Oxford Economic Papers, 2024, **76**, 351–374
https://doi.org/10.1093/oep/gpad012
Advance access publication 21 April 2023
Article

Macroprudential policy implementation in a heterogeneous monetary union

Margarita Rubio[1]*

[1]School of Economics, University of Nottingham, NG7 2RD Nottingham, UK
*Corresponding author: Email: margarita.rubio@nottingham.ac.uk

Abstract

In this article, I develop a two-country new Keynesian general equilibrium model with housing and collateral constraints to explore how macroprudential policies should be conducted in a heterogeneous monetary union. I consider several types of cross-country heterogeneity: asymmetric shocks, different leveraged countries, and mortgage contract heterogeneity (fixed and variable rates). As a macroprudential tool, I propose a Taylor-type rule for the loan-to-value ratio, which responds to deviations in output and house prices. This policy can be applied at a national or union level. Results show that structural asymmetries matter for the implementation of macroprudential policies, especially when the heterogeneity delivers differences in economic and financial volatilities. It seems then adequate to delegate macroprudential policies to national authorities. However, a supranational institution could also help stabilize the whole union when there are asymmetric shocks.

JEL classifications: E32, E44, F36

> Looking ahead, I am convinced that the complementarity of the ECB's monetary policy strategy to the new EU framework for macro-prudential oversight will contribute to enhancing crisis prevention and to strengthening the resilience of the European financial system, in an environment of price stability. We should not forget—and the crisis will not allow us to forget at least for some time—that prevention is always better than cure. Lucas Papademos, 3 May 2010.

1. Introduction

The severe crisis we experienced in 2008 taught us that we need to use policies to prevent such episodes from happening again. The crisis has made it clear the necessity of introducing policies and regulations that restrict credit and contribute to financial stability. The new direction of policy interventions is the so-called macroprudential approach. As opposed to microprudential policies, the macroprudential approach is systemwide in the supervision of financial institutions. Macroprudential policies aim at building defences that contain the effects of downturns on the economy and avoid sources of contagion and spillover risks. Scholars and policymakers agree that macroprudential measures could help avoid systemic risks and ensure a more stable financial system.

Although the empirical evidence is still scarce, some central banks and institutions have already successfully implemented policies of this type, including the euro area. Yet the European Union (EU) institutional framework for macroprudential policy is complex and still developing. It comprises various authorities with a macroprudential mandate at national level, the European Central Bank (ECB) with specific macroprudential competences at the Banking Union level, and the European Systemic Risk Board (ESRB) with no binding powers but a broad mandate at EU level.

In the euro area, macroprudential policy is of particular relevance. Indeed, within the framework of the single monetary policy, member states can no longer use the interest rate to address domestic imbalances. Countries in the euro zone are no longer able to manage their own monetary policy and rely on a single central bank that acts in favour of majority. This always calls for the needs of other policies to complement monetary policy because the interest-rate policy alone cannot be used to stabilize the economy of a particular member if the economy is hit by an asymmetric shock or when there are structural differences across members. One of the candidates is macroprudential policy.

In this context, cross-country asymmetries or country-specific shocks are certainly an issue of concern when designing the optimal implementation of macroprudential policy. Asymmetries in a monetary union are relevant for the conduct of macroprudential policies, especially when heterogeneity results in differences in aggregate financial and macroeconomic volatility. Countries in Europe clearly differ in their housing markets. There is evidence of different loan-to-value (LTV) ratios, different proportions of residential debt relative to GDP across countries, and heterogeneous mortgage contracts. Table A1 in the Supplementary Appendix shows that countries in Europe have different LTVs, as well as different residential-debt-to-GDP ratios. LTVs are as low as 50% in Italy and as high as 90% in the Netherlands, where the residential debt-to-GDP ratio exceeds 100%. In countries such as Germany or France, the majority of mortgages are fixed rate. Conversely, the predominant type of mortgages in such countries as the Spain or Greece is variable rate. Broadly speaking, we can distinguish two groups of countries: the peripheral countries (Greece, Ireland, Italy, Portugal, and Spain; known as GIIPS) and the remaining countries.

The EU has already set up an institutional framework for macroprudential policy, which includes countries in the euro area. It comprises various authorities with a macroprudential mandate at national level, the ECB with specific macroprudential competences at the Banking Union level, and the ESRB, with no binding powers but a broad mandate at EU level. The ESRB is the main body responsible for monitoring macroprudential policies, although each country can implement its own policy. That is, macroprudential policies are implemented at a national level, but within a system of central supervision. The single supervisory mechanism (SSM) regulation assigns macroprudential responsibilities to both the national authorities and the ECB, who are thus jointly responsible for macroprudential policy.[1] The ESRB is responsible for the macroprudential oversight of the EU's financial system and contributes to the prevention or mitigation of systemic risks to financial stability arising from developments within financial markets. Along these lines, the ESRB recommended in 2011 that Member States should designate a national authority entrusted with the conduct of macroprudential policy. Therefore, the solution that has been adopted so far is a hybrid one, inclined towards decentralization but with a strong component of centralization in the form of supervision, monitoring, and coordination. An important issue that arises, given this framework, is whether the division of labour among the ECB/SSM, the ESRB, and the national authorities is sufficiently clear and adequate, and which institution should have a higher weight in the design of macroprudential policies.

In light of all these issues, this article tries to answer a very important research question: How prudential regulation should be conducted in a heterogeneous monetary union? And

[1] The SSM is the first pillar of the banking union. Under the SSM, the ECB is the central prudential supervisor of financial institutions in the euro area and in non-euro EU countries that choose to join the SSM.

in particular, should this policy be centralized or decentralized? To give an answer to this question, I study what the welfare effects of macroprudential policy in a monetary union with heterogeneous countries are. This is very intriguing, from both a theoretical and practical perspective. The theoretical challenge is to understand how macroprudential policy alleviates inefficiencies introduced by collateral constraints, and how these inefficiencies and the policy channel change with the underlying asymmetries. Practically, it has been argued that macroprudential policy could have helped to cushion the drop in welfare during the recent European crisis, but a careful analysis that takes into account the differences across countries in the European Union is missing. This article aims at filling this important gap.

From a modelling perspective, I develop a two-country new Keynesian general equilibrium model with housing and collateral constraints, allowing for cross-country differences in mortgage and housing markets as well as asymmetric technology shocks. Specifically, I allow for differences in leverage across countries, as a proxy for different strengths of the financial accelerator. I also consider differences in the structure of mortgage contracts (fixed versus variable rate).

I propose an implementation of the macroprudential policy which is analogous to how monetary policy is conducted. I assume the same way that the central bank follows a Taylor rule for monetary policy, the macroprudential authority also follows a linear rule to carry out the macroprudential policy, using the LTV as an instrument. The monetary policy literature has extensively shown that simple rules result in a good performance; therefore, it seems sensible to apply this kind of rule to macroprudential supervision.[2] I consider a rule for the LTV ratio which responds to output and house prices. In this way, booms that lead to an increase in borrowing are moderated.[3] Since the implementation of macroprudential policies is still at its infancy, this approach is very useful because it helps seeing these new policies through the lens of traditional policies.

The basic modelling framework follows Rubio (2014), to which I add macroprudential measures. In each country, there is a group of individuals that are credit constrained and need housing collateral to obtain loans. Countries trade goods, and savers in each country have access to foreign assets. I obtain the optimal combination of LTV rule reaction parameters that maximizes welfare for each source of asymmetry, given monetary policy.

This article relates to different strands of the literature. The model constitutes a two-country version of the seminal paper of Iacoviello (2005), that introduces a financial accelerator that works through the housing sector, in the flavour of Aspachs and Rabanal (2010). However, it introduces cross-country housing-market heterogeneity as in Rubio (2014). This article is also related to the recent literature on macroprudential and monetary policies in Iacoviello-type models such as in the aforementioned Kannan *et al.* (2012) or Rubio and Carrasco-Gallego (2013, 2014). However, it explores the issue in a two-country setting as in Brzoza-Brzezina *et al.* (2015). However, the mentioned paper only considers country size and asymmetric shocks as the only source of heterogeneity; it is silent about the effects of institutional or housing market asymmetries on the implementation of macroprudential measures. In the same way, Quint and Rabanal (2014) estimate a similar two-country model using data on core and periphery countries of the EU, but assume the same LTVs, fraction of borrowers, and mortgage contracts across the two regions. My article tries to remedy this shortcoming. The novelty of my article is that I introduce structural differences across countries, namely differences in the financial accelerator strength and different mortgage structures, and I find that they matter for the optimal conduct of

[2] We can find other examples of LTV rules in the literature. Funke and Paetz (2012) use a non-linear rule on the LTV and find that it can help reduce the transmission of house price cycles to the real economy. In a similar way, Kannan *et al.* (2012) examine a monetary policy rule that reacts to prices, output, and changes in collateral values with a macroprudential instrument based on the LTV. Lambertini *et al.* (2013) allow for the implementation of both interest-rate and LTV policies in a model with news shocks.

[3] The IMF (2008) states that a macroeconomic environment which gives rise to credit growth will contribute to the build-up of systemic risk.

macroprudential policies. It is not the focus of this article to study the coordination problem between the two policies as in Quint and Rabanal (2014) and Angelini *et al.* (2014). In this article, I restrict the problem to the special case in which the macroprudential regulator takes monetary policy as given, and study if it should be conducted at a national or at a union level, depending on the structure of the economy. I strictly focus on the effect of cross-country structural asymmetries strictly on macroprudential policies, which is the topic that is unexplored. On the other hand, this article also represents a general framework to similar papers that restrict the analysis to specific countries such as Rubio and Comunale (2017) for Lithuania or Rubio and Carrasco-Gallego (2016) for Spain. These latter papers cover questions that are related with a particular periphery country in the euro area, while the present contribution is to cover more general questions related to the euro area. Therefore, the model is calibrated in a general way and counterfactuals are undertaken from a theoretical point of view, without having in mind any particular country. This contribution is important because it provides a general theoretical framework that can shed some light to some applied issues in the euro area and then be calibrated to different countries as the abovementioned studies do.

Results show that asymmetries in a monetary union are relevant for the conduct of macroprudential policies, especially when heterogeneity results in differences in aggregate volatility. When the heterogeneity only comes from asymmetric shocks, centralized policies are acceptable. If business cycles are not synchronized, having decentralized macroprudential policies which are not well coordinated worsens the situation. Macroprudential policies can help re-synchronize business cycles. However, when the asymmetry comes from structural differences in the economy such as more leveraged housing markets or different mortgage contracts, decentralized macroprudential policies are advisable. In more leveraged countries, as it is the case of peripheral economies, financial accelerator effects are stronger. When implementing a countercyclical LTV rule, it would be optimal to respond more strongly to developments in the macroeconomy and not only to credit markets in order to equalize the effects of the financial accelerator across countries. A very interesting case is the asymmetry coming from different mortgage contracts. Under fixed rates, monetary policy is less effective in stabilizing the macroeconomy. Therefore, in countries in which mortgages are mostly fixed rate, as it usually happens in core economies, macroprudential policies could be used to compensate for this lack of effectiveness.[4]

This article is organized as follows. Section 2 describes the model. Section 3 presents the parameter values. Section 4 presents the results. Section 5 concludes. Tables, steady-state relationships, and the linearized model are shown in the Supplementary Appendix.

2. Model setup

I consider an infinite-horizon, two-country economy inside a monetary union. The home country is denoted by A and the rest of the union by B. Households consume, work, and demand real estate. There is a financial intermediary in each country that provides mortgages and accepts deposits from consumers. Each country produces one differentiated intermediate good, but households consume goods from both countries. For simplicity, housing is a non-traded good. I assume that labour is immobile across the countries. Firms follow a standard Calvo problem. In this economy, both final and intermediate goods are produced. Prices are sticky in the intermediate-goods sector. Monetary policy is conducted by a single central bank that responds to a weighted average of inflation in both countries. There is a rule to the LTV which serves as a macroprudential measure. I explore two scenarios; one in which macroprudential policies are centralized at the union level and a second one in which

[4] There is evidence of different monetary policy transmission in the euro area depending on the mortgage rate that is prevalent in the country. See for instance Calza *et al.* (2009), Carstensen *et al.* (2009), and Assenmacher-Wesche and Gerlach (2010).

each country can conduct its own macroprudential policy. I allow for housing-market heterogeneity across the countries.

2.1 The consumer's problem

There are three types of consumers in each country: unconstrained consumers, constrained consumers who borrow at a variable rate, and constrained consumers who borrow at a fixed rate. The proportion of each type of borrower is fixed and exogenous.[5] Consumers can be constrained or unconstrained in the sense that constrained individuals need to collateralize their debt repayments in order to borrow from the financial intermediary. Interest payments in the next period cannot exceed a proportion of the future value of the current house stock. In this way, the financial intermediary ensures that borrowers are going to be able to fulfil their debt obligations in the next period. As in Iacoviello (2005), I assume that constrained consumers are more impatient than unconstrained ones.[6] There is a financial intermediary in each country. The financial intermediary in Country A accepts deposits from domestic savers and it extends both fixed- and variable-rate loans to domestic borrowers.

2.1.1 Unconstrained consumers (savers)

Unconstrained consumers in Country A maximize as follows:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left(\ln C_t^u + j \ln H_t^u - \frac{(L_t^u)^\eta}{\eta} \right). \tag{1}$$

Here, E_0 is the expectation operator; $\beta \in (0,1)$ is the discount factor; and C_t^u, H_t^u, and L_t^u are consumption at t, the stock of housing, and hours worked, respectively.[7] j represents the weight of housing in the utility function. $1/(\eta - 1)$ is the aggregate labour-supply elasticity.[8]

Consumption is a bundle of domestically and foreign-produced goods, defined as $C_t^u = (C_{At}^u)^n (C_{Bt}^u)^{1-n}$, where n is the size of Country A.

The budget constraint for Country A is as follows:

$$\begin{aligned} &P_{At}C_{At}^u + P_{Bt}C_{Bt}^u + Q_{At}H_t^u + R_{At-1}B_{t-1}^u + R_{t-1}D_{t-1} + \frac{\psi}{2}D_t^2 \\ &\leq Q_{At}H_{t-1}^u + W_t^u L_t^u + B_t^u + D_t + P_{At}F_t + P_{At}S_t, \end{aligned} \tag{2}$$

where P_{At} and P_{Bt} are the prices of the goods produced in Countries A and B, respectively, Q_{At} is the housing price in Country A, and W_t^u is the wage for unconstrained consumers. B_t^u represents domestic bonds denominated in the common currency. R_{At} is the nominal

[5] According to the European Mortgage Federation, the type of mortgage contracts across countries responds to a large extent to institutional or cultural factors, which are out of the scope of the present model. In the short run, the proportion of each type of mortgage contract can fluctuate, but typically it does not imply a change in the fixed- or variable-rate category of the country.

[6] This assumption ensures that the borrowing constraint is binding in the steady state and that the economy is endogenously split into borrowers and savers.

[7] It is assumed that housing services are proportional to the housing stock.

[8] As wealth effects are important in this model, I have performed some robustness of the results by changing the value of the relative risk aversion coefficient. A further robustness is to shut down the wealth effects by employing a Greenwood–Hercowitz–Huffman (GHH) utility function. For different values of the relative risk aversion coefficient, results are qualitatively similar but quantitatively, dynamics are affected, especially for financial variables. In terms of using GHH preferences, this is an important point. With the type of preferences used in standard real business cycle models, labour effort is determined together with the intertemporal consumption choice. When consumption is reduced, individuals tend to work more to compensate and smooth consumption. Using GHH preferences, this effect is eliminated. GHH preferences have the property of shutting down the income effect on the labour supply decision. In these preferences, labour and consumption are non-separable. This makes labour effort to be determined independently from the intertemporal consumption-savings choice. In this case, real effects of shocks are amplified. Details are available in the Supplementary Appendix.

interest rate in Country A. Positive bond holdings signify borrowing and negative signify savings. However, as we will see, this group will choose not to borrow at all: they are the savers in this economy. D_t are foreign-bond holdings by savers in Country A.[9] R_t is the nominal rate of foreign bonds, which are denominated in euros. As is common in the literature, to ensure stationarity of net foreign assets I introduced a small quadratic cost of deviating from zero foreign borrowing, $\frac{\psi}{2} D_t^2$.[10] Savers obtain interest on their savings. S_t and F_t are lump-sum profits received from the firms and the financial intermediary in Country A, respectively.

Dividing by P_{At}, we can rewrite the budget constraint in terms of goods A:

$$C_{At}^u + \frac{P_{Bt}}{P_{At}} C_{Bt}^u + q_{At} H_t^u + \frac{R_{At-1} b_{t-1}^u}{\pi_{At}} + \frac{R_{t-1} d_{t-1}}{P_{At}} + \frac{\psi}{2} d_t^2 \\ \leq q_{At} H_{t-1}^u + w_t^u L_t^u + b_t^u + d_t + F_t + S_t, \tag{3}$$

where π_{At} denotes inflation for the goods produced in Country A, defined as P_{At}/P_{At-1}.

Maximizing Equation (1), subject to Equation (3), we obtain the first-order conditions for the unconstrained group as:

$$\frac{C_{At}^u}{C_{Bt}^u} = \frac{n P_{Bt}}{(1-n) P_{At}}, \tag{4}$$

$$\frac{1}{C_{At}^u} = \beta E_t \left(\frac{R_{At}}{\pi_{At+1} C_{At+1}^u} \right), \tag{5}$$

$$\frac{1 - \psi d_t}{C_{At}^u} = \beta E_t \left(\frac{R_t}{\pi_{At+1} C_{At+1}^u} \right), \tag{6}$$

$$w_t^u = (L_t^u)^{\eta - 1} \frac{C_{At}^u}{n}, \tag{7}$$

$$\frac{j}{H_t^u} = \frac{n}{C_{At}^u} q_{At} - \beta E_t \frac{n}{C_{At+1}^u} q_{At+1}. \tag{8}$$

Equation (4) equates the marginal rate of substitution between goods to the relative price. Equation (5) is the Euler equation for consumption. Equation (6) is the first-order condition for net foreign assets. Equation (7) is the labour-supply condition. These equations are standard. Equation (8) is the Euler equation for housing and states that at the margin the benefits from consuming housing have to be equal to the costs.

Combining Equations (5) and (6), we obtain a non-arbitrage condition between home and foreign bonds[11]:

$$R_{At} = \frac{R_t}{(1 - \psi d_t)}. \tag{9}$$

Since all consumption goods are traded and there are no barriers to trade, I assume in this article that the law of one price holds:

[9] Savers have access to international financial markets. However, for simplicity, I assume that borrowers do not. Constrained consumers do not have free access to financial markets. They need to collateralize their debt. Allowing them to invest in foreign bonds would pose the problem of dealing with an extra collateral constraint on these bonds, which would complicate the solving of the model.

[10] See Iacoviello and Smets (2006) for a similar specification of the budget constraint.

[11] The log-linearized version of this equation could be interpreted as the uncovered interest-rate parity.

$$P_{At} = P^*_{At}, \tag{10}$$

where variables with a star denote foreign variables.

2.1.2 Constrained consumers (borrowers)

Constrained consumers in Country A are of two types: those who borrow at a variable rate and those who do so at a fixed rate. The difference between them is the interest rate they are charged. The variable-rate constrained-consumer faces R_{At}, which will coincide with the rate set by the central bank. The fixed-rate borrower pays $\overline{R}_{At}$, derived from the financial intermediary's problem. The proportion of variable-rate consumers in Country A is constant and exogenous and is equal to $\alpha_A \in [0, 1]$.

Constrained consumers are more impatient than unconstrained ones, that is, $\tilde{\beta} < \beta$. Constrained consumers face a collateral constraint: the expected debt repayment in the next period cannot exceed a proportion of the expectation of tomorrow's value of today's stock of housing:

$$E_t \frac{R^i_{At}}{\pi_{At+1}} b^{ci}_t \leq k_{At} E_t q_{At+1} H^{ci}_t, \tag{11}$$

where the superscript $i \in (v, f)$ indicates the variable and fixed rates, respectively. Equation (11) represents the collateral constraint for the variable- and fixed-rate borrower, respectively. k_{At} can be interpreted as the LTV ratio in Country A. Notice that such models with collateral constraints, the LTV is typically considered exogenous. At the macroeconomic level, LTVs partly depend on exogenous factors such as regulation. This parameter is usually calibrated to match the average LTV in the country analysed. However, in this model, it can vary depending on economic conditions, as a macroprudential policy variable. As it will be pointed out when I introduce the problem of the financial intermediary, R^f_{At} is an aggregate interest rate that contains information on all the past fixed-interest rates associated with past debt. Each period, this aggregate interest rate is updated with a new interest rate linked to the new amount of debt originating in that period. $R^v_{At} = R_{At}$.

Borrowers maximize their lifetime utility function:

$$\max E_0 \sum_{t=0}^{\infty} \tilde{\beta}^t \left(\ln C^{ci}_t + j \ln H^{ci}_t - \frac{(L^{ci}_t)^\eta}{\eta} \right), \tag{12}$$

where $C^{ci}_t = (C^{ci}_{At})^n (C^{ci}_{Bt})^{1-n}$, subject to the budget constraint (in terms of good A):

$$C^{ci}_{At} + \frac{P_{Bt}}{P_{At}} C^{ci}_{Bt} + q_{At} H^{ci}_t + \frac{R^i_{At-1} b^{ci}_{t-1}}{\pi_{At}} \leq q_{At} H^{ci}_{t-1} + w^{ci}_t L^{ci}_t + b^{ci}_t, \tag{13}$$

and subject to the collateral constraint (Equation 11). Notice that variable-rate borrowers repay all debt every period and acquire new debt at the current new interest rate. This assumption implies that the interest rate on variable-rate mortgages is revised every period for the whole stock of debt and changed according to the policy rate.[12] To make the problem for fixed-rate borrowers symmetrical and analogous to existing models with borrowing constraints, I assume the same debt-repayment structure for this type of borrower. Obviously, fixed-rate contracts are not revised every period. However, to make the model more realistic, but still tractable, the fixed-interest rate will be such that a revised fixed rate will be applied

[12] This assumption is consistent with reality, in which variable-interest rates are revised very frequently and changed according to an interest-rate index tied to the interest rate set by the central bank.

only on new debt, keeping constant the interest rate applied to existing debt. In this way, I reconcile the structure of the model with the fact that fixed-rate contracts are long term.[13]

The first-order conditions for these consumers are as follows:

$$\frac{C_{At}^{ci}}{C_{Bt}^{ci}} = \frac{nP_{Bt}}{(1-n)P_{At}}, \tag{14}$$

$$\frac{n}{C_{At}^{ci}} = \tilde{\beta} E_t\left(\frac{nR_{At}}{\pi_{At+1} C_{At+1}^{ci}}\right) + \lambda_{At}^{ci} R_{At}^{i}, \tag{15}$$

$$w_t^{ci} = (L_t^{ci})^{\eta-1}\frac{C_{At}^{ci}}{n}, \tag{16}$$

$$\frac{j}{H_t^{ci}} = \frac{n}{C_{At}^{ci}} q_{At} - \tilde{\beta} E_t \frac{n}{C_{At+1}^{ci}} q_{At+1} - \lambda_t^{ci} k_{At} E_t q_{At+1}\pi_{At+1}. \tag{17}$$

These first-order conditions differ from those of unconstrained individuals. In the case of constrained consumers, the Lagrange multiplier on the borrowing constraint (λ_t^{ci}) appears in Equations (15) and (17). As in Iacoviello (2005), the borrowing constraint is always binding, so that constrained individuals borrow the maximum amount they are allowed, and their saving is zero.[14] The problem for consumers is analogous in Country B.

2.2 The financial intermediary

I assume a competitive framework, and thus the intermediary takes the variable interest rate as given.[15] The profits of the financial intermediary are defined as[16]:

$$F_t = \alpha_A R_{At-1} b_{t-1}^{cv} + (1-\alpha_A) R_{At-1}^{f} b_{t-1}^{cf} - R_{At-1} b_{t-1}^{u}. \tag{18}$$

In equilibrium, aggregate borrowing and saving must be equal, that is,

$$\alpha_A b_t^{cv} + (1-\alpha_A) b_t^{cf} = b_t^{u}. \tag{19}$$

Substituting Equation (19) into Equation (18), we obtain,

$$F_t = (1-\alpha_A) b_{t-1}^{cf}(R_{At-1}^{f} - R_{At-1}). \tag{20}$$

Thus, the financial intermediary chooses the amount of fixed-rate mortgages to maximize her expected discounted profits. The objective function of intermediaries is

$$E_\tau \sum_{k=\tau+1}^{\infty} \beta^{k-\tau}\Lambda_{\tau,k} F_k = (1-\alpha_A) E_\tau \sum_{k=\tau+1}^{\infty} \beta^{k-\tau}\Lambda_{\tau,k} b_{k-1}^{cf}(R_{Ak-1}^{f} - R_{Ak-1}), \tag{21}$$

where $\Lambda_{t,k} = \frac{C_{At}^{u}}{C_{At+i}^{u}}$ is the unconstrained-consumer relevant discount factor. Since the financial intermediary is owned by the savers, their stochastic discount factor is applied to the

[13] Another option would be to have an overlapping generation model in which we are able to keep track of the debt issued each period. However, the model would become more complex and less comparable with the standard collateral constraint DSGE models, such as that of Iacoviello (2005).

[14] From the Euler equations for consumption of the unconstrained consumers, we know that $R_A = 1/\beta$, where variables without a time subscript denote steady-state variables. If we combine this result with the Euler equation for consumption for the constrained individual, we have $\lambda^{cv} = n(\beta - \tilde{\beta})/C_A^{cv} > 0$. Given that $\beta > \tilde{\beta}$, the borrowing constraint holds with equality in steady state. Since the model is log-linearized around the steady state and low uncertainty is assumed, this result can be generalized to off-steady-state dynamics.

[15] See Andrés and Arce (2008) for a housing model with collateral constraints in which banks are imperfectly competitive and are able to set optimal lending rates.

[16] The superscript *cv* signifies 'constrained variable' and *cf* 'constrained fixed'.

financial intermediary's problem. Notice that, as stated before, variable-rate debt is in one period, but the portion of new debt acquired at a fixed rate is associated with a long-term contract. Since the agent is infinitely lived, I assume here that the maturity of fixed-rate mortgages is also infinity.

Denote the amount of new debt as $\Delta b_t^{cf} = b_t^{cf} - b_{t-1}^{cf}$. Then, for $k > t$,

$$b_{k-1}^{cf} = b_{t-1}^{cf} + \sum_{u=\tau}^{k-1} \Delta b_u^{cf}. \tag{22}$$

We can define an aggregate fixed-interest rate as the one the financial intermediary effectively charges every period for the whole stock of mortgages. As an assumption, this aggregate fixed-interest rate is composed of all past fixed-interest rates and past debt, together with the current-period equilibrium fixed-interest rate and new amount of debt. Therefore, the effective fixed-interest rate that the financial intermediary charges for the stock of fixed-rate debt every period is as follows:

$$R_{At}^f = \left\{ \begin{array}{c} \dfrac{R_{At-1}^f b_{t-1}^{cf} + R_{At}^{f\mathrm{OPT}} \Delta b_t^{cf}}{b_t^{cf}} \text{ if } b_t^{cf} > b_{t-1}^{cf} \\ R_{At-1}^f \text{ if } b_t^{cf} \le b_{t-1}^{cf} \end{array} \right\}. \tag{23}$$

Equation (23) states that the fixed-interest rate that the financial intermediary charges today is an average of what it charged the previous period for the previous stock of mortgages and what it charges in the current period for the new amount. If there is no new debt, the fixed-interest rate will be equal to that of the previous period. Then, in the same way that variable rates are revised every period, fixed rates are revised by including the new optimal fixed-interest rate for the new debt originating in this period. Importantly, this assumption is not crucial for results. This assumption is a way to make the model compatible with the fact that fixed-rate loans are not one-period assets but longer-term ones.

Equation (23) implies that $R_{At}^f b_t^{cf} = R_{At-1}^f b_{t-1}^{cf} + R_{At}^{f\mathrm{OPT}} \Delta b_t^{cf}$, and $R_{At}^{f\mathrm{OPT}} = R_{At-1}^f$ if $\Delta b_t^{cf} \le 0$. Solving it backwards, we get:

$$R_{Ak-1}^f b_{k-1}^{cf} = R_{At-1}^f b_{t-1}^{cf} + \sum_{u=\tau}^{k-1} R_{Au}^{f\mathrm{OPT}} \Delta b_u^{cf}. \tag{24}$$

Substituting b_{k-1}^{cf} and $R_{Ak-1}^f b_{k-1}^{cf}$, and using Equations (22) and (24), the objective function becomes

$$(1-\alpha_A) E_\tau \sum_{k=\tau+1}^{\infty} \beta^{k-\tau} \Lambda_{\tau,k} \left[R_{At-1}^f b_{t-1}^{cf} + \sum_{u=\tau}^{k-1} R_{Au}^{f\mathrm{OPT}} \Delta b_u^{cf} - R_{Ak-1} \left(b_{t-1}^{cf} + \sum_{u=\tau}^{k-1} \Delta b_u^{cf} \right) \right]. \tag{25}$$

Banks choose Δb_t^{cf} to maximize the objective function, subject to the constraint that $R_{At}^{f\mathrm{OPT}} = R_{At-1}^f$ if $\Delta b_t^{cf} \le 0$.

When $\Delta b_t^{cf} > 0$, the FOC of Δb_t^{cf} is

$$R_{At}^{f\mathrm{OPT}} E_\tau \sum_{k=\tau+1}^{\infty} \beta^{k-\tau} \Lambda_{\tau,k} - E_\tau \sum_{k=\tau+1}^{\infty} \beta^{k-\tau} \Lambda_{\tau,i} R_{Ak-1} = 0. \tag{26}$$

Therefore,[17]

$$R_{At}^{f\mathrm{OPT}} = \frac{E_\tau \sum_{k=\tau+1}^{\infty} \beta^{k-\tau}\Lambda_{\tau,k}R_{Ak-1}}{E_\tau \sum_{k=\tau+1}^{\infty} \beta^{k-\tau}\Lambda_{\tau,k}}. \tag{27}$$

The financial intermediary problem for Country B is symmetrical.

2.3 Firms

2.3.1 Final-goods producers

In Country A, there is a continuum of final-goods producers that aggregate intermediate goods according to the production function:

$$Y_{At} = \left[\int_0^1 Y_{At}(z)^{\frac{\varepsilon-1}{\varepsilon}} dz\right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{28}$$

where $\varepsilon > 1$ is the elasticity of substitution among intermediate goods. Final-goods producers act in a perfectly competitive market.

The total demand of intermediate good z is given by $Y_{At}(z) = \left(\frac{P_{At}(z)}{P_{At}}\right)^{-\varepsilon} Y_{At}$, and the price index is $P_{At} = [\int_0^1 P_{At}(z)^{1-\varepsilon}dz]^{\frac{1}{\varepsilon-1}}$.

2.3.2 Intermediate-goods producers

The intermediate-goods market is monopolistically competitive. Following Iacoviello (2005), intermediate goods are produced according to the following production function:

$$Y_{At}(z) = \xi_t \left(L_t^u(z)\right)^{\gamma} \left(L_t^c(z)\right)^{(1-\gamma)}, \tag{29}$$

where ξ_t represents the technology. I assume that $\log \xi_t = \rho_\xi \log \xi_{t-1} + u_{\xi t}$, where ρ_ξ is the autoregressive coefficient and $u_{\xi t}$ is a normally distributed shock to technology. $\gamma \in [0, 1]$ measures the relative size of each group in terms of labour. We make this parameter country-specific, as a proxy for the different debt-to-GDP ratios we observe across countries. L_t^c is labour supplied by constrained consumers, defined as $\alpha_A L_t^{cv} + (1-\alpha_A)L_t^{cf}$.

The first-order conditions for labour demand are the following[18]:

$$w_t^u = \frac{1}{X_t}\gamma \frac{Y_{At}}{L_t^u}, \tag{30}$$

$$w_t^{ci} = \frac{1}{X_t}(1-\gamma)\frac{Y_{At}}{L_t^c}, \tag{31}$$

where X_t is the markup or the inverse of marginal cost.

The price-setting problem for the intermediate-goods producers is a standard Calvo–Yun case. An intermediate-goods producer sells goods at price $P_{At}(z)$ and $1-\theta$ is the probability

[17] This expression is equivalent to a long-term interest rate. If, instead of this specification, we used the current variable rate as the optimal new fixed rate, then the fixed rate would be closer to the variable rate. Results within scenarios would also be close. See Table A3 in the Supplementary Appendix for details (Table A3 is the counterpart of Table 5).

[18] Symmetry across firms allows avoiding index z.

of being able to change the sale price in every period. The optimal reset price $P_{At}^{\mathrm{OPT}}(z)$ solves the following:

$$\sum_{k=0}^{\infty}(\theta\beta)^k E_t\left\{\Lambda_{t,k}\left[\frac{P_{At}^{\mathrm{OPT}}(z)}{P_{At+k}}-\frac{\varepsilon/(\varepsilon-1)}{X_{t+k}}\right]Y_{At+k}^{\mathrm{OPT}}(z)\right\}=0. \tag{32}$$

The aggregate price level is given as follows:

$$P_{At}=[\theta P_{At-1}^{1-\varepsilon}+(1-\theta)(P_{At}^{\mathrm{OPT}})^{1-\varepsilon}]^{1/(1-\varepsilon)}. \tag{33}$$

Using Equations (32) and (33) and log-linearizing, we can obtain the standard forward-looking Phillips curve.[19] The firm problem is similar in Country B.

2.4 Aggregate variables and market clearing

Given α_A, the fraction of variable-rate borrowers in Country A, we can define aggregates across constrained consumers as the sum of variable-rate and fixed-rate aggregates, so that $C_t^c\equiv\alpha_A C_t^{cv}+(1-\alpha_A)C_t^{cf}$, $H_t^c\equiv\alpha_A H_t^{cv}+(1-\alpha_A)H_t^{cf}$ and $b_t^c\equiv\alpha_A b_t^{cv}+(1-\alpha_A)b_t^{cf}$.

Therefore, economy-wide aggregates in Country A are $C_t\equiv C_t^u+C_t^c$ and $L_t\equiv L_t^u+L_t^c$. The aggregate supply of housing is fixed, so that market clearing requires $H_t\equiv H_t^u+H_t^c=H$.[20]

The market clearing condition for the final good in Country A is $nY_{At}=nC_{At}+(1-n)C_{At}^*+n\frac{\psi}{2}d_t^2$. Domestic financial markets clear: $b_t^c=b_t^u$. The world bond market clearing condition is $nd_t+(1-n)\frac{P_{Bt}}{P_{At}}d_t^*=0$, where d_t denotes the foreign bonds in real terms. The net foreign asset position follows as: $d_t=\frac{R_{t-1}}{(1-\psi d_t)\pi_{At}}d_{t-1}+Y_{At}-C_{At}-\frac{P_{Bt}}{P_{At}}C_{Bt}$. Everything is similar in Country B.

2.5 Monetary policy

The model closes with a Taylor rule, with interest-rate smoothing for interest-rate setting by a single central bank,[21]

$$R_t=(R_{t-1})^{\rho}\left([(\pi_{At})^n(\pi_{Bt})^{(1-n)}]^{(1+\phi_\pi)}R\right)^{1-\rho}\varepsilon_{R,t}, \tag{34}$$

$0\le\rho\le1$ is the parameter associated with interest-rate inertia. $(1+\phi_\pi)$ measures the sensitivity of interest rates to current inflation. $\varepsilon_{R,t}$ is a white noise shock process with zero mean and variance σ_ε^2. This rule is consistent with the primary objective of the ECB being price stability.

2.6 Macroprudential policy

As an approximation for a realistic macroprudential policy, I consider a Taylor-type rule for the LTV ratio.[22] In standard models, the LTV ratio is a fixed parameter which is not affected by economic conditions. However, we can think of regulations of LTV ratios as a way to moderate credit booms. When the LTV ratio is high, the collateral constraint is less

[19] This Phillips curve is consistent with other two-country models with financial accelerator. See, for instance, Gilchrist *et al.* (2002) or Iacoviello and Smets (2006).

[20] An endogenous supply of housing could be easily introduced in a two-sector version of this model. However, the qualitative results would not change for the demand side of the model which is the focus of this article. For two-sector models, see, for example, Iacoviello and Smets (2006) or Iacoviello and Neri (2010).

[21] This type of rule is also used in other monetary-union models. See Iacoviello and Smets (2006) or Aspachs and Rabanal (2010). Furthermore, as shown in Iacoviello (2005) and Rubio and Carrasco-Gallego (2013), a rule that only responds to inflation enhances the financial accelerator.

[22] I call it 'Taylor type' because its structure reminds that of the traditional Taylor rule.

tight. And, since the constraint is binding, borrowers will borrow as much as they are allowed to. Lowering the LTV tightens the constraint and therefore restricts the loans that borrowers can obtain. Recent research on macroprudential policies has proposed Taylor-type rules for the LTV ratio so that it reacts inversely to variables such that the growth rates of GDP, credit, the credit-to-GDP ratio, or house prices. These rules can be a simple illustration of how a macroprudential policy could work in practice. Here, I assume that there exists a macroprudential Taylor-type rule for the LTV ratio, so that it responds to output and house prices.[23] The first variable would correspond to the objective of the macroprudential regulator to moderate booms in the economy that could lead to an excessive credit growth. As for the house prices, given collateral constraints, they are the key causal variable for the dynamics of loans to households, and it appears to correspond to the actual behaviour of policymakers.[24] We consider first a case in which the macroprudential policy is centralized, that is, as monetary policy is implemented by a simple regulator that takes into account an average of output and house price deviations in each country:

$$k_t = k_{SS}\left[\left(\frac{Y_{At}}{Y_A}\right)^n\left(\frac{Y_{Bt}}{Y_B}\right)^{1-n}\right]^{-\phi_y^k}\left[\left(\frac{q_{At}}{q_A}\right)^n\left(\frac{q_{Bt}}{q_B}\right)^{1-n}\right]^{-\phi_q^k}, \tag{35}$$

where k_{SS}, Y_A, and q_A are the steady-state values for the LTV ratio, output, and house prices in country A. $\phi_y^k \geq 0,\ \phi_q^k \geq 0$ measure the response of the LTV to output and house prices, respectively. This kind of rule would deliver a lower LTV ratio in booms, when output and house prices are high, therefore, restricting the credit in the economy and avoiding a credit boom derived from good economic conditions.

The second case is the decentralized macroprudential policy in which each country can implement its own rule[25]:

$$k_{At} = k_{SSA}\left(\frac{Y_{At}}{Y_A}\right)^{-\phi_{Ay}^k}\left(\frac{q_{At}}{q_A}\right)^{-\phi_{Aq}^k}, \tag{36}$$

$$k_{Bt} = k_{SSB}\left(\frac{Y_{Bt}}{Y_B}\right)^{-\phi_{By}^k}\left(\frac{q_{Bt}}{q_B}\right)^{-\phi_{Bq}^k}. \tag{37}$$

2.7 Welfare measure

In order to provide a measure for welfare, I numerically evaluate how cross-country asymmetries affect welfare for a given policy rule and for technology shocks. As discussed in Benigno and Woodford (2008), the two approaches that have recently been used for welfare analysis in Dynamic Stochastic General Equilibrium (DSGE) models include either characterizing the optimal Ramsey policy or solving the model using a second-order approximation to the structural equations for given policy and then evaluating welfare using this solution. As in Mendicino and Pescatori (2007), I take this latter approach to be able to evaluate the welfare of the three types of agents separately.[26] The individual welfare for savers and borrowers in Country A is defined, respectively, as follows:

[23] I have also experimented with rules that react directly to credit growth and results for the dynamics of the model are similar.
[24] See Angelini *et al.* (2014) for further discussion.
[25] Notice that even though the policy is decentralized, I am considering the case in which countries act in a coordinated way.
[26] I used the software Dynare to obtain a solution for the equilibrium implied by a given policy by solving a second-order approximation to the constraints, then evaluating welfare under the policy using this approximate solution, as in Schmitt-Grohé and Uribe (2004). See Monacelli (2008) for an example of the Ramsey approach in a model with heterogeneous consumers.

$$V_{u,t} \equiv E_t \sum_{m=0}^{\infty} \beta^m \left(\ln C^u_{t+m} + j \ln H^u_{t+m} - \frac{(L^u_{t+m})^\eta}{\eta} \right), \tag{38}$$

$$V^i_{c,t} \equiv E_t \sum_{m=0}^{\infty} \tilde{\beta}^m \left(\ln C^{ci}_{t+m} + j \ln H^{ci}_{t+m} - \frac{(L^{ci}_{t+m})^\eta}{\eta} \right). \tag{39}$$

Following Mendicino and Pescatori (2007), I define social welfare in Country A as a weighted sum of the individual welfare for the different types of households:

$$V_t = (1-\beta)V_{u,t} + (1-\tilde{\beta})[\alpha_A V^v_{c,t} + (1-\alpha_A)V^i_{c,t}]. \tag{40}$$

Borrowers and savers' welfare are weighted by $(1-\tilde{\beta})$ and $(1-\beta)$, respectively, so that the two groups receive the same level of utility from a constant consumption stream. Everything is symmetrical for Country B.

Total welfare is defined as a weighted sum of the welfare in the two countries:

$$W_t = nV_t + (1-n)V^*_t. \tag{41}$$

In order to make the results more intuitive, I present welfare changes in terms of consumption equivalents. I use as a benchmark the welfare evaluated when the macroprudential policy is not active and compare it with the welfare obtained when such policy is implemented.[27]

3. Parameter values

Having in mind the euro area, parameters are calibrated to reflect this economy. However, the aim of this article is to provide a general theoretical framework that can shed some light to some applied issues in the euro area. Therefore, the model will be calibrated as generally as possible and counterfactuals will be undertaken from a theoretical point of view, without having in mind any particular country. For cleaner results, I consider the two countries to be equal in size.

The discount factor for savers, β, is set to 0.99 so that the annual interest rate is 4% in steady state. The discount factor for borrowers, $\tilde{\beta}$, is set to 0.98.[28] The steady-state weight of housing in the utility function, j, is set to 0.1 in order for the ratio of housing wealth to GDP to be approximately 1.40 in the steady state.[29] I set $\eta = 2$, implying a value of the labour-supply elasticity of 1.[30] For the LTV ratio, I considered a steady-state value of 0.9, as in order to emphasize the financial accelerator mechanism for a high leveraged economy. The labour-income share of unconstrained consumers γ was set to 0.7.[31] I picked a value of 6 for ε, the elasticity of substitution among intermediate goods. This value implies a steady-state markup of 1.2. The probability of not changing prices, θ, is set to 0.75, implying that prices change every four quarters on average. For the Taylor rule parameters, I used $\rho = 0.8$ and $\phi_\pi = 0.5$. The first value reflects a realistic degree of interest-rate smoothing.[32] ϕ_π

[27] I follow Ascari and Ropele (2009).

[28] Lawrance (1991) estimated discount factors for poor consumers at between 0.95 and 0.98 at quarterly frequency.

[29] Following Aspachs and Rabanal (2010), I use this value that reflects the ratio of housing wealth to GDP across most industrialized countries.

[30] Microeconomic estimates usually suggest values in the range of 0–0.5 (for males). Domeij and Flodén (2006) showed that in the presence of borrowing constraints, this estimate could have a downwards bias of 50%.

[31] This value is in the range of the estimates of Campbell and Mankiw, (1991) for the USA, Canada, France, and Sweden, and Iacoviello (2005) and Iacoviello and Neri (2010) for the USA. Therefore, I take it as valid for most of the countries of the euro area.

[32] See McCallum (2001).

is consistent with the original parameters proposed by Taylor in 1993. For the baseline model, I considered $\alpha_A = \alpha_B = 1$, that is, all mortgages are variable rate.[33] However, I also considered the case of fixed-rate mortgages. In order to focus on the rest of asymmetries, I consider that the two countries are equal in size.[34] A technology shock was a 1% positive technology with 0.9 persistence.[35] I consider ψ, the adjustment cost on net foreign assets to be 0.001, large enough to obtain stationarity on foreign assets but small enough so that there is not an interest rate spread.[36] Table A2 in the Supplementary Appendix presents a summary of the parameter values.

4. Results

In this section, I study first the dynamics of the model by showing impulse responses to a technology shock, abstracting from macroprudential policies, and using the parameter values shown in the previous section. Second, I calculate the optimal macroprudential policy, that is, the reaction parameters of the macroprudential rule that maximize welfare.[37] Then, I compare macroeconomic volatilities with and without the macroprudential policy. Finally, I compare the impulse responses of the main variables of the model when the LTV rule is not in place and under the optimal macroprudential policy. I do this for three different cases; an asymmetric technology shock, asymmetric LTVs, and mortgage contract heterogeneity. For comparison, I first show the symmetric case.

4.1 Symmetric case

Figure 1 reports impulse responses for the symmetric case, that is, a symmetric productivity shock with two symmetric countries. This figure serves as a benchmark case. Then by comparing this benchmark with each case of asymmetry, we can see the effects they played.

4.2 Asymmetric technology shock

In this subsection, I present the first case of asymmetry: a technology shock only in one of the countries (Country A), everything else equal. Evidence shows that the productivity in the core evolved better than in the periphery. Even though the peripheral productivity was not improving as much as in the core, those countries benefited from the lower common interest rates stemming from low inflation in the more productive region.

The literature on currency unions has focused on the analysis of the optimality of a single monetary policy when there are non-synchronized business cycles across members. Here, I perform an analogous experiment applied to macroprudential policies.

In order to understand how the shock to Country A is transmitted to Country B, I display Figure 2, which presents impulses responses for the baseline case (no macroprudential) for

[33] This value makes the model comparable with the standard models, where fixed-rate mortgages are not considered.

[34] Notice that this value could be changed if one wants to study one particular country inside the euro area. However, since this is a general theoretical exercise, it is kept symmetric.

[35] This high persistence value for technology shocks is consistent with what is commonly reported in the literature. Smets and Wouters (2002) estimated a value of 0.822 for this parameter in Europe; Iacoviello and Neri (2010) estimated it as 0.93 for the USA.

[36] In this article, this parameter serves as a modelling device ensure stationarity of net foreign assets, as it is common in the literature. It does not introduce an additional channel for dynamics or policy. For instance, Bosca *et al.* (2022) have a model in which preferences differ between public and private bonds because of differences in safety and/or liquidity, and also differ between domestic and foreign bonds, due to imperfect financial market integration. Thus, they consider an endogenous risk premium that varies over time. The risk premium arises as an external effect that creates an additional wedge between domestic and foreign issued bonds. Borrowers from relatively more indebted countries will have to pay higher interest rates. In this way, borrowing entails an external effect in the form of a risk premium, which evolves according to relative total debt-to-GDP.

[37] I have experimented allowing foreign lending in the rules in optimal policy. Results show that the response to this variable is very small in the case of decentralized policies in both countries and minimal (close to zero) in the case of centralized ones. Exact results are available upon request.

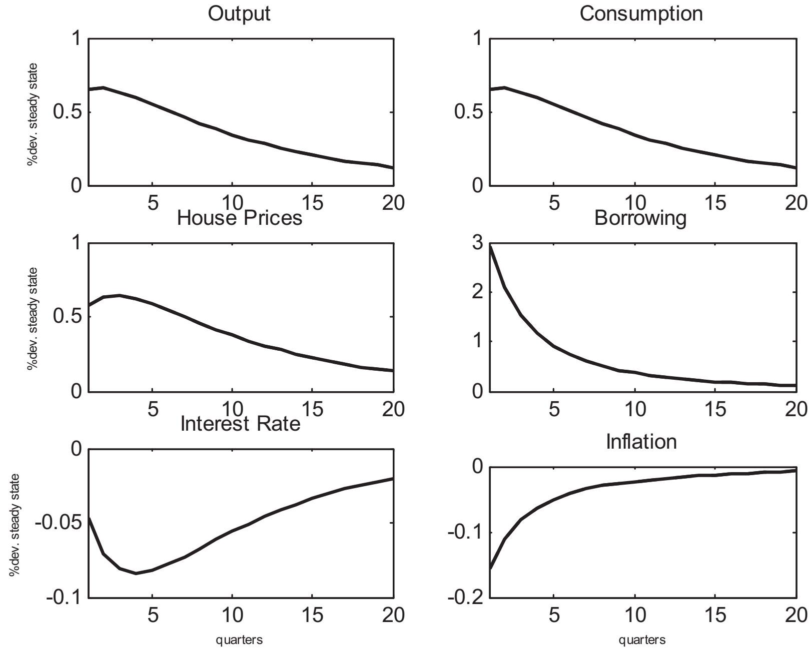

Figure 1. Impulse responses. Symmetric case.

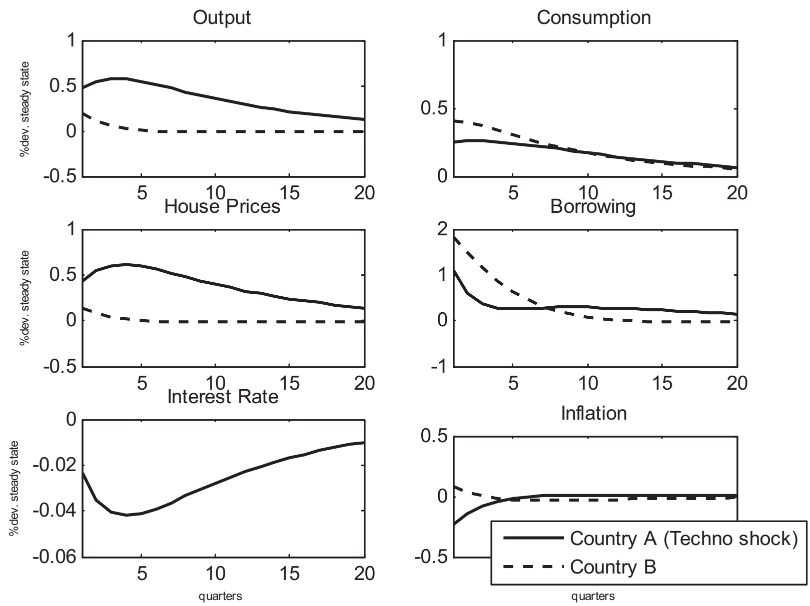

Figure 2. Impulse responses to a technology shock in Country *A*. No macroprudential policy. Country *A* versus Country *B*.

both countries. In such a setting, in which countries share the same monetary policy and are linked through trade and financial markets, even if the shock happens just in one of the countries, it is rapidly transmitted to the other one. We see that output in Country *A*

Table 1. Optimal macroprudential policy, given TR. Techno shock in *A*

	Centralized	Decentralized	
		Country *A*	Country *B*
ϕ_y^{k*}	0.02	0.02	0.02
ϕ_q^{k*}	0.34	0.03	0.5
Welfare gain A/B	−0.103/0.047	−0.046/0.178	
welfare gain union	0.171	0.0824	

increases because of the effects of the shock and, since producing is more efficient, inflation in that country decreases. However, Country *B* wants to benefit from the shock and labour and borrowing in that country go up, increasing the demand in consumption. Furthermore, monetary policy reacts to inflation and the common interest rate goes down. This expansionary monetary policy measure makes production in *B* also increase. As a result, they import more goods from Country *A* but they also are able to produce more increasing their labour supply.[38] The interest rate, which is common to both countries, slightly decreases because, on average, inflation goes down. In Country *B*, the production expansion comes from the demand side of the economy, and thus inflation increases. Therefore, in real terms, the interest rate is decreasing by more in Country *B*, giving an important impulse to borrowing. House prices are increasing because they move inversely with the interest rate. Then, since the collateral is also worth more, borrowing is increasing even further and by more than in Country *A*. House prices increase in both countries but they do by a larger amount in Country *A*, the country that receives the shock. Borrowing in Country *B* is increasing more strongly on impact but, given that house prices are not increasing as much in this country, it decreases rapidly, showing less persistence as the increase in Country *A*. We see that this type of shock, even though it is happening just in one of the countries, it is affecting both of them through different mechanisms.

Next, I explore the optimality of macroprudential policies in the context of this asymmetric technology shock. I can find which combination of the LTV rule parameters maximizes welfare (see Table 1). I consider both the centralized and the decentralized scenario. Results show that optimal parameters in the centralized case are the same as in the symmetric scenario. However, allowing for decentralized policies, the optimal rule is different across countries. For Country *A*, the country that receives the shock, it is optimal not to respond too aggressively to any of the variables. However, Country *B* should respond more strongly to house price deviations. Interestingly, what we observe is that if the policy is decentralized, it is optimal not to have an aggressive macroprudential policy in the country that is producing more efficiently. Having a more stable financial system is desirable, but not at the expense of efficiency. Overall, the centralized policy is more desirable in this case because Country *A*, the country that receives the shock does not benefit from the policy in the decentralized case.[39]

Table 2 presents the volatilities generated by the model, for each country, both for the baseline (no macroprudential policy) and for the optimized macroprudential policy for the centralized and the decentralized case. We observe that, for the baseline model, the country that receives the shock displays higher macroeconomic volatility, in terms of both inflation and output. However, it is Country *B* in which the volatility of borrowing is higher. Remember that given that the common interest rate was decreasing, inflation in Country *B*

[38] Notice that in this kind of models with collateral constraints, wealth effects coming from the labour supply are important.

[39] When countries and shocks are symmetric, there is no difference between the centralized and the decentralized case. However, for completeness, I have also calculated optimal parameters and welfare gains for the symmetric case. I find $\phi_y^{k*} = 0.27$ and ϕ_q^{k*} =0.08 with an associated welfare gain of 1.821.

Table 2. Volatilities. Techno shock in *A*

	Country A			Country B		
	Baseline	MP Cent	MP Dec	Baseline	MP Cent	MP Dec
stdev (y)	1.7218	1.6953	1.7185	0.2259	0.1766	0.2105
stdev (π)	0.2903	0.3095	0.2938	0.1354	0.1189	0.1337
stdev (b)	1.6720	0.9691	1.3406	2.9039	1.2525	2.3829

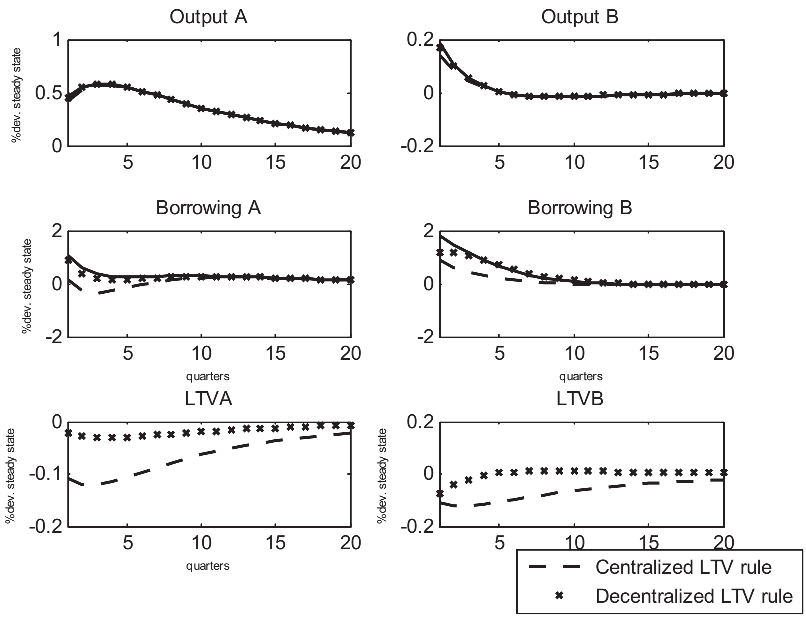

Figure 3. Impulse responses to a technology shock in Country *A*. Symmetric countries. Optimized macroprudential rule.

was increasing and house prices were also increasing, borrowing in Country *B* was increasing by more than in Country *A*, both because real debt repayments were decreasing and because the value of the collateral was increasing. That makes the optimal decentralized policy more aggressive for Country *B*. We see that in terms of reducing both economic and financial volatilities, the centralized policy does a better job for both countries. This is why the centralized policy delivers higher welfare gains.[40]

Looking at the impulse responses (Figure 3), we see that the LTV responds by more in the centralized case, cutting borrowing by more in both countries. This is why this scenario delivers the lowest values for borrowing volatilities in both countries, producing a more stable financial system for the whole union and therefore higher welfare.

Thus, if the only source of asymmetry comes from asymmetric shocks, a centralized system of macroprudential policy implementation is advisable, so that the lack of synchronization does not exacerbate further. However, there can be other structural differences across countries that may change this result. The following subsections touch upon this issue.

[40] An asymmetric technology shock is an example of a scenario in which centralized policies are desirable because of spillover effects. Optimal decentralized policies are more aggressive, to compensate for this fact, but not even with that, they manage to stabilize the economy as much as centralized policies.

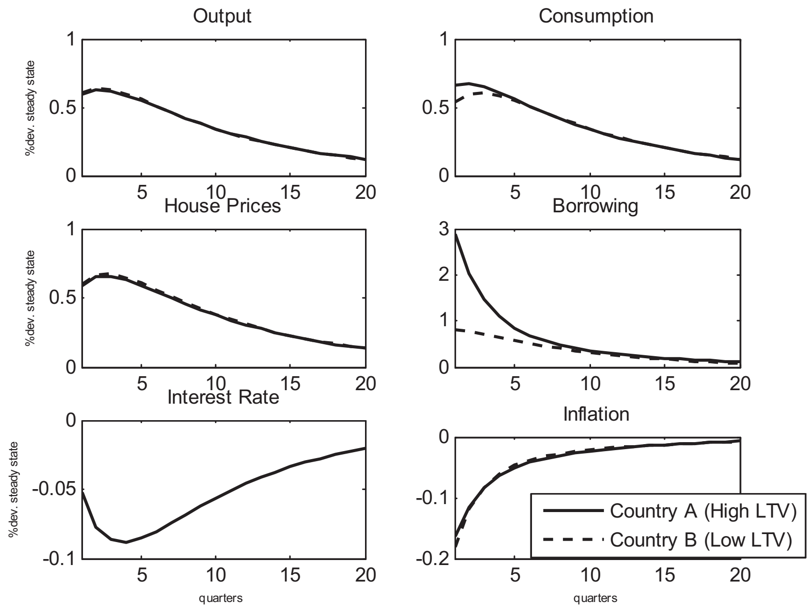

Figure 4. Impulse responses to a common technology shock. High LTV in Country *A*, low LTV in Country *B*.

4.3 Different leverage

Let us consider now the case in which there is a structural difference across countries that implies that one of the countries has a highly leveraged economy, with a stronger financial accelerator.

Figure 4 presents impulse responses to a common technology shock when countries have different steady-state LTV ratios. In particular, Country *A* has a high LTV and Country *B* has a low LTV, namely 0.9 and 0.5, respectively.[41] The LTV ratio dictates the strength of the financial accelerator, since it is directly related to the tightness of the collateral constraint. In a country in which the LTV is higher, the financial accelerator effects will be stronger. Looking at Figure 4, we can see that these differences in LTVs have an impact on borrowing. In Country *A*, the country with a higher LTV, borrowing increases by more than in the other country. Also, consumption increases by more. However, in aggregate terms, differences are not as noticeable.

Table 3 displays the optimized parameters for the LTV rule. We can observe that, even though there are welfare gains in both cases, the centralized and the decentralized, the optimized parameters are different. Country *A*, the one with high LTV benefits the most in the decentralized case. For the centralized case, I find that it is optimal to respond more aggressively to output than in the previous cases. The fact that there is a country in which the financial accelerator is stronger makes it optimal to respond more aggressively to output, so that the financial accelerator effects are not as strong and they balance out across countries. This is even more noticeable in the decentralized case. In the country with a stronger financial accelerator, the output response is higher, so that its effects are softened.

In Table 4, we see that even though this asymmetry generates very similar aggregate macroeconomic volatilities, the volatility of borrowing is higher in the country with the highest LTV. The high LTV makes borrowers in this country have easier access to credit and

[41] These values would illustrate a case of high LTV ratios like the Netherlands versus a low LTV like, for instance, Italy, which represent the most extreme cases in the euro area. The experiment could of course be calibrated to illustrate other countries or groups of countries in the EMU.

Table 3. Optimal macroprudential policy, given TR. High LTV in *A*

	Centralized	Decentralized	
		Country *A*	Country *B*
ϕ_y^{k*}	0.12	0.26	0.01
ϕ_q^{k*}	0.23	0.1	0.1
Welfare gain A/B	0.752/0.019	1.474/0.074	
Welfare gain union	0.334	0.614	

Table 4. Volatilities. High LTV in *A*

	Country *A*			Country *B*		
	Baseline	MP Cent	MP Dec	Baseline	MP Cent	MP Dec
stdev (y)	1.7813	1.7510	1.7520	1.8066	1.7785	1.7790
stdev (π)	0.2484	0.2655	0.2651	0.2582	0.2698	0.2688
stdev (b)	4.2801	1.4055	1.3467	1.9128	0.6097	1.3940

therefore the volatility of borrowing is larger in this country. The macroprudential policy manages to reduce the volatility of borrowing for both countries. However, when the policy is decentralized, it equalizes volatilities across countries more effectively than in the centralized case. As in the previous cases, macroprudential policies generate financial and output stability but inflation volatility is negatively affected, harming savers.

In Figure 5, we can see the response of the LTV to the increase in the shock. We see that, since this is an expansionary shock that increases borrowing, the LTV decreases. However, in the decentralized case, the LTV response for Country *B* is weaker. This leads to a smaller decrease in borrowing in this country when the rule is decentralized.

4.4 Different mortgage contracts

Here, I consider a second source of structural asymmetry, which is different mortgage contracts across countries. In core countries such as Germany, the majority of mortgage contracts have been traditionally signed as fixed rate. However, peripheral countries such as Spain or Portugal used to be mainly variable rate. This difference may have implications for the conduct of monetary and macroprudential policies.

Here, I consider that borrowers in Country *A* take mortgages at a variable interest rate, while borrowers in Country *B* do it at a fixed rate.[42] Figure 6 presents this case. Given a common technology shock, the union interest rate goes down. This affects more strongly borrowers in Country *A*, since their mortgage rates vary one for one with the policy rate. However, in Country *B* the nominal interest rate is fixed. Since inflation is decreasing in both countries, in real terms, the interest rate in Country *B* increases. House prices are increasing in both countries. That makes borrowers in Country *A* take out more loans. However, the fact that house prices are not increasing as much, combined with the increase in real rates, makes borrowing in Country *B* decrease. In Country *B*, there is an initial redistribution of housing to consumption, which fades away quickly.

When looking at the optimal macroprudential policy, I find that, in the centralized case, it is optimal to respond to house prices in a very aggressive fashion. For the decentralized case, Country *B*, the one with fixed rates is the one that should respond relatively more strongly to house prices (see Table 5).

[42] This could illustrate for instance the cases of Germany and Spain, with high and low proportion of fixed-rate mortgages, respectively.

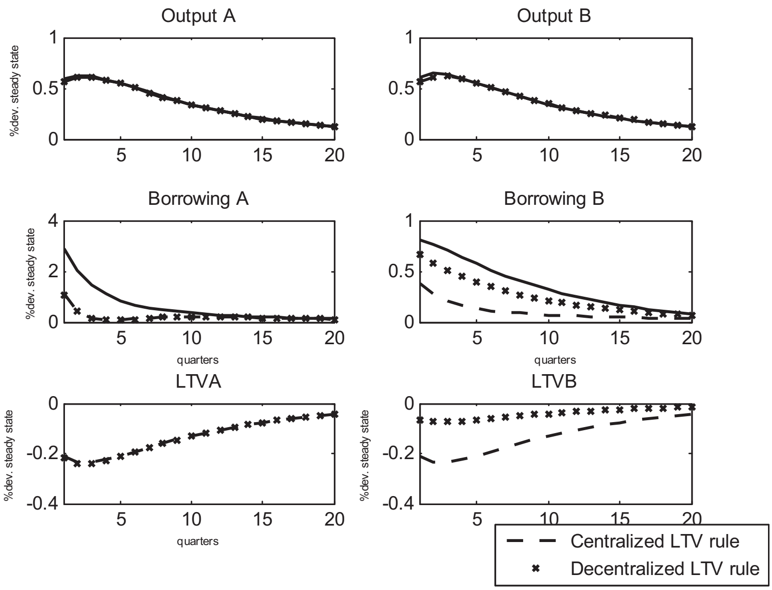

Figure 5. Impulse responses to a common technology shock. High LTV in Country *A*. Optimized macroprudential rule.

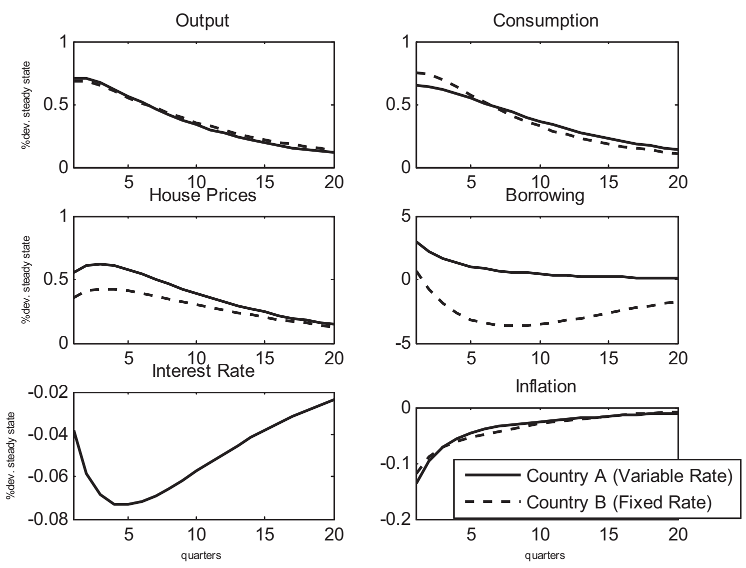

Figure 6. Impulse responses to a common technology shock. Variable rates in Country *A*, fixed rates in Country *B*.

The decentralized policy calls for a stronger response to both output and house prices in Country *B* because it is the country with fixed rates. With fixed-rate mortgages, monetary policy is less efficient to stabilize the macroeconomy.[43] An aggressive macroprudential

43 See Rubio (2011) for a detailed discussion on this issue.

Table 5. Optimal macroprudential policy, given TR. Variable rates in *A*

	Centralized	Decentralized	
		Country *A*	Country *B*
ϕ_y^{k*}	0.01	0.02	0.03
ϕ_q^{k*}	1.13	0.48	1.45
Welfare gain A/B	0.136/0.486	0.482/1.372	
Welfare gain union	0.857	0.937	

Table 6. Volatilities. Variable rates in *A*

	Country *A*			Country *B*		
	Baseline	MP Cent	MP Dec	Baseline	MP Cent	MP Dec
stdev (y)	1.8687	1.7105	1.7422	1.8819	1.7513	1.7772
stdev (π)	0.2167	0.2946	0.2720	0.2123	0.2824	0.2730
stdev (b)	4.6647	4.6620	0.9552	12.9066	19.7884	20.0673

policy compensates the lack of effectiveness of monetary policy. The optimal macroprudential policy responds more strongly to house prices than in the previous cases. The decentralized case is preferred overall, especially for Country *B*, the one with fixed rates.

Table 6 shows the volatilities. We are in a situation of asymmetry in the volatility in financial markets that the same shock produces. For Country *A*, the variable-rate country, the macroprudential policy does its job when it is decentralized. However, for the fixed-rate case, the macroprudential policy is not able to stabilize financial markets. Under this situation, the cost of borrowing is determined by inflation. Since macroprudential policies are increasing the volatility of inflation with respect to the baseline case, this is producing even more instability in financial markets. However, the stabilization of output produces welfare improvements.

Figure 7 shows the LTV response in the case of different mortgage contracts across countries. Especially for Country *A*, it matters if the rule is centralized or decentralized since the LTV is not decreasing as much in the latter case, therefore, borrowing does not decrease as much.

5. Concluding remarks

In this article, I build a two-country DSGE model, with housing, and collateral constraints in order to explore the effects of macroprudential policies. Countries take part of a monetary union in which monetary policy is set by a single central bank. For the case of macroprudential policies, I experiment with two scenarios; one in which they are implemented at a national level and a second one in which they are set at a union level.

This setting represents a general framework in which theoretical experiments related to potential asymmetries in the euro area can be studied. I consider several sources of asymmetries across union members: the first one comes from non-synchronized business cycles, in the spirit of studies that analysed the optimality of currency areas. The second one comes from asymmetries on the strength of financial accelerator effects, namely different LTVs. The third one presents differences in mortgage contracts, in the sense that in one of the countries borrowers own variable-rate mortgages while fixed rate in the other one.

Results show that asymmetries matter for the conduct of macroprudential policies, especially when heterogeneity results in differences in aggregate volatility. When there is an

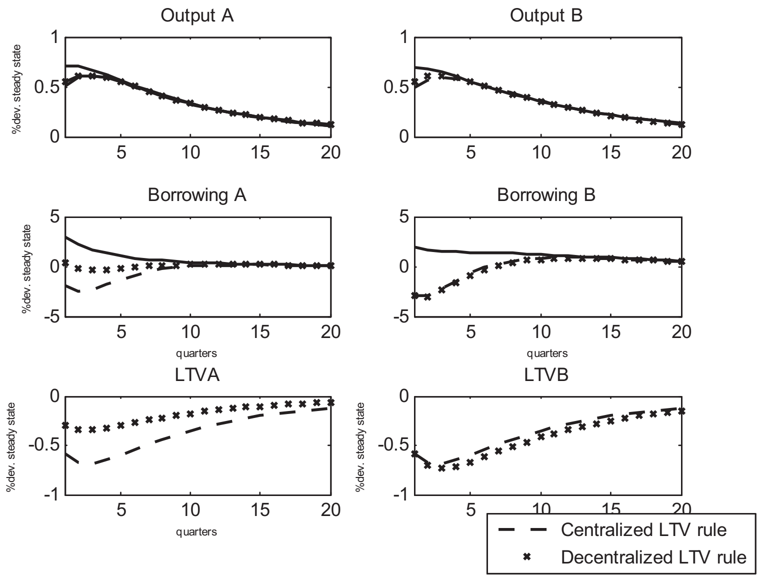

Figure 7. Impulse responses to a common technology shock. Variable rates in Country *A*. Fixed rates in Country *B*. Optimized macroprudential rule.

asymmetric shock, centralized policies are preferred, since they help balancing out the asymmetric effects of the shock. However, if the asymmetry is structural, this is not the case. For different leveraged countries, a decentralized rule that fights more aggressively against output fluctuations helps equalize the financial accelerator effects. Finally, when the asymmetry comes from different mortgage contracts, the decentralized policy is also better, being more aggressive for the fixed-rate country, to compensate for the lack of effectiveness of monetary policy in that case.

In light of the above results, it seems then adequate to delegate macroprudential policies to national authorities. However, a supranational institution could also help stabilize the whole union when there are asymmetric shocks.

Supplementary material

Supplementary material is available on the OUP website. These are the replication codes and the Supplementary Appendix. There was no data used in this article.

Funding

No funding was received for this study.

Acknowledgements

I thank Matteo Iacoviello, Antonio Mele, Carlos Thomas, and Egon Zakrajsek for very useful discussions and comments. I would also like to mention the conference participants at the MMF, the conference on Banking, Finance, Money, and Institutions at the University of Surrey, SAEe, XXI EEP, the Birmingham Macroeconomics and Econometrics Conference 2014, XVII Encuentro de Economía Aplicada, XXI Encuentro de Economia Publica, the ECOBATE, ICMAIF, XVI Conference on International Economics, as well as the seminar participants at the University of Valencia, the Bank of England, the Central Bank of Ireland,

and the University of Milano-Bicocca. Special thanks to Caterina Mendicino, who served as a discussant at the ECB conference on ‘Heterogeneity in Currency Areas and Macroeconomic Policies’, Jean-Bernard Chatelain, who discussed the paper at the CEUS Workshop 2014 ‘Challenges of European Monetary Union at the Age of 15’, Iryna S. Stewen, who was the discussant at the ICMAIF conference, and Carmen Diaz-Roldan, discussant at the XXI Encuentro de Economia Publica and the XVI Conference on International Economics. All errors are mine.

References

Andrés, J. and Arce, O. (2008) Banking competition, housing prices and macroeconomic stability. Bank of Spain, Working Paper, No. 0830.

Angelini, P., Neri, S., and Panetta, F. (2014) The interaction between capital requirements and monetary policy, *Journal of Money, Credit and Banking*, **46**, 1073–112.

Ascari, G. and Ropele, T. (2009) Disinflation in a DSGE perspective: sacrifice ratio or welfare gain ratio? Kiel Institute for the World Economy, Working Paper, No. 1499.

Aspachs, O. and Rabanal, P. (2010) The drivers of housing prices in Spain, *SERIEs*, **1**, 101–30.

Assenmacher-Wesche, K. and Gerlach, S. (2010) Financial structure and the impact of monetary policy on property prices. Mimeo.

Benigno, P. and Woodford, M. (2008) Linear-quadratic approximation of optimal policy problems. Mimeo.

Bosca, J.E., Ferri, J., and Rubio, M. (2022) Fiscal and macroprudential policies in a monetary union. CFCM, No. 22/01.

Brzoza-Brzezina, M., Kolasaz, M., and Makarskix, K. (2015) Macroprudential policy and imbalances in the euro area, *Journal of International Money and Finance*, **51**, 137–54.

Calza, A., Monacelli, T., and Stracca, L. (2009) Housing finance and monetary policy. ECB, Working Paper, No. 1069.

Campbell, J. and Mankiw, N.G. (1991) The response of consumption to income: *A cross-country investigation. European Economic Review*, **35**, 723–756.

Carstensen, K., Hülsewig, O., and Wollmershäuser, T. (2009) Monetary policy transmission and house prices: European cross-country evidence. CESifo, Working Paper, No. 2750.

Domeij, D. and Flodén, M. (2006) The labor-supply elasticity and borrowing constraints: Why estimates are biased, *Review of Economic Dynamics*, **9**, 242–62.

Funke, M. and Paetz, M. (2012) A DSGE-based assessment of nonlinear loan-to-value policies: Evidence from Hong Kong, BOFIT, Discussion Paper, No. 11/2012.

Gilchrist, S., Hairault, J., and Kempf, H. (2002) Monetary policy and the financial accelerator in a Monetary Union. ECB, Working Paper, No. 175.

Iacoviello, M. (2005) House prices, borrowing constraints and monetary policy in the business cycle, *American Economic Review*, **95**, 739–64.

Iacoviello, M. and Neri, S. (2010) Housing market spillovers: Evidence from an estimated DSGE model, *American Economic Journal: Macroeconomics*, **2**, 125–64.

Iacoviello, M. and Smets, F. (2006) House prices and the transmission mechanism in the euro area: Theory and evidence from a Monetary Union model. Mimeo.

IMF. (2008) *World Economic Outlook April 2008*, International Monetary Fund.

Kannan, P., Rabanal, P., and Scott, A.M. (2012) Monetary and macroprudential policy rules in a model with house price booms, *The B.E. Journal of Macroeconomics*, De Gruyter, **12**, 1–44.

Lambertini, L., Mendicino, C., and Punzi, M. (2013) Leaning against boom–bust cycles in credit and housing prices, *Journal of Economic Dynamics and Control*, **37**, 1500–22.

Lawrance, E.C. (1991) Poverty and the Rate of Time Preference: Evidence from Panel Data. *Journal of Political Economy*, **99**, 54–77.

McCallum, B. (2001) Should monetary policy respond strongly to output gaps? *American Economic Review*, **91**, 258–62.

Mendicino, C. and Pescatori, A. (2007) Credit frictions, housing prices and optimal monetary policy rules. Mimeo.

Monacelli, T. (2008) Optimal monetary policy with collateralized household debt and borrowing constraint, NBER Chapters, in Campbell J. (ed.) *Asset Prices and Monetary Policy*. National Bureau of Economic Research, Inc., 103–46.

Quint, D. and Rabanal, P. (2014) Monetary and macroprudential policy in an estimated DSGE model of the euro area, *International Journal of Central Banking*, **10**, 169–236.

Rubio, M. (2011) Fixed- and variable-rate mortgages, business cycles, and monetary policy, *Journal of Money, Credit and Banking*, **43**, 657–88.

Rubio, M. (2014) Housing market heterogeneity in a monetary union, *Journal of International Money and Finance*, **40**, 163–84.

Rubio, M. and Comunale, M. (2017) Lithuania in the Area: Monetary Transmission and Macroprudential Policies, *Eastern European Economics*, **55**, 29–49.

Rubio, M. and Carrasco-Gallego, J.A. (2013) Macroprudential measures, housing markets, and monetary policy, *Moneda y Credito*, 235.

Rubio, M. and Carrasco-Gallego, J.A. (2014) Macroprudential and monetary policies: Implications for financial stability and welfare, *Journal of Banking & Finance*, **49**, 326–36.

Rubio, M. and Carrasco-Gallego, J.A. (2016) Coordinating macroprudential policies within the euro area: the case of Spain, *Economic Modelling*, **59**, 570–82.

Schmitt-Grohé, S. and Uribe, M. (2004) Solving dynamic general equilibrium models using a second-order approximation to the policy function, *Journal ofEconomic Dynamics and Control*, **28**, 755–75.

Smets, F. and Wouters, W. (2002) An estimated stochastic dynamic general equilibrium model of the euro area. No 171, Working Paper Series from European Central Bank.