} \left(L_t^{D,j} \right)^{1 + \iota_L} \right]^{\frac{1}{1 + \iota_L}}, \text{ where } \iota_L > 0. \qquad (3)$$

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, governed by parameter ι_L.[6] The budget constraint in nominal euro terms reads:

$$P_t^C C_t^j + P_t^D I_t^{D,j} + P_t^A A_t^j + S_t^j \qquad (4)$$
$$\leq R_{t-1} S_{t-1}^j + W_t^C L_t^{C,j} + W_t^D L_t^{D,j} + (R_t^A + P_t^A) A_{t-1}^j + \Pi_t^j,$$

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[6]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.

where P_t^C and P_t^D are the price indices of non-durable and durable goods, respectively, to be defined below. Nominal wages paid in the two sectors are denoted by W_t^C and W_t^D. Savers have two assets to choose from. They have access to deposits in the domestic financial system (S_t^j), that pay the deposit interest rate (R_t). Households also invest in land A_t^j, purchased at a price P_t^A and rented to the durable goods producers at a rental rate of R_t^A. In addition, savers also receive profits (Π_t^j) from intermediate goods producers in the durable and the non-durable sectors, and from domestic and financial intermediaries.

Residential investment $I_t^{D,j}$ is used to increase the housing stock D_t^j, according to the following law of motion:

$$D_t^j = (1 - \delta)D_{t-1}^j + \left[1 - F\left(\frac{I_t^{D,j}}{I_{t-1}^{D,j}}\right)\right] I_t^{D,j} \tag{5}$$

where δ denotes the depreciation rate and $F(\cdot)$ an adjustment cost function. Following Christiano, Eichenbaum, and Evans (2005), $F(\cdot)$ is a convex function ($F''(\cdot) > 0$), which in steady state meets the following criteria: $\bar{F} = \bar{F}' = 0$ and $F'' > 0$.[7]

2.1.2 Borrowers

Borrowers are indexed in each country by $j \in [\lambda, 1]$, and they differ from savers along three dimensions: their discount factor, the range of financial assets that they have access to, and the fact that they receive no profits from firms. The discount factor of borrowers is smaller than the factor of savers ($\beta^B < \beta$). 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 credits. Denoting all variables for borrowers with the subscript B, the utility function reads:

$$E_0\left\{\sum_{t=0}^{\infty} \beta^{B,t}\left[\gamma\xi_t^C \log(C_t^{B,j} - \varepsilon C_{t-1}^B) + (1 - \gamma)\xi_t^D \log(D_t^{B,j}) - \frac{\left(L_t^{B,j}\right)^{1+\varphi}}{1 + \varphi}\right]\right\}, \tag{6}$$

where all the indices of consumption and hours worked have the same functional form as in the case of savers. The budget constraint for borrowers in nominal terms

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[7]This cost function can help the model to replicate hump-shaped responses of residential investment to shocks.

is given by:

$$P_t^C C_t^{B,j} + P_t^D I_t^{B,j} + R_{t-1}^L S_{t-1}^{B,j} \leq S_t^{B,j} + W_t^C L_t^{B,C,j} + W_t^D L_t^{B,D,j} \qquad (7)$$

Borrowers consume non-durables and invest in the housing stock, subject to the same investment adjustment cost as savers (equation 5). They obtain credits $S_t^{B,j}$ from financial intermediaries at a lending rate R_t^L which includes a spread over the deposit rate R_t paid to savers. The wedge between these two rates is determined in the financial market (discussed below). Borrowers also supply labor for which they also suffer a cost of switching sectors (as in equation 3). Savers and borrowers are paid the same wages W_t^C and W_t^D in both sectors. That is, firms are not able to discriminate types of labor depending on whether a household is a saver or a borrower. Below, we describe the wage setting process.

2.1.3 Wage Setting

Nominal wages are assumed to be sticky as in Smets and Wouters (2007) and Iacoviello and Neri (2010). Households provide their homogenous labor services to labor unions, which differentiate these services, negotiate wages, and sell them to labor packers afterwards. These perfectly competitive wholesale labor packers reassemble these services into homogenous labor composites and offer them to intermediate goods producers. There exist two unions in each country, one for each sector, which set nominal wages for the respective sector subjected to a Calvo scheme. The probabilities of being able to readjust wages in a given period for the non-durable and durable sector are given by $1 - \theta_{C,W}$ and $1 - \theta_{D,W}$, respectively. In addition, remaining wages which are not readjusted are partially indexed to past CPI inflation (with the fractions $\varphi_{C,W}$ and $\varphi_{D,W}$, respectively). We assume that wages are the same in the non-durable and durable sector, regardless of the type of households. Unions are run by savers while borrowers are merely members. Thus, unions maximize the utility of savers (1) subject to their budget constraint (4) and to the demand schedule of labor packers.[8]

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[8] Borrowers take wages as given and supply labor to both sectors by equating their marginal rate of substitution to that of savers. We assume that shocks are never large enough such that either type of worker would not want to supply labor at the prevailing wage.

2.2　Financial Intermediaries

2.2.1　Domestic Intermediaries

Domestic financial intermediaries collect deposits from savers and extend loans to borrowers within each country. In addition, they can issue bonds to the international financial intermediaries, for which they also pay the deposit rate in the home country, R_t. Hence, if credit demand in one country exceeds the amount of loanable funds, domestic intermediaries can tap international financial markets issuing bonds. If credit demand is smaller than the amount available from deposits, then banks can opt for buying bonds from international financial intermediaries at the rate R_t. As in Kannan, Rabanal, and Scott (2009) the wedge between the deposit rate R_t and the lending rate R_t^L is time-varying and depends on the aggregate net worth of borrowers or, given the assumptions of the model, the loan-to-value ratio of borrowers. While admittedly a reduced form mechanism, this assumption allows for an endogenous variation in the balance sheets of households to influence lending conditions, as in models of the financial accelerator.[9] It also embeds the idea that the supply of credit is an upward-sloping curve with respect to lending interest rates.[10]

Hence, the lending rate is given by the following functional form:

$$R_t^L = \upsilon_t R_t F\left(\frac{S_t^B}{P_t^D D_t^B}\right) \eta_t. \tag{8}$$

$F\left(\cdot\right)$ is an increasing function of the loan-to-value ratio of borrowers $(S_t^B/P_t^D D_t^B)$. Furthermore, we assume $F\left(1-\chi\right)=1$, with χ being the steady state down-payment required from borrowers. The parameter $1-\chi$ denotes the loan-to-value ratio, which in the model is viewed as a suggested value by regulatory authorities rather than a legally binding one.[11] If borrowers do not meet this requirement and demand a higher leveraged loan, they are charged a higher lending rate. Evidence for the euro area suggests that mortgage spreads are an increasing function of the loan-to-value ratio, as discussed in Sorensen and Lichtenberger (2007) and ECB (2009).

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[9]Models with explicit default risk such as Aoki et al. (2004) and Forlati and Lambertini (2011) derive an expression relating credit spreads with the net worth of agents that borrow using housing as collateral.

[10]Cúrdia and Woodford (2010) assume that the spread between borrowing and deposit rates depend on the level of credit produced on a given period.

[11]This is actually the case in most advanced and emerging economies, see IMF (2011) and Crowe et al. (2011).

This mechanism is a generalization of the borrowing constraint that is usually introduced in models of borrowers and savers. In Iacoviello (2005), the equilibrium real interest rate is smaller than the inverse of the discount factor of borrowers. Hence, borrowers would like to borrow an infinite amount and the borrowing constraint is always binding: that is, $S_t^B = (1 - \chi) P_t^D D_t^B$. Our model can accommodate Iacoviello's mechanism by assuming that $F(\cdot) = \infty$ whenever S_t^B differs from $(1 - \chi) P_t^D D_t^B$, in addition to $F(1 - \chi) = 1$. In Iacoviello's model an increase of house prices always leads to more borrowing due to a relaxation of the constraint. In the mechanism of the present paper, when house prices increase, then borrowers can either borrow more, refinance their debt at a lower rate, or a combination of both.

The financial shock υ_t, can be perceived as a change in market conditions (for instance, deregulation that leads to more competition), a change in the riskiness of mortgages, or a lowering of credit standards.[12] It follows an AR(1) process in logs. The last element in the spread equation is the macroprudential instrument η_t. We assume that national policy makers can affect market rates by imposing additional capital requirements or loan-loss provisions on financial intermediaries, such that they are able to affect conditions in the retail credit markets.[13] When estimating the model we assume that this rule is absent and set $\eta_t = 1$. In Section 4 we discuss several possibilities in defining countercyclical macroprudential rules and analyze them according to their ability for lowering macroeconomic volatility. In the steady state, both interest rates equal the inverse of the relevant discount factors: $R^L = (\beta^B)^{-1}$ and $R = \beta^{-1}$, and hence the mean of the financial shock, together with the assumption that $F(1 - \chi) = 1$, ensures that this is the case: $\upsilon\eta = \beta/\beta^B$.

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 (8). In the next subsection, we explain how the deposit rate in the foreign country R_t^* is determined.

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[12] Fernández-Villaverde and Ohanian (2010) show, in a financial accelerator model, that shocks to volatility and shocks to the spread equation have similar quantitative effects.

[13] In the case of Spain, loan-loss provisions have not had enough bite in the past in affecting credit conditions (Lim et al. 2011). Another macroeconomic tool that directly affects the lending-deposit rate is the use of reserve requirements.

2.2.2 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^*):

$$R_t^* = R_t + \left\{ \vartheta_t \exp\left[\kappa_B \left(\frac{B_t}{PY} - \frac{B}{PY} \right) \right] - 1 \right\}. \tag{9}$$

In this case, the spread depends on the ratio of net foreign assets to steady-state nominal GDP in the home country (which we define below). If the home country domestic intermediaries have an excess of funds that wish to lend to the foreign country domestic intermediaries, then $B_t > 0$ and 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 debtor, 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 $B_t < 0$.

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 shock follows a zero-mean, AR(1) process in logs. This functional form is also chosen for modeling convenience: Since international intermediaries are owned by savers, optimality conditions will ensure that the net foreign asset position of both countries (which is indeed B_t) is stationary.[14]

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

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[14]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 (9) 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).

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.[15] Durable good producers are 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:

$$Y_t^k \equiv \left[\left(\frac{1}{n} \right)^{\frac{1}{\sigma_k}} \int_0^n Y_t^k(h)^{\frac{\sigma_k-1}{\sigma_k}} dh \right]^{\frac{\sigma_k}{\sigma_k-1}}, \text{ for } k = C, D \tag{10}$$

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:

$$Y_t^k(h) = \left(\frac{P_t^k(h)}{P_t^k} \right)^{-\sigma_C} Y_t^k, \text{ for } k = C, D \tag{11}$$

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

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[15]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.

of imported non-durables (P_t^F):

$$P_t^C = \left[\tau \left(P_t^H \right)^{1-\iota_C} + (1 - \tau) \left(P_t^F \right)^{1-\iota_C} \right]^{\frac{1}{1-\iota_C}}. \tag{12}$$

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 $1 - \theta_C \left(1 - \theta_D \right)$ of intermediate good producers in the non-durable (durable) sector receive a signal to re-optimize their price. For the remaining fraction $\theta_C \left(\theta_D \right)$ we assume that their prices are simply indexed partially to past sector-specific inflation (with factor ϕ_C, ϕ_D in each sector).

In the non-durable good sector, intermediate goods are produced solely with labor, while in the durable good sector producers combine labor and land:

$$Y_t^C(h) = Z_t Z_t^C L_t^C(h), \;\; Y_t^D(h) = Z_t Z_t^D (A_{t-1}(h))^{1-\alpha_D} \left[L_t^D(h) \right]^{\alpha_D}, \;\; \text{for all } h \in [0, n] \tag{13}$$

where α_D is the labor share in the production of durables. 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:

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

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. Since labor is the only production input in the non-durable sector, cost minimization implies that real marginal costs in this sector are given by:

$$MC_t^C = \frac{W_t^C / P_t^C}{Z_t Z_t^C}. \tag{14}$$

In the durable sector, we assume that the supply of land is fixed ($A_t = \bar{A}$) and

obtain the following real marginal costs of production:[16]

$$MC_t^D = \frac{\left(W_t^D/P_t^C\right)\left(L_t^D\right)^{1-\alpha^D}\left(\bar{A}\right)^{-(1-\alpha^D)}}{\alpha^D Z_t Z_t^D}.\tag{15}$$

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:

$$P_t^D=\left[\theta_D\left(\widehat{P_t^D}\right)^{1-\sigma_D}+(1-\theta_D)[P_{t-1}^D(P_{t-1}^D/P_{t-2}^D)^{\phi_D}]^{1-\sigma_D}\right]^{\frac{1}{1-\sigma_D}}.\tag{16}$$

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.

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[16]We substitute for the optimal expression of the rental rate of land:

$$R_t^A=\left(\frac{1-\alpha^D}{\alpha^D}\right)\frac{W_t^D L_t^D}{\bar{A}},$$

and choose the level of $\bar{A}=\left(\frac{1}{\alpha^D}\right)^{\frac{1}{1-\alpha^D}}L^D$, such that the level of real wages is the same across sectors in the steady state. This allows us to keep defining α as the share of employment in the non-durables sector.

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 $C_{H,t}^{B*}$ from abroad):

$$nY_t^C = n\left[\lambda C_{H,t} + (1-\lambda) C_{H,t}^B\right] + (1-n)\left[\lambda^* C_{H,t}^* + (1-\lambda^*) C_{H,t}^{B*}\right]. \qquad (17)$$

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

$$nY_t^D = n\left[\lambda I_t^D + (1-\lambda) I_t^{D,B}\right]. \qquad (18)$$

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

$$\int_0^n L_t^k(h)dh = \lambda \int_0^n L_t^{k,j}dj + (1-\lambda) \int_0^n L_t^{k,B,j}dj, \text{ for } k = C, D. \qquad (19)$$

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

$$n\lambda S_t + n\lambda B_t = n(1-\lambda) S_t^B,$$
$$n\lambda B_t + (1-n)\lambda^* B_t^* = 0.$$

Nominal GDP in the home country is defined as:

$$P_t Y_t = P_t^H Y_t^C + P_t^D Y_t^D$$

Finally, aggregating the resource constrains 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, which can also be viewed as the evolution of net foreign assets (NFA) of the home

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country:

$$n\lambda B_t = n\lambda R_{t-1}B_{t-1} + \left\{ (1-n) P_{H,t} \left[\lambda^* C_{H,t}^* + (1-\lambda^*) C_{H,t}^{B*} \right] - n P_{F,t} \left[\lambda C_{F,t} - (1-\lambda) C_{F,t}^B \right] \right\},$$
(20)

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 ECB with an interest rate rule that targets union-wide CPI inflation, following the mandate to keep inflation close to but below 2 percent. We assume that the ECB sets the deposit rate in the home-country. Let $\bar{\Pi}^{EMU}$ be the steady state level of union-wide 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:

$$R_t = \left[\bar{R} \left(\frac{P_t^{EMU}/P_{t-1}^{EMU}}{\bar{\Pi}^{EMU}} \right)^{\gamma_\Pi} \right]^{1-\gamma_R} R_{t-1}^{\gamma_R} \exp(\varepsilon_t^m).$$
(21)

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:

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

In section 4, we augment the interest rate rule and allow monetary policy to react to further variables besides the above mentioned when discussing the optimal policy mix.

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.[17] Third, the solution of the model is expressed in state-space form 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.[18]

3.1 Data

We distinguish between a core (home country) and a periphery (foreign country) regions of the euro area. Data for the core is obtained by aggregating data for France, Germany, and Italy whereas the periphery is represented by Greece, Portugal, and Spain. We use quarterly data ranging from 1995q4-2010q4.[19] For both regions we obtain six observables: real private consumption spending, real residential investment, the harmonized index of consumer prices (HICP), housing prices, a lending rate for household purchases, and a deposit rate.[20] 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 $\beta^B = \beta^{B*}$) and set the discount factor of savers $\beta = 0.99$ and the discount factor of borrowers $\beta^B = 0.98$ as in Iacoviello (2005). The depreciation rate is assumed to be 10 percent annually and equal across countries ($\delta = \delta^* = 0.025$). The degree of monopolistic competition markets is the same across sectors and countries, in the goods and labor markets, implying mark-ups of 10 percent. The steady state down payment is set equally

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

[18]The estimation is done using Dynare 4.2. The posteriors are based on 250,000 draws of the Metropolis-Hastings algorithm.

[19]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.

[20]See appendix B for further details on the data set.

across countries $\chi = \chi^* = 0.3$ according to euro area data such as Gerali et al. (2010). As we do not have distinctive data on wages for the euro area we calibrate the Calvo lottery parameter to imply 4 quarters of average wage duration contracts, and we assume a high degree of indexation of wages to past CPI inflation, based on Smets and Wouters (2003) and ECB (2009). Both parameters are the same across sectors as well as countries. Finally, we assume that the labor share in the production function of durable intermediate goods is the same across countries ($\alpha^D = \alpha^{D*}$) and set to 0.7, as in Iacoviello and Neri (2010).

Table 1: Calibrated Parameters

β	Discount factor savers	0.99
β^B	Discount factor borrowers	0.98
δ	Depreciation rate	0.025
σ	Elasticity of substitution between intermediate goods	10
σ_L	Elasticity of substitution between labor types	10
χ	Steady state down-payment	0.3
$\theta_{W,C}$	Calvo lottery, wage-setting in non-durable sector	0.75
$\theta_{W,D}$	Calvo lottery, wage-setting in durable sector	0.75
$\varphi_{W,C}$	Indexation wage setting in non-durable sector	0.66
$\varphi_{W,C}$	Indexation wage setting in durable sector	0.66
α^D	Labor share in the durable sector	0.7
$\tilde{\alpha}$	Size of non-durable sector in core economies GDP	0.95
$\tilde{\alpha}^*$	Size of non-durable sector in periphery economies GDP	0.91
$1 - \tau$	Fraction of imported goods from periphery to core economies	0.03
$1 - \tau^*$	Fraction of imported goods from core to periphery economies	0.12
n	Size core economies	0.81

The size of the construction sector differs between core and periphery countries. In the model, the fraction of work allocated to the durable production (construction) sector is $1 - \alpha$. However, this is not the size of the fraction of construction activities in real GDP because the labor shares in the production of durables and non-durables are different. Hence, the share of durables activities in GDP is given by $\tilde{\alpha} = \frac{\alpha}{\alpha + \frac{1-\alpha}{\alpha^D}}$. We calibrate the size of the construction sector $1 - \tilde{\alpha}$ by calculating the weighted average of the construction sector for France, Germany, and Italy. A value of $1 - \tilde{\alpha}^*$ is attained by doing the same for Greece, Portugal, and Spain. 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 chosen to ensure that the trade balance and the net foreign asset position are zero in the steady state. The relative economic size of the core economies n is given by comparing the average

GDP of the core and periphery countries.

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.[21] 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, fraction of savers, and the elasticity of spreads 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.

First, we comment on the parameters that relate to financial frictions in the model. 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 slightly larger fraction (0.59) to fit the macro data.[22] The relationship between the spread and the loan-to-value ratio is key in our model, since it determines the size of the accelerator effect when house prices change. ECB (2009) mentions that it is difficult to measure this effect due to the lack of available individual loan data. However, the same study mentions that on average, an increase of loan-to-value ratios from 75 to 95 percent is associated with an increase of mortgage spreads of about 20 to 40 basis points. However, this relationship is non-linear since an increase of loan-to-value ratios from 50 to 75 percent is associated with an increase of mortgage spreads of between 0 and 20 basis points. Ambrose et al. (2004) report estimates of κ_L between 0.02 and 0.68 by estimating a similar equation as (8) using individual loan data for the U.S. Aoki

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[21]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, α^D, δ, λ, β, β^B, ε and φ.

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

et al. (2004) calibrate κ_L to 0.1. Given this evidence, we opt for a Gamma prior distribution centered at 0.4. We find that the posterior mean is somewhat lower, with a value of 0.07, denoting that perhaps it is difficult to estimate this relationship with aggregate data. We opt for priors for the risk premia elasticity between countries with a mean of 0.01. As in Aspachs-Bracons and Rabanal (2011), we find that the risk premium elasticity between countries is about 0.9 basis points. This result is not surprising since nominal risk premia have been negligible in most of the sample. The coefficients on the Taylor rule suggest a strong response to inflation fluctuations in the euro area (coefficient of 1.47, close to the prior mean) and a high degree of interest rate inertia (0.86).

Table 2: Prior and Posterior Distributions

	Parameters		Prior		Posterior	
			Mean	Std.Dev.	Mean	90% C.S.
λ	Fraction of savers	Beta	0.5	0.1	0.59	[0.47,0.73]
κ_L	Domestic risk premium	Gamma	0.4	0.05	0.08	[0.06,0.10]
κ_B	International risk premium	Gamma	0.01	0.005	0.009	[0.002,0.015]
γ_π	Taylor rule reaction to inflation	Normal	1.5	0.1	1.47	[1.31,1.64]
γ_r	Interest rate smoothing	Beta	0.66	0.15	0.86	[0.84,0.89]
θ_C	Calvo lottery, non-durables	Beta	0.75	0.15	0.47	[0.31,0.62]
θ_C^*	Calvo lottery, non-durables	Beta	0.75	0.15	0.56	[0.45,0.69]
θ_D	Calvo lottery, durables	Beta	0.75	0.15	0.61	[0.51,0.70]
θ_D^*	Calvo lottery, durables	Beta	0.75	0.15	0.30	[0.18,0.41]
ϕ_C	Indexation, non-durables	Beta	0.33	0.15	0.16	[0.02,0.28]
ϕ_C^*	Indexation, non-durables	Beta	0.33	0.15	0.16	[0.03,0.27]
ϕ_D	Indexation, durables	Beta	0.33	0.15	0.29	[0.07,0.50]
ϕ_D^*	Indexation, durables	Beta	0.33	0.15	0.25	[0.04,0.43]
ε	Habit formation	Beta	0.66	0.15	0.77	[0.71,0.83]
φ	Labor disutility	Gamma	1	0.5	1.16	[0.48,1.78]
ι_C	Elasticity of subst. between goods	Gamma	1	0.5	2.65	[1.11,3.93]
ι_L	Labor reallocation cost	Gamma	1	0.5	0.22	[0.09,0.35]
ψ	Investment adjustment costs	Gamma	2	1	1.03	[0.67,1.36]

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. In the core, prices are reset optimally every 2 to 3 quarters in both sectors. A similar estimate is obtained in the non-durable sector in the periphery. Interestingly, the

way the model captures high volatility of house prices in the periphery is by assigning a higher frequency of price adjustment, with a posterior probability of the Calvo lottery of just 0.3. 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.

The next block of parameters includes those related to preferences. We center the priors related to the utility function, elasticity of substitution between home and foreign non-durables, and adjustment costs to residential investment to parameters available in the literature (Smets and Wouters, 2003; Christiano, Eichenbaum and Evans, 2005). We find a large degree of habit formation (posterior mean of 0.77) and a large elasticity of substitution between home and foreign goods (the posterior mean of 2.65 is much higher than the prior mean of 1). Regarding the coefficients that determine labor supply, we find that the posterior mean of the labor disutility coefficient φ is just above one, as in Smets and Wouters (2003), while contrary to Iacoviello and Neri (2010), we find that the coefficient on costly labor reallocation is low, with a posterior mean of 0.22.

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 non-durables. The risk premium shocks are also highly autocorrelated. Table 3 also shows that for both technology and preference shocks, the standard deviations tend to be larger for shocks affecting non-durables, and for shocks affecting the periphery. Finally, shocks to monetary policy and of the international risk premia are less volatile than the domestic lending-deposit risk premia.

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 model implied by the posterior mode. In Table 4, the first row in each case is the data, the second row is the model. The model does reasonably well in explaining the

Table 3: Prior and Posterior Distributions, Shock Processes

	Parameters		Prior		Posterior	
	AR(1) coefficients		Mean	Std.Dev.	Mean	90% C.S.
$\rho_{Z,C}$	Technology, non-durables	Beta	0.7	0.1	0.81	[0.72,0.90]
$\rho_{Z,D}$	Technology, durables	Beta	0.7	0.1	0.88	[0.84,0.94]
$\rho_{\xi,C}$	Preference, non-durables	Beta	0.7	0.1	0.74	[0.63,0.87]
$\rho_{\xi,D}$	Preference, durables	Beta	0.7	0.1	0.98	[0.97,0.99]
ρ_L	Risk premium, lending-deposit	Beta	0.7	0.1	0.95	[0.92,0.97]
ρ_ϑ	Risk premium, core-periphery	Beta	0.7	0.1	0.87	[0.84,0.91]
	Std. Dev. Shocks					
σ_Z	Technology, EMU-wide	Gamma	0.7	0.2	0.78	[0.54,0.97]
σ_Z^C	Technology, non-durables, core	Gamma	0.7	0.2	0.54	[0.37,0.71]
σ_Z^D	Technology, durables, core	Gamma	0.7	0.2	1.51	[1.16,1.88]
σ_Z^{C*}	Technology, non-durables, periphery	Gamma	0.7	0.2	0.94	[0.64,1.22]
σ_Z^{D*}	Technology, durables, periphery	Gamma	0.7	0.2	1.60	[1.30,1.93]
σ_ξ^C	Preference, non-durables, core	Gamma	1	0.5	1.97	[1.28,2.63]
σ_ξ^D	Preference, durables, core	Gamma	1	0.5	3.41	[2.57,4.42]
σ_ξ^{C*}	Preference, non-durables, periphery	Gamma	1	0.5	2.47	[1.84,3.11]
σ_ξ^{D*}	Preference, durables, periphery	Gamma	1	0.5	4.53	[3.56,5.46]
σ_m	Monetary	Gamma	0.4	0.2	0.07	[0.05,0.08]
σ_ϑ	Risk premium, international	Gamma	0.4	0.2	0.09	[0.08,0.11]
σ_L	Risk premium, domestic, core	Gamma	0.4	0.2	0.08	[0.06,0.11]
σ_{L*}	Risk premium, domestic, periphery	Gamma	0.4	0.2	0.17	[0.12,0.21]

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 volatilities of the different shocks. We also note those variables in the core are less volatile than the same variables in the periphery. It appears that business cycles, in that dimension, are less pronounced in the core.

The model does also a fair job in explaining the persistence of variables. It underpredicts the persistence of all interest rates. It slightly overpredicts the persistence of CPI inflation in the periphery, and slight underpredicts the persistence of residential investment and 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. At this point, we note that we estimated versions of the model assuming that: i) wages are flexible, and ii) the ECB reacts to the EMU output gap, and we did not obtain a better fit to the data.

Given that the fit to the data is quite good, we proceed to ask which shocks explain

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

	Std. Dev.	Autocorrelation				
		1	2	3	4	5
R	0.18	0.93	0.76	0.56	0.35	0.15
	0.22	0.91	0.77	0.63	0.49	0.38
R^L	0.39	0.98	0.94	0.87	0.79	0.70
	0.27	0.89	0.75	0.61	0.47	0.36
Δp^C	0.26	0.26	0.11	0.17	-0.25	0.18
	0.40	0.64	0.33	0.11	-0.02	-0.09
$\Delta \log C$	0.41	0.05	0.26	0.33	-0.02	0.49
	0.61	0.58	0.31	0.13	0.01	-0.06
$\Delta \log Y^D$	2.44	0.01	0.07	-0.10	0.07	0.03
	2.95	0.46	0.13	-0.05	-0.12	-0.13
Δp^D	0.77	0.71	0.75	0.66	0.57	0.47
	1.04	0.65	0.30	0.07	-0.04	-0.09
R^*	0.39	0.96	0.89	0.79	0.65	0.62
	0.29	0.88	0.75	0.62	0.50	0.40
R^{L*}	0.50	0.98	0.94	0.87	0.78	0.68
	0.51	0.89	0.75	0.62	0.50	0.39
Δp^{C*}	0.38	0.44	0.22	0.01	-0.31	-0.21
	0.46	0.66	0.35	0.13	-0.01	-0.09
$\Delta \log C^*$	0.69	0.68	0.58	0.45	0.40	0.35
	0.75	0.59	0.31	0.12	0.01	-0.06
$\Delta \log Y^{D*}$	3.49	0.61	0.56	0.51	0.42	0.44
	3.34	0.41	0.09	-0.04	-0.09	-0.10
Δp^{D*}	1.63	0.66	0.61	0.52	0.67	0.66
	1.69	0.42	0.09	-0.02	-0.06	-0.06

Note: For each variable, the top row denotes second moments in the data, and the bottom row denotes posterior second moments in the estimated model.

the volatility of each variable, always through the lens of the estimated model. The results are presented in Table 5. First of all, we note that a range of different factors affect the four interest rates in the model. Second, and perhaps a bit more surprisingly, each variable in each country and sector is mostly explained by technology and preference shocks in that country and sector. There are no important spillovers from shocks in another country or sector. In addition, the unit root shock to technology explains an important fraction of volatility of consumption and residential investment growth in both the periphery and the core. However, monetary and risk premium shocks do not have an important impact on the volatility of most macroeconomic variables. Perhaps, this could be the effect of the sample period that we are analyzing, with mostly tranquil times (1995-2007) until the crisis hit.

Table 5: Posterior Variance Decomposition

	σ_m	σ_ϑ	σ_L	σ_{L^*}	σ_ξ^D	$\sigma_\xi^{D^*}$	σ_ξ^C	$\sigma_\xi^{C^*}$	σ_Z^C	σ_Z^D	$\sigma_Z^{C^*}$	$\sigma_Z^{D^*}$	σ_Z
R	3.9	1.4	5.0	0.9	0.4	0.2	52.7	1.7	26.3	0	4.9	0	2.5
R^L	3.8	1.3	7.4	0.8	0.1	0.2	53.8	1.5	24.0	0.1	4.6	0	2.5
Δp^C	8.1	0.5	3.3	0.3	0.4	0.1	16.2	0.7	64.5	0.1	1.8	0	4.1
$\Delta \log C$	2.2	0.1	1.4	0	0.2	0	42.3	0.1	18.4	0	0.4	0	34.8
$\Delta \log Y^D$	1.9	0	0.3	0	51.2	0	7.9	0	2.6	21.4	0.1	0	14.5
Δp^D	0.6	0.1	0.1	0	48.4	0	12.3	0	15.9	17.5	0.3	0	4.9
R^*	3.9	17.1	3.8	2.2	0.3	0.4	30.0	10.5	22.7	0	6.7	0	2.5
R^{L^*}	3.2	14.3	2.9	19.0	0.2	0.1	22.7	11.9	18.0	0	5.4	0.1	2.2
Δp^{C^*}	7.1	5.2	1.6	2.2	0.1	1.2	13.8	1.6	9.5	0	54.2	0.1	3.5
$\Delta \log C^*$	1.4	3.1	0.1	2.0	0	0.5	0.3	56.4	0.7	0	12.9	0	22.7
$\Delta \log Y^{D^*}$	0.9	1.9	0	0.8	0	63.3	0.1	7.3	0.2	0	1.1	15	9.5
Δp^{D^*}	0.2	0.7	0	0.4	0	58.7	0.1	9.7	0.4	0	10.6	16.6	2.7

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. First, we study optimal monetary policy rules when the central bank wants to achieve its targets in terms of CPI inflation and output gap volatility. Second, we include macroprudential rules that help the central bank achieve its targets. That is, macroprudential is a second instrument that the central bank can use, but the macroprudential regulator does not have a loss function of her own. Third, we introduce a loss function for the macroprudential regulator that aims at minimizing the volatility of the credit/GDP ratio and the output gap, and we consider both the case when monetary policy and macroprudential are conducted in a coordinated and in an uncoordinated way.

It is important to note from the start that we are only computing how the variance of main macroeconomic aggregates (CPI inflation, output gap, and credit aggregates) changes when we introduce different monetary policies and macroprudential instruments. Hence, we are not measuring other potentially large benefits from improving banking regulation at the macro and the micro level such as: (i) reducing the frequency and cost of financial and banking crisis, (ii) reducing the probability of tail events materializing, and (iii) improved macroeconomic and financial environment due to a reduction in volatility and uncertainty.

4.1 Monetary Policy

We assume that the ECB aims at stabilizing the EMU-wide aggregate inflation rate as well as the deviation of output from its potential (i.e. the output gap):

$$L_t^{ECB} = var\left(\Delta p_t^{C,EMU}\right) + \lambda_{ECB}var\left(y_t^{GAP,EMU}\right) \tag{22}$$

where the two components of the loss function denote the variance of the euro area CPI inflation rate ($\Delta p_t^{C,EMU} = \log(P_t^{C,EMU}/P_{t-1}^{C,EMU}) - \log(\Pi^{EMU})$) and the variance of the union-wide output gap, respectively. The output gap $y_t^{GAP,EMU}$ is the percent (log) deviation of the union-wide real GDP Y_t^{EMU} from its potential $\tilde{Y}_t^{EMU}$, which is defined as real GDP when all agents are savers and all prices and wages are flexible (i.e. without financial frictions and nominal rigidities).

The relative weight that should be placed on the two components of the loss function is given by λ_{ECB}. The ECB has the mandate to keep inflation close to, but below 2 percent. Taking this mandate at face value, we should set $\lambda_{ECB} = 0$. Also, microfounded versions of equation (22) that come from taking a second order approximation to the utility function of a representative household (in a one-sector, one-country economy) tend to give a low value for λ_{ECB}, because the presence of nominal rigidities is the most important friction in the economy, and giving a high relative weight to CPI inflation stabilization is optimal.[23] We will obtain the optimal monetary policy under the assumptions that the ECB is a hawkish central bank, in which case we set $\lambda_{ECB} = 0.1$, and the more dovish case where the ECB cares equally about stabilizing inflation and the output gap, and hence $\lambda_{ECB} = 1$.

Starting with the simple Taylor rule used in the estimation, we extend the policy reaction function by adding several variables to study whether welfare can be improved:

$$r_t = \gamma_R r_{t-1} + (1 - \gamma_R)\left[\gamma_\pi \Delta p_t^{C,EMU} + \gamma_y y_t^{GAP,EMU} + \gamma_S\left(s_t^{EMU} - s_{t-1}^{EMU}\right)\right] \tag{23}$$

where the (linearized) Taylor rule is augmented by the union-wide output gap $y_t^{GAP,EMU}$ as well as the union-wide nominal credit growth ($s_t^{EMU} - s_{t-1}^{EMU}$), which is simply a weighted average of credit growth in the core and periphery.

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[23]See Schmitt-Grohé and Uribe (2007).

Table 6: Monetary Policy Only

	γ_π	γ_y	γ_s	γ_r	Π^{EMU}	$Y_t^{GAP,EMU}$	L_t^{ECB}
	$\lambda_{ECB}=1$				Std. Dev.		
I	1.46*	-	-	0.86*	0.39	0.41	0.3222
II	Optimal Rule				0.24	0.14	0.0781
III	1.46*	1.76	-	0.86*	0.34	0.21	0.1619
IV	1.46*	1.88	0.25	0.86*	0.34	0.19	0.1545
V**	0.78	0.68	-	-	0.25	0.19	0.0975
VI**	0.77	0.63	0.04	-	0.25	0.19	0.0968
	$\lambda_{ECB}=.1$				Std. Dev.		
I	1.46*	-	-	0.86*	0.39	0.41	0.1688
II	Optimal Rule				0.14	0.39	0.0348
III	1.46*	1.04	-	0.86*	0.33	0.25	0.1162
IV	1.46*	1.02	0.11	0.86*	0.33	0.236	0.1145
V**	2.46	0.20	-	-	0.14	0.42	0.0380
VI**	2.45	0.19	0.04	-	0.14	0.42	0.0379

Note: One star indicates that the parameter is calibrated and not determined by the optimization. Two stars indicate a first-differenceTaylor rule.

Table 6 presents the results. Let's focus first on the top half of Table 6, where we evaluate several monetary policy rules assuming that the central bank is a dove ($\lambda_{ECB}=1$). In row I, we evaluate the loss function when the central bank follows the estimated monetary policy rule. In row II, we present the solution to the problem of optimal monetary policy under commitment, where the central bank maximizes $E_0 \sum_{t=0}^{\infty} \beta^t L_t^{ECB}$ and it is able to affect expectations of the private sector (Clarida, Galí and Gertler, 1999). This exercise allows us to quantify the best outcome for monetary policy given all rigidities in place.

In rows III-IV, we extend the Taylor rule including the output gap and nominal credit growth. We optimize over those coefficients but leaving the coefficients on the reaction to inflation and interest rate smoothing unchanged to their estimated values. We find that allowing for the output gap delivers an important gain in welfare, which keeps improving if nominal credit growth is also included.[24] Since the welfare criterion includes the output gap, it comes to no surprise that including this measure allows for a reduction in the volatility of inflation and the output gap and, thus, the implied loss. When we optimize over the output gap coefficient, we

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[24]We also included reacting to deviations of credit/GDP and loan-to-value ratios from their steady-state values in the augmented Taylor rule (23). We found that the optimal coefficient was always zero on those variables.

obtain a strong reaction of 1.76 without credit in the Taylor rule and a coefficient of 1.88 when nominal credit is allowed. The optimal response to nominal credit fluctuations is smaller, with a coefficient of 0.25.

Finally, in the last two rows (V and VI) of the top panel of Table 6, we optimize over all the coefficients of the Taylor rule, with and without nominal credit growth. When running the optimization algorithm, we encountered the problem that the coefficient γ_R was getting very close to one, and the coefficients γ_π and γ_y became too large. This leads us to specify a rule in first differences of the type:

$$ r_t = r_{t-1} + \left[\gamma_\pi \Delta p_t^{C,EMU} + \gamma_y y_t^{GAP,EMU} + \gamma_S \left(s_t^{EMU} - s_{t-1}^{EMU} \right) \right] \qquad (24) $$

A first difference rule reduces the loss function even further, bringing inflation volatility very close to its optimal level.[25] The optimal coefficients that appear to be numerically reasonable as well, but the response to nominal credit growth, while positive, is quite small in this case (0.04).

In the second half of Table 6, we follow the same logic but assuming that the central bank is an inflation hawk and places low weight on stabilizing the output gap ($\lambda_{ECB} = 0.1$). As expected with this new mandate, the optimal monetary policy with the original coefficients on inflation and interest rate smoothing calls for a less aggressive response to the output gap. There is some gain involved in reacting to credit growth, but the optimal coefficient is small (0.11). When all coefficients are optimized, we find that, again, a rule specified in first differences is optimal. Consistent with its mandate as a hawk, the ECB targets inflation more aggressively and the output gap less aggressively than when it is a dove. The optimal response to nominal credit is still positive but small. Interestingly, when the central bank is a hawk, the optimized first-difference rule brings welfare very close to the fully optimal case.

4.2 Macroprudential Regulation

Monetary policy in a currency union can only react to union-wide aggregate variables as its mandate calls for a stabilization of the union as a whole and its policy instruments only work at the union-wide level. However, build-ups of risk in the

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[25] The optimality of first-difference rules in New Keynesian models was studied in Levin, Wieland and Williams (1999).

financial sector, due to liquidity mismatches, 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 to accrue in a particular member state.

As in Kannan, Rabanal and Scott (2009) we introduce a macroprudential tool that aims at affecting the lending-deposit spread countercyclically. As already explained in Section 2, the macroprudential instrument affects the spread between the lending and the borrowing rate. We assume that the macroprudential rule affects spreads by 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 $1/\eta_t < 1$ of loanable funds that they are able to collect $(S_t + B_t)$. This fraction could be thought of a liquidity ratio, a reserve requirement, or a capital requirement.[26] Hence, financial intermediaries will pass the costs of not being able to lend a given amount of funds to their customers, and this explains the term η_t in equation (8).

We specify the macroprudential instrument as reacting to an indicator variable:

$$\eta_t = \gamma_\eta \Upsilon_t \qquad (25)$$

where Υ_t is either nominal credit growth or the credit/GDP ratio (in deviations from steady-state values). We assume that the macroprudential indicator responds to domestic variables and aims at affecting the domestic spread, but the coefficient can either be set at the euro area level, or at the national level. What we find in the exercises below is that there are virtually no gains from allowing the coefficient to vary between the core and the periphery. In subsection 4.2.1, macroprudential policy helps the central bank achieve its objectives. In subsection 4.2.2, we introduce an explicit loss function for the regulator and consider two scenarios: when the central

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[26]For instance, the macro-prudential regulator could increase the capital-asset ratio requirement and hence force financial intermediaries to restrict their supply of credit. We would implictly assume that the capital of the financial intermediary is fixed at $\bar{K}$, and hence it does not enter the flow budget constraint of savers (4).

bank and the regulator minimize their loss functions jointly, and when they do it separately.

4.2.1 Macroprudential Regulation Helps Monetary Policy

We analyze the optimal policy regime consisting of the augmented Taylor rule (23) or (24) together with a national macroprudential rule (25) and optimize over the parameters of both rules in order to minimize the welfare criterion (22). These results are summarized in the first row of Table 7. Since we allow the macroprudential rule to affect credit spreads directly, we no longer include the reaction to credit 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 the output gap. Given that the policy regimes are comparable to those of Table 6, we keep referring to them with consecutive roman numbers.

Rules VII and VIII include a Taylor rule where the coefficient on the output gap has been optimized but the coefficients on inflation and interest rate smoothing are kept at their original values. In rule VII, we include nominal credit growth while rule VIII includes the credit/GDP ratio. There is some role for macroprudential yet welfare gains are comparable to those with extending monetary policy with nominal credit growth, but not better. In particular, including the credit/GDP ratio in the macroprudential rule delivers virtually the same welfare than having monetary policy react to credit (rule IV in Table 6). When we optimize over all coefficients, however (rules IX and X, including nominal credit growth and the credit/GDP ratio, respectively) we do find that there is a role for macroprudential policy and that welfare is improved with respect to the extended monetary policy rule with credit. Interestingly, allowing for different macroprudential instruments in the core and in the periphery delivers negligible improvements in welfare compared to the case of policy set as in the euro area as a whole (rule XI and XII, including credit growth and the credit/GDP ratio, respectively). Since it is difficult to give a "partial equilibrium" explanation to what the coefficients mean, we leave the explanation of their implementation in terms of capital requirements in Section 5, when we discuss impulse-responses.

In the second half of Table 7, we present the same results but assuming that the central bank is a hawk. In this case, when the central bank is a hawk, an aggressive use of the macroprudential instrument that reacts to deviations of the credit/GDP

Table 7: Macroprudential Helps Monetary Policy

	γ_π	γ_y	γ_r	γ_η	γ_η^*	Π^{EMU}	$Y_t^{GAP,EMU}$	L_t^{ECB}
			$\lambda_{ECB} = 1$				Std. Dev.	
VII	1.46*	1.71	0.86*	1.07	-	0.34	0.20	0.1531
VIII	1.46*	1.76	0.86*	0	-	0.34	0.21	0.1619
IX**	0.74	0.61	-	1.21	-	0.24	0.19	0.0938
X**	0.78	0.68	-	0	-	0.25	0.19	0.0975
XI**	0.74	0.61	-	0.82	5.89	0.24	0.19	0.0936
XII**	0.79	0.68	-	0	3.89	0.25	0.19	0.0975
			$\lambda_{ECB} = .1$				Std. Dev.	
VII	1.46*	1.05	0.86*	0.71	-	0.33	0.23	0.1123
VIII	1.46*	1.04	0.86*	0	-	0.33	0.25	0.1162
IX**	2.52	0.21	-	1.11	-	0.14	0.41	0.0373
X**	2.53	0.22	-	0.86	-	0.14	0.42	0.0377
XI**	2.54	0.21	-	0.75	10.00	0.14	0.41	0.0373
XII**	2.62	0.22	-	1.26	0	0.14	0.42	0.0377

Note: Stars indicate that the parameter is calibrated and not determined by the optimization. Two stars indicate a first-difference Taylor rule.

ratio or nominal credit growth virtually deliver the same welfare. However, we still find that welfare improvements are quite minor, and that they come from optimizing over the coefficients of the Taylor rule mostly.

4.2.2 Macroprudential Regulation Has Its Own Objectives

In this subsection, we assume that the macroprudential regulator has its own loss function that includes stabilizing the output gap and the credit/GDP ratio at the euro area-wide level. This loss function is in the spirit of Basel III which requires regulators to intervene when there is excessive credit growth (see BCBS, 2011). Reasons for such an intervention include avoiding large boom and bust financial and economic cycles, and also to avoid undesirable tail events due to excessive leverage and credit. Taken at face value, our model cannot provide a rationale for this type of intervention since it does not have risk or defaults. Hence, in the spirit of Basel III we take as a given that regulators have reasons beyond the model to want to reduce the volatility of financial variables:

$$L_t^{MP} = var\left(y_t^{GAP,EMU}\right) + \lambda_{MP} var\left(cre_t^{EMU}\right) \tag{26}$$

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where cre_t^{EMU} denotes the log-deviation of the EMU credit/GDP ratio from steady-state values. We also include some interest on the side of the macroprudential regulator to stabilize the business cycle, and we measure by λ_{MP} its willingness to stabilize financial variables. In the case of the euro area, equation (26) could be the loss function of the newly created ESRB.

We consider two cases here. First, we assume that the loss functions of the ECB and the macroprudential regulator are jointly minimized by one entity that sets monetary and macroprudential policy in the euro area. Contrary to the case of subsection 4.2.1, we assume here that the ECB would expand its mandate to both price stability and financial stability in the euro area, using all the available tools at its disposal. We refer to this setup as the *coordination* case. Formally, the centralized authority chooses all parameters to minimize the joint loss function:

$$\underset{\gamma_\pi,\gamma_y,\gamma_R,\gamma_\eta}{Min} \; L_t^{ECB} + L_t^{MP} = var\left(\Delta p_t^{C,EMU}\right) + (1+\lambda_{ECB})var\left(y_t^{GAP,EMU}\right) + \lambda_{MP}var(cre_t^{EMU}).$$

In the second case, that we call the *no-coordination* case, we assume that both entities minimize their loss functions. We assume that, first, the macroprudential authority sets the coefficient for the macroprudential instrument, and second, the ECB sets monetary policy taking as given macroprudential policy: the regulator acts as a "Stackelberg leader" in a game with the central bank. The reason for setting this sequence of events is that macroprudential decisions are likely to be taken with a lower frequency than monetary policy decisions. In the non-coordination case, the macroprudential authority first chooses

$$\underset{\gamma_\eta}{Min} L_t^{MP}(\gamma_\pi, \gamma_y, \gamma_R, ...)$$

and then the central bank chooses its parameters to minimize its loss function taking the macroprudential response as given:

$$\underset{\gamma_\pi,\gamma_y,\gamma_R}{Min} \; L_t^{ECB}(\gamma_\eta, ...).$$

In the second stage, we can obtain the parameters of the monetary policy rule as a function of the macroprudential rule $\gamma_\pi(\gamma_n), \gamma_y(\gamma_n), \gamma_R(\gamma_n)$, which we plug in the

Table 8: Coordination between Monetary and Macroprudential Policy

	γ_π	γ_y	γ_η	Π^{EMU}	$Y_t^{GAP,EMU}$	cre_t^{EMU}	L_t^{ECB}	L_t^{MP}
					Std. Dev.			
DDC	0.81	1.19	1.34	0.28	0.16	0.71	0.105	0.026
DDNC	0.86	0.72	2.13	0.25	0.20	0.46	0.099	0.039
DHC	0.88	1.31	7.40	0.28	0.16	0.15	0.106	0.026
DHNC	0.91	0.78	15.03	0.25	0.20	0.07	0.101	0.039
HDC	0.83	0.76	1.75	0.25	0.19	0.55	0.067	0.037
HDNC	2.57	0.22	1.29	0.14	0.42	0.73	0.038	0.179
HHC	0.89	0.82	10.16	0.25	0.19	0.11	0.067	0.037
HHNC	2.71	0.24	7.36	0.14	0.43	0.14	0.038	0.181

Note: In all cases, the optimal monetary policy rule is a first-difference rule, and the macro-prudential instrument responds to the credit/GDP ratio.

loss function of the macroprudential agency such that it minimizes:

$$\underset{\gamma_\eta}{Min} L_t^{MP} \left[\gamma_\pi(\gamma_n), \gamma_y(\gamma_n), \gamma_R(\gamma_n), ... \right].$$

We consider all combinations where the ECB is a dove and a hawk ($\lambda_{ECB} = 1$ and $\lambda_{ECB} = 0.1$, respectively) and when the macroprudential regulator is a dove and a hawk ($\lambda_{MP} = 0.001$ and $\lambda_{MP} = 0.01$, respectively). The values in the macro-prudential loss function reflect the preference for smoothing out fluctuations in the credit/GDP ratio with respect to reducing the volatility of the output gap. Hence, a dove will attach lower weight to stabilizing credit/GDP with respect to smoothing the economic cycle. We choose these numbers just as an illustration, and also because in the estimated model credit/GDP is much more volatile than CPI inflation or the output gap. If λ_{MP} is too large, then the financial stability motive becomes too dominant. In Table 8 we present the optimal monetary and macroprudential rules under all the scenarios. In the first row, the first letter of the acronym denotes the type of the central bank, the second one denotes the type of the macroprudential regulator, and the last one denotes the case of coordination or non-coordination.

Several interesting results stand out. First of all, first-difference rules are optimal in all the scenarios we consider. Second, the macroprudential authority is always targeting the credit/GDP ratio (targeting nominal credit growth gave lower outcomes in terms of welfare, and hence we do not report it). Third, when the regulator is a hawk it wants to set a higher value for the parameter of the macroprudential instrument with respect to the case when she is a dove. But the optimal monetary

policy rule and the outcome for inflation and output gap volatility seems to be unaffected by the choice of the macroprudential. Next, it is worth noting that the ECB always obtains a better value of the loss function under no-coordination than under coordination, even when differences are not large numerically. It appears that when the central bank and the macroprudential regulator minimize the joint loss function, then the central bank incorporates the credit/GDP target in its choice of parameters and becomes less aggressive on inflation stabilization (for the same parameters of its loss function). On the other hand, under lack of coordination, the loss function of the macroprudential regulator is always worse. Hence, this exercise interestingly shows the trade-offs faced in designing the new regulatory regimes, in particular in the euro area.

Finally, we would like to comment on an additional exercise. In Tables 6 to 8, we have used the estimated variance-covariance matrix for the shocks of the model, using the posterior means of Table 3. Our parameter estimates hence combine the 1995-2007 sample, which was mostly a period without large shocks, with the post-summer 2007 period when financial market turbulences started. Therefore, our historical estimates are likely to underestimate the volatility in financial markets. Hence, we repeated the exercises of this section assuming that the standard deviation of all the spread shocks is multiplied by a scalar greater than one. We find that as the standard deviation of the volatility shocks increases, the optimal response of the macroprudential instrument also increases, in line with the results found by Kannan, Rabanal, and Scott (2009).

5 Impulse Responses

In this section, we comment on the transmission mechanism of the main shocks in the estimated model, and also in the optimal policy regimes that we obtained in section 4. We quantify the optimal response of the macroprudential tool by using additional capital requirements. As an illustration, we plot the impulse response to a domestic spread shock (a shock to the lending-deposit spread) in the periphery and a housing demand shock in the periphery. We compare three different policy regime rules: (i) the estimated Taylor rule without macroprudential regulation; (ii) optimal monetary policy when the central bank is a dove but only reacts to inflation and output gap (rule V, top panel, Table 6), and (iii) the optimal monetary-macroprudential policy

when the central bank is a hawk, the macroprudential regulator is a dove under coordination (rule HDC, Table 8). We pick these two optimal rules because rule (iii) contains basically the same coefficients than rule (ii) but is extended with the macroprudential instrument. Hence, it allows us to quantify the contribution of the macroprudential instrument on top of the optimal monetary policy rule.

In Figure 6 we plot the impulse response to a shock that reduces the lending-deposit spread by one standard deviation (which is about 100 basis points on an annualized basis). In the estimated model, the output gap, CPI inflation and real house prices increase in the periphery, and there is a credit boom. Interestingly, the consumption boom in the periphery has some spillover effects to the core: The output gap and CPI inflation also increase, but the overall quantitative effect is less than one tenth that of the periphery. Due to inflationary pressures, the ECB increases the deposit rates, and this leads to a small decline in credit in the core. The optimal monetary policy response is more aggressive than the estimated one, which leads to the output gap and CPI inflation increasing less in the periphery, and the output gap and CPI inflation declining in the core: the ECB can achieve its objective that the euro area CPI and output gaps remain close to the target. If a macroprudential instrument is also allowed, the accelerator effect of financial shocks is greatly reduced: The spread between the lending and deposit rate is much less persistent, and goes back to negligible levels after 8 quarters. With macro-prudential policies in effect, the periphery does not experience an important credit boom, and this helps in overall macroeconomic stability. In particular, the core does not have to pay for financial excesses in the periphery.

So what policy instrument would allow the macroprudential regulator to smooth the financial cycle? Until now, we have been referring to a simple macroprudential instrument that would aim at moving spreads countercyclically. In the BIS studies that quantified the costs and benefits of introducing the Basel III regulations, many of the DSGE models that were considered did not have an explicit role for bank capital or bank liquidity. Hence, Angelini et al. (2011a) include some estimations on the effects of increased capital requirements on lending spreads, and feed those spreads into the models. We perform the opposite exercise here by reverse engineering. Using the estimates of Angelini et al. (2011a), in order to offset a spread of 50 basis points (on an annualized basis), an increase of 4 percentage points in the capital-asset ratio is needed. The results in the model are linear, so, for instance, a two-standard deviation shock to the lending-deposit spread would need an increase

of 8 percentage points in the capital-asset ratio.

In Figure 7 we plot the impulse response to the housing demand shock in the periphery. As we showed in Table 5, this shock is important to explain the boom of house prices and residential investment. Similar to the case of a financial shock, a housing demand shock leads to positive output gaps, CPI inflation, real house price appreciation and a credit boom and a reduction of spreads in the periphery. Under the optimal monetary policy only, it is not possible to stop the credit boom and house price boom in the periphery, although it appears possible to slow down the periphery output gap and CPI inflation. The tougher monetary policy stance leads to a negative output gap and CPI inflation in the core, and a tightening of spreads, although the results are quantitatively small. The use of a macro-prudential instrument helps in slowing down credit, the output gap and real house prices in the periphery, and also helps stabilize CPI inflation. However, the instrument is not strong enough to offset the initial effects of the housing boom. The implementation of the macro-prudential rule implies that from quarters 3 to 8 after the shock spreads should rise between 20-25 basis points (annualized) with respect to the case of no-macroprudential. This would call for a tightening of 2 percent in the capital-asset ratio using the estimates of Angelini et al (2011a). In the model, a one-standard deviation shock leads to an increase of real house prices of 2 percent, and an increase of credit of about 2.5 percent. Since the shock experienced by southern european economies was of several standard deviations, there are limits to the use of countercyclical capital surcharges. Hence, other liquidity measures or limits to credit growth measures should also be included to complement tighter capital standards.

6 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 that the introduction of a macroprudential rule would help in reducing macroeconomic volatility and hence in improving welfare. At the same time, we find that the effects of macroprudential regulations tend to be modest and numerically much smaller than those achieved when the central bank implements monetary policy rules that are close to the optimal one. When the macroprudential regulator has an objective to minimize the volatility of credit/GDP

to avoid the build up of excessive risks, then macroprudential policy becomes more important.

Our model is more simplified than the ones studied by the BIS to quantify the effects of implementing the Basel III capital and liquidity requirements (BCBS, 2010). For instance, the model does not feature business investment and a financial accelerator on the firms' side, and the financial system is quite simple. Yet, we reach similar conclusions to that study, in the sense that the introduction of macroprudential instruments is likely to have minor effects on main macroeconomic variables. To the extent that we are overlooking the main benefits of introducing such regulations, such as a reduction in the probability and the severity of future crisis which we cannot measure, then we can safely claim that the introduction of these measures will improve welfare.

As in any model-based study, the conclusions are always determined by the assumptions of the model, the calibration and the solution method. Here, we rely on linearizing the model and hence non-linear effects are absent by construction. But, in addition to introducing these effects, it would be desirable to introduce more interconnectedness between banking systems in a multi-country model. This difficult task is left for future research.

References

[1] Ambrose, B., M. LaCour-Little and A. Sanders, 2004. The Effect of Conforming Loan Status on Mortgage Yield Spreads: A Loan Level Analysis. *Real Estate Economics*, Vol. 32(4), pp. 541-569, December.

[2] An, S. and F. Schorfheide, 2007. Bayesian Analysis of DSGE Models. *Econometric Reviews*, 26(2-4), pp. 113-172.

[3] Angelini, P., Clerc, L., Cúrdia, V., Gambacorta, L., Gerali, A., Locarno, A., Motto, R., Roeger, W., Van den Heuvel, S. and J. Vlcek, 2011a. BASEL III: Long-term impact on economic performance and fluctuations. BIS Working Papers 338.

[4] Angelini, P., Neri, S., and F. Panetta, 2011b. Monetary and macroprudential policies. Temi di discussione (Economic working papers) 801, Bank of Italy, Economic Research Department.

[5] Aoki, K., Proudman, J., and G. Vlieghe, 2004. House Prices, Consumption, and Monetary Policy: A Financial Accelerator Approach, *Journal of Financial Intermediation,* Vol. 13, No. 4, pp. 414–35.

[6] Aspachs-Bracons, O. and P. Rabanal, 2011. The Effects of Housing Prices and Monetary Policy in a Currency Union. *International Journal of Central Banking,* Vol. 7, No. 1, pp. 225-274.

[7] Bank of England, 2009. The Role of Macroprudential Policies. Discussion Paper.

[8] Basel Committee on Banking Supervision, 2010. An assessment of the long-term economic impact of stronger capital and liquidity requirements.

[9] Basel Committee on Banking Supervision, 2011. Basel III: A global regulatory framework for more resilient banks and banking systems.

[10] Bean, C. , Paustian, M., Penalver, A. and T. Taylor, 2010. Monetary Policy after the Fall. Paper presented at the Federal Reserve Bank of Kansas City Annual Conference, Jackson Hole, Wyoming, 16 September 2010.

[11] Bernanke, B., Gertler, M., and S. Gilchrist, 1998. The Financial Accelerator in a Quantitative Business Cycle Framework, NBER Working Paper No. 6455.

[12] Bianchi, J. and E. Mendoza, 2011. Overborrowing, Financial Crises and 'Macro-prudential' Policy, IMF Working Paper 11/24.

[13] Blanchard, O, Dell'Ariccia, G., and P. Mauro, 2010. Rethinking Macroeconomic Policy. *Journal of Money, Credit and Banking*, 42(s1), 199–215.

[14] Borio, C. and I. Shim, 2008. What can (macro-)prudential policy do to support monetary policy?. Bank for International Settlements Working Paper 242

[15] Calvo, G., 1983. Staggered prices in a utility maximizing framework. *Journal of Monetary Economics,* 12, pp. 383-398.

[16] Claessens, S., Kose, A., and M. E. Terrones, 2008. What Happens During Recessions, Crunches and Busts?. IMF Working Paper No. 08/274.

[17] Clarida, R., Galí, J. and M. Gertler, 1999. The Science of Monetary Policy. The Science of Monetary Policy: A New Keynesian Perspective. *Journal of Economic Literature*, vol. 37(4), pages 1661-1707, December.

[18] Crowe, C., Dell'Ariccia, G., Igan, D., and P. Rabanal, 2011. How to Deal with Real Estate Booms: Lessons from Country Experiences. IMF Working Paper 11/91

[19] Christiano, L., Eichenbaum, M., and C. Evans, 2005. Nominal rigidities and the dynamic effects of a shock to monetary policy. Journal of Political Economy 113, pp. 1-45.

[20] Cúrdia, V. and M. Woodford, 2010. Credit Spreads and Monetary Policy. Journal of Money, Credit and Banking, Blackwell Publishing, vol. 42(s1), pages 3-35.

[21] European Central Bank, 2009a. New Survey Evidence on Wage Setting in Europe. ECB Monthly Bulletin, February, pp. 69-83.

[22] European Central Bank, 2009b. Housing Finance in the Euro Area. ECB Occasional Paper 101.

[23] Fabiani, S., M. Druant, I. Hernando, C. Kwapil, B. Landau, C. Loupias, F. Martins, T. Mathä, R. Sabbatini, H. Stahl, and A. Stokman, 2006. What Firms' Surveys Tell Us About Price-Setting Behavior in the Euro Area. *International Journal of Central Banking*, Vol. 2, Number 3, pp. 3-47.

[24] Fernández-Villaverde, J. and L. Ohanian, 2010. The Spanish Crisis from a Global Perspective. FEDEA Working Paper No. 2010-03.

[25] Forlati, C., and L. Lambertini, 2011. Risky Mortgages in a DSGE Model. *International Journal of Central Banking,* Vol. 7, No. 1, pp. 285-336.

[26] Gerali, A., Neri, S., Sessa, L., and F. Signoretti, 2010. Credit and Banking in a DSGE Model of the Euro Area. *Journal of Money, Credit and Banking*, 42(s1), 107-141.

[27] Gorodnichenko, Y., Mendoza, E., and L. Tesar, 2011. The Finnish Great Depression: From Russia with love. *American Economic Review*, forthcoming.

[28] Gruss, B., and S. Sgherri, 2009. The Volatility Costs of Procyclical Lending Standards: An Assessment Using a DSGE Model, IMF Working Paper No. 09/35.

[29] Iacoviello M., and S. Neri, 2010. The role of housing collateral in an estimated two-sector model of the U.S. economy. *American Economic Journal: Macroeconomics*, Vol. 2, No. 2, April, pp. 125-64.

[30] Iacoviello, M., 2005. House prices, borrowing constraints and monetary policy in the business cycle. *American Economic Review*, 95 (3), pp. 739-764.

[31] International Monetary Fund, 2009. Lessons from Asset Price Fluctuations for Monetary Policy. Chapter 3 of *World Economic Outlook*, October 2009, Washington, DC: International Monetary Fund.

[32] International Monetary Fund, 2011. Housing Finance and Financial Stability: Back to Basics? Chapter 3 in *Global Financial Stability Report*, April 2011, Washington, DC: International Monetary Fund.

[33] Kaminsky, G. and C. M. Reinhart, 1999. The Twin Crises: The Causes of Banking and Balance-of-Payments Problems, *American Economic Review*, vol. 89(3), pages 473-500, June.

[34] Kannan, P., Rabanal, P., and A. Scott, 2009. Monetary and Macroprudential Policy Rules in a Model with House Price Booms. IMF Working Paper 09/251.

[35] Levin, A., Wieland, V., and J. Williams, 1999. The Robustness of Simple Monetary Policy Rules under Model Uncertainty, in John B. Taylor, ed., Monetary Policy Rules. Chicago: University of Chicago.

[36] Lim, C.-H., Columba, F., Costa, A., Kongsamut, P., Otani, A., Saiyid, M., Wezel, T., and X. Wu, 2011. Macroprudential Policy: What Instruments and How to Use Them? Lessons from Country Experiences, IMF Working Paper 11/238.

[37] Macroeconomic Assessment Group (MAG), 2010a. Assessing the Macroeconomic Impact of the transition to Stronger Capital and Liquidity Requirements—Interim Report. Group established by the Financial Stability Board and the Basel Committee on Banking Supervision, August.

[38] Macroeconomic Assessment Group (MAG), 2010b. Assessing the Macroeconomic Impact of the transition to Stronger Capital and Liquidity Requirements—Final Report. Group established by the Financial Stability Board and the Basel Committee on Banking Supervision, December.

[39] Roger, S. and J. Vlcek, 2011. Macroeconomic Costs of Higher Bank Capital and Liquidity Requirements. IMF Working Paper 11/103.

[40] Schmitt-Grohé, S. and M. Uribe, 2003. Closing small open economy models. *Journal of International Economics*, vol. 61, pp. 163-185.

[41] Schmitt-Grohé, S. and M. Uribe, 2007. Optimal Inflation Stabilization in a Medium-Scale Macroeconomic Model, in Monetary Policy Under Inflation Targeting, edited by Klaus Schmidt-Hebbel and Rick Mishkin, Central Bank of Chile, Santiago, Chile, p. 125-186.

[42] Sorensen, C., and J. Lichtenberger, 2007. Mortgage Interest Rate Dispersion in the Euro Area. ECB Working Paper 733.

[43] Smets, F. and R. Wouters, 2003. An estimated stochastic dynamic general equilibrium model for the Euro Area. Journal of the European Economic Association 1, 1123-1175.

[44] Smets, F. and R. Wouters, 2007. Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach. American Economic Review, 97(3), p. 586-606.

[45] Unsal, F., 2011. Capital Flows and Financial Stability: Monetary Policy and Macroprudential Responses. IMF Working Paper 11/189.

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 ($Q_t \equiv \frac{P_t^D}{P_t^C}$)

- ω_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 GDP from its steady state value of zero ($b_t = \frac{B_t}{P_t Y_t}$).

- The terms of trade is given by $T_t = \frac{P_{F,t}}{P_{H,t}}$.

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^D, $I_t^{D,B}$, D_t, D_t^B,

- real wages in both sectors: ω_t^C, and ω_t^D,

- the production of durable and non-durable goods: Y_t^C, and Y_t^D,

- 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:[27]

$$q_t + \xi_t^C - \frac{c_t - \varepsilon(c_{t-1} - \varepsilon_t^z)}{1 - \varepsilon} + \psi(i_t - i_{t-1} + \varepsilon_t^z) = \mu_t + \beta\psi(E_t i_{t+1} - i_t), \qquad (27)$$

where $\psi = F''(.)$ and μ_t is the normalized Lagrange multiplier associated with the law of motion of the housing stock (5) for savers, and

$$[1 - \beta(1 - \delta)](\xi_t^D - d_t) = \mu_t - \beta(1 - \delta)E_t\mu_{t+1}, \qquad (28)$$

$$\varepsilon(\Delta c_t + \varepsilon_t^z) = E_t\Delta c_{t+1} - (1 - \varepsilon)(r_t + \Delta\xi_t^C - E_t\Delta p_{t+1}^C). \qquad (29)$$

The same conditions for borrowers are:

$$q_t + \xi_t^C - \frac{c_t^B - \varepsilon(c_{t-1}^B - \varepsilon_t^z)}{1 - \varepsilon} + \psi(i_t^B - i_{t-1}^B + \varepsilon_t^z) = \mu_t^B + \beta^B\psi(E_t i_{t+1}^B - i_t^B), \qquad (30)$$

with μ_t^B being the Lagrange multiplier associated with the law of motion of the housing stock (5) for borrowers, and

$$[1 - \beta^B(1 - \delta)](\xi_t^D - d_t^B) = \mu_t^B - \beta^B(1 - \delta)E_t\mu_{t+1}^B, \qquad (31)$$

$$\varepsilon(\Delta c_t^B + \varepsilon_t^z) = E_t\Delta c_{t+1}^B - (1 - \varepsilon)(r_t^L + \Delta\xi_t^C - E_t\Delta p_{t+1}^C). \qquad (32)$$

The effective interest rate for borrowers is:

$$r_t^L = r_t + \kappa_l(\tilde{s}_t^B - d_t^B - q_t) + \eta_t + \upsilon_t^L. \qquad (33)$$

And the budget constraint of borrowers is:

$$C^B c_t^B + \delta D^B(q_t + i_t^B) + R^L \tilde{S}^B(r_{t-1}^L + \tilde{s}_{t-1}^B - \Delta p_t^C - \varepsilon_t^z)$$
$$= \tilde{S}^B \tilde{s}_t^B + \alpha W L^B(\omega_t^C + l_t^{B,C}) + (1 - \alpha)W L^B(\omega_t^D + l_t^{B,D}). \qquad (34)$$

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

The marginal rate of substitution between consumption and leisure for savers when they work in the non-durable sector is given by:

$$mrs_t^C = \frac{c_t - \varepsilon(c_{t-1} - \varepsilon_t^z)}{1 - \varepsilon} - \xi_t^C + [(\varphi - \iota_L)\alpha + \iota_L] l_t^C + (\varphi - \iota_L)(1 - \alpha)l_t^D, \quad (35)$$

while when they work in the non-durable sector it is:

$$mrs_t^D = \frac{c_t - \varepsilon(c_{t-1} - \varepsilon_t^z)}{1 - \varepsilon} - \xi_t^C + [(\varphi - \iota_L)(1 - \alpha) + \iota_L] l_t^D + (\varphi - \iota_L)\alpha l_t^C. \quad (36)$$

The same conditions for borrowers are given by:

$$mrs_t^{C,B} = \frac{c_t^B - \varepsilon(c_{t-1}^B - \varepsilon_t^z)}{1 - \varepsilon} - \xi_t^C + [(\varphi - \iota_L)\alpha + \iota_L] l_t^{B,C} + (\varphi - \iota_L)(1 - \alpha)l_t^{B,D}, \quad (37)$$

while when they work in the non-durable sector it is:

$$mrs_t^{D,B} = \frac{c_t - \varepsilon(c_{t-1} - \varepsilon_t^z)}{1 - \varepsilon} - \xi_t^C + [(\varphi - \iota_L)(1 - \alpha) + \iota_L] l_t^{B,D} + (\varphi - \iota_L)\alpha l_t^{B,C}. \quad (38)$$

We assume that wages are set for each sector by a union that negotiates on behalf of the savers. The resulting wage Phillips Curves are given by:

$$\omega_t^C - \omega_{t-1}^C + \Delta p_t^C - \varphi_{C,W}\Delta p_{t-1}^C = \beta E_t \left(\omega_{t+1}^C - \omega_t^C + \Delta p_{t+1}^C - \varphi_{C,W}\Delta p_t^C \right) + \kappa^{C,W} \left(mrs_t^C - \omega_t^C \right), \quad (39)$$

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

$$\omega_t^D - \omega_{t-1}^D + \Delta p_t^C - \varphi_{D,W}\Delta p_{t-1}^C = \beta E_t \left(\omega_{t+1}^D - \omega_t^D + \Delta p_{t+1}^C - \varphi_{D,W}\Delta p_t^C \right) + \kappa^{C,W} \left(mrs_t^D - \omega_t^D \right) \quad (40)$$

where $\kappa^{D,W} = \frac{(1 - \theta_{D,W})(1 - \beta\theta_{D,W})}{\theta_{D,W}}$.

We assume that borrowers are also on board for this decision, because their labor supply schedules are such that marginal rates of substitution are equalized between types of agents (however, consumption levels and hours worked do not):

$$mrs_t^C = mrs_t^{C,B}, \tag{41}$$

and

$$mrs_t^D = mrs_t^{D,B}. \tag{42}$$

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

$$c_{H,t} = \iota_C(1-\tau)t_t + c_t^{TOT}, \tag{43}$$

$$c_{F,t} = -\iota_C\tau t_t + c_t^{TOT}. \tag{44}$$

where aggregate non-durable consumption is:

$$\left[\lambda C + (1-\lambda)C^B\right] c_t^{TOT} = \lambda C c_t + (1-\lambda)C^B c_t^B. \tag{45}$$

The production functions are given by:

$$y_t^C = z_t^C + l_t^{C,TOT}, \tag{46}$$

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

where total hours in each sector are given by:

$$\left[\lambda L^C + (1-\lambda)L^{B,C}\right] l_t^{C,TOT} = \lambda L^C l_t^C + (1-\lambda)L^{B,C} l_t^{B,C}, \tag{48}$$

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

and aggregate total hours worked is:

$$l_t^{TOT} = \alpha l_t^{C,TOT} + (1-\alpha)l_t^{D,TOT}. \tag{50}$$

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:

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

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

$$\Delta p_t^D - \varphi_D \Delta p_{t-1}^D = \beta E_t(\Delta p_{t+1}^D - \varphi_D \Delta p_t^D) + \kappa^D \left[\omega_t^D + (1-\alpha^D)l_t^{D,TOT} - q_t - z_t^D \right], \qquad (54)$$

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:

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

Aggregate investment expenditures equal production of investment goods:

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

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

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

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

Aggregated output is given by:

$$y_t = \tilde{\alpha} y_t^C + (1-\tilde{\alpha}) y_t^D. \qquad (59)$$

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:

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

$$[1 - \beta(1 - \delta)](\xi_t^{D*} - d_t^*) = \mu_t^* - \beta(1 - \delta)E_t\mu_{t+1}^*, \qquad (61)$$

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

The same conditions for borrowers are:

$$q_t^* + \xi_t^{C*} - \frac{c_t^{B*} - \varepsilon(c_{t-1}^{B*} - \varepsilon_t^z)}{1 - \varepsilon} + \psi(i_t^{B*} - i_{t-1}^{B*} + \varepsilon_t^z) = \mu_t^{B*} + \beta^{B*}\psi(E_t i_{t+1}^{B*} - i_t^{B*}), \quad (63)$$

$$\left[1 - \beta^B(1 - \delta)\right](\xi_t^{D*} - d_t^{B*}) = \mu_t^{B*} - \beta^B(1 - \delta)E_t\mu_{t+1}^{B*}, \qquad (64)$$

$$\varepsilon(\Delta c_t^{B*} + \varepsilon_t^z) = E_t\Delta c_{t+1}^{B*} - (1 - \varepsilon)(r_t^{L*} + \Delta\xi_t^{C*} - E_t\Delta p_{t+1}^{C*}). \qquad (65)$$

The effective interest rate for borrowers is:

$$r_t^{L*} = r_t^* + \kappa_l\left(\tilde{s}_t^{B*} - d_t^{B*} - q_t^*\right) + \eta_t^* + \upsilon_t^{L*}. \qquad (66)$$

And the budget constraint of borrowers is:

$$C^{B*}c_t^{B*} + \delta D^{B*}(q_t^* + i_t^{B*}) + R^{L*}\tilde{S}^{B*}(r_{t-1}^L + \tilde{s}_{t-1}^{B*} - \Delta p_t^{C*} - \varepsilon_t^z)$$
$$= \tilde{S}^{B*}\tilde{s}_t^{B*} + \alpha^* W^* L^{B*}(\omega_t^{C*} + l_t^{B,C*}) + (1 - \alpha^*)W^* L^{B*}(\omega_t^{D*} + l_t^{B,D*}). \quad (67)$$

The labor market and wage setting equations are given by:

$$mrs_t^{C*} = \xi_t^{C*} - \frac{c_t^{B*} - \varepsilon(c_{t-1}^{B*} - \varepsilon_t^z)}{1 - \varepsilon} + [(\varphi - \iota_L)\alpha + \iota_L] l_t^{C*} + (\varphi - \iota_L)(1 - \alpha)l_t^{D*}, \quad (68)$$

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

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

(70)

$$mrs_t^{D,B*} = \xi_t^{C*} - \frac{c_t^{B*} - \varepsilon(c_{t-1}^{B*} - \varepsilon_t^z)}{1 - \varepsilon} + [(\varphi - \iota_L)(1 - \alpha) + \iota_L]l_t^{B,D*} + (\varphi - \iota_L)\alpha l_t^{B,C*}.$$

(71)

We assume that wages are set for each sector by a union that negotiates on behalf of the savers. The resulting wage Phillips Curves are given by:

$$\omega_t^{C*} - \omega_{t-1}^{C*} + \Delta p_t^{C*} - \varphi_{C,W}\Delta p_{t-1}^{C*} = \beta E_t \left(\omega_{t+1}^{C*} - \omega_t^{C*} + \Delta p_{t+1}^{C*} - \varphi_{C,W}\Delta p_t^{C*} \right) + \kappa^{C,W} \left(mrs_t^{C*} - \omega_t^{C*} \right),$$

(72)

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

$$\omega_t^{D*} - \omega_{t-1}^{D*} + \Delta p_t^{C} - \varphi_{D,W}\Delta p_{t-1}^{C*} = \beta E_t \left(\omega_{t+1}^{D*} - \omega_t^{D*} + \Delta p_{t+1}^{C*} - \varphi_{D,W}\Delta p_t^{C*} \right) + \kappa^{C,W} \left(mrs_t^{D} - \omega_t^{D} \right).$$

(73)

We assume that borrowers are also on board for this decision, because their labor supply schedules are such that marginal rates of substitution are equalized between types of agents (however, consumption levels and hours worked do not):

$$mrs_t^{C*} = mrs_t^{C,B*},$$

(74)

and

$$mrs_t^{D*} = mrs_t^{D,B*}.$$

(75)

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

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

(76)

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

(77)

where aggregate non-durable consumption is:

$$\left[\lambda C^* + (1-\lambda)C^{B*}\right] c_t^{TOT*} = \lambda C^* c_t^* + (1-\lambda)C^{B*} c_t^{B*}. \tag{78}$$

The production functions are given by:

$$y_t^{C*} = z_t^{C*} + l_t^{C,TOT*}, \tag{79}$$

$$y_t^{D*} = z_t^{D*} + \alpha^D l_t^{D,TOT*}, \tag{80}$$

where total hours in each sector are given by:

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

$$\left[\lambda L^{D*} + (1-\lambda)L^{B,D*}\right] l_t^{D,TOT*} = \lambda L^{D*} l_t^{D*} + (1-\lambda)L^{B,D*} l_t^{B,D*}, \tag{82}$$

and aggregate total hours worked is:

$$l_t^{TOT*} = \alpha^* l_t^{C,TOT*} + (1-\alpha^*) l_t^{D,TOT*}. \tag{83}$$

The CPI is:
$$\Delta p_t^{C*} = (1-\tau^*)\Delta p_{H,t} + \tau^* \Delta p_{F,t}. \tag{84}$$

The relative price of housing is:

$$q_t^* = q_{t-1}^* + \Delta p_t^{D*} - \Delta p_t^{C*}. \tag{85}$$

And the pricing equations are given by:

$$\Delta p_t^F - \varphi_C^* \Delta p_{t-1}^F = \beta E_t(\Delta p_{t+1}^F - \varphi_C^* \Delta p_t^F) + \kappa^{C*}\left[\omega_t^{C*} - (1-\tau^*)t_t - z_t^{C*}\right], \tag{86}$$

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

$$\Delta p_t^{D*} - \varphi_D^* \Delta p_{t-1}^{D*} = \beta E_t(\Delta p_{t+1}^{D*} - \varphi_D^* \Delta p_t^{D*}) + \kappa^{D*}\left[\omega_t^{D*} + (1-\alpha^D)l_t^{D,TOT*} - q_t^* - z_t^{D*}\right], \tag{87}$$

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:

$$y_t^{C*} = \tau^* c_{F,t}^* + \frac{n(1-\tau)}{1-n} c_{F,t}. \tag{88}$$

Aggregate investment expenditures equal production of investment goods:

$$y_t^{D*} = \frac{\lambda \delta D^* i_t^{D*} + (1-\lambda)\delta D^{B*} i_t^{D,B*}}{\lambda \delta D^* + (1-\lambda)\delta D^{B*}}. \tag{89}$$

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

$$d_t^* = (1-\delta)(d_{t-1}^* - \varepsilon_t^z) + \delta i_t^*, \tag{90}$$

$$d_t^{B*} = (1-\delta)(d_{t-1}^{B*} - \varepsilon_t^z) + \delta i_t^{B*}. \tag{91}$$

Aggregated output is given by:

$$y_t^* = \tilde{\alpha}^* y_t^{C*} + (1-\tilde{\alpha}^*) y_t^{D*}. \tag{92}$$

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:

$$r_t^* = r_t + \kappa_b b_t + \vartheta_t. \tag{93}$$

The evolution of net foreign assets is:

$$b_t = \frac{1}{\beta}(b_{t-1} - \varepsilon_t^z) + \frac{(1-n)(1-\tau^*)}{n} \left(c_{H,t}^* - t_t \right) - (1-\tau)c_{F,t}, \tag{94}$$

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

$$t_t = t_{t-1} + \Delta p_t^F - \Delta p_t^H. \tag{95}$$

The monetary policy Taylor rule conducted by the ECB reads:

$$r_t = \gamma_r r_{t-1} + (1 - \gamma_R) \left[\gamma_\pi \Delta p_t^{EMU} \right] + \varepsilon_t^m, \tag{96}$$

where the euro area CPI is given by:

$$\Delta p_t^{EMU} = n \Delta p_t^C + (1 - n) \Delta p_t^{C*}. \tag{97}$$

Finally, in Sections 4 and 5, 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:

$$\eta_t = \gamma_\eta \Upsilon_t, \tag{98}$$

$$\eta_t^* = \gamma_\eta \Upsilon_t^*. \tag{99}$$

A.4   Shock Processes

All shocks included in the model evolve according to:

$$\xi_t^H \quad = \quad \rho_{\xi,H} \xi_{t-1}^H + \varepsilon_t^{\xi,H} \tag{100}$$

$$\xi_t^{H*} \quad = \quad \rho_{\xi,H} \xi_{t-1}^{H*} + \varepsilon_t^{\xi,H*} \tag{101}$$

$$\xi_t^D \quad = \quad \rho_{\xi,D} \xi_{t-1}^D + \varepsilon_t^{\xi,D} \tag{102}$$

$$\xi_t^{D*} \quad = \quad \rho_{\xi,D} \xi_{t-1}^{D*} + \varepsilon_t^{\xi,D*} \tag{103}$$

$$z_t^C \quad = \quad \rho_{Z,C} z_{t-1}^C + \varepsilon_t^{Z,C} \tag{104}$$

$$z_t^{C*} \quad = \quad \rho_{Z,C} z_{t-1}^{C*} + \varepsilon_t^{Z,C*} \tag{105}$$

$$z_t^D \quad = \quad \rho_{Z,D} z_{t-1}^D + \varepsilon_t^{Z,D} \tag{106}$$

$$z_t^{D*} \quad = \quad \rho_{Z,D} z_{t-1}^{D*} + \varepsilon_t^{Z,D*} \tag{107}$$

$$v_t^L \quad = \quad \rho_{v,L} v_{t-1}^L + \varepsilon_t^{v,L} \tag{108}$$

$$v_t^{L*} \quad = \quad \rho_{v,L} v_{t-1}^{L*} + \varepsilon_t^{v,L*} \tag{109}$$

$$\vartheta_t \quad = \quad \rho_\vartheta \vartheta_{t-1} + \varepsilon_t^\vartheta, \tag{110}$$

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, Germany, and Italy, while for the periphery data for 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 GDP).

Inflation: Quarter on quarter log differences in the Harmonized Index of Consumer Prices (HICP), seasonally adjusted. Source: ECB

House Price Data: Quarter on quarter log differences in real housing prices. All data is provided by the OECD, except Portugal (provided by the BIS).
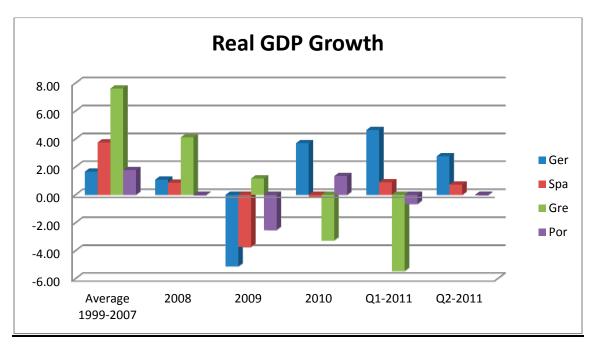
Real Private Consumption: Final consumption of households and nonprofit institutions serving households (NPISH), seasonally adjusted. Source: Eurostat

Real Residential Investment: Gross fixed capital formation in construction work for housing, seasonally adjusted. Data for Greece is only available from 2000 onwards on an annual basis. We interpolate the Greek data to obtain quarterly values and compute the periphery real residential investment before 2000 by using only data from Portugal and Spain. Source: Eurostat
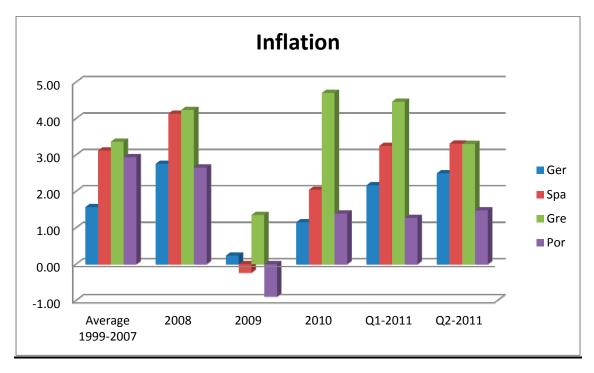
Lending Rate for Household Purchases: Agreed rate on loans for household purchases, total maturity, new business coverage. We combine two ECB datasets: For the period 1995q4-2002q4 we use the Retail Interest Rate (RIR) dataset while using the MFI Interest Rate (MIR) set from 2003q1 onwards. Since the method of collecting data differs across these two dataset, we accept a possible break in the series resulting from this change.

Deposit Rate: Rate for deposits up to 1 year. We have to combine several datasets: For Greece and Portugal we combine data from the RIR set (from 1995q4-2002q4) with the MFI set (from 2003q1 onwards). For Spain we use an interbank deposit rate with maturity up to 1 year for the period 1995q4-2002q4 (provided by Datastream) and combine it with the corresponding deposit rate from the MFI set from 2003q1 onwards. For the core countries (France, Germany, and Italy) we proxy the deposit rate by taking a euro area wide deposit rate and subtracting the counterparts of the periphery. The euro area wide deposit rate is extracted from Datastream for the period 1995q4-2002q4 and from the MFI set from 2003q1 onwards.
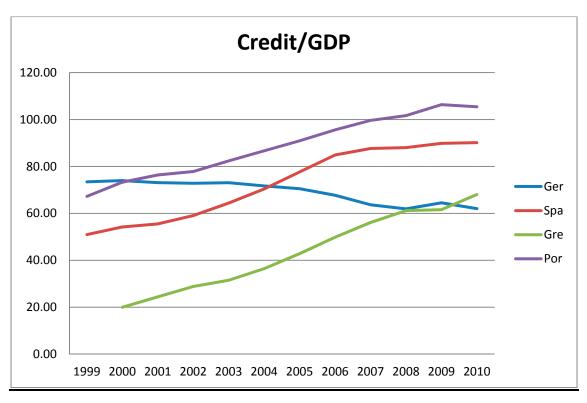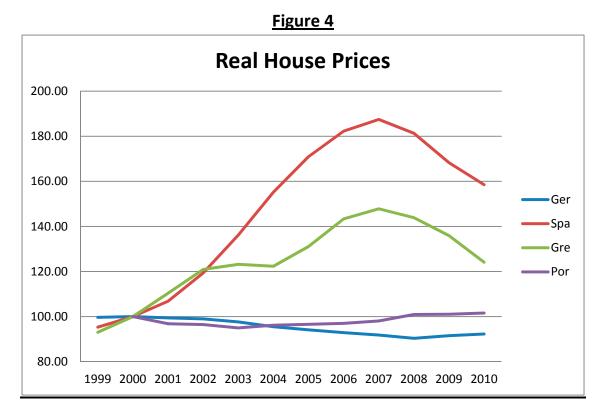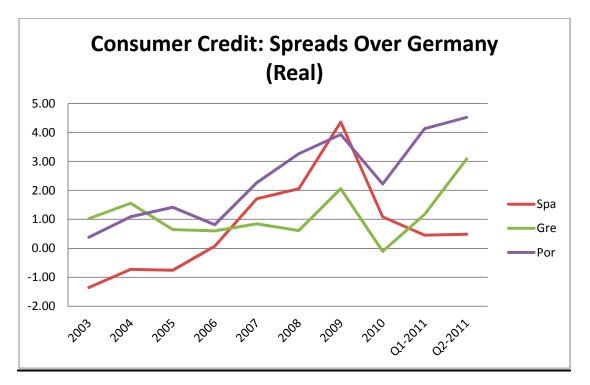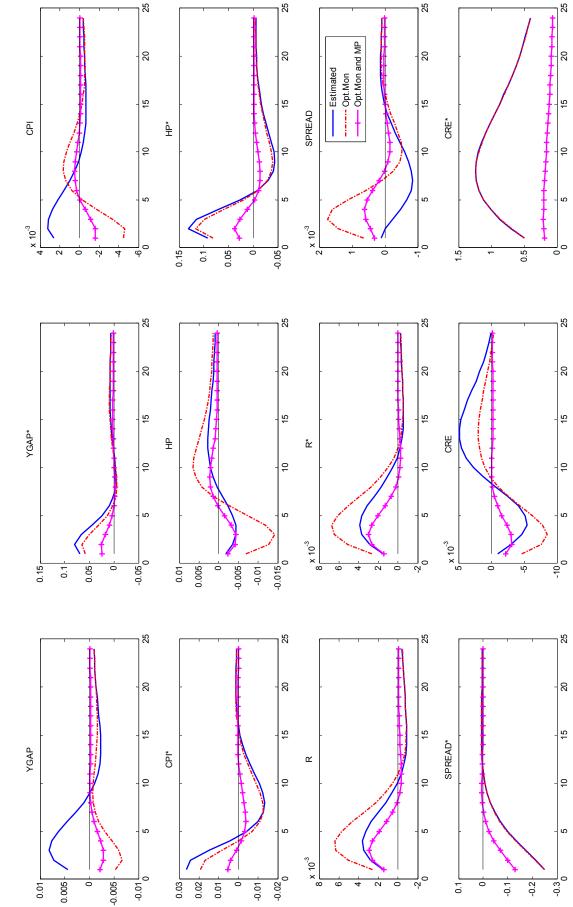
Figure 1

Real GDP Growth

Figure 2

Inflation

Figure 3

Credit/GDP

Figure 4

Real House Prices

Figure 5

Consumer Credit: Spreads Over Germany (Real)

Figure 6: Risk-Premium Shock, Lending-Deposit Periphery

Figure 7: Housing Demand Shock, Periphery