Freie Universität Berlin

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

Dominic Quint
Pau Rabanal

School of Business & Economics
Discussion Paper

Economics

2014/5

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

Dominic Quint† Pau Rabanal‡

January 2014

Abstract

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

Key words: Monetary Policy, EMU, Basel III, Financial Frictions.
JEL Codes: C51, E44, E52.

---

*We thank Pierpaolo Benigno, Helge Berger, Larry Christiano, Chris Erceg, Ivo Krznar, Vivien Lewis, Jesper Lindé, Olivier Loisel, Stephen Murchinson, Jorge Roldós, Thierry Tressel and participants at various conferences and seminars for useful comments and discussions. This paper should not be reported as reflecting the views of the International Monetary Fund. Any errors and omissions are our own. Additional material on the derivation of the model and estimation results can be found at http://www.paurabanal.net/research.html.

†Contact details: Free University Berlin, Boltzmannstr. 20, 14195 Berlin, Germany, dominic.quint@fu-berlin.de

‡Contact details: International Monetary Fund, 700 19th Street, N.W., Washington, D.C. 20431, prabanal@imf.org

1. Introduction

The recent financial crisis, that started in the summer of 2007, lead to the worst recession since World War II. Before the crisis, a combination of loose monetary and regulatory policies encouraged excessive credit growth and a housing boom in many countries. This turned out to be a problem when the world economy slowed down: as Claessens, Kose and Terrones (2009), Crowe et al. (2011) and IMF (2012) show, the combination of credit and housing boom episodes amplifies the business cycle and in particular, the bust side of the cycle (measured as the amplitude and duration of recessions). Excessive leverage has complicated the recovery and the return to pre-crisis growth rates in several advanced countries, in particular in the group of peripheral European countries known as GIIPS (Greece, Ireland, Italy, Portugal and Spain). Developments in those countries since the launch of the European Economic and Monetary Union (EMU) in 1999 shared many characteristics with the run-up to other crises. Real exchange rate appreciation (which in the EMU took the form of persistent inflation differentials), large capital inflows mirrored by large current account deficits, and above-potential GDP growth rates fuelled by cheap credit as well as asset price bubbles are the traditional symptoms of ensuing financial, banking and balance of payments crises in emerging and developed economies alike.[1] In addition to all these overheating symptoms, the GIIPS countries faced prolonged negative real interest rates, which magnified the boom side of the business cycle. When the crisis hit, all problems came at once: a sudden stop of capital flows, concerns about debt sustainability, low or negative real GDP growth, and increased credit spreads that helped to amplify the bust side of the business cycle.

There is an increasing consensus 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.[2] However, the search for the appropriate toolkit to deal with financial and housing cycles is still in its infancy. There is high uncertainty on which measures can be more effective at delivering results. Conventional monetary policy is too blunt of an instrument to address imbalances within the financial sector or overheating in one sector of the economy (such as housing). There is a need to further strengthen other instruments of economic policy in dealing with sector-specific fluctuations.[3] In particular, a key question to be addressed is the role of macroprudential regulation. Should it be used as a countercyclical policy tool, leaning against the wind of large credit, asset and house price fluctuations, or should it take a more passive role and just aim at increasing the buffers of the banking

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

[2] See Galati and Moessner (2013) and the references therein.

[3] See Blanchard, Dell'Ariccia and Mauro (2010).

system (provisions and capital requirements), thereby minimizing financial sector risk, as currently envisioned in Basel III?

Our paper contributes to this debate by studying the optimal policy mix needed within a currency union, where country- and sector-specific boom and bust cycles cannot be directly addressed with monetary policy. Specifically, we focus on the case of the EMU, where the European Central Bank (ECB) has the mandate of price stability at the union-wide level. Before the crisis, the GIIPS countries were not able to use monetary policy to cool down their economies and financial systems, address asset and house price bubbles or abnormal credit growth. Therefore, the use of other policy instruments in a currency union can potentially help in stabilizing the business and financial cycle. We provide a quantitative study on how monetary and macroprudential measures could interact in the euro area.

Early contributions to the debate on the role of macroprudential policies include several quantitative studies conducted by the Bank for International Settlements (BIS) on the costs and benefits of adopting the new regulatory standards of Basel III (see Angelini et al., 2011a; and MAG, 2010a,b), and in other policy institutions (see Bean et al., 2010; and Roger and Vlcek, 2011). Other authors have also suggested that the use of macroprudential tools could improve welfare by providing instruments that target large fluctuations in credit markets. In an international real business cycle model with financial frictions, Gruss and Sgherri (2009) study the role of loan-to-value (LTV) limits in reducing credit cycle volatility in a small open economy with borrowing constraints. Bianchi and Mendoza (2011) analyze the effectiveness of macroprudential taxes to avoid the externalities associated with "overborrowing". Borio and Shim (2008) point out the prerequisite of a sound financial system for an effective monetary policy and, thus, the need to strengthen the interaction of prudential and monetary policy.[4]

Our paper fits in the recent (and growing) literature that embeds financial frictions in a DSGE model and searches for optimal monetary and macroprudential policy rules. Closest to our contribution are the papers by Brzoza-Brzezina, Kolasa and Makarski (2013) and Rubio (2013), who also study the role of macroprudential policies in a two-country currency area, but calibrate instead of estimate the model, as we do in this paper. Beau, Clerc and Mojon (2012) and Angelini et al. (2011b) analyze macroprudential policies in an estimated DSGE model of the euro area but do not distinguish between different countries in the union. In these four cases, the credit friction consists in a borrowing constraint à la Iacoviello (2005), and hence there is no default. Lambertini, Mendicino and Punzi (2013) study the effect of LTV ratios on welfare in a calibrated closed economy model with housing and risky

[4]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.

mortgages, which is similar to our setup for the financial friction. Other contributions of DSGE models with a financial accelerator include Unsal (2013) and Medina and Roldós (2014), who study the role of macroprudential policy when a small open emerging economy receives large capital inflows. A common result in this literature is that the optimal macroprudential policy is state-dependent, and, therefore, simple operational rules that react to observable variables may lead to policy mistakes. For instance, if the source of a credit boom is a productivity shock, and the macroprudential authority reacts mechanically to a credit variable (rather than to the effects of the shock), then welfare might decrease.

In all these previous contributions, and in the present paper, macroprudential policies aim at reducing the volatility effects of a built-in financial accelerator but do not affect the risk-taking behavior of agents. An important exception to the literature is the paper by Collard et al. (2013), who include risky technologies in a DSGE model, and study how macroprudential policies can reduce risk-taking behavior. In Collard et al. (2013), firms can either use a riskless or a risky technology to produce capital goods. The risky technology is socially inefficient because it delivers, in expected value, a lower return than the riskless technology. However, limited liability and deposit insurance provides an incentive to "gamble" and collect the profits when the risky technology delivers a high payoff. In their model, monetary policy can only affect the quantity but not the composition of credit. The optimal macroprudential policy sets the capital requirement to a sufficiently high level, such that firms internalize the riskiness of their choices and only adopt the riskless, socially optimal technology. Hence, the optimal capital asset ratio moves with shocks that affect risk in the economy (such as the return of the risky technology), but it stays constant when shocks do not affect risk (such as an economy-wide productivity shock).

In this paper, we quantify the role of monetary and macroprudential policies in stabilizing the business cycle in the euro area using an estimated Dynamic Stochastic General Equilibrium (DSGE) model. The model includes: (i) two countries (a core and a periphery) which share the same currency and monetary policy; (ii) two sectors (non-durables and durables, which can be thought of as housing); and (iii) two types of agents (savers and borrowers) such that there is a credit market in each country and across countries in the monetary union. The model also includes a financial accelerator mechanism on the household side, such that changes in the balance sheet of borrowers due to house price fluctuations affect the spread between lending and deposit rates. In addition, risk shocks in the housing sector 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, as in Smets and Wouters (2003) and Iacoviello and Neri (2010).

Basel III calls for regulators to step in when there is excessive credit growth in the

economy.[5] We want to study the pros and cons of reacting to credit indicators, either by using monetary or macroprudential policies. Having obtained estimates for the parameters of the model and for the exogenous shock processes, we proceed to study different policy regimes. In all cases, we assume that the optimal policy aims at maximizing the welfare of all households in the EMU by maximizing their utility function, taking into account the population weights of each type of household in each country. First, we derive the optimal monetary policy when the ECB optimizes over the coefficients of the Taylor rule that reacts to EMU-wide consumer price index (CPI) inflation and real output growth. We find that the optimal Taylor rule strongly reacts to deviations of CPI inflation and output growth from their steady state values, as is typical in the literature. Afterwards, we extend the monetary policy rule to react to credit aggregates. We find that the extended Taylor rule improves welfare with respect to the original one, with borrowers being worse off under some conditions.

Next, we introduce a macroprudential instrument that influences credit market conditions above and beyond current regulations. This instrument targets credit spreads by affecting the fraction of liabilities (deposits and bonds) that financial intermediaries can lend. Spreads can be increased by imposing e.g. additional capital surcharges, liquidity ratios, loan-loss provisions, or reserve requirements, whereas the direct provision of liquidity to the banking sector (either through conventional or unconvential policies) can decrease spreads.[6] This could be achieved via measures such as widening of collateral standards, the *Funding for Lending Scheme* launched by the Bank of England in 2012, or even liquidity provision to the real economy as in Gertler and Karadi (2011). We find that by introducing macroprudential policies welfare further increases, but that there are winners and losers of including these measures. As we discuss in Section 4, optimal monetary and macroprudential policies are welfare improving under housing demand or risk shocks: these measures reduce the volatility of real variables by offsetting accelerator effects triggered by these shocks. However, when technology shocks hit the economy, macroprudential policies have the opposite effect and magnify the countercyclical behavior of the lending-deposit spread. This imposes larger fluctuations of consumption, housing investment and hours worked for borrowers and, thus, reduces their welfare. Therefore, identifying the source of the credit and house price boom is crucial for the success of policy measures that react to financial variables.

The rest of the paper is organized as follows: Section 2 presents the model and Section 3 discusses the data as well as the econometric methodology to estimate the parameters of the model. In Section 4, we discuss the different exercises of optimal

[5] See Basel Committee on Banking Supervision (2011).

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

monetary and macroprudential policies, while we leave Section 5 for concluding remarks.

2. The Model

The theoretical framework consists of a two-country, two-sector, two-agent general equilibrium model of a single currency area. The two countries, home and foreign, are of size n and $1-n$. There are two types of goods, durables and non-durables, that are produced under monopolistic competition and nominal rigidities. While non-durables are traded across countries, durable goods are non-tradable. In each country, there are two types of agents, savers (size λ in each country) and borrowers $(1-\lambda)$, who differ in their discount factor and habit formation parameter. Both agents consume non-durable goods and purchase durable goods to increase their housing stock. Borrowers are more impatient than savers and have preference for early consumption, which creates the condition for credit to occur in equilibrium. In addition, borrowers are hit by an idiosyncratic quality shock to their housing stock, which affects the value of collateral that they can use to borrow against.[7] Hence, we adapt the mechanism of Bernanke, Gertler and Gilchrist (1999), henceforth BGG, to the household side and to residential investment: shocks to the valuation of housing affect the balance sheet of borrowers, which in turn affect the default rate on mortgages and the lending-deposit spread.

There are two types of financial intermediaries. Domestic financial intermediaries take deposits from savers, grant loans to borrowers, and issue bonds. International financial intermediaries trade these bonds across countries to channel funds from one country to the other. Therefore, savings and (residential) investment need not to be balanced at the country level period by period, since excess credit demand in one region can be met by funding coming from elsewhere in the monetary union. In compensation for this service, international financial intermediaries charge a risk premium which depends on the net foreign asset position of the country.

In what follows, we only present the home country block of the model, by describing the domestic and international credit markets, households, and firms. Monetary policy is conducted by a central bank that targets the union-wide CPI inflation rate, and also reacts to fluctuations in the union-wide real GDP growth. As the foreign country block is characterized by a similar structure regarding credit markets, households and firms, we abstract from presenting it. Unless specified, all shocks

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

follow zero-mean AR(1) processes in logs.

A. Credit Markets

We adapt the BGG financial accelerator idea to the housing market, by introducing default risk in the mortgage market, and a lending-deposit spread that depends on housing market conditions. There are two main differences with respect to the BGG mechanism. First, there are no agency problems or asymmetric information in the model, and borrowers will only default if they find themselves underwater: that is, when the value of their outstanding debt is higher than the value of the house they own. Second, unlike the BGG setup, we assume that the one-period lending rate is pre-determined and does not depend on the state of the economy, which seems to be a more realistic assumption.[8]

A.1 Domestic Intermediaries and Macroprudential Policy

Domestic financial intermediaries collect deposits from savers S_t, for which they pay a deposit rate R_t, and extend loans to borrowers S_t^B for which they charge the lending rate R_t^L. Credit granted to borrowers is backed by the value of the housing stock that they own ($P_t^D D_t^B$), where P_t^D is the nominal house price and D_t^B is the housing stock owned by borrowers. We introduce risk in the credit and housing markets by assuming that each borrower (indexed by j) is subject to an idiosyncratic quality shock to the value of her housing stock, ω_t^j, that is log-normally distributed with CDF $F(\omega)$. We choose the mean and standard deviation so that $E\omega_t = 1$ and, hence, there is idiosyncratic risk but not aggregate risk in the housing market. This assumption implies that $\log(\omega_t^j) \sim N(-\frac{\sigma_{\omega,t}^2}{2}, \sigma_{\omega,t}^2)$, with $\sigma_{\omega,t}$ being the standard deviation characterizing the quality shock. This standard deviation is time-varying, and follows an AR(1) process in logs:

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

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

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

[8] A similar approach is taken by Suh (2012) and Zhang (2009).

the household defaults on her loan, the bank calls a debt-collection agency that forces the household to repay the value of the housing stock after the shock has realized, $\omega_{t-1}^{j} P_t^D D_t^B$. After paying this amount, the household keeps her house. These debt-collection agencies charge banks a fraction μ of the value of the house. The profits of these agencies are transferred to savers, who own them. The value of the idiosyncratic shock is common knowledge, so households will only default when they are underwater.[9]

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

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

Intermediaries behave in a risk-neutral way and require the expected return from granting one euro of credit to be equal to the funding rate of banks, which equals the deposit rate (R_t):

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

with $\left[1 - F\left(\bar{\omega}_t^a, \sigma_{\omega,t}\right) \right] = \int_{\bar{\omega}_t^a}^{\infty} dF(\omega; \sigma_{\omega,t}) d\omega$ being the expected probability that the shock exceeds the ex-ante threshold $\bar{\omega}_t^a$ and $G\left(\bar{\omega}_t^a, \sigma_{\omega,t}\right) = \int_0^{\bar{\omega}_t^a} \omega dF(\omega; \sigma_{\omega,t})$ being the expected value of the shock conditional on the shock being less than $\bar{\omega}_t^a$. The participation constraint (2) ensures that the opportunity costs R_t are equal to the expected returns, which are given by the expected foreclosure settlement as percent of outstanding credit (the first term of the right hand side of equation 2) and the expected repayment of households with higher housing values (the second term). Due to the fees paid to debt-collection agencies to make defaulting households pay their debts, financial intermediaries only receive a fraction $(1-\mu)$ of the mortgage settlement.

We introduce the macroprudential instrument, denoted by η_t, that influences credit market conditions by affecting the fraction of liabilities that banks can lend. We discuss its properties in Section 2.D.3. The aggregate balance sheet of domestic

[9] Under this assumption, no fraction of the housing stock is destroyed during the foreclosure process. If, as in BGG, a fraction of the collateral was lost during foreclosure, risk shocks might have unrealistic expansionary effects on housing and residential investment. See Forlati and Lambertini (2010).

financial intermediaries in the home country is:

$$n\lambda\frac{1}{\eta_t}\left(S_t - B_t\right) = n\left(1-\lambda\right)S_t^B, \tag{3}$$

where B_t are claims on financial intermediaries in the foreign country (as explained below). Combined with the participation constraint equation (2), we obtain the following relationship between the lending-deposit spread and macroprudential policy:

$$\frac{R_t^L}{R_t} = E_t\left\{\frac{\eta_t}{\frac{(1-\mu)G(\bar{\omega}_t^a,\sigma_{\omega,t})}{\bar{\omega}_t^a} + \left[1 - F\left(\bar{\omega}_t^a,\sigma_{\omega,t}\right)\right]}\right\}. \tag{4}$$

According to equation (4), for a given demand of credit from borrowers, observed values of risk $\sigma_{\omega,t}$, a stance of macroprudential policy η_t, and expected values of the housing stock $E_t\left[P_{t+1}^D D_{t+1}^B\right]$, intermediaries passively set the lending rate R_t^L and the expected (ex-ante) threshold $\bar{\omega}_t^a$ so that equation (1) and the participation constraint (2) are fulfilled. Unlike the original BGG set-up, the one-period lending rate R_t^L is determined at time t, and does not depend on the state of the economy at $t+1$. This means that the participation constraint of financial intermediaries delivers ex-ante zero profits. However, it is possible that, ex-post, they make profits or losses. We assume that savers collect profits or recapitalize financial intermediaries as needed.

It is worth emphasizing that the participation constraint delivers a positive relationship between LTV ratios ($S_t^B/P_{t+1}^D D_{t+1}^B$) and the spread between the funding and the lending rate, due to the probability of default. Let's first assume that $\eta_t = \mu = 1$ in equation (4), so there is no macroprudential regulation and in case of default, the financial intermediary recovers nothing from the defaulted loan. According to equation (1), the higher is the LTV ratio, the higher is the threshold $\bar{\omega}_t^a$ that leads to default. This shrinks the area of no-default $\left[1 - F\left(\bar{\omega}_t^a,\sigma_{\omega,t}\right)\right]$, and therefore increases the spread between R_t^L and R_t. Similarly, an increase in the standard deviation $\sigma_{\omega,t}$ increases the spread between the lending and the deposit rates. When $\sigma_{\omega,t}$ rises, it leads to a mean-preserving spread for the distribution of ω_t^j: the tails of the distribution become fatter while the mean remains unchanged. As a result, lower realizations of ω_t^j are more likely so that more borrowers will default on their loans. More generally, when the financial intermediary is able to recover a fraction $(1-\mu)$ of the collateral value, it can be shown (using the properties of the lognormal distribution when $E\omega_t = 1$) that the denominator in the spread equation (4) is always declining in $\bar{\omega}_t^a$, and hence the spread is always an increasing function of the LTV. Evidence for the euro area suggests that mortgage spreads are an increasing function of the LTV ratio, as discussed in Sørensen and Lichtenberger (2007) and ECB (2009).

Finally, we assume that the deposit rate in the home country equals the risk-free

rate set by the central bank. In the foreign country, domestic financial intermediaries behave the same way. In their case, they face a deposit rate R_t^* and a lending rate $R_t^{L^*}$, and the spread is determined in an analogous way to equation (2), including a macroprudential instrument η_t^*. We explain below how the deposit rate in the foreign country R_t^* is determined.

A.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 (issued at an interest rate R_t) and the foreign country (issued at R_t^*):

$$R_t^* = R_t + \left\{ \vartheta_t \exp\left[\kappa_B \left(\frac{B_t}{P_t^C Y^C} \right) \right] - 1 \right\}. \tag{5}$$

The spread depends on the ratio of real net foreign assets B_t/P_t^C to steady state non-durable GDP (Y^C) in the home country (to be defined below). When home country domestic intermediaries have an excess of funds that they wish to lend to the foreign country domestic intermediaries, then $B_t > 0$. Hence, the foreign country intermediaries will pay a higher interest rate $R_t^* > R_t$. 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 deposit rates. International intermediaries are owned by savers in each country, and optimality conditions will ensure that the net foreign asset position of both countries is stationary.[10] They always make positive profits $(R_t^* - R_t)\, B_t$, which are equally split across savers of both countries.

[10] 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 (5) 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).

B. Households

B.1 Savers

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

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

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 (housing) and the labor disutility of agent j. Following Smets and Wouters (2003) as well as 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, affecting the marginal utility of either non-durable consumption (ξ_t^C) or housing (ξ_t^D). The parameter β stands for the discount factor of savers, γ measures the share of non-durable consumption in the utility function, and φ denotes the inverse elasticity of labor supply. Moreover, non-durable consumption is an index composed of home ($C_{H,t}^j$) and foreign ($C_{F,t}^j$) goods:

$$C_t^j = \left[\tau^{\frac{1}{\iota_C}} \left(C_{H,t}^j\right)^{\frac{\iota_C - 1}{\iota_C}} + (1-\tau)^{\frac{1}{\iota_C}} \left(C_{F,t}^j\right)^{\frac{\iota_C - 1}{\iota_C}} \right]^{\frac{\iota_C}{\iota_C - 1}}, \tag{7}$$

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. Following Iacoviello and Neri (2010), we introduce imperfect substitutability of labor supply between the durable and non-durable sector to explain comovement at the sector level:

$$L_t^j = \left[\alpha^{-\iota_L} \left(L_t^{C,j}\right)^{1+\iota_L} + (1-\alpha)^{-\iota_L} \left(L_t^{D,j}\right)^{1+\iota_L} \right]^{\frac{1}{1+\iota_L}}. \tag{8}$$

The labor disutility index consists of hours worked in the non-durable sector $L_t^{C,j}$ and durable sector $L_t^{D,j}$, with α denoting the share of employment in the non-durable sector. Reallocating labor across sectors is costly, and is governed by the parameter ι_L.[11] Wages are flexible and set to equal the marginal rate of substitution between consumption and labor in each sector.

The budget constraint of savers in nominal terms reads:

$$P_t^C C_t^j + P_t^D I_t^j + S_t^j \leq R_{t-1} S_{t-1}^j + W_t^C L_t^{C,j} + W_t^D L_t^{D,j} + \Pi_t^j, \tag{9}$$

[11] 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, which are defined below. Nominal wages paid in the two sectors are denoted by W_t^C and W_t^D. Savers allocate their expenditures between non-durable consumption C_t^j and residential investment I_t^j. They have access to deposits in the domestic financial system S_t^j, that pay the deposit interest rate R_t. In addition, savers also receive profits Π_t^j from intermediate goods producers in the durable and the non-durable sector, from domestic and international financial intermediaries, and from debt-collection agencies that charge fees to domestic financial intermediaries to make defaulting households pay their debts.

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

$$D_t^j = (1-\delta)D_{t-1}^j + \left[1 - \digamma\left(\frac{I_{t-1}^j}{I_{t-2}^j}\right)\right] I_{t-1}^j \tag{10}$$

where δ denotes the depreciation rate of the housing stock and $\digamma(\cdot)$ an adjustment cost function. Following Christiano, Eichenbaum, and Evans (2005), $\digamma(\cdot)$ is a convex function, which in steady state meets the following criteria: $\bar{\digamma} = \bar{\digamma}' = 0$ and $\bar{\digamma}'' > 0$.[12]

B.2 Borrowers

Borrowers differ from savers along three main dimensions. First, their preferences are different. The discount factor of borrowers is smaller than the respective factor of savers ($\beta^B < \beta$), and we allow for different habit formation coefficients ε^B. Second, borrowers do not earn profits from intermediate goods producers, financial intermediaries, or debt-collection agencies. Finally, as discussed above, borrowers are subject to a quality shock to the value of their housing stock ω_t^j. Since borrowers are more impatient, in equilibrium, savers are willing to accumulate assets as deposits, and borrowers are willing to pledge their housing wealth as collateral to gain access to loans. Analogously to savers, the utility function for each borrower $j \in [\lambda, 1]$ reads:

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^{B,t} \left[\gamma \xi_t^C \log(C_t^{B,j} - \varepsilon^B C_{t-1}^B) + (1-\gamma)\xi_t^D \log(D_t^{B,j}) - \frac{\left(L_t^{B,j}\right)^{1+\varphi}}{1+\varphi} \right] \right\}, \tag{11}$$

[12] This cost function allows us to replicate hump-shaped responses of residential investment to shocks, and reduce residential investment volatility.

where all variables and parameters with the superscript B denote that they are specific to borrowers. The indices of consumption and hours worked, and the law of motion of the housing stock have the same functional form as in the case of savers (equations 7, 8, and 10). The budget constraint for borrowers differs among those who default and those who repay their loans in full. Hence, aggregating borrowers' budget constraints and dropping the j superscripts, we obtain the following:

$$P_t^C C_t^B + P_t^D \left[I_t^B + G\left(\bar{\omega}_{t-1}^p, \sigma_{\omega,t-1}\right) D_t^B\right] + \left[1 - F\left(\bar{\omega}_{t-1}^p, \sigma_{\omega,t-1}\right)\right] R_{t-1}^L S_{t-1}^B \leq S_t^B + W_t^C L_t^{C,B} + W_t^D L_t^{D,B}. \tag{12}$$

Borrowers consume non-durables C_t^B, invest in the housing stock I_t^B, and supply labor to both sectors ($L_t^{C,B}$ and $L_t^{D,B}$). Savers and borrowers are paid the same wages W_t^C and W_t^D in both sectors. That is, hiring firms are not able to discriminate types of labor depending on whether a household is a saver or a borrower. Borrowers obtain loans S_t^B from financial intermediaries at a lending rate R_t^L. After aggregate and idiosyncratic shocks hit the economy, borrowers will default if the realization of the idiosyncratic shock falls below the ex-post threshold:

$$\bar{\omega}_{t-1}^p = \frac{R_{t-1}^L S_{t-1}^B}{P_t^D D_t^B}. \tag{13}$$

Since investment increases the housing stock with a lag (equation 10), D_t^B is a pre-determined variable. Because the lending rate is also pre-determined and is not a function of the state of the economy, it is possible that $\bar{\omega}_t^a$ and $\bar{\omega}_t^p$ differ. Note, however, that when the loan is signed, $\bar{\omega}_t^a = E_t \bar{\omega}_t^p$. The term $\left[1 - F\left(\bar{\omega}_{t-1}^p, \sigma_{\omega,t-1}\right)\right] = \int_{\bar{\omega}_{t-1}^p}^{\infty} dF(\omega; \sigma_{\omega,t-1}) d\omega$ defines the fraction of loans which are repaid by the borrowers, because they were hit by a realization of the shock above the threshold $\bar{\omega}_{t-1}^p$. Similarly, $P_t^D G\left(\bar{\omega}_{t-1}^p, \sigma_{\omega,t-1}\right) D_t^B = P_t^D \int_0^{\bar{\omega}_{t-1}^p} \omega dF(\omega; \sigma_{\omega,t-1}) D_t^B$ is the value of the housing stock on which borrowers have defaulted on and which is paid to banks after a debt-collection agency intervenes.

C. Firms, Technology, and Nominal Rigidities

In each country, homogeneous final non-durable and durable goods are produced using a continuum of intermediate goods in each sector (indexed by $h \in [0, n]$ in the home, and by $f \in [n, 1]$ in the foreign country). Intermediate goods in each sector are imperfect substitutes of each other, and there is monopolistic competition as well as staggered price setting à la Calvo (1983). Intermediate goods are not traded across countries and are bought by domestic final goods producers. In the final goods sector, non-durables are sold to domestic and foreign households.[13] Durable goods

[13] 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

are solely sold to domestic households, who use them to increase the housing stock. Both final goods sectors are perfectly competitive, operating under flexible prices.

C.1 Final Goods Producers

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

$$Y_t^k \equiv \left[\left(\frac{1}{n} \right)^{\frac{1}{\sigma_k}} \int_0^n Y_t^k(h)^{\frac{\sigma_k - 1}{\sigma_k}} dh \right]^{\frac{\sigma_k}{\sigma_k - 1}}, \text{ for } k = \{C, D\} \tag{14}$$

where σ_k represents the price elasticity of intermediate goods. Profit maximization leads to the following demand function for individual intermediate goods:

$$Y_t^C(h) = \left(\frac{P_t^H(h)}{P_t^H} \right)^{-\sigma_C} Y_t^C \text{ and } Y_t^D(h) = \left(\frac{P_t^D(h)}{P_t^D} \right)^{-\sigma_D} Y_t^D \tag{15}$$

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 of imported non-durables (P_t^F):

$$P_t^C = \left[\tau \left(P_t^H \right)^{1-\iota_C} + (1-\tau) \left(P_t^F \right)^{1-\iota_C} \right]^{\frac{1}{1-\iota_C}}. \tag{16}$$

C.2 Intermediate Goods Producers

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

---

price index P_t^C, which will be a combination of these two price levels.

sectors, intermediate goods are produced solely with labor:

$$Y_t^C(h) = A_t Z_t^C L_t^C(h), \quad Y_t^D(h) = A_t Z_t^D L_t^D(h) \quad \text{for all } h \in [0, n] \tag{17}$$

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:

$$\log(A_t) = \log(A_{t-1}) + \varepsilon_t^A.$$

This shock introduces non-stationarity to the model and constitutes a model-consistent way of detrending the data by taking logs and first differences to the real variables that inherit the random-walk behavior. In addition, it adds some correlation of technology shocks across sectors and countries, which is helpful from the empirical point of view because it allows to explain comovement of main real variables. Since labor is the only production input, cost minimization implies that real marginal costs in both sectors are given by:

$$MC_t^C = \frac{W_t^C / P_{H,t}}{A_t Z_t^C}, \quad MC_t^D = \frac{W_t^D / P_t^D}{A_t Z_t^D}. \tag{18}$$

Intermediate goods producers solve a standard Calvo model profit maximization problem with indexation. As shown in appendix B, inflation dynamics in each sector depend on one expected lead and one lag of inflation, and the sector-specific real marginal cost.

D. Closing the Model

D.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 the foreign country):

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

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

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

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

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

Credit market clearing implies that for domestic credit and international bond markets, the balance sheets of financial intermediaries are satisfied. Besides equation (3), this requires:

$$n\lambda B_t + (1-n)\lambda^* B_t^* = 0. \tag{22}$$

Finally, aggregating the resource constraints of borrowers and savers, and the market clearing conditions for goods and financial intermediaries, we obtain the law of motion of bonds issued by the home-country international financial intermediaries. This can also be viewed as the evolution of net foreign assets (NFA) of the home country:

$$\begin{aligned} n\lambda B_t &= n\lambda R_{t-1} B_{t-1} \\ &\quad + \left\{ (1-n) P_{H,t} \left[\lambda^* C_{H,t}^* + (1-\lambda^*) C_{H,t}^{B^*} \right] - n P_{F,t} \left[\lambda C_{F,t} + (1-\lambda) C_{F,t}^B \right] \right\}, \end{aligned} \tag{23}$$

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

D.2 Monetary Policy and Interest Rates

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

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

The euro area CPI (P_t^{EMU}) and real GDP (Y_t^{EMU}) are given by geometric averages of the home and foreign country variables, using the country size as a weight:

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

where the national real GDPs are expressed in terms of non-durables:

$$Y_t = Y_t^C + Y_t^D \frac{P_t^D}{P_t^C}, \text{ and } Y_t^* = Y_t^{C^*} + Y_t^{D^*} \frac{P_t^{D^*}}{P_t^{C^*}}.$$

D.3 Macroprudential Policy

Similar to Kannan, Rabanal, and Scott (2012) we introduce a macroprudential tool that aims at affecting the credit market conditions countercyclically. As shown in equations (3) and (4), the macroprudential instrument η_t affects the equilibrium in the domestic credit market and affects the lending-deposit spread in each country. We interpret this macroprudential instrument as being deployed above and beyond current rules, which are static to a large degree. Hence, when we estimate the model, we set η_t to a constant value of one. When we conduct an optimal macroprudential policy exercise in Section 4.B, we allow the instrument to be changed in order to maximize the weighted utility of all the citizens in the monetary union. A tightening of macroprudential policies will be reflected in a higher η_t, which will translate into a higher lending-deposit spread. Although we leave it unspecified, this could be implemented via additional capital surcharges, liquidity ratios, loan-loss provisions, or reserve requirements that reduce the amount of loanable funds by financial intermediaries. We assume that the instrument, in principle, can behave symmetrically and it can go below one. In that case, the central bank or any other regulatory agency would provide liquidity to the banking sector to reduce the lending-deposit spread. This could be achieved via (conventional or unconventional) measures like a widening of collateral standards, the *Funding for Lending Scheme* launched by the Bank of England in 2012, or even a direct provision of liquidity to the real economy as in Gertler and Karadi (2011). In the welfare maximizing exercise, we specify the macroprudential instrument as reacting to an indicator variable (Υ_t):

$$\eta_t = (\Upsilon_t)^{\gamma_\eta}, \quad \eta_t^* = (\Upsilon_t^*)^{\gamma_\eta^*}. \tag{25}$$

We study two main cases. In each country the macroprudential instrument reacts to: (i) nominal credit growth, or (ii) the credit-to-GDP ratio. For both cases, the parameters γ_η and γ_η^* are either allowed to be different, or are forced to be the same in the monetary union. In all cases, the indicator reacts to deviations from steady state values.

This concludes the explanation of the model. In Section 3, we conduct a Bayesian estimation of the model's parameters. In Section 4, we examine optimal monetary and macroprudential policy rules by obtaining the optimal values of $\gamma_\pi, \gamma_y, \gamma_R, \gamma_\eta$ and γ_{η^*} using the utility function of the four types of households in the monetary union (patient and impatient, in the home and foreign countries).

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, A_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.[14] Third, the solution of the model is expressed in state-space form and the likelihood function of the model is computed using a Kalman filter recursion. 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.[15]

A. Data

We distinguish between a core (home country) and a periphery (foreign country) region of the euro area. Data for the core is obtained by aggregating data for France and Germany, whereas the periphery is represented by the GIIPS countries (Greece, Ireland, Italy, Portugal, and Spain). We use quarterly data ranging from 1995q4-2011q4 and eleven macroeconomic time series.[16] For both regions we use five observables: real private consumption spending, real residential investment, the harmonized index of consumer prices (HICP), housing prices, and outstanding debt for households. We also include the 3-month Euribor rate, which we use as counterpart of the deposit rate in the core.[17] 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 400 to obtain a quarterly and logged equivalent variable to the model. All data is finally demeaned.

---

[14] Appendix B details the full set of normalized, linearized equilibrium conditions of the model.

[15] The estimation is done using Dynare 4.3.2. The posterior distributions are based on 250,000 draws of the Metropolis-Hastings algorithm.

[16] Due to the short history of the EMU we face a short time series. We include the years 1995-1998 to increase the sample size. During those years most EMU countries were conducting monetary policy in a coordinated way.

[17] See Appendix A for further details on the data set.

B. Calibrated Parameters

Some parameters are calibrated because the set of observable variables that we use does not provide information to estimate them (Table 1). We assume that the discount factors are the same in both countries ($\beta = \beta^*$ and $\beta^B = \beta^{B^*}$). We set the discount factor of savers to $\beta = 0.99$. The steady state LTV ratio, which also determines the cut-off point for defaulting on a loan, is set to $\bar{\omega} = 0.7$ and equally across countries, according to euro area data such as Gerali et al. (2010). We set the default rate on loans, $\bar{F}(.)$ to 2.5 percent.[18] As a result, the steady state value of the risk shock is $\bar{\sigma}_\omega = 0.1742$. We set the housing agent fee to $\mu = 0.2$, which is a value higher than that calibrated by Forlati and Lambertini (2010), but lower than the recovery rates for loans estimated for the United States.[19] Using these values, the zero-profit condition for financial intermediaries, and the consumption Euler equation for borrowers, we obtain a discount factor of borrowers of $\beta^B = 0.985$. As discussed in the previous section, we set the macroprudential instrument to $\eta = 1$ to estimate the model.

The depreciation rate is assumed to be 5 percent (annual) and equal across countries ($\delta = \delta^* = 0.0125$). The degree of monopolistic competition in the goods markets σ is the same across sectors and countries, implying mark-ups of 10 percent. We set the size of the core countries in the euro area to $n = 0.6$, based on GDP data. The bilateral trade parameter $1 - \tau$ is calibrated based on the weighted average of total imports to private consumption from periphery to core economies. The analogous parameter for the periphery $1 - \tau^*$ is calculated in a similar way, but is rounded to ensure that the trade balance and the net foreign asset position are zero in the steady state. Finally, we assume that the size of the durable and non-durable sectors is the same for the core and the periphery of the euro area ($\alpha = \alpha^*$). The assumptions of symmetry and balanced trade makes it easier to compute a steady state where all relative prices in all sectors are equal to one, and where all per capita quantities are the same.

---

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

[19] See Mortgage Bankers Association (2008).

Table 1: Calibrated Parameters

β	Discount factor savers	0.99
$\bar{\omega}$	Loan-to-value ratio	0.7
$\bar{F}$	Default rate on loans	0.025
$\bar{\sigma}_\omega$	Steady state risk	0.1742
μ	Proportion of housing value paid to debt-collection agency	0.2
β^B	Discount factor borrowers	0.985
η	Macroprudential instrument	1
δ	Depreciation rate	0.0125
σ	Elasticity of substitution between intermediate goods	10
n	Size core economies	0.6
$1-\tau$	Fraction of imported goods from periphery to core economies	0.06
$1-\tau^*$	Fraction of imported goods from core to periphery economies	0.09
α	Size of non-durable sector in GDP	0.94

C. Prior and Posterior Distributions

In Table 2 we present the prior distributions, the posterior mean and 90 percent credible set of selected estimated parameters.[20] To save space, we present the estimated parameters of the shock processes in Appendix C. As we face the problem of a short sample, in addition to calibrating some parameters, we restrict others to be the same across countries. More specifically, we only allow the parameters related to nominal rigidities to differ across sectors and countries, in order to permit quantitatively different transmission channels of monetary policy. On the other hand, the parameters relating to preferences, adjustment costs, and the fraction of savers are assumed to be the same in both countries. We assume that the AR(1) coefficients of the shocks are the same across countries, but we allow the standard deviation of the shocks to differ across countries. Also, in order to better capture the correlation of key macro variables across countries, we assume that the housing demand shock and the TFP shock in non-durables has a common component across countries. For instance, the housing demand shock follows:

$$\begin{aligned} \log(\xi_t^D) &= \rho_{\xi,D}\log(\xi_{t-1}^D) + \varepsilon_t^{\xi,D} + \varepsilon_t^{\xi,D,COM} \\ \log(\xi_t^{D^*}) &= \rho_{\xi,D}\log(\xi_{t-1}^{D^*}) + \varepsilon_t^{\xi,D^*} + \varepsilon_t^{\xi,D,COM} \end{aligned} \tag{26}$$

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

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

First, we comment on the parameters that relate to preferences of borrowers and savers. We opt for a prior distribution centered at 0.5 for the fraction of savers in the economy. We set a highly informative prior by setting a small standard deviation of 0.05. The posterior mean suggests a somewhat larger fraction (0.61) to fit the macro data.[21] Interestingly, we find that the habit formation coefficient for borrowers is smaller than the one of savers even though we set the same prior for both coefficients. These estimates suggest that above and beyond the effect of the financial accelerator, consumption of savers is less volatile than consumption of borrowers, who will react more to changes in their relevant (lending) interest rates. We center the priors related to the elasticity of substitution between home and foreign non-durables, the elasticity of labor supply and the coefficient measuring costly labor reallocation to parameters available in the literature (Smets and Wouters, 2003; Iacoviello and Neri, 2010; and Adolfson et al., 2007). We find a large elasticity of substitution between home and foreign goods (the posterior mean of 1.9 is higher than the prior mean of 1.5). Regarding the coefficients that determine labor supply, we find that the posterior mean of the labor disutility coefficient φ and the degree of costly labor reallocation is about one third, which is similar to Iacoviello and Neri (2010).

Table 2: Prior and Posterior Distributions

			Prior		Posterior	
	Parameters		Mean	SD	Mean	90% C.S.
λ	Fraction of savers	Beta	0.5	0.05	0.61	[0.53,0.68]
ε	Habit formation savers	Beta	0.5	0.15	0.72	[0.65,0.80]
ε^B	Habit formation borrowers	Beta	0.5	0.15	0.46	[0.26,0.66]
φ	Labor disutility	Gamma	1	0.5	0.37	[0.22,0.52]
ι_C	Elasticity of subst. between goods	Gamma	1.5	0.5	1.90	[1.05,2.67]
ι_L	Labor reallocation costs	Gamma	1	0.5	0.72	[0.51,0.93]
ψ	Investment adjustment costs	Gamma	2	1	1.75	[1.10,2.35]
γ_π	Taylor rule reaction to inflation	Normal	1.5	0.1	1.56	[1.41,1.71]
γ_y	Taylor rule reaction to real growth	Gamma	0.2	0.05	0.20	[0.12,0.28]
γ_r	Interest rate smoothing	Beta	0.66	0.15	0.80	[0.77,0.84]
κ_B	International risk premium	Gamma	0.01	0.005	0.0043	[0.002,0.007]
θ_C	Calvo lottery, non-durables	Beta	0.75	0.15	0.62	[0.56,0.69]
θ_C^*	Calvo lottery, non-durables	Beta	0.75	0.15	0.72	[0.67,0.77]
θ_D	Calvo lottery, durables	Beta	0.75	0.15	0.64	[0.57,0.72]
θ_D^*	Calvo lottery, durables	Beta	0.75	0.15	0.59	[0.52,0.67]
ϕ_C	Indexation, non-durables	Beta	0.33	0.15	0.15	[0.02,0.26]
ϕ_C^*	Indexation, non-durables	Beta	0.33	0.15	0.13	[0.02,0.23]
ϕ_D	Indexation, durables	Beta	0.33	0.15	0.25	[0.06,0.43]
ϕ_D^*	Indexation, durables	Beta	0.33	0.15	0.43	[0.21,0.68]

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

The coefficients on the Taylor rule suggest a strong response to inflation fluctuations in the euro area (coefficient of 1.56, close to the prior mean), a moderate response to real GDP growth (posterior mean of 0.2) and a high degree of interest rate inertia (0.80). We opt for a gamma prior for the risk premia elasticity κ_B between countries with a mean of 0.01. We find that the risk premium elasticity between countries moves about 0.43 basis points with a one percent increase in the external debt-to-GDP ratio.

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

Table C.1 in the appendix presents the prior and posterior distributions for the shock processes. We comment on two results. First, the common innovations to non-durable technology shocks and durable preference shocks are important, and as we discuss in the next subsection they are key to match cross-country correlations of some key macro variables. Second, the mean of the (log) risk shock is $\log(0.1742) = -1.74$. We set a prior standard deviation for the innovation to the housing risk shock of 0.25 (that is, 25 percent), such that, roughly, the two-standard deviation prior interval is between -1.25 and -2.25. Given the properties of the log-normal distribution, this means that the default rate for mortgages ranges between 0.04 and 13.6 percent with 95 percent probability. This seems to be an acceptable range for euro area member states.[22] The estimates for the quality shock in the periphery are similar to the prior, while in the core there seems to be much less risk volatility, as reflected by the posterior.

D. Model Fit and Variance Decomposition

We present the standard deviation and first five autocorrelations of the observable variables, and their counterpart in the model implied by the posterior distribution of the parameters, to understand how well the model fits the data. In Table 3, the first

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

row for each entry is the data, the second row is the 90 percent confident set implied by the model estimates. The model does reasonably well in explaining the standard deviation of all variables in the periphery. However, the model overpredicts the volatility of prices and quantities in both sectors in the core of the euro area, despite having allowed for different degrees of nominal rigidities, indexation, and different standard deviations of shocks. Finally, the model correctly implies that credit growth in the periphery is more volatile than in the core. The model also does a better job in explaining the persistence of variables in the periphery than in the core, and does a good job in predicting the persistence of interest rates. It slightly overpredicts the persistence of CPI inflation in the periphery, and slight underpredicts the persistence of residential investment, consumption growth, and house prices. In the core, the model has a harder time fitting the lack of persistence in CPI inflation, residential investment and consumption growth.

Table 3: Posterior Second Moments in the Data and in the Model

	Std. Dev.	Autocorrelation				
		1	2	3	4	5
r	0.34	0.91	0.78	0.63	0.47	0.32
	[0.22,0.31]	[0.84,0,91]	[0.65,0.80]	[0.49,0.68]	[0.35,0.57]	[0.25,0.48]
Δp^C	0.30	0.21	0.09	0.21	-0.15	-0.19
	[0.35,0.47]	[0.47,0.59]	[0.14,0.29]	[-0.01,0.14]	[-0.06,0.06]	[-0.08,0.04]
Δc	0.46	-0.13	0.12	0.12	-0.08	0.26
	[0.64,0.82]	[0.44,0.57]	[0.13,0.29]	[-0.01,0.13]	[-0.08,0.03]	[-0.10,-0.02]
Δy^D	1.67	0.04	0.09	0.06	0.12	-0.03
	[1.99,2.65]	[0.45,0.63]	[0.11,0.37]	[-0.05,0.18]	[-0.12,0.06]	[-0.13,-0.01]
Δp^D	0.70	0.56	0.54	0.41	0.30	0.11
	[0.88,1.25]	[0.54,0.70]	[0.17,0.41]	[-0.03,0.20]	[-0.12,0.05]	[-0.12,-0.01]
Δs	0.45	0.30	0.34	0.16	0.49	0.01
	[0.82,1.03]	[0.56,0.71]	[0.44,0.61]	[0.33,0.51]	[0.24,0.43]	[0.16,0.35]
Δp^{C*}	0.31	0.41	0.21	0.02	-0.28	-0.22
	[0.34,0.45]	[0.56, 0.67]	[0.24,0.39]	[0.05,0.25]	[-0.03,0.11]	[-0.07,0.04]
Δc^*	0.59	0.60	0.52	0.44	0.32	0.24
	[0.55,0.71]	[0.48, 0.60]	[0.18,0.34]	[0.03,0.18]	[-0.05,0.08]	[-0.09,0.02]
Δy^{D*}	2.22	0.62	0.55	0.58	0.50	0.48
	[1.97,2.56]	[0.38, 0.62]	[0.05,0.33]	[-0.08,0.15]	[-0.11,0.04]	[-0.12,-0.01]
Δp^{D*}	1.44	0.87	0.84	0.76	0.71	0.64
	[0.99,1.31]	[0.58, 0.73]	[0.15,0.37]	[-0.06,0.10]	[-0.14,0.03]	[-0.15,-0.07]
Δs^*	1.36	0.48	0.68	0.42	0.64	0.28
	[1.19,1.55]	[0.45, 0.61]	[0.35,0.51]	[0.25,0.43]	[0.16,0.33]	[0.09,0.25]

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 (90 percent credible set). Standard deviations for all variables are in percent terms.

The model captures most of the comovement between main aggregates within and across countries of the euro area, which is especially important for the design of

Table 4: Correlation Matrix

	Δc	Δy^D	Δp^D	Δs	Δc^*	Δy^{D^*}	Δp^{D^*}
Δy^D	0.09	1					
	[0.10,0.25]	1					
Δp^D	0.30	0.34	1				
	[-0.01,0.18]	[0.19,0.48]	1				
Δs	0.20	0.21	0.35	1			
	[0.04,0.21]	[0.26,0.43]	[0.42,0.59]	1			
Δc^*	0.31	0.15	0.28	0.64	1		
	[0.28,0.49]	[0.12,0.26]	[0.11,0.23]	[0.08,0.18]	1		
Δy^{D^*}	0.37	0.27	0.37	0.48	0.65	1	
	[0.10,0.24]	[0.12,0.33]	[0.05,0.23]	[0.05,0.16]	[0.16, 0.33]	1	
Δp^{D^*}	0.17	0.03	0.36	0.27	0.54	0.62	1
	[0.08,0.19]	[0.06,0.23]	[0.07,0.32]	[0.07,0.20]	[0.05,0.27]	[0.22,0.50]	1
Δs^*	0.14	0.06	0.27	0.43	0.61	0.58	0.73
	[0.04,0.11]	[0.04,0.13]	[0.10,0.18]	[0.10,0.23]	[-0.03,0.11]	[0.23,0.34]	[0.34,0.44]

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

optimal monetary and macroprudential policies. In Table 4 we present the contemporaneous correlation of selected observable variables in the data and in the model (90 percent confidence set).[23] Among the successes, we note that the model explains the correlation between house prices and residential investment within each area well. The model also fits well the correlation of house price inflation, consumption growth and residential investment growth across countries. The model can explain the comovement between consumption and residential investment in the core, but fails at explaining the comovement in the periphery. Finally, the model does a good job in explaining the correlation of credit with main macroeconomic variables in the core. The model does a worse job in explaining the correlation of credit with other macro aggregates in the periphery, because it implies a correlation that is smaller than in the data, while still getting the sign right.

We briefly discuss the results from the variance decomposition exercise. To save space, we present the table with the 90 percent confidence set for the share of the variance of each variable explained by the two most important shocks in the appendix (Table C.3). For all variables, two shocks are enough to explain at least half of their variance, while the remaining shocks explain a small fraction of the variance one at a time. In most cases, each variable in each country and sector is mostly explained by technology and preference shocks in that country and sector. For instance, residential investment and housing prices are mostly explained by a combination of supply and demand shocks. There are no important spillovers from shocks originating in one country or sector to another. There are two exceptions to this pattern. CPI inflation in both areas is explained by the common innovation

[23] Table C.2 in the appendix presents contemporaneous correlation of all observable variables.

component to nondurable technology, and monetary shocks. The unit root shock to aggregate technology explains an important fraction of volatility of consumption growth in both areas. Finally, it is worth noting that in each country, the volatility of credit is mostly explained by risk shocks and by housing demand (durable preference) shocks. But risk shocks do not have an important impact on the volatility of real macroeconomic variables.

E. Model Comparison: A Brief Discussion

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

First, we discuss the main findings of estimating a model with only savers by setting $\lambda = 1$. In this case, the model abstracts from financial frictions and, thus, we also dropped the risk shocks in the housing market. Furthermore, credit growth did not enter the set of observable variables anymore, which complicated using the marginal likelihood as a model comparison statistic. Omitting financial frictions, we found that most parameter estimates turn out to be very similar to what we reported in Table 2, and the posterior second moments are also very similar to the model with borrowers and savers. Hence, we find that in order to fit macroeconomic variables such as CPI inflation, house prices, consumption and residential investment, it is not necessary to introduce financial frictions in the model. However, the model we present in this paper allows us to analyze the interaction between credit aggregates and other macroeconomic variables.

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

Third, instead of assuming that the AR(1) coefficients of the shocks are the same across countries, we allowed them to be different. But this did not improve the model fit. In addition, following the results in Christiano, Motto and Rostagno

(2013), we also introduced news shocks in the housing quality shocks as follows:

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

for $s = 1$ to 4. We found that the marginal likelihood favored the model without news shocks and, therefore, we excluded them from the analysis. When we performed a posterior variance decomposition exercise, we found that lagged innovations to risk explained a fraction of the variance of credit, but they explained a very small fraction (less than 1 percent) of the variance of observed real macroeconomic variables.

Finally, we estimated the model with a targeting rule of the type:

$$\frac{P_t^{EMU}/P_{t-1}^{EMU}}{\bar{\Pi}^{EMU}} + \lambda_p\left(Y_t^{EMU}/Y_{t-1}^{EMU}\right) = 0$$

instead of a Taylor-type rule as equation (24). We also estimated a version of the model where funding costs for financial intermediaries are the same across countries.[24] None of these two extensions improved model fit so they were discarded.

4. Policy Experiments

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

$$\begin{aligned} \mathcal{W}^{EMU} &= n\mathcal{W} + (1-n)\mathcal{W}^* \\ \text{with } \mathcal{W} &= \lambda\mathcal{W}^S + (1-\lambda)\mathcal{W}^B \text{ and } \mathcal{W}^* = \lambda^*\mathcal{W}^{S^*} + (1-\lambda^*)\mathcal{W}^{B^*}, \end{aligned} \tag{27}$$

where $\mathcal{W}^S$ is the welfare of core savers, which is evaluated by taking a second order approximation to the utility function (6) and subtracting the value of the utility

[24] In this case, in order to achieve stationarity in the model, we assumed that there are complete markets for securities traded internationally.

function at the non-stochastic steady state.[25] $\mathcal{W}^B$ is the welfare of core borrowers, which is evaluated similarly using their utility function (11). $\mathcal{W}^{S^*}$ and $\mathcal{W}^{B^*}$ are defined analogously for the periphery households.

Basel III calls for regulators to intervene in case of excessive credit growth. We aim at studying the pros and cons of reacting to credit indicators, either by using monetary or macroprudential policies. First, we study optimal monetary policy rules by optimizing over the coefficients of the estimated Taylor rule. Second, we extend the Taylor rule to react to different measures involving credit (nominal credit growth and the credit-to-GDP ratio), and optimize over the additional coefficient. Third, we include a macroprudential rule that "leans against the wind" of credit cycles. As we discussed in Section 2.D.3, we assume that macroprudential policies affect the credit market clearing condition (3) by using the η_t instrument directly. To increase lending spreads, different measures could be used, such as additional capital surcharges, liquidity ratios, loan-loss provisions, or reserve requirements. We assume that the steady-state value of $\eta = 1$, and that the instrument may also take values smaller than one. In this latter case, commercial banks could lend beyond their loanable funds (i.e. the deposit base and foreign bonds) by obtaining liquidity from the central bank. As in the case of extended optimal monetary policy, the macroprudential instrument reacts whenever these different measures involving credit deviate from their steady state values. To obtain the optimal policy response of the central bank using the nominal interest rate, we exclude the monetary policy shock ε_t^m in all of these simulations.[26]

A. Optimal Monetary Policy

A.1 Estimated Taylor Rule

We start by optimizing over the coefficients of the estimated Taylor rule (27). In particular, we optimize over the coefficients of the reaction to area-wide CPI inflation, area-wide real GDP growth, and interest rate smoothing. We truncate the coefficients of the response to inflation and output growth in the Taylor rule. As in Schmitt-Grohé and Uribe (2007), we find that the welfare improvements are numerically negligible when the coefficients of the Taylor rule have reached a certain

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

[26] Including the monetary policy shock in our policy experiments primarilys affect the results for the inertia coefficient. With iid monetary shocks as in the estimated model, the optimal degree of inertia moves towards zero in most simulations.

value but are left unbounded. In order to speed up the maximization routines, it is thus helpful to restrict the coefficients γ_π and γ_y to the interval $[0, 5]$, while the coefficient on interest rate smoothing is restricted to the interval $[0, 1]$.

In the first row of Table 5, we show the optimized coefficients of the estimated Taylor rule. We also compute the improvement in welfare with respect to the estimated Taylor rule in percentage terms. The optimal monetary policy suggests stronger responses to euro area CPI inflation and output growth than the estimated coefficients, and less interest-rate smoothing. In this case, the welfare of all households in the euro area improves by 0.03 percent of steady state consumption, but more so for savers in both countries. In fact, welfare for borrowers in the periphery declines slightly.

Table 5: Optimal Taylor Rule Coefficients

	γ_π	γ_y	γ_r	γ_s	$\mathcal{W}^S$	$\mathcal{W}^B$	$\mathcal{W}^{S^*}$	$\mathcal{W}^{B^*}$	$\mathcal{W}^{EMU}$
Original	5.00	0.61	0.43	-	0.03	0.01	0.05	-0.01	0.03
w Nom. Cred. Gr.	5.00	0.00	0.65	1.31	0.06	-0.03	0.11	-0.08	0.04
	1.56	*0.20*	*0.80*	0.46	0.03	-0.02	0.06	-0.06	0.02
w Credit/GDP	5.00	0.60	0.43	0.00	0.03	0.01	0.05	-0.01	0.03
	1.56	*0.20*	*0.80*	0.00	0.00	0.00	0.00	0.00	0.00

NOTE: Parameter values in italics are not optimized over but calibrated at their estimated posterior mean. Welfare results are presented in terms of percentage changes in steady state consumption that would leave agents indifferent between the relevant rule and the estimated rule.

A.2 Extending the Taylor Rule with Financial Variables

Next, we examine the welfare improvement when the ECB is allowed to react to credit indicators (nominal credit growth and the credit-to-GDP ratio in the euro area). We either optimize over: (i) all the coefficients of the Taylor rule, including the coefficient of the financial variable, or (ii) only over the coefficient of the additional indicator, leaving the others at their estimated values. In all cases the coefficients are again truncated to a maximum value of 5. There is some welfare improvement in reacting to nominal credit growth, but no welfare improvement in reacting to the credit-to-GDP ratio. The optimal response to nominal credit growth is $\gamma_s = 1.31$. The same qualitative results hold when we keep the coefficients of the Taylor rule at their estimated values and only optimized over the additional parameter.

Having monetary policy react to euro area nominal credit growth improves on EMU welfare. Welfare of savers increases between 0.03 and 0.11 percent of lifetime consumption, compared to the estimated Taylor rule. Yet, welfare of borrowers declines in both areas. This captures an interesting aspect of our results. The

heterogeneity in the model allows us to identify the winners and losers of different policy regimes in the EMU. We will further examine this result below in the context of impulse response functions, after discussing macroprudential regulation.

B. Macroprudential Regulation

In this subsection, we focus on macroprudential policies that are set countercyclically to maximize EMU-welfare, but are implemented at the national level. Hence, we analyze the optimal policy regime consisting of the estimated Taylor rule together with national macroprudential rules (25) and optimize over the parameters of these three rules in order to maximize the welfare criterion (27). In this scenario, monetary policy reacts to union-wide developments, while macroprudential policy responds to domestic developments in each country. The coefficients of these policy rules are jointly decided to maximize welfare at the aggregate (EMU) level. Since we allow the macroprudential rule to affect credit variables directly, we no longer include the reaction to credit in the Taylor rule. Therefore, the macroprudential instrument can be viewed as an alternative to having monetary policy react to indicators beyond CPI inflation and output growth. In this sense, we study the Svensson (2012) suggestion that monetary policy should be in charge of price stability while macroprudential policy should address financial stability.

In Table 6 we consider the following combinations of cases: (i) macroprudential regulation either reacts to nominal credit growth or the credit-to-GDP ratio, (ii) the coefficients of the Taylor rule are the estimated ones, or are optimized with the parameters of the macroprudential rule, and (iii) the coefficients of the macroprudential policies are allowed to change across countries, or are restricted to be the same.

Several interesting results arise from this exercise. First of all, in some cases there are winners and losers of introducing macroprudential policies. The only policy that improves welfare for each type of agent, yet it does not maximize EMU-wide welfare, is to have macroprudential policy react to nominal credit growth. In this regime, all households experience increases in welfare between 0.01 and 0.19 percent of lifetime consumption. Furthermore, there are no big numerical differences in welfare if we impose the restriction that the coefficients are the same across countries. Second, the macrprudential policy that delivers the highest welfare (reacting to the credit-to-GDP ratio) is highly divisive, since savers benefit greatly from it, especially in the periphery where they experience a welfare gain of 0.62 percent of lifetime consumption, while borrowers witness an important decrease of welfare with respect to the estimated rule (a decline of 0.73 percent of lifetime consumption in the

Table 6: Optimal Monetary and Macroprudential Policy at the EMU Level

Using Optimized Taylor Rule										
	γ_π	γ_y	γ_r	γ_η	γ_η^*	$\mathcal{W}^S$	$\mathcal{W}^B$	$\mathcal{W}^{S^*}$	$\mathcal{W}^{B^*}$	$\mathcal{W}^{EMU}$
Nom. Cred. Gr.	4.05	0.24	0.70	0.59	0.97	0.02	0.07	0.05	0.19	0.06
Restricted	3.96	0.24	0.69	0.79	-	0.01	0.10	0.07	0.14	0.06
Credit/GDP	5.00	0.84	0.62	1.97	4.63	0.12	-0.07	0.62	-0.73	0.12
Restricted	5.00	0.86	0.61	2.97	-	0.12	-0.08	0.62	-0.72	0.12
Using Estimated Taylor Rule										
	γ_π	γ_y	γ_r	γ_η	γ_η^*	$\mathcal{W}^S$	$\mathcal{W}^B$	$\mathcal{W}^{S^*}$	$\mathcal{W}^{B^*}$	$\mathcal{W}^{EMU}$
Nom. Cred. Gr.	*1.56*	*0.20*	*0.80*	0.98	1.48	0.02	0.04	0.05	0.17	0.05
Restricted	*1.56*	*0.20*	*0.80*	1.26	-	0.01	0.07	0.05	0.17	0.05
Credit/GDP	*1.56*	*0.20*	*0.80*	0.59	1.20	0.06	-0.05	0.55	-0.71	0.09
Restricted	*1.56*	*0.20*	*0.80*	0.82	-	0.07	-0.07	0.53	-0.67	0.08

NOTE: Parameter values in italics are not optimized over but calibrated at their estimated posterior mean. Welfare results are presented in terms of percentage changes in steady state consumption that would leave agents indifferent between the relevant rule and the estimated rule.

periphery). These results hold when we use the estimated Taylor rule, and when we optimize over the coefficients of the Taylor rule.

Why is it the case that the welfare of borrowers declines under some optimal regimes of monetary and macroprudential policy? We discuss several impulse responses to understand under which conditions macroprudential policy improves welfare. In Figures 1 and 2 we plot the impulse responses to a housing demand shock and a risk shock in the periphery. We choose these shocks because the periphery of the euro area experienced a larger boom-bust cycle in housing prices and credit than in the core, especially in Spain and Ireland. After a housing demand shock (normalized such that nominal house prices increase by 1 percent in the periphery), GDP, CPI inflation, house prices and credit-to-GDP increase in the periphery under the estimated rule (Figure 1). In the core, GDP increases slightly, while all other variables fall because the ECB tightens rates due to above-normal CPI inflation and growth in the periphery. But the spillover effects tend to be quantitatively small. In the periphery, both borrowers and savers increase residential investment demand, and consumption behaves very differently. Savers reduce their consumption expenditures because they want to tilt spending towards housing, but borrowers increase non-durable consumption because higher house prices and residential investment improve their ability to borrow. This is the accelerator mechanism at work.

The optimal monetary policy response leads to a decline in the response of all real quantities in the core and a smaller response of CPI inflation in the periphery, but to a recession in the core. In this sense, the core is forced to pay for excesses committed by the periphery. But even in this case, the stronger monetary policy stance on CPI inflation and growth does not contain accelerator effects to really

affect credit-to-GDP ratio in the periphery. In order to achieve this, the use of macroprudential measures is necessary: For this reason, we now add the macroprudential rule that reacts to the credit-to-GDP ratio optimally (Table 6). As a result, credit-to-GDP in the periphery increases to a lesser extent, there are less accelerator effects, and hence the stance of monetary policy can be softened in the EMU as a whole (compared to the optimal monetary policy case). Overall, the regime of optimal monetary plus macroprudential policy delivers more stability on all real quantities in the periphery, and this improves welfare. However, this last regime cannot fully offset the negative spillover effects from the periphery to the core borrowers. Similar qualitative results would hold if the housing boom was in the core, but with core savers and borrowers benefitting more from stability using macroprudential policies.

A negative risk shock in the periphery has very similar effects on most variables in the periphery as the housing demand shock. When risk declines, the lending-deposit spread falls in the periphery (the shock is normalized such that spreads decline by 25 basis points on an annualized basis), triggering an increase in the credit-to-GDP ratio. Under the estimated rule, consumption and residential investment by borrowers increase in the periphery, but that of savers decline. In the aggregate, GDP increases in the periphery, and increased demand by borrowers also increases GDP in the core, mostly through the net exports channel. However, higher inflation leads to an increase of interest rates that makes spending fall for both borrowers and savers in the core. The optimal monetary policy tries to stabilize CPI inflation by increasing interest rates, which leads to reductions of spending for all other households in the EMU, and a recession and deflation in the core. As in the case of the housing demand shock, optimal monetary policy cannot do much to offset the accelerator effects, while the use of macroprudential tools delivers overall stability and takes the pressure off the EMU-wide interest rate. If the risk shock had affected the core, it would have had a similar impact on core variables as the one described here for periphery variables, and vice versa.

When does the use of macroprudential tools lead to inferior welfare outcomes, specially for borrowers? In Figure 3 we plot the effect of an innovation to the EMU-wide (one standard deviation) permanent technology shock. In this case, macroprudential policies increase the countercyclicality of the lending-deposit premium, increasing the volatility of borrower-specific variables and reducing their welfare. When a permanent technology hits the economy, this increases the level of real variables permanently (however, growth rates and transformed variables remain stationary). Since this is a permanent shock and both economies are quite symmetric, the effects are similar in both areas of the EMU. Under the estimated policy rule, consumption and residential investment by all agents moves smoothly to the new level. CPI inflation falls in both areas due to the decline in real marginal costs, while (nominal and real) house prices increase. Interestingly, under the

estimated rule, credit-to-GDP falls, even though both quantities (credit and GDP) increase. The lending-deposit spread changes only slightly, reflecting minimal movements in the LTV ratios.

Optimal monetary policy aims at bringing CPI inflation back to target so that the ECB cuts nominal interest rates and CPI inflation falls to a lesser extent. Moreover, most real variables display less volatility and a faster transition to their new steady state values. The macroprudential policy aims at addressing the decline of the credit-to-GDP ratio by allowing banks to lend more. As a result, the credit-to-GDP ratio falls by much less and the lending-deposit rate becomes more volatile. This generates a higher countercyclical response of the lending rate, which finally increases the volatility of consumption and residential investment by borrowers. Because they have access to cheap credit, borrowers spend more and supply less labor, making hours worked for borrowers also more volatile, which further adds to their welfare cost. On the other hand, savers still face a smooth consumption and investment plan. By picking up the labor slack left by borrowers their overall labor supply is less volatile, contributing to their welfare increase.

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

We conduct an additional robustness result by looking at the optimal response of monetary and macroprudential policies if the policy makers were able to identify the source of the shock. To that end, we simulate the model with either technology shocks only (including all sectors and countries and the unit root shock), preference shocks only (including all countries and sectors), and financial shocks only (including the housing quality risk shock and the risk premium shock across countries). The optimal responses are quite different when the monetary and macroprudential authorities can identify the source of the shock (Table 7). A key difference, that we identified in the impulse response analysis, is that the optimal monetary and macroprudential response to any credit aggregate becomes zero under technology shocks. As we already saw from Figure 3, including macroprudential policies when technology shocks are present reduced welfare of borrowers by inducing too much volatility in the lending-deposit spread. However, when financial and demand shocks hit the economy, the optimal macroprudential responses calls for

Table 7: Optimal Monetary and Macroprudential Policy, Conditional on Shocks

Technology Shocks	γ_π	γ_y	γ_r	γ_s	γ_η	γ_η^*
Nominal Credit Growth						
Monetary Policy	5.00	0.00	0.90	0.00	-	-
Mon. and Macropru. Pol.	5.00	0.00	0.90	-	0.00	0.00
Credit/GDP Ratio						
Optimal Monetary Policy	4.82	0.00	0.90	0.00	-	-
Mon. and Macropru. Pol.	5.00	0.00	0.90	-	0.00	0.00
Preference Shocks	γ_π	γ_y	γ_r	γ_s	γ_η	γ_η^*
Nominal Credit Growth						
Monetary Policy	3.36	5.00	0.99	0.70	-	-
Mon. and Macropru. Pol.	2.42	5.00	0.98	-	0.34	0.34
Credit/GDP Ratio						
Optimal Monetary Policy	2.33	5.00	0.98	0.01	-	-
Mon. and Macropru. Pol.	4.13	5.00	0.96	-	0.86	1.26
Financial Shocks	γ_π	γ_y	γ_r	γ_s	γ_η	γ_η^*
Nominal Credit Growth						
Monetary Policy	5.00	5.00	0.00	0.98	-	-
Mon. and Macropru. Pol.	5.00	5.00	0.00	-	1.60	1.96
Credit/GDP Ratio						
Optimal Monetary Policy	5.00	5.00	0.00	5.00	-	-
Mon. and Macropru. Pol.	5.00	5.00	0.00	-	5.00	5.00

responding to credit aggregates to offset their effects.

5. Conclusions

In this paper, we have studied the optimal mix of monetary and macroprudential policy rules in an estimated DSGE model of the euro area. We have found that in a variety of scenarios and calibrations, the introduction of a macroprudential rule would help in reducing macroeconomic volatility and hence in improving EMU-wide welfare. At the same time, macroprudential policies "lend a hand" to monetary policy by reducing accelerator effects and thus, requiring smaller responses of the nominal interest. We have also shown that the effects of macroprudential regulations can affect savers and borrowers differently. The policy that improves welfare in the EMU the most - which would have macroprudential policies respond to the credit-to-GDP ratio - reduces the welfare of borrowers by inducing a too countercyclical response of the lending-deposit spread. A welfare improvement for all citizens in the EMU is achieved when macroprudential policies respond to nominal credit growth.

References

Adolfson, M., Laseen, S., Lindé, J., and M. Villani, 2007. Bayesian Estimation of an Open Economy DSGE Model with Incomplete Pass-Through. *Journal of International Economics*, Vol. 72(2), pp. 481-511.

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

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 No. 338.

Angelini, P., Neri, S., and F. Panetta, 2011b. Monetary and Macroprudential Policies. Temi di discussione (Economic working papers) No. 801, Bank of Italy, Economic Research Department.

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

Basel Committee on Banking Supervision, 2011. Basel III: A Global Regulatory Framework for More Resilient Banks and Banking Systems.

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.

Beau, D., Clerc, L. and B. Mojon, 2012. Macro-Prudential Policy and the Conduct of Monetary Policy. Working papers No. 390, Banque de France.

Bernanke, B., Gertler, M., and S. Gilchrist, 1999. The Financial Accelerator in a Quantitative Business Cycle Framework. In: Taylor, J., Woodford, M. (Eds.), Handbook of Macroeconomics, Vol. 1, pp. 1341-1393.

Bianchi, J. and E. Mendoza, 2011. Overborrowing, Financial Crises and 'Macro-prudential' Policy? IMF Working Paper No. 11/24.

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

Borio, C. and I. Shim, 2008. What can (Macro-)Prudential Policy Do to Support Monetary Policy? Bank for International Settlements Working Paper No. 242.

Brzoza-Brzezina, M., Kolasa, M., and K. Makarski, 2013. Macroprudential Policy and Imbalances in the Euro Area. National Bank of Poland Working Paper No. 138.

Calvo, G., 1983. Staggered Prices in a Utility Maximizing Framework. *Journal of Monetary Economics,* Vol. 12(3), pp. 383-398.

Christiano, L., Eichenbaum, M., and C. Evans, 2005. Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy. *Journal of Political Economy* Vol. 113(1), pp. 1-45.

Christiano, L., Motto, R., and M. Rostagno, 2013. Risk Shocks. NBER Working Paper No. 18682.

Claessens, S., Kose, A., and M. E. Terrones, 2009. What Happens During Recessions, Crunches and Busts? *Economic Policy*, Vol. 24, pp. 653-700.

Collard,. F., Dellas, H., Diba, B., and O. Loisel, 2013. Optimal Monetary and Prudential Policies. Bank of France Working Paper No. 413.

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 No. 11/91.

European Central Bank, 2009. Housing Finance in the Euro Area. ECB Occasional Paper No. 101.

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(3), pp. 3-47.

Forlati, C., and L. Lambertini, 2011. Risky Mortgages in a DSGE Model. *International Journal of Central Banking,* Vol. 7(1), pp. 285-336.

Galati, G. and R. Moessner, 2013. Macroprudential Policy - A Literature Review. *Journal of Economic Surveys*, Vol. 27(5), pp. 846–878.

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*, Vol. 42(s1), pp. 107-141.

Gertler, M., and P. Karadi, 2011. A Model of Unconventional Monetary Policy. *Journal of Monetary Economics,* Vol. 58(1), pp. 17–34.

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.

Iacoviello, M., 2005. House Prices, Borrowing Constraints and Monetary Policy in the Business Cycle. *American Economic Review*, Vol. 95(3), pp. 739-764.

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(2), pp. 125-164.

International Monetary Fund, 2012. Dealing with Household Debt. Chapter 3 of *World Economic Outlook*, April 2012, International Monetary Fund, Washington, DC.

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), pp. 473-500.

Kannan, P., Rabanal, P., and A. Scott, 2012. Monetary and Macroprudential Policy Rules in a Model with House Price Booms. *The B.E. Journal of Macroeconomics*, Vol. 12(1), pp. 1-44.

Lambertini, L., Mendicino, C., and M.T. Punzi, 2011. Leaning Against Boom-Bust Cycles in Credit and Housing Prices: Monetary and Macroprudential Policy. *Journal of Economic Dynamics and Control*, Vol. 37(8), pp. 1500-1522.

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.

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.

Medina, J.P. and J. Roldós, 2014. Monetary and Macroprudential Policies to Manage Capital Flows. IMF Working Paper, forthcoming.

Mortgage Banker Association, 2008. Lenders' Cost of Foreclosure, Policy Paper Congressional Education Series Briefing.

Roger, S. and J. Vlcek, 2011. Macroeconomic Costs of Higher Bank Capital and Liquidity Requirements. IMF Working Paper No. 11/103.

Rubio, M., 2013. Macroprudential Policy Implementation in a Heterogeneous Monetary Union. Mimeo, University of Nottingham.

Schmitt-Grohé, S. and M. Uribe, 2003. Closing Small Open Economy Models. *Journal of International Economics*, Vol. 61(1), pp. 163-185.

Schmitt-Grohé, S. and M. Uribe, 2007. Optimal, Simple, and Implementable Monetary and Fiscal Rules. *Journal of Monetary Economics,* Vol. 54(6), pp.

1702-1725.

Smets, F. and R. Wouters, 2003. An Estimated Stochastic Dynamic General Equilibrium Model for the Euro Area. *Journal of the European Economic Association*, Vol. 1(5), 1123-1175.

Sørensen, C., and J. Lichtenberger, 2007. Mortgage Interest Rate Dispersion in the Euro Area. ECB Working Paper No. 733.

Suh, H., 2012. Macroprudential Policy: Its Effects and Relationship to Monetary Policy. Federal Reserve Bank of Philadelphia Working Paper No. 12-28.

Svensson, L., 2012. Comment on Michael Woodford: "Inflation Targeting and Financial Stability". *Sveriges Riksbank Economic Review* 2012:1, pp. 33-39.

Unsal, F., 2013. Capital Flows and Financial Stability: Monetary Policy and Macroprudential Responses. *International Journal of Central Banking*, Vol. 9(1), pp. 233-285.

Vandenbussche, J., Vogel, U. and E. Detragiache, 2012. Macroprudential Policies and Housing Prices—A New Database and Empirical Evidence for Central, Eastern, and Southeastern Europe. IMF Working Paper No. 12/303.

Zhang, L., 2009. Bank Capital Regulation, the Lending Channel and Business Cycles. Discussion Paper Series 1: Economic Studies No. 2009,33, Deutsche Bundesbank, Research Centre.

Appendix

A Data and Sources

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

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

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

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

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

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

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

Nominal GDP for computing the weights used in the aggregation is taken from the

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

B Linearized Conditions

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

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

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

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

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

Home Country

From the optimal decision by savers we get the following:[27]

$$q_t + \xi_t^C - \frac{c_t - \varepsilon(c_{t-1} - \varepsilon_t^A)}{1-\varepsilon} + \psi(i_t - i_{t-1} + \varepsilon_t^A) = E_t\varrho_{t+1} + \beta\psi(E_t i_{t+1} - i_t), \quad \text{(B.1)}$$

where $\psi = F"(.)$ and ϱ_t is the normalized Lagrange multiplier associated with the law of motion of the housing stock (10) for savers, and

$$[1-\beta(1-\delta)]\,(\xi_t^D - d_t) = \varrho_t - \beta(1-\delta)E_t\varrho_{t+1}, \quad \text{(B.2)}$$

$$\varepsilon(\Delta c_t + \varepsilon_t^A) = E_t\Delta c_{t+1} - (1-\varepsilon)(r_t + E_t\Delta\xi_{t+1}^C - E_t\Delta p_{t+1}^C). \quad \text{(B.3)}$$

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

$$[(\varphi-\iota_L)\alpha + \iota_L]\,l_t^C + (\varphi-\iota_L)(1-\alpha)l_t^D = \tilde{w}_t^C + \xi_t^C - \frac{c_t - \varepsilon(c_{t-1} - \varepsilon_t^A)}{1-\varepsilon}, \quad \text{(B.4)}$$

$$[(\varphi-\iota_L)(1-\alpha) + \iota_L]\,l_t^D + (\varphi-\iota_L)\alpha l_t^C = \tilde{w}_t^D + \xi_t^C - \frac{c_t - \varepsilon(c_{t-1} - \varepsilon_t^A)}{1-\varepsilon}. \quad \text{(B.5)}$$

[27] Since all households behave the same way, we henceforth drop the j superscript.

The same conditions for borrowers are:

$$q_t + \xi_t^C - \frac{c_t^B - \varepsilon^B(c_{t-1}^B - \varepsilon_t^A)}{1-\varepsilon^B} + \psi(i_t^B - i_{t-1}^B + \varepsilon_t^A) = E_t\varrho_{t+1}^B + \beta^B\psi(E_t i_{t+1}^B - i_t^B), \quad \text{(B.6)}$$

with ϱ_t^B being the Lagrange multiplier associated with the law of motion of the housing stock (10) for borrowers, and

$$\left[1-\beta^B(1-\delta)\right](\xi_t^D - d_t^B) = \varrho_t^B - \beta^B(1-\delta)E_t\varrho_{t+1}^B, \quad \text{(B.7)}$$

$$\begin{aligned} & \varepsilon^B(\Delta c_t^B + \varepsilon_t^A) \\ = \; & E_t\Delta c_{t+1}^B - (1-\varepsilon^B)\left(\beta^B R^D E_t r_{t+1}^D + E_t\Delta\xi_{t+1}^C - E_t\Delta p_{t+1}^C\right) \quad \text{(B.8)} \\ & -(1-\varepsilon^B)\beta^B R^L\left[1-F\left(\bar{\omega},\sigma_\omega\right)\right]\left(r_t^L - \frac{F_\omega\left(\bar{\omega},\sigma_\omega\right)\bar{\omega}}{1-F\left(\bar{\omega},\sigma_\omega\right)}\hat{\bar{\omega}}_t^a - \frac{F_{\sigma_\omega}\left(\bar{\omega},\sigma_\omega\right)\sigma_\omega}{1-F\left(\bar{\omega},\sigma_\omega\right)}\hat{\sigma}_{\omega,t}\right), \end{aligned}$$

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

$$r_t^D = d_t^B - \tilde{s}_{t-1}^B + \frac{G_\omega\left(\bar{\omega},\sigma_\omega\right)\bar{\omega}}{G\left(\bar{\omega},\sigma_\omega\right)}\hat{\bar{\omega}}_{t-1}^p + \frac{G_{\sigma_\omega}\left(\bar{\omega},\sigma_\omega\right)\sigma_\omega}{G\left(\bar{\omega},\sigma_\omega\right)}\hat{\sigma}_{\omega,t-1} + q_t + \Delta p_t^C + \varepsilon_t^A. \quad \text{(B.9)}$$

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

$$\left[(\varphi-\iota_L)\alpha+\iota_L\right]l_t^{B,C} + (\varphi-\iota_L)(1-\alpha)\,l_t^{B,D} = \tilde{w}_t^C + \xi_t^C - \frac{c_t^B - \varepsilon^B\left(c_{t-1}^B - \varepsilon_t^A\right)}{1-\varepsilon^B}, \quad \text{(B.10)}$$

$$\left[(\varphi-\iota_L)(1-\alpha)+\iota_L\right]l_t^{B,D} + (\varphi-\iota_L)\alpha l_t^{B,C} = \tilde{w}_t^D + \xi_t^C - \frac{c_t^B - \varepsilon^B\left(c_{t-1}^B - \varepsilon_t^A\right)}{1-\varepsilon^B}. \quad \text{(B.11)}$$

The budget constraint of borrowers is:

$$\begin{aligned} & C^B c_t^B + \delta D^B(q_t + i_t^B) + R^D\tilde{S}^B\left[r_t^D + \tilde{s}_{t-1}^B - \Delta p_t^C - \varepsilon_t^A\right] \\ & + \left[1-F\left(\bar{\omega},\sigma_\omega\right)\right]R^L\tilde{S}^B\left[r_{t-1}^L + \tilde{s}_{t-1}^B - \Delta p_t^C - \varepsilon_t^A\right] \\ & - \left[1-F\left(\bar{\omega},\sigma_\omega\right)\right]R^L\tilde{S}^B\left[\frac{F_\omega\left(\bar{\omega},\sigma_\omega\right)\bar{\omega}}{1-F\left(\bar{\omega},\sigma_\omega\right)}\hat{\bar{\omega}}_{t-1}^p + \frac{F_{\sigma_\omega}\left(\bar{\omega},\sigma_\omega\right)\sigma_\omega}{1-F\left(\bar{\omega},\sigma_\omega\right)}\hat{\sigma}_{\omega,t-1}\right] \\ = \; & \tilde{S}^B\tilde{s}_t^B + \alpha WL^B(\tilde{w}_t^C + l_t^{B,C}) + (1-\alpha)WL^B(\tilde{w}_t^D + l_t^{B,D}). \quad \text{(B.12)} \end{aligned}$$

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

$$\begin{aligned}
&\frac{1}{\beta}\tilde{S}^B\left(r_t+\tilde{s}_t^B+\eta_t\right)\\
=\;&(1-\mu)D^BG\left(\bar{\omega},\sigma_\omega\right)\left[\frac{G_\omega\left(\bar{\omega},\sigma_\omega\right)\bar{\omega}}{G\left(\bar{\omega},\sigma_\omega\right)}\hat{\bar{\omega}}_t^a+\frac{G_{\sigma_\omega}\left(\bar{\omega},\sigma_\omega\right)\sigma_\omega}{G\left(\bar{\omega},\sigma_\omega\right)}\hat{\sigma}_{\omega,t}\right]\\
&+(1-\mu)D^BG\left(\bar{\omega},\sigma_\omega\right)\left[E_tq_{t+1}+E_td_{t+1}^B+E_t\Delta p_{t+1}^C\right]\\
&+\left[1-F\left(\bar{\omega},\sigma_\omega\right)\right]R^L\tilde{S}^B\left[r_t^L+\tilde{s}_t^B-\frac{F_\omega\left(\bar{\omega},\sigma_\omega\right)\bar{\omega}}{1-F\left(\bar{\omega},\sigma_\omega\right)}\hat{\bar{\omega}}_t^a-\frac{F_{\sigma_\omega}\left(\bar{\omega},\sigma_\omega\right)\sigma_\omega}{1-F\left(\bar{\omega},\sigma_\omega\right)}\hat{\sigma}_{\omega,t}\right].
\end{aligned}\tag{B.13}$$

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

$$\hat{\bar{\omega}}_t^a+E_t\left[q_{t+1}+d_{t+1}^B\right]=r_t^L+\tilde{s}_t^B-E_t\Delta p_{t+1}^C,\tag{B.14}$$

$$\hat{\bar{\omega}}_{t-1}^p+q_t+d_t^B=r_{t-1}^L+\tilde{s}_{t-1}^B-\Delta p_t^C-\varepsilon_t^A.\tag{B.15}$$

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

$$c_{H,t}=\iota_C(1-\tau)t_t+c_t^{TOT},\tag{B.16}$$

$$c_{F,t}=-\iota_C\tau t_t+c_t^{TOT},\tag{B.17}$$

where aggregate non-durable consumption is:

$$\left[\lambda C+(1-\lambda)C^B\right]c_t^{TOT}=\lambda Cc_t+(1-\lambda)C^Bc_t^B.\tag{B.18}$$

The production functions are given by:

$$y_t^C=z_t^C+l_t^{C,TOT},\tag{B.19}$$

$$y_t^D=z_t^D+l_t^{D,TOT},\tag{B.20}$$

where total hours in each sector are given by:

$$\left[\lambda L^C+(1-\lambda)L^{B,C}\right]l_t^{C,TOT}=\lambda L^Cl_t^C+(1-\lambda)L^{B,C}l_t^{B,C},\tag{B.21}$$

$$\left[\lambda L^D+(1-\lambda)L^{B,D}\right]l_t^{D,TOT}=\lambda L^Dl_t^D+(1-\lambda)L^{B,D}l_t^{B,D}.\tag{B.22}$$

The CPI is given by:

$$\Delta p_t^C=\tau\Delta p_{H,t}+(1-\tau)\Delta p_{F,t}.\tag{B.23}$$

The relative price of housing is:

$$q_t=q_{t-1}+\Delta p_t^D-\Delta p_t^C,\tag{B.24}$$

and the pricing equations are given by:

$$\Delta p_t^H-\varphi_C\Delta p_{t-1}^H=\beta E_t(\Delta p_{t+1}^H-\varphi_C\Delta p_t^H)+\kappa^C\left[\tilde{w}_t^C+(1-\tau)t_t-z_t^C\right],\tag{B.25}$$

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

$$\Delta p_t^D - \varphi_D \Delta p_{t-1}^D = \beta E_t(\Delta p_{t+1}^D - \varphi_D \Delta p_t^D) + \kappa^D \left[\tilde{w}_t^D - q_t - z_t^D\right], \tag{B.26}$$

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

$$y_t^C = \tau c_{H,t} + \frac{(1-n)(1-\tau^*)}{n} c_{H,t}^*. \tag{B.27}$$

Aggregate investment expenditures equal production of investment goods:

$$y_t^D = \frac{\lambda\delta D i_t + (1-\lambda)\delta D^B i_t^B}{\lambda\delta D + (1-\lambda)\delta D^B}, \tag{B.28}$$

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

$$d_t = (1-\delta) d_{t-1} + \delta i_{t-1} - \varepsilon_t^A, \tag{B.29}$$

$$d_t^B = (1-\delta) d_{t-1}^B + \delta i_{t-1}^B - \varepsilon_t^A. \tag{B.30}$$

Aggregated output is given by:

$$y_t = \alpha y_t^C + (1-\alpha)\left(y_t^D + q_t\right). \tag{B.31}$$

Foreign Country

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

$$q_t^* + \xi_t^{C^*} - \frac{c_t^* - \varepsilon(c_{t-1}^* - \varepsilon_t^A)}{1-\varepsilon} + \psi(i_t^* - i_{t-1}^* + \varepsilon_t^A) = E_t \varrho_{t+1}^* + \beta\psi(E_t i_{t+1}^* - i_t^*), \tag{B.32}$$

$$[1-\beta(1-\delta)]\left(\xi_t^{D^*} - d_t^*\right) = \varrho_t^* - \beta(1-\delta) E_t \varrho_{t+1}^*, \tag{B.33}$$

$$\varepsilon(\Delta c_t^* + \varepsilon_t^A) = E_t \Delta c_{t+1}^* - (1-\varepsilon)(r_t^* + E_t \Delta \xi_{t+1}^{C^*} - E_t \Delta p_{t+1}^{C^*}), \tag{B.34}$$

$$[(\varphi - \iota_L)\alpha + \iota_L]\, l_t^{C^*} + (\varphi - \iota_L)(1-\alpha) l_t^{D^*} = \tilde{w}_t^{C^*} + \xi_t^{C^*} - \frac{c_t^* - \varepsilon(c_{t-1}^* - \varepsilon_t^A)}{1-\varepsilon}, \tag{B.35}$$

$$\left[(\varphi-\iota_L)(1-\alpha)+\iota_L\right] l_t^{D^*}+(\varphi-\iota_L)\alpha l_t^{C^*}=\tilde{w}_t^{D^*}+\xi_t^{C^*}-\frac{c_t^*-\varepsilon(c_{t-1}^*-\varepsilon_t^A)}{1-\varepsilon}. \quad \text{(B.36)}$$

The same conditions for borrowers are:

$$q_t^*+\xi_t^{C^*}-\frac{c_t^{B^*}-\varepsilon^B(c_{t-1}^{B^*}-\varepsilon_t^A)}{1-\varepsilon^{B^*}}+\psi(i_t^{B^*}-i_{t-1}^{B^*}+\varepsilon_t^A)=E_t\varrho_{t+1}^{B^*}+\beta^B\psi(E_t i_{t+1}^{B^*}-i_t^{B^*}), \quad \text{(B.37)}$$

$$\left[1-\beta^B(1-\delta)\right]\left(\xi_t^{D^*}-d_t^{B^*}\right)=\varrho_t^{B^*}-\beta^B(1-\delta)E_t\varrho_{t+1}^{B^*}, \quad \text{(B.38)}$$

$$\begin{aligned}
& \varepsilon^B(\Delta c_t^{B^*}+\varepsilon_t^A) \\
= \;& E_t\Delta c_{t+1}^{B^*}-(1-\varepsilon^B)\left(\beta^B R^{D^*}E_t r_{t+1}^{D^*}+E_t\Delta\xi_{t+1}^{C^*}-E_t\Delta p_{t+1}^{C^*}\right) \quad \text{(B.39)} \\
& -(1-\varepsilon^B)\beta^B R^{L^*}\left[1-F\left(\bar{\omega},\sigma_\omega\right)\right]\left(r_t^{L^*}-\frac{F_\omega\left(\bar{\omega},\sigma_\omega\right)\bar{\omega}}{1-F\left(\bar{\omega},\sigma_\omega\right)}\hat{\bar{\omega}}_t^{a^*}-\frac{F_{\sigma_\omega}\left(\bar{\omega},\sigma_\omega\right)\sigma_\omega}{1-F\left(\bar{\omega},\sigma_\omega\right)}\hat{\sigma}_{\omega,t}^*\right),
\end{aligned}$$

$$r_t^{D^*}=d_t^{B^*}-\tilde{s}_{t-1}^{B^*}+\frac{G_\omega\left(\bar{\omega},\sigma_\omega\right)\bar{\omega}}{G\left(\bar{\omega},\sigma_\omega\right)}\hat{\bar{\omega}}_{t-1}^{p^*}+\frac{G_{\sigma_\omega}\left(\bar{\omega},\sigma_\omega\right)\sigma_\omega}{G\left(\bar{\omega},\sigma_\omega\right)}\hat{\sigma}_{\omega,t-1}^*+q_t^*+\Delta p_t^{C^*}+\varepsilon_t^A, \quad \text{(B.40)}$$

$$\left[\left(\varphi-\iota_L\right)\alpha+\iota_L\right] l_t^{B,C^*}+\left(\varphi-\iota_L\right)\left(1-\alpha\right) l_t^{B,D^*}=\tilde{w}_t^{C^*}+\xi_t^{C^*}-\frac{c_t^{B^*}-\varepsilon^B\left(c_{t-1}^{B^*}-\varepsilon_t^A\right)}{1-\varepsilon^B}, \quad \text{(B.41)}$$

$$\left[\left(\varphi-\iota_L\right)\left(1-\alpha\right)+\iota_L\right] l_t^{B,D^*}+\left(\varphi-\iota_L\right)\alpha l_t^{B,C^*}=\tilde{w}_t^{D^*}+\xi_t^{C^*}-\frac{c_t^{B^*}-\varepsilon^B\left(c_{t-1}^{B^*}-\varepsilon_t^A\right)}{1-\varepsilon^B}. \quad \text{(B.42)}$$

The budget constraint of borrowers is:

$$\begin{aligned}
& C^{B*}c_t^{B*}+\delta D^{B*}(q_t^*+i_t^{B*})+R^{D*}\tilde{S}^{B*}\left[r_t^{D*}+\tilde{s}_{t-1}^{B*}-\Delta p_t^{C*}-\varepsilon_t^A\right] \\
& +\left[1-F\left(\bar{\omega},\sigma_\omega\right)\right]R^{L*}\tilde{S}^{B*}\left[r_{t-1}^{L*}+\tilde{s}_{t-1}^{B*}-\Delta p_t^{C*}-\varepsilon_t^A\right] \\
& -\left[1-F\left(\bar{\omega},\sigma_\omega\right)\right]R^{L*}\tilde{S}^{B*}\left[\frac{F_\omega\left(\bar{\omega},\sigma_\omega\right)\bar{\omega}}{1-F\left(\bar{\omega},\sigma_\omega\right)}\hat{\bar{\omega}}_{t-1}^{p*}+\frac{F_{\sigma_\omega}\left(\bar{\omega},\sigma_\omega\right)\sigma_\omega}{1-F\left(\bar{\omega},\sigma_\omega\right)}\hat{\sigma}_{\omega,t-1}^*\right] \\
= \;& \tilde{S}^{B*}\tilde{s}_t^{B*}+\alpha W^*L^{B*}(\tilde{w}_t^{C*}+l_t^{B,C*})+(1-\alpha)W^*L^{B*}(\tilde{w}_t^{D*}+l_t^{B,D*}). \quad \text{(B.43)}
\end{aligned}$$

The participation constraint of financial intermediaries:

$$\begin{aligned}
& \frac{1}{\beta}\tilde{S}^{B^*}\left(r_t^*+\tilde{s}_t^{B^*}+\eta_t^*\right) \\
= \;& (1-\mu)D^{B^*}G\left(\bar{\omega},\sigma_\omega\right)\left[\frac{G_\omega\left(\bar{\omega},\sigma_\omega\right)\bar{\omega}}{G\left(\bar{\omega},\sigma_\omega\right)}\hat{\bar{\omega}}_t^{a*}+\frac{G_{\sigma_\omega}\left(\bar{\omega},\sigma_\omega\right)\sigma_\omega}{G\left(\bar{\omega},\sigma_\omega\right)}\hat{\sigma}_{\omega,t}^*\right] \\
& +(1-\mu)D^{B^*}G\left(\bar{\omega},\sigma_\omega\right)\left[E_t q_{t+1}^*+E_t d_{t+1}^{B^*}+E_t\Delta p_{t+1}^{C^*}\right] \quad \text{(B.44)} \\
& +\left[1-F\left(\bar{\omega},\sigma_\omega\right)\right]R^{L^*}\tilde{S}^{B^*}\left[r_t^{L^*}+\tilde{s}_t^{B^*}-\frac{F_\omega\left(\bar{\omega},\sigma_\omega\right)\bar{\omega}}{1-F\left(\bar{\omega},\sigma_\omega\right)}\hat{\bar{\omega}}_t^{a*}-\frac{F_{\sigma_\omega}\left(\bar{\omega},\sigma_\omega\right)\sigma_\omega}{1-F\left(\bar{\omega},\sigma_\omega\right)}\hat{\sigma}_{\omega,t}^*\right].
\end{aligned}$$

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

$$\hat{\bar{\omega}}_t^{a*} + E_t\left[q_{t+1}^* + d_{t+1}^{B^*}\right] = r_t^{L*} + \tilde{s}_t^{B^*} - E_t\Delta p_{t+1}^{C^*}, \tag{B.45}$$

$$\hat{\bar{\omega}}_{t-1}^{p*} + q_t^* + d_t^{B^*} = r_{t-1}^{L*} + \tilde{s}_{t-1}^{B^*} - \Delta p_t^{C^*} - \varepsilon_t^A. \tag{B.46}$$

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

$$c_{H,t}^* = \iota_C \tau^* t_t + c_t^{TOT^*}, \tag{B.47}$$

$$c_{F,t}^* = -\iota_C(1-\tau^*)t_t + c_t^{TOT^*}, \tag{B.48}$$

where aggregate non-durable consumption is:

$$\left[\lambda C^* + (1-\lambda)C^{B^*}\right] c_t^{TOT^*} = \lambda C^* c_t^* + (1-\lambda)C^{B^*} c_t^{B^*}. \tag{B.49}$$

The production functions are given by:

$$y_t^{C^*} = z_t^{C^*} + l_t^{C,TOT^*}, \tag{B.50}$$

$$y_t^{D^*} = z_t^{D^*} + l_t^{D,TOT^*}, \tag{B.51}$$

where total hours in each sector are given by:

$$\left[\lambda L^{C^*} + (1-\lambda)L^{B,C^*}\right] l_t^{C,TOT^*} = \lambda L^{C^*} l_t^{C^*} + (1-\lambda)L^{B,C^*} l_t^{B,C^*}, \tag{B.52}$$

$$\left[\lambda L^{D^*} + (1-\lambda)L^{B,D^*}\right] l_t^{D,TOT^*} = \lambda L^{D^*} l_t^{D^*} + (1-\lambda)L^{B,D^*} l_t^{B,D^*}. \tag{B.53}$$

The CPI is:

$$\Delta p_t^{C^*} = (1-\tau^*)\Delta p_{H,t} + \tau^* \Delta p_{F,t}. \tag{B.54}$$

The relative price of housing is:

$$q_t^* = q_{t-1}^* + \Delta p_t^{D^*} - \Delta p_t^{C^*}, \tag{B.55}$$

and the pricing equations are given by:

$$\Delta p_t^F - \varphi_C^* \Delta p_{t-1}^F = \beta E_t(\Delta p_{t+1}^F - \varphi_C^* \Delta p_t^F) + \kappa^{C^*}\left[\tilde{w}_t^{C^*} - (1-\tau^*)t_t - z_t^{C^*}\right], \tag{B.56}$$

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

$$\Delta p_t^{D^*} - \varphi_D^* \Delta p_{t-1}^{D^*} = \beta E_t(\Delta p_{t+1}^{D^*} - \varphi_D^* \Delta p_t^{D^*}) + \kappa^{D^*}\left[\tilde{w}_t^{D^*} - q_t^* - z_t^{D^*}\right], \tag{B.57}$$

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

$$y_t^{C^*} = \tau^* c_{F,t}^* + \frac{n(1-\tau)}{1-n} c_{F,t}. \tag{B.58}$$

Aggregate investment expenditures equal production of investment goods:

$$y_t^{D^*} = \frac{\lambda\delta D^* i_t^* + (1-\lambda)\delta D^{B^*} i_t^{B^*}}{\lambda\delta D^* + (1-\lambda)\delta D^{B^*}}, \tag{B.59}$$

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

$$d_t^* = (1-\delta)d_{t-1}^* + \delta i_{t-1}^* - \varepsilon_t^A, \tag{B.60}$$

$$d_t^{B^*} = (1-\delta)d_{t-1}^{B^*} + \delta i_{t-1}^{B^*} - \varepsilon_t^A. \tag{B.61}$$

Aggregated output is given by:

$$y_t^* = \alpha^* y_t^{C^*} + (1-\alpha^*)\left(y_t^{D^*} + q_t^*\right). \tag{B.62}$$

Euro Area Variables and Other Equations

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

$$r_t^* = r_t + \beta\left(\kappa_b b_t + \vartheta_t\right). \tag{B.63}$$

The evolution of net foreign assets is:

$$\lambda b_t = \lambda\frac{1}{\beta}b_{t-1} + \frac{(1-n)(1-\tau^*)}{n}\left(c_{H,t}^* - t_t\right) - (1-\tau)c_{F,t}, \tag{B.64}$$

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

$$t_t = t_{t-1} + \Delta p_t^F - \Delta p_t^H. \tag{B.65}$$

The monetary policy Taylor rule conducted by the ECB reads:

$$r_t = \gamma_R r_{t-1} + (1-\gamma_R)\left[\gamma_\pi \Delta p_t^{EMU} + \gamma_\pi\left(y_t^{EMU} - y_{t-1}^{EMU} + \varepsilon_t^A\right)\right] + \varepsilon_t^m, \tag{B.66}$$

where the euro area CPI and output is given by:

$$\Delta p_t^{EMU} = n\Delta p_t^C + (1-n)\Delta p_t^{C^*}, \tag{B.67}$$

$$y_t^{EMU} = n y_t + (1-n)y_t^*. \tag{B.68}$$

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

$$\eta_t = \gamma_\eta \Upsilon_t, \tag{B.69}$$

$$\eta_t^* = \gamma_\eta \Upsilon_t^*. \tag{B.70}$$

Shock Processes

All shocks included in the model evolve according to:

$$\begin{aligned}
\xi_t^C &= \rho_{\xi,H}\xi_{t-1}^C + \varepsilon_t^{\xi,C}, && \text{(B.71)}\\
\xi_t^{C^*} &= \rho_{\xi,H}\xi_{t-1}^{C^*} + \varepsilon_t^{\xi,C^*}, && \text{(B.72)}\\
\xi_t^D &= \rho_{\xi,D}\xi_{t-1}^D + \varepsilon_t^{\xi,D} + \varepsilon_t^{\xi,D,COM}, && \text{(B.73)}\\
\xi_t^{D^*} &= \rho_{\xi,D}\xi_{t-1}^{D^*} + \varepsilon_t^{\xi,D^*} + \varepsilon_t^{\xi,D,COM}, && \text{(B.74)}\\
z_t^C &= \rho_{Z,C} z_{t-1}^C + \varepsilon_t^{Z,C} + \varepsilon_t^{Z,C,COM}, && \text{(B.75)}\\
z_t^{C^*} &= \rho_{Z,C} z_{t-1}^{C^*} + \varepsilon_t^{Z,C^*} + \varepsilon_t^{Z,C,COM}, && \text{(B.76)}\\
z_t^D &= \rho_{Z,D} z_{t-1}^D + \varepsilon_t^{Z,D}, && \text{(B.77)}\\
z_t^{D^*} &= \rho_{Z,D} z_{t-1}^{D^*} + \varepsilon_t^{Z,D^*}, && \text{(B.78)}\\
\sigma_{\omega,t} &= (1-\rho_{\sigma\omega})\,\bar{\sigma}_\omega + \rho_{\sigma\omega}\sigma_{\omega,t-1} + u_{\omega,t}, && \text{(B.79)}\\
\sigma_{\omega,t}^* &= (1-\rho_{\sigma\omega})\,\bar{\sigma}_\omega + \rho_{\sigma\omega}\sigma_{\omega,t-1}^* + u_{\omega,t}^*, && \text{(B.80)}\\
\vartheta_t &= \rho_\vartheta \vartheta_{t-1} + \varepsilon_t^\vartheta, && \text{(B.81)}
\end{aligned}$$

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

C Additional Estimation Results

Table C.1: Prior and Posterior Distributions, Shock Processes

	Parameters		Prior		Posterior	
	AR(1) coefficients		Mean	S.D.	Mean	90% C.S.
$\rho_{Z,C}$	Technology, non-durables	Beta	0.7	0.1	0.79	[0.72,0.87]
$\rho_{Z,D}$	Technology, durables	Beta	0.7	0.1	0.86	[0.79,0.93]
$\rho_{\xi,C}$	Preference, non-durables	Beta	0.7	0.1	0.66	[0.52,0.82]
$\rho_{\xi,D}$	Preference, durables	Beta	0.7	0.1	0.98	[0.97,0.99]
ρ_{ω}	Risk shock, durables	Beta	0.7	0.1	0.84	[0.80,0.88]
ρ_{ϑ}	Risk premium, core-periphery	Beta	0.7	0.1	0.78	[0.67,0.90]
	Std. Dev. Shocks (in percent)					
σ_A	Technology, EMU-wide	Gamma	0.7	0.2	0.83	[0.61,1.04]
σ_Z^C	Tech., non-durables, core	Gamma	0.7	0.2	0.62	[0.42,0.83]
$\sigma_Z^{C^*}$	Tech., non-durables, periphery	Gamma	0.7	0.2	0.66	[0.40,0.90]
$\sigma_Z^{C,COM}$	Tech., non-durables, common	Gamma	0.7	0.2	0.74	[0.54,0.95]
σ_Z^D	Tech., durables, core	Gamma	0.7	0.2	1.62	[1.27,1.68]
$\sigma_Z^{D^*}$	Tech., durables, periphery	Gamma	0.7	0.2	1.43	[1.10,1.74]
σ_ξ^C	Preference, non-durables, core	Gamma	1	0.5	1.87	[1.35,2.41]
$\sigma_\xi^{C^*}$	Pref., non-durables, periphery	Gamma	1	0.5	1.41	[0.90,1.95]
σ_ξ^D	Pref., durables, core	Gamma	1	0.5	3.09	[2.19,3.97]
$\sigma_\xi^{D^*}$	Pref., durables, periphery	Gamma	1	0.5	3.25	[2.39,4.06]
$\sigma_\xi^{D,COM}$	Pref., durables, common	Gamma	1	0.5	1.46	[0.62,2.22]
σ_m	Monetary	Gamma	0.4	0.2	0.12	[0.1,0.14]
σ_ϑ	Risk premium, international	Gamma	0.4	0.2	0.2	[0.1,0.3]
$\sigma_{u_{\omega,t}}$	Risk shock, durables, core	Gamma	25	12.5	11.79	[8.74,15.00]
$\sigma_{u^*_{\omega,t}}$	Risk shock, durables, periphery	Gamma	25	12.5	23.06	[17.25, 28.53]

Table C.2: Correlation Matrix

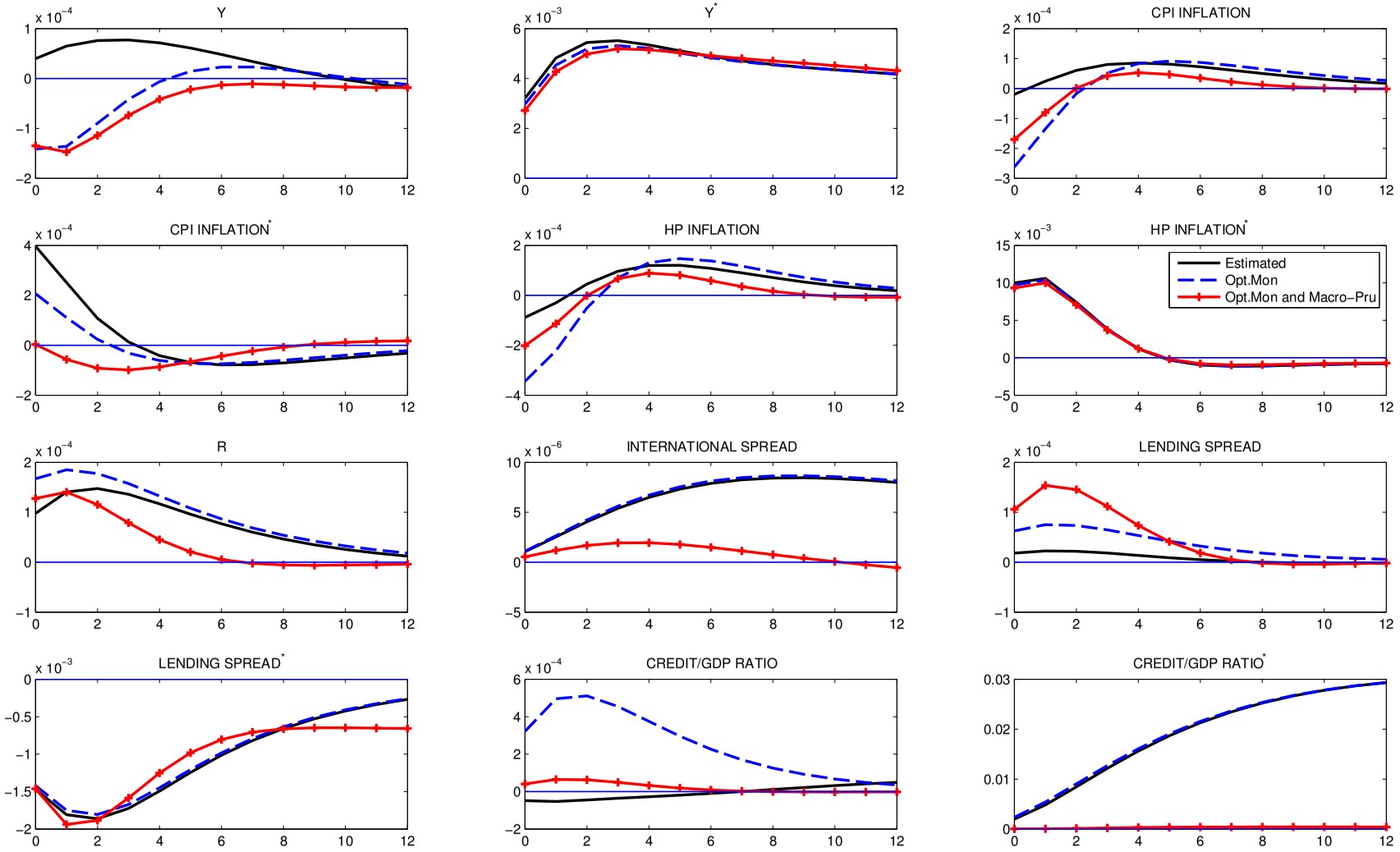
	r	Δp^C	Δc	Δy^D	Δp^D	Δs	Δp^{C*}	Δc^*	Δy^{D*}	Δp^{D*}
Δp^C	0.01	1								
	[0.25,0.45]	1								
Δc	0.08	-0.17	1							
	[-0.25, -0.18]	[-0.26,-0.08]	1							
Δy^D	-0.21	-0.04	0.09	1						
	[-0.03,0.03]	[0.03,0.12]	[0.10,0.25]	1						
Δp^D	-0.49	0.03	0.30	0.34	1					
	[-0.08,0.03]	[-0.36,0.04]	[-0.01,0.18]	[0.19,0.48]	1					
Δs	0.09	-0.03	0.20	0.21	0.35	1				
	[0.08,0.31]	[-0.07,0.13]	[0.04,0.21]	[0.26,0.43]	[0.42,0.59]	1				
Δp^{C*}	0.20	0.74	-0.12	0.13	0.13	0.05	1			
	[0.25,0.46]	[0.49,0.73]	[-0.21,-0.10]	[-0.02,0.06]	[-0.21,-0.08]	[-0.02,0.09]	1			
Δc^*	0.20	-0.03	0.31	0.15	0.28	0.64	0.14	1		
	[-0.25,-0.18]	[-0.25,-0.11]	[0.28,0.49]	[0.12,0.26]	[0.11,0.23]	[0.08,0.18]	[-0.15,0.07]	1		
Δy^{D*}	0.19	0.12	0.37	0.27	0.37	0.48	0.33	0.65	1	
	[-0.05,0.00]	[-0.03,0.05]	[0.10,0.24]	[0.12,0.33]	[0.05,0.23]	[0.05,0.16]	[0.09,0.19]	[0.16, 0.33]	1	
Δp^{D*}	0.12	-0.09	0.17	0.03	0.36	0.27	0.10	0.54	0.62	1
	[-0.07,0.00]	[-0.21,-0.07]	[0.08,0.19]	[0.06,0.23]	[0.07,0.32]	[0.07,0.20]	[-0.11,0.08]	[0.05,0.27]	[0.22,0.50]	1
Δs^*	0.31	0.04	0.14	0.06	0.27	0.43	0.25	0.61	0.58	0.73
	[0.13,0.25]	[-0.06,0.05]	[0.04,0.11]	[0.04,0.13]	[0.10,0.18]	[0.10,0.23]	[0.05,0.25]	[-0.03,0.11]	[0.23,0.34]	[0.34,0.44]

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

Table C.3: Posterior Variance Decomposition (90 percent confidence set)

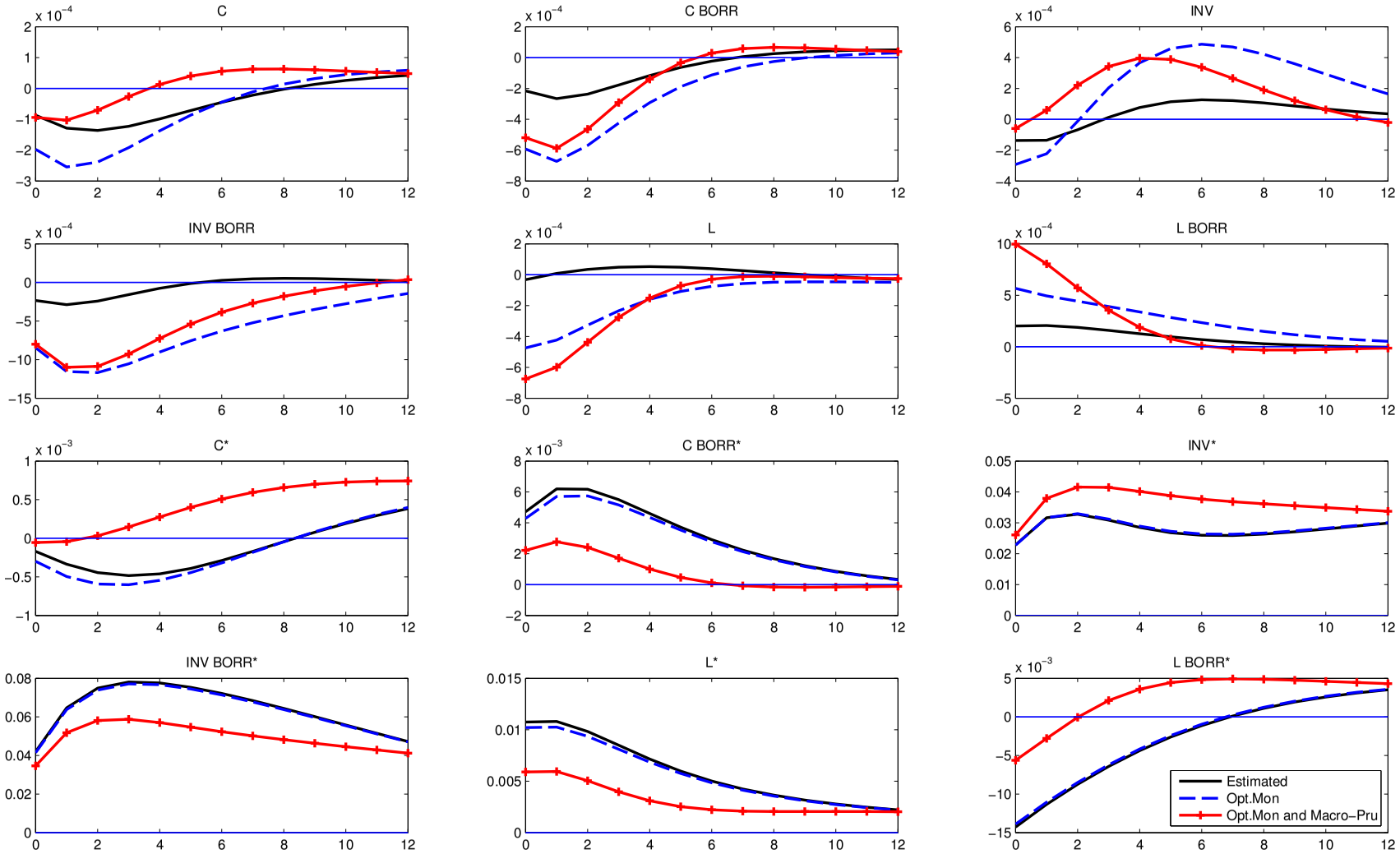
	Shocks	
r	Common Nondurable Technology [31.9, 60.2]	Core Nondurable Technology [8.3, 27.3]
Δp^C	Common Nondurable Technology [25.5, 51.1]	Core Nondurable Technology [15.5, 40.9]
Δc	Core Nondurable Preference [48.5, 71.6]	EMU-wide Technology [15.5, 36.7]
Δy^D	Core Durable Preference [31.2, 60.3]	Core Durable Technology [19.5, 40.0]
Δp^D	Core Durable Preference [30.4, 54.7]	Core Durable Technology [16.8, 29.5]
Δs	Risk Core [34.9, 59.8]	Core Durable Preference [17.2, 41.7]
Δp^{C*}	Common Nondurable Technology [19.2, 39.6]	Country Risk Premium [13.8, 36.8]
Δc^*	Periphery Nondurable Preference [23.1, 56.7]	EMU-wide Technology [21.0, 49.0]
Δy^{D*}	Periphery Durable Preference [34.3, 58.2]	Periphery Durable Technology [19.4, 33.3]
Δp^{D*}	Periphery Durable Preference [31.5, 61.2]	Periphery Durable Technology [13.4, 33.1]
Δs^*	Risk Periphery [62.3, 81.8]	Periphery Durable Preference [8.9, 19.6]

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



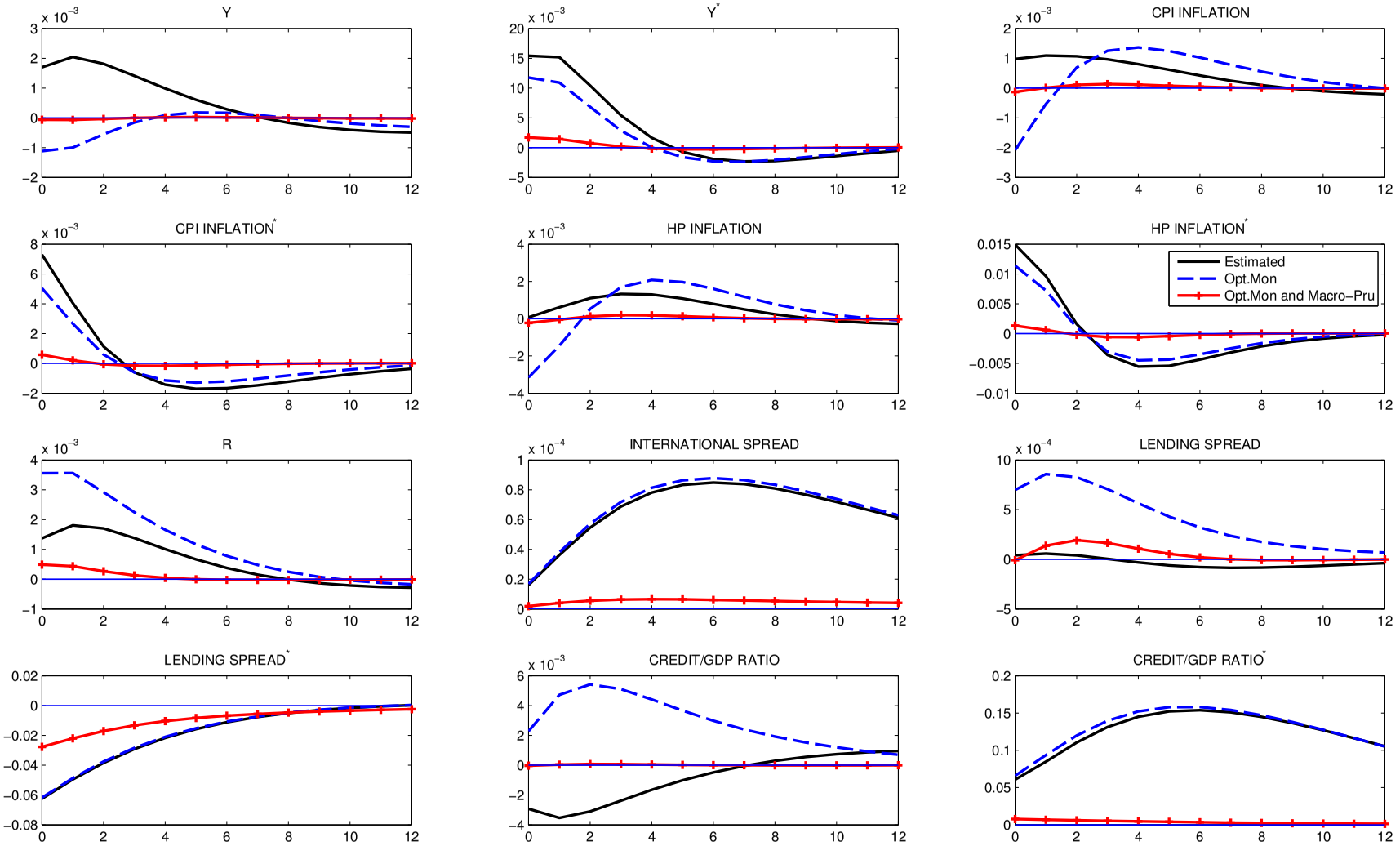
NOTE: Three different policy regimes are compared: Using the estimated Taylor rule, the optimized Taylor rule (Table 5, first row) and the optimal monetary and macroprudential policy (Table 6, third row).

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



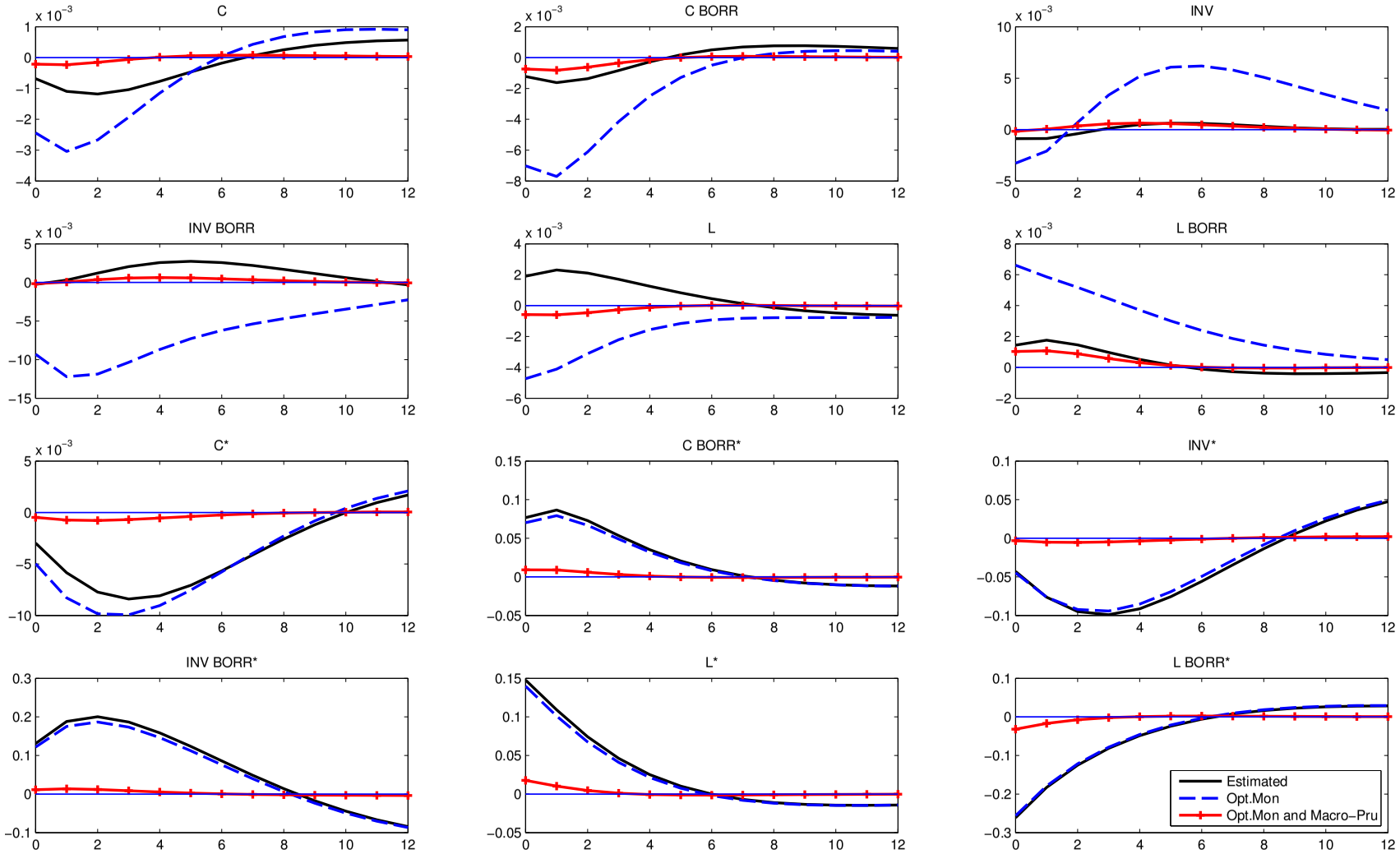
NOTE: Three different policy regimes are compared: Using the estimated Taylor rule, the optimized Taylor rule (Table 5, first row) and the optimal monetary and macroprudential policy (Table 6, third row).

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



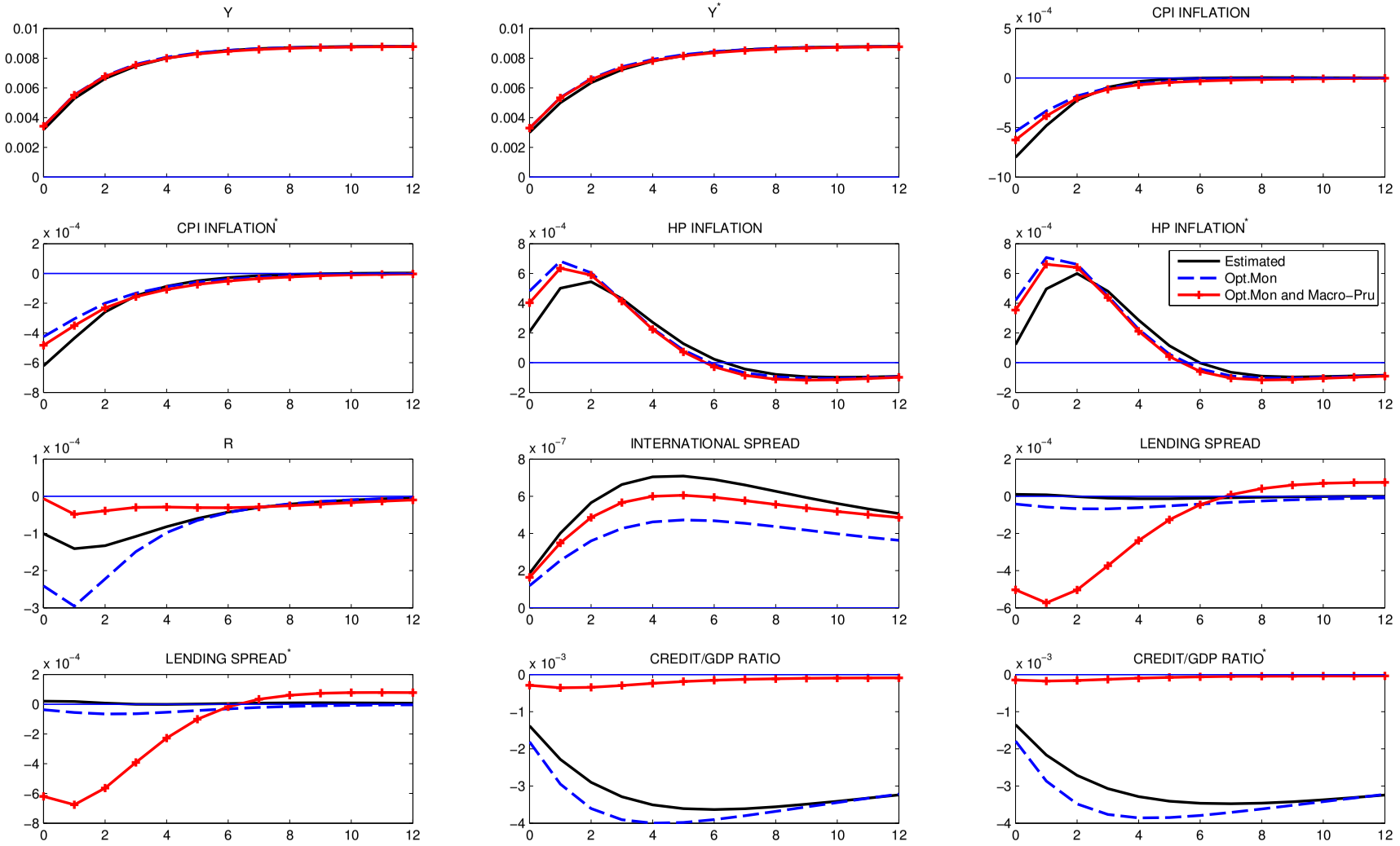
NOTE: Three different policy regimes are compared: Using the estimated Taylor rule, the optimized Taylor rule (Table 5, first row) and the optimal monetary and macroprudential policy (Table 6, third row).

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



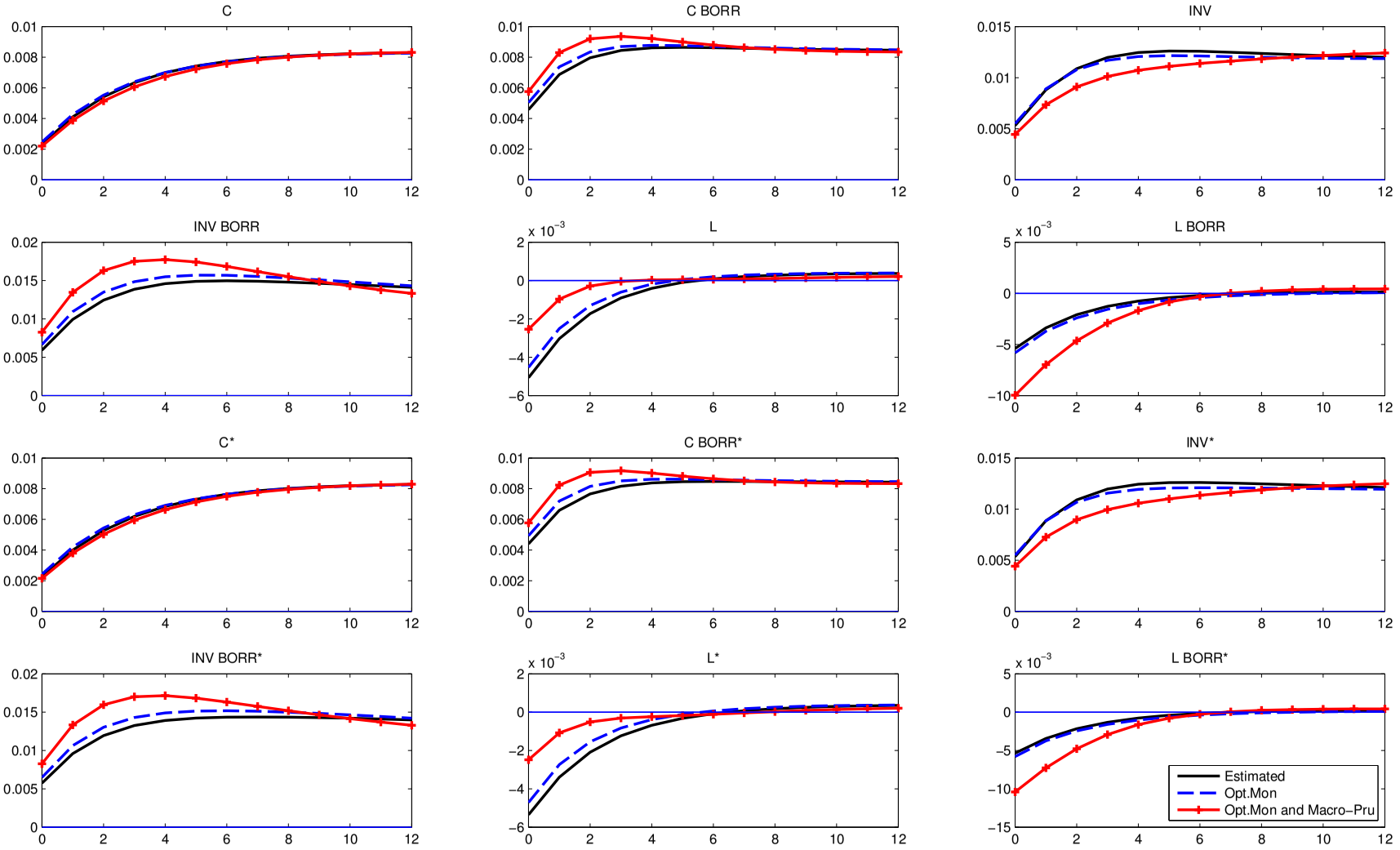
NOTE: Three different policy regimes are compared: Using the estimated Taylor rule, the optimized Taylor rule (Table 5, first row) and the optimal monetary and macroprudential policy (Table 6, third row).

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



NOTE: Three different policy regimes are compared: Using the estimated Taylor rule, the optimized Taylor rule (Table 5, first row) and the optimal monetary and macroprudential policy (Table 6, third row).

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



NOTE: Three different policy regimes are compared: Using the estimated Taylor rule, the optimized Taylor rule (Table 5, first row) and the optimal monetary and macroprudential policy (Table 6, third row).

Diskussionsbeiträge - Fachbereich Wirtschaftswissenschaft - Freie Universität Berlin
Discussion Paper - School of Business and Economics - Freie Universität Berlin

2014 bereits erschienen:

2014/1 FOSSEN, Frank M.; Ronny FREIER und Thorsten MARTIN
Race to the debt trap? : Spatial econometric evidence on debt in German municipalities
Economics

2014/2 SCHREIBER, Sven
Anticipating business-cycle turning points in real time using density forescasts from a VAR
Economics

2014/3 FOSSEN, Frank M. und Daniela Glocker
Stated and revealed heterogeneous risk preferences in educational choice
Economics

2014/4 KNABE, Andreas, Ronnie SCHÖB und Marcel THUM
Der flächendeckende Mindestlohn
Economics