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Margarita Rubio

Produced By:

Centre for Finance, Credit and Macroeconomics
School of Economics
Sir Clive Granger Building
University of Nottingham
University Park
Nottingham
NG7 2RD

Tel: +44(0) 115 951 5619
Fax: +44(0) 115 951 4159
enquiries@cfcm.org.uk

Macroprudential Policy Implementation in a Heterogeneous Monetary Union

Margarita Rubio*

University of Nottingham

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Abstract

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 four types of cross-country heterogeneity: asymmetric shocks, different loan-to-value ratios (LTV), different proportion of borrowers, and mortgage contract heterogeneity (fixed and variable rates). As a macroprudential tool, I propose a Taylor-type rule for the LTV which responds to deviations in output and house prices. This policy can be applied at a national or union level. Results show that asymmetries matter for the implementation of macroprudential policies, especially when the heterogeneity delivers differences in economic and financial volatilities. A centralized macroprudential policy is preferred if there is an asymmetric shock, to balance out the cross-country different financial volatilities. For the mortgage contract heterogeneity, the economy is better off with a decentralized policy that compensates the lack of effectiveness of monetary policy in the fixed-rate country. For the LTV asymmetry and the different proportion of borrowers, conducting the macroprudential policy at a national or union level produces similar welfare gains.

Keywords: Macroprudential, Housing market, LTV, monetary union, financial stability

JEL Codes: E32, E44, F36

*University of Nottingham, Sir Clive Granger Building, NG7 2RD Nottingham, UK. E-mail: margarita.rubio@nottingham.ac.uk. I thank Matteo Iacoviello, J. A. Carrasco-Gallego, Antonio Mele, Carlos Thomas and Egon Zakrajsek for very useful discussions and comments. The author would also like to mention the conference participants at the MMF and the conference on Banking, Finance, Money and Institutions at the University of Surrey, the SAEe, the XXI EEP, as well as the seminar participants at the University of Valencia and the Bank of England. Special thanks to Caterina Mendicino, who served as a discussant at the ECB conference on "Heterogeneity in Currency Areas and Macroeconomic Policies." All errors are mine.

"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 have experienced has taught us that we need to use policies to avoid such episodes happening again. Scholars and policy makers 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. We can find some examples in emerging markets, especially in Asia. These macroprudential measures include countercyclical capital buffers linked to credit growth, countercyclical provisioning, loan-to-value (LTV) limits or direct controls on lending to specific sectors.

When applying macroprudential policies, it has to be taken into account that these measures need to coexist with other policies such as monetary policy. Monetary policy aims at ensuring price stability while macroprudential measures focus on maintaining financial stability. The implementation of these macroprudential tools becomes more complex if countries are not able to manage their own monetary policy and rely on a single central bank that acts in favor of majority. Cross-country asymmetries or country-specific shocks may be an issue of concern.

Countries in Europe clearly differ in their housing markets. There is evidence of different loan-to-value ratios (LTVs), different proportions of residential debt relative to GDP across countries, and heterogeneous mortgage contracts. Table A1 in the 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 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 United Kingdom, Spain, and Greece is variable rate.

There is an extensive literature that shows that institutional, consumption, financial or housing market heterogeneity can endanger the optimality of EMU as a currency area (See Maclennan et al., 1998, ECB, 2009, Rubio, 2014). However, if an extra set of policies, namely macroprudential, are to be introduced in the European context, researchers and policy-makers also have to ask what the optimal design for such policies is. Macroprudential regulation could be implemented at a union level, like monetary policy, and respond to the average performance of the whole area. The alternative would be to have a decentralized system of national regulators which would take into account the economic conditions of their specific region. This question is irrelevant in a homogeneous union. However, given the single monetary policy restriction, if we find important cross-country differences or asymmetric shocks, we need to assess if the best option is having centralized or decentralized macroprudential policies.

In this paper, I analyze the implementation of macroprudential policies, in particular a rule for the LTV, in the context of a monetary union with heterogeneous members. 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. In particular, I allow for differences in borrower's labor-income shares and LTVs 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).

In this paper, I propose an implementation of the macroprudential policy which is analogous to how monetary policy is conducted. In particular, I assume that 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 (See Yellen, 2010).[1] 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.[2]

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 paper relates to different strands of the literature. The model constitutes a two-country version

[1] We can find other examples of LTV rules in the literature. Funke and Paetz (2012) uses a non-linear rule on the LTV and finds that it can help reduce the transmission of house price cycles to the real economy. In a similar way, Kannan, Rabanal and Scott (2012) examines 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.

[2] The IMF (2013) states that a macroeconomic environment which gives rise to credit growth will contribute to the build-up of systemic risk.

of the seminal paper of Iacoviello (2005), that introduces a financial accelerator that works through the housing sector, in the flavor of Aspachs and Rabanal (2010). However, it introduces cross-country housing-market heterogeneity as in Rubio (2014). This paper is also related to the recent literature on macroprudential and monetary policies in Iacoviello-type models such in the aforementioned Kannan, Rabanal and Scott (2012) or Rubio and Carrasco-Gallego (2013, 2014). However, it explores the issue in a two-country setting as in Quint and Rabanal (2013) and Brzoza-Brzezina et al. (2012). However, these two latter papers only consider country size and asymmetric shocks as the only source of heterogeneity; they are silent about the effects of institutional or housing market asymmetries on the implementation of macroprudential measures. The novelty of this paper 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 macroprudential policies. It is not the focus of this paper to study the coordination problem between the two policies as in Quint and Rabanal (2013) and Angelini et al. (2012). In the present paper, 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.

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. For the case of symmetry across countries, which I take as a benchmark, introducing an LTV rule is unambiguously welfare-enhancing for the economy. Although at the expense of the savers, borrowers benefit from a more stable financial system that helps them smooth consumption. Given monetary policy, the combination of parameters that maximizes welfare is one in which the LTV rule reacts relatively more aggressively to house prices rather than to deviations in output. However, when there is an asymmetric shock, welfare gains appear especially in the case of a centralized policy because, since the shock is transmitted to the other country, the whole union can benefit from a more stable financial system. For the case of different proportions of borrowers, the union also benefits if there are macroprudential policies, however, there is no difference between the centralized and the decentralized case, since the shock causes distributional effects but not differences in aggregate volatility. The optimal combination of parameters does not differ whether we are in a centralized or decentralized setting. For different LTVs it is optimal to respond more strongly to output, to equalize the effects of the financial accelerator across countries. Finally, when the asymmetry comes from different mortgage contracts, the same shock delivers different volatilities in each country. In this case, the optimal rule should respond even more aggressively to house prices than with the other asymmetries. Furthermore, if the rule is implemented at the national level, the fixed-rate country should implement a rule which reacts even more strongly to house price movements, as compared with the variable-rate country, to compensate for the lack of effectiveness of monetary policy.

The paper is organized as follows. Section 2 describes the model. Section 3 presents the parameter values. Section 4 presents results. Section 5 concludes. Tables, steady-state relationships, and the linearized model are shown in the 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 labor 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 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.[3] 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 fulfill their debt obligations in the next period. As in Iacoviello (2005), I assume that

[3] 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.

constrained consumers are more impatient than unconstrained ones.[4] 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 The Financial Intermediary

I assume a competitive framework, and thus the intermediary takes the variable interest rate as given.[5] The profits of the financial intermediary are defined as:[6]

$$F_t = \alpha_A R_{At-1} b_{t-1}^{cv} + (1-\alpha_A)\,\overline{R}_{At-1} b_{t-1}^{cf} - R_{At-1} b_{t-1}^{u}. \tag{1}$$

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

$$\alpha_A b_t^{cv} + (1-\alpha_A)\, b_t^{cf} = b_t^{u}. \tag{2}$$

Substituting (2) into (1), we obtain,

$$F_t = (1-\alpha_A)\, b_{t-1}^{cf}\left(\overline{R_{A}}_{t-1} - R_{At-1}\right). \tag{3}$$

For the two types of mortgage to be offered, the fixed-interest rate has to be such that the intermediary is indifferent between lending at a variable or fixed rate. Hence, the expected discounted profits that the intermediary obtains by lending new debt in a given period at a fixed-interest rate must be equal to the expected discounted profits the intermediary would obtain by lending it at a variable rate:

$$E_\tau \sum_{i=\tau+1}^{\infty} \beta^{i-\tau} \Lambda_{\tau,i} \overline{R_{A_\tau}}^{OPT} = E_\tau \sum_{i=\tau+1}^{\infty} \beta^{i-\tau} \Lambda_{\tau,i} R_{Ai-1}, \tag{4}$$

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

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

[5] 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.

[6] The superscript cv signifies "constrained variable," cf "constrained fixed".

We can obtain the equilibrium value of the fixed rate in period τ from expression (4) :

$$\overline{R}_{A\tau}^{OPT}=\frac{E_{\tau}\sum\limits_{i=\tau+1}^{\infty}\beta^{i-\tau}\Lambda_{\tau,i}R_{Ai-1}}{E_{\tau}\sum\limits_{i=\tau+1}^{\infty}\beta^{i-\tau}\Lambda_{\tau,i}}. \tag{5}$$

Equation (5) states that for every new debt issued at date τ, there is a different fixed-interest rate that has to be equal to a discounted average of future variable-interest rates. Notice that this is not a condition on the stock of debt, but on the new amount obtained in a given period. New debt at a given point in time is associated with a different fixed-interest rate. Both the fixed-interest rate in period τ and the new amount of debt in period τ are fixed for all future periods. However, the fixed-interest rate varies with the date the debt was issued, so that in every period there is a new fixed-interest rate associated with new debt in this period. If we consider fixed-rate loans to be long term, the financial intermediary obtains interest payments every period from the whole stock of debt, not only from the new ones. Hence, we can define an aggregate fixed-interest rate as the one the financial intermediary effectively charges every period for the whole stock of mortgages. 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:

$$\overline{R}_{At}=\left\{\begin{array}{c}\frac{\overline{R}_{At-1}b_{t-1}^{cf}+\overline{R}_{At}^{OPT}\left(b_t^{cf}-b_{t-1}^{cf}\right)}{b_t^{cf}}\text{ if } b_t^{cf}>b_{t-1}^{cf}\\ \overline{R}_{At-1}\text{ if } b_t^{cf}\leq b_{t-1}^{cf}\end{array}\right\}. \tag{6}$$

Equation (6) 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. Both $\overline{R}_{A\tau}^{OPT}$ and $\overline{R}_{At}$ are practically unaffected by interest rate shocks.[7] 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.

As noted above any profits from financial intermediation are rebated to the unconstrained consumers

[7] In log-linearized terms, the new fixed interest rate is always equal to the past fixed interest rate, therefore, equation (6) does not introduce a kink.

every period. Even if the financial intermediary is competitive and does not make profits in the absence of shocks, should a shock occur, the fact that only the variable-interest rate is directly affected can generate non-zero profits.[8]

The financial intermediary problem for Country B is symmetrical.

2.1.2 Unconstrained Consumers (Savers)

Unconstrained consumers in Country A maximize as follows:

$$\max \ E_0 \sum_{t=0}^{\infty} \beta^t \left(\ln C_t^u + j \ln H_t^u - \frac{(L_t^u)^\eta}{\eta} \right), \tag{7}$$

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.[9] j represents the weight of housing in the utility function. $1/(\eta - 1)$ is the aggregate labor-supply elasticity.

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:

$$P_{At} C_{At}^u + P_{Bt} C_{Bt}^u + Q_{At} H_t^u + R_{At-1} B_{t-1}^u + R_{t-1} D_{t-1} + \frac{\psi}{2} D_t^2 \leq Q_t H_{t-1}^u + \\ W_t^u L_t^u + B_t^u + D_t + P_{At} F_t + P_{At} S_t, \tag{8}$$

where P_{At} and P_{Bt} are the prices of the goods produced in Countries A and B, respectively, Q_t 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 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.[10] 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, $\frac{\psi}{2} D_t^2$.[11] Savers obtain interest on their savings. S_t and F_t are

[8] This modelling of the fixed interest rate follows Rubio (2011) and Rubio (2014).
[9] It is assumed that housing services are proportional to the housing stock.
[10] Savers have access to international financial markets.
[11] See Iacoviello and Smets (2006) for a similar specification of the budget constraint.

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:

$$C^u_{At} + \frac{P_{Bt}}{P_{At}} C^u_{Bt} + q_{At} H^u_t + \frac{R_{At-1} b^u_{t-1}}{\pi_{At}} + \frac{R_{t-1} d_{t-1}}{P_{At}} + \frac{\psi}{2} d_t^2 \leq q_t H^u_{t-1} + w^u_t L^u_t + b^u_t + d_t + F_t + S_t, \quad (9)$$

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

Maximizing (7) subject to (9), we obtain the first-order conditions for the unconstrained group:

$$\frac{C^u_{At}}{C^u_{Bt}} = \frac{nP_{Bt}}{(1-n)P_{At}} \quad (10)$$

$$\frac{1}{C^u_{At}} = \beta E_t \left(\frac{R_{At}}{\pi_{At+1} C^u_{At+1}} \right), \quad (11)$$

$$\frac{1-\psi d_t}{C^u_{At}} = \beta E_t \left(\frac{R_t}{\pi_{At+1} C^u_{At+1}} \right), \quad (12)$$

$$w^u_t = (L^u_t)^{\eta-1} \frac{C^u_{At}}{n}, \quad (13)$$

$$\frac{j}{H^u_t} = \frac{n}{C^u_{At}} q_{At} - \beta E_t \frac{n}{C^u_{At+1}} q_{At+1}. \quad (14)$$

Equation (10) equates the marginal rate of substitution between goods to the relative price. Equation (11) is the Euler equation for consumption. Equation (12) is the first-order condition for net foreign assets. Equation (13) is the labor-supply condition. These equations are standard. Equation (14) 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 (11) and (12) we obtain a non-arbitrage condition between home and foreign bonds:[12]

$$R_{At} = \frac{R_t}{(1-\psi d_t)}. \quad (15)$$

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

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

$$P_{At} = P_{At}^{*}, \tag{16}$$

where variables with a star denote foreign variables.

2.1.3 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 $\widetilde{\beta} < \beta$. 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:

$$E_t \frac{R_{At}}{\pi_{At+1}} b_t^{cv} \leq k_{At} E_t q_{t+1} H_t^{cv}, \tag{17}$$

$$E_t \frac{\overline{R}_{At}}{\pi_{At+1}} b_t^{cf} \leq k_{At} E_t q_{t+1} H_t^{cf}, \tag{18}$$

where equations (17) and (18) represent the collateral constraint for the variable- and fixed-rate borrower, respectively. k_{At} can be interpreted as the loan-to-value 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 analyzed. However, in this model, it can vary depending on economic conditions, as a macroprudential policy variable. As I pointed out when I introduced the problem of the financial intermediary, $\overline{R}_{At}$ 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.

Without loss of generality, I present the problem for the variable-rate borrower since that for the fixed rate is symmetrical. Variable-rate borrowers maximize their lifetime utility function:

$$\max\ E_0 \sum_{t=0}^{\infty} \widetilde{\beta}^t \left(\ln C_t^{cv} + j \ln H_t^{cv} - \frac{(L_t^{cv})^\eta}{\eta} \right), \tag{19}$$

where $C_t^{cv} = (C_{At}^{cv})^n (C_{Bt}^{cv})^{1-n}$, subject to the budget constraint (in terms of good A):

$$C_{At}^{cv} + \frac{P_{Bt}}{P_{At}} C_{Bt}^{cv} + q_{At} H_t^{cv} + \frac{R_{At-1} b_{t-1}^{cv}}{\pi_{At}} \leq q_{At} H_{t-1}^{cv} + w_t^{cv} L_t^{cv} + b_t^{cv}, \tag{20}$$

and subject to the collateral constraint (17). 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.[13] 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 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.[14]

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

$$\frac{C_{At}^{cv}}{C_{Bt}^{cv}} = \frac{n P_{Bt}}{(1-n) P_{At}} \tag{21}$$

$$\frac{n}{C_{At}^{cv}} = \widetilde{\beta} E_t \left(\frac{n R_{At}}{\pi_{At+1} C_{At+1}^{cv}} \right) + \lambda_{At}^{cv} R_{At}, \tag{22}$$

$$w_t^{cv} = (L_t^{cv})^{\eta-1} \frac{C_{At}^{cv}}{n}, \tag{23}$$

$$\frac{j}{H_t^{cv}} = \frac{n}{C_{At}^{cv}} q_{At} - \widetilde{\beta} E_t \frac{n}{C_{At+1}^{cv}} q_{At+1} - \lambda_t^{cv} k_{At} E_t q_{At+1} \pi_{At+1}. \tag{24}$$

[13] 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.

[14] 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).

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^{cv}) appears in equations (22) and (24). 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.[15]

The problem for consumers is analogous in Country B.

2.2 Firms

2.2.1 Final-Goods Producers

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

$$Y_{1t}^{k} = \left[\int_0^1 Y_{1t}^{k} \left(z \right)^{\frac{\varepsilon - 1}{\varepsilon}} dz \right]^{\frac{\varepsilon}{\varepsilon - 1}}, \tag{25}$$

where $\varepsilon > 1$ is the elasticity of substitution among intermediate goods.

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

2.2.2 Intermediate-Goods Producers

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

$$Y_{At}\left(z\right) = \xi_t \left(L_t^u\left(z\right)\right)^{\gamma_A} \left(L_t^c\left(z\right)\right)^{\left(1-\gamma_A\right)}, \tag{26}$$

where ξ_t represents 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. $\gamma_A \in [0, 1]$ measures the relative size of each group in terms of labor. We make this parameter country specific, as a proxy for the different deb-to-GDP ratios we observe across countries. L_t^c is labor supplied by constrained consumers, defined as $\alpha_A L_t^{cv} + \left(1 - \alpha_A\right) L_t^{cf}$.

[15] 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 $\lambda^{cv} = n\left(\beta - \widetilde{\beta}\right)/C_A^{cv} > 0$. Given that $\beta > \widetilde{\beta}$, 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.

The first-order conditions for labor demand are the following:[16]

$$w_t^u = \frac{\xi_t}{X_t} \gamma_A \frac{Y_{At}}{L_t^u}, \tag{27}$$

$$w_t^{cv} = w_t^{cf} = \frac{\xi_t}{X_t} \left(1 - \gamma_A\right) \frac{Y_{At}}{L_t^c}, \tag{28}$$

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

$$\sum_{k=0}^{\infty} (\theta\beta)^k E_t \left\{ \Lambda_{t,k} \left[\frac{P_{At}^{OPT}(z)}{P_{At+k}} - \frac{\varepsilon/(\varepsilon-1)}{X_{t+k}} \right] Y_{At+k}^{OPT}(z) \right\} = 0. \tag{29}$$

The aggregate price level is given as follows:

$$P_{At} = \left[\theta P_{At-1}^{1-\varepsilon} + (1-\theta) \left(P_{At}^{OPT}\right)^{1-\varepsilon} \right]^{1/(1-\varepsilon)}. \tag{30}$$

Using (29) and (30) and log-linearizing, we can obtain the standard forward-looking Phillips curve (see equation $(A41)$ in the Appendix).[17]

The firm problem is similar in Country B.

2.3 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 $C_t \equiv C_t^u + C_t^c$, $L_t \equiv L_t^u + L_t^c$. The aggregate supply of housing is fixed, so that market clearing requires $H_t \equiv H_t^u + H_t^c = H$.[18]

The market clearing condition for the final good in Country A is $nY_{At} = nC_{At} + (1-n) C_{At}^* +$

[16] Symmetry across firms allows avoiding index z.

[17] 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).

[18] 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 paper. For two-sector models, see, for example, Iacoviello and Smets (2006) or Iacoviello and Neri (2010).

$n\frac{\psi}{2}d_t^2$. 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 $d_t = \frac{R_{t-1}}{(1-\psi d_t)\pi_{At}}d_{t-1} + Y_{At} - C_{At} - \frac{P_{Bt}}{P_{At}}C_{Bt}$. Everything is similar in Country B.

2.4 Monetary Policy

The model closes with a Taylor rule, with interest-rate smoothing for interest-rate setting by a single central bank,[19]

$$R_t = (R_{t-1})^{\rho}\left(\left[(\pi_{At})^n(\pi_{Bt})^{(1-n)}\right]^{(1+\phi_\pi)}R\right)^{1-\rho}\varepsilon_{R,t}, \tag{31}$$

$0 \le \rho \le 1$ 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.

2.5 Macroprudential Policy

As an approximation for a realistic macroprudential policy, I consider a Taylor-type rule for the loan-to-value ratio. 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 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.[20] 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

[19] This type of rule is also used in other monetary-union models. See Iacoviello and Smets (2006) or Aspachs and Rabanal (2008). Furthermore, as shown in Iacoviello (2005) and Rubio and Carrasco-Gallego (2013), a rule that only responds to inflation enhances the financial accelerator.

[20] I have also experimented with rules that react directly to credit growth and results for the dynamics of the model are similar.

the actual behavior of policymakers.[21] 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:

$$k_t = k_{SS} \left[\left(\frac{Y_{At}}{Y_A} \right)^n \left(\frac{Y_{Bt}}{Y_B} \right)^{1-n} \right]^{-\phi_y^k} \left[\left(\frac{q_{At}}{q_A} \right)^n \left(\frac{q_{Bt}}{q_B} \right)^{1-n} \right]^{-\phi_q^k}, \tag{32}$$

where k_{SS}, Y_A, and q_A are the steady-state values for the loan-to-value ratio, output and house prices in country A. $\phi_y^k \geq 0$, $\phi_q^k \geq 0$ measure the response of the loan-to-to value 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:[22]

$$k_{At} = k_{SSA} \left(\frac{Y_{At}}{Y_A} \right)^{-\phi_{Ay}^k} \left(\frac{q_{At}}{q_A} \right)^{-\phi_{Aq}^k}, \tag{33}$$

$$k_{Bt} = k_{SSB} \left(\frac{Y_{Bt}}{Y_B} \right)^{-\phi_{By}^k} \left(\frac{q_{Bt}}{q_B} \right)^{-\phi_{Bq}^k}. \tag{34}$$

2.6 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 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.[23] The individual welfare for savers and borrowers in Country A is defined, respectively, as follows:

[21] See Angelini et al. (2012) for further discussion.

[22] Notice that even though the policy is decentralized, I am considering the case in which countries act in a coordinated way.

[23] 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-Grohe and Uribe (2004). See Monacelli (2006) for an example of the Ramsey approach in a model with heterogeneous consumers.

$$V_{u,t} \equiv E_t \sum_{m=0}^{\infty} \beta^m \left(\ln C^u_{t+m} + j_t \ln H^u_{t+m} - \frac{\left(L^u_{t+m}\right)^\eta}{\eta} \right), \tag{35}$$

$$V_{cv,t} \equiv E_t \sum_{m=0}^{\infty} \widetilde{\beta}^m \left(\ln C^{cv}_{t+m} + j_t \ln H^{cv}_{t+m} - \frac{\left(L^{cv}_{t+m}\right)^\eta}{\eta} \right), \tag{36}$$

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:

$$V_t = (1-\beta) V_{u,t} + \left(1-\widetilde{\beta}\right) \left[\alpha_A V_{cv,t} + (1-\alpha_A) V_{cf,t}\right]. \tag{37}$$

Borrowers and savers' welfare are weighted by $\left(1-\widetilde{\beta}\right)$ 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:

$$W_t = nV_t + (1-n) V_t^*. \tag{38}$$

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.[24]

3 Parameter Values

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, $\widetilde{\beta}$, is set to 0.98.[25] 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.[26] I set $\eta = 2$, implying a value of the labor supply elasticity of 1.[27] For the loan-to-value ratio I considered a steady-state value of 0.9, as in Iacoviello, 2013, in order to emphasize the financial accelerator mechanism. The labor-income share of unconstrained consumers, $\gamma_A = \gamma_B$, was set to 0.7

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

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

[26] This value corresponds to the US. I assume here that the ratio is similar across most industrialized countries, given the lack of housing wealth data for European countries. See Aspachs and Rabanal (2008).

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

for the symmetric case.[28] 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 $\rho = 0.8$, $\phi_\pi = 0.5$. The first value reflects a realistic degree of interest-rate smoothing.[29] ϕ_π 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.[30] 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. A technology shock was a 1% positive technology with 0.9 persistence.[31] Table A2 in the 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. 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 the different cases considered; the symmetric one, the asymmetric technology shock, asymmetric LTVs, different proportion of borrowers and mortgage contract heterogeneity.

4.1 The Symmetric Case

In this section, I present impulse-response functions for the symmetric case, when the macroprudential rule is absent. Here, countries do not differ in their housing markets, are equal in size and suffer the same shocks. Figure 1 displays responses of the main variables to a technology shock. We can see that this shock generates a boom in the economy, since countries are able to produce more efficiently. Output increases at a lower cost and therefore inflation decreases. The decrease in inflation makes monetary

[28] This value is in the range of the estimates of Iacoviello (2005) and Iacoviello and Neri (2010) for the US, and Campbell and Mankiw (1991) for the US, Canada, France, and Sweden. Table 4 in the Appendix shows robustness checks for welfare considering different values of this parameter.

[29] See McCallum (2001).

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

[31] 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 US.

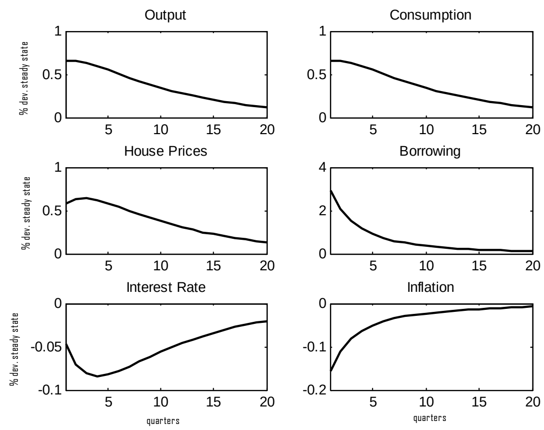

Figure 1: Impulse Responses to a Technology Shock. Symmetric Countries

policy react and interest rates go down. House prices, which move inversely with the interest rate, go up generating collateral effects. Since the collateral has more value now, borrowing can increase, making consumption and output increase even further.

Here, for the symmetric case, to gain some insight about the normative aspects of the model, I analyze how introducing a macroprudential rule affects welfare. I consider a symmetric case in which there is a common technology shock affecting two countries that are equal in all aspects.[32] I use different values of the reaction parameters in the LTV rule to see how welfare is affected by the rule aggressiveness. As a first step and to give a graphical view of the results, I restrict to the case in which the two parameters are equal in value. Then, I drop this restriction and I search for the optimal combination of parameters that maximizes welfare.

Figures 2 and 3 show that for low values of the reaction parameters in the LTV rule, introducing a macroprudential policy unambiguously increases total welfare. We can see that borrowers in both countries are better off with the macroprudential rule because this is introducing financial stability. Welfare, for these agents, increases unambiguously for low values of the reaction parameters, reaches its maximum at around 0.2 and starts to decrease until it turns negative when the LTV rule becomes too aggressive for them (at around 0.4). The intuition for that is the following; since borrowers are constrained they do not have the possibility to smooth consumption. However, if policies reduce aggregate volatility by ensuring a more stable financial system, they will be able to enjoy a more stable consumption path.[33]

[32] All values are presented in consumption equivalents with respect to the benchmark case in which there is no macroprudential policy. Therefore, a positive value means that when the macroprudential rule is active, there is a welfare improvement with respect to the benchmark.

[33] Andres et al. (2013) show analytically that, in this kind of models, welfare depends on the difference in consumption

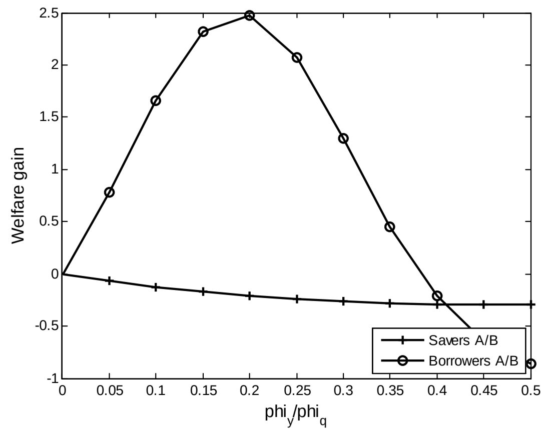

Figure 2: Welfare gains from Macroprudential Policy. Different values of reaction parameters. Symmetric case

Nevertheless, a too aggressive LTV rule limits their ability to access financial markets to a great extent and this is not welfare enhancing anymore. These gains are made at the expense of savers, that reduce their capacity to save, generating a trade-off between the welfare of the two agents. In the aggregate, the welfare improvement of borrowers compensates the loss of the savers and we find an overall welfare improvement. However, results depend on the reaction parameters of the LTV rule. We see that when we start from low values of these parameters, increasing the aggressiveness of the rule is beneficial for the economy but there is a point in which, even if we still obtain gains with respect to the benchmark case, they start to diminish until they reach a negative value. This case would be analogous to a closed economy setting, given that both countries are exactly equal, suffer common shocks and can set their own monetary policy. Results are equivalent to what other studies find for this setting, that is, the introduction of macroprudential policies is unambiguously welfare increasing for the whole economy but we observe a trade-off between borrowers and savers welfare.[34]

If we look at the behavior of the whole economy, we see that welfare mimics the pattern of borrowers, softened by the negative effects produced on the welfare of savers. The point at which welfare is maximized is when $\phi_y^k = \phi_q^k = 0.19$, reflecting the fact that, at least in this benchmark case, the economy is better off with macroprudential rules that are not too aggressive and do not cut credit excessively, allowing borrowers to enjoy an acceptable consumption level.

Next, I calculate the optimal values of the parameters in the LTV rule. Allowing for different values

between borrowers and savers. Therefore, making borrowers' consumption more stable minimizes the gap and thus it is welfare enhancing.

[34] See Rubio and Carrasco-Gallego (2014)

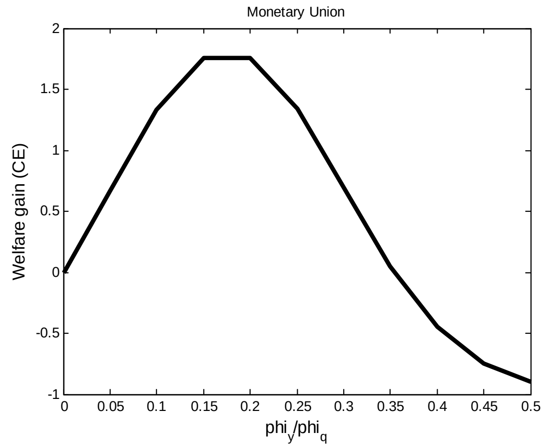

Figure 3: Welfare gains from Macroprudential Policy. Different values of reaction parameters. Symmetric case

of the reaction parameters, results show that the optimal macroprudential policy is one in which the LTV responds little to changes in output while relatively more aggressively to changes in house prices. This result is intuitive, since house prices are a variable that enters directly in the collateral constraint. However, output affects borrowing in an indirect way. Therefore, in order to decrease the negative effects that the collateral constraint may have for financial stability, house prices are the variable to target. These results are in line with Rubio and Carrasco-Gallego (2013) which show similar values in a closed economy setting.[35]

Table 1: Optimal Macroprudential Policy, given TR. Symmetric Case

	Country A/Country B
ϕ_y^{k*}	0.02
ϕ_q^{k*}	0.34
Welfare gain	0.975

Table 2 displays the volatilities, as measured by the standard deviations of output, inflation and borrowing, generated by the model. The first two serve as a proxy for economic stability while the latter one would measure financial stability. I present volatilities for the baseline case, in which there is no macroprudential policy in place, and the ones corresponding to the model with the optimized parameters of the LTV rule. We see that the model with the macroprudential rule presents more stability in terms of output but at the expense of more volatility in inflation, given the trade-off between these two. In

[35] Welfare gains seem rather large with respect to other studies. However, we have to take into account that the benchmark situation I consider is not the optimal one, since I am not optimizing monetary policy.

terms of the volatility of credit, the macroprudential policy manages to reduce it, delivering a more stable financial system.[36]

Table 2: Volatilities. Symmetry		
	Baseline	Optimal Macroprudential
stdev (y)	1.8204	1.7587
stdev (π)	0.2382	0.2672
stdev (b)	4.3871	1.3309

Figures A1 and A2 in the Appendix show the impulse responses for the baseline and the macroprudential case, when the parameters of the LTV rule are optimized. We compare the baseline case in which there is no macroprudential policy with the case in which the loan-to-value rule is active. Since countries are symmetric, it is irrelevant if the rule is centralized or decentralized. Given a technology shock, output increases and inflation decreases in both cases. However, if a macroprudential policy is implemented, output does not increase as much as in the baseline case. The reason for that is that the macroprudential rule cuts borrowing (see lower-right panel). This depresses housing and goods demand for borrowers, which in turn slows down aggregate activity making the increase in output less pronounced. Inflation decreases slightly more in the macroprudential case, due to the fall in demand by borrowers. Monetary policy reacts to this change in inflation, reducing interest rates slightly by more in the macroprudential case. Asset prices move inversely with the interest rate and produce a slight larger increase in the macroprudential case due to the interest-rate response. Figure A2 displays the evolution of the loan-to-value ratio, the instrument of the macroprudential regulator, after the shock hits the economy. We see that, since output and house prices are increasing and this could potentially generate a situation of excessive credit growth, the regulator cuts the LTV with respect to its steady-state value.

4.2 Asymmetric Technology Shock

In this section I present the first case of asymmetry: a technology shock only in one of the countries (Country A), everything else equal. 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.

[36] Results are in line with Gelain et al (2013) which show that while macroprudential policies can stabilize some variables, they can magnify the volatility of others, especially inflation.

In order to understand how the shock to Country A is transmitted to Country B, I display figure 4, which presents impulses responses for the baseline case (no macroprudential) for 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 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 labor 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 labor supply. 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 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.

Now, 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 3). 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.

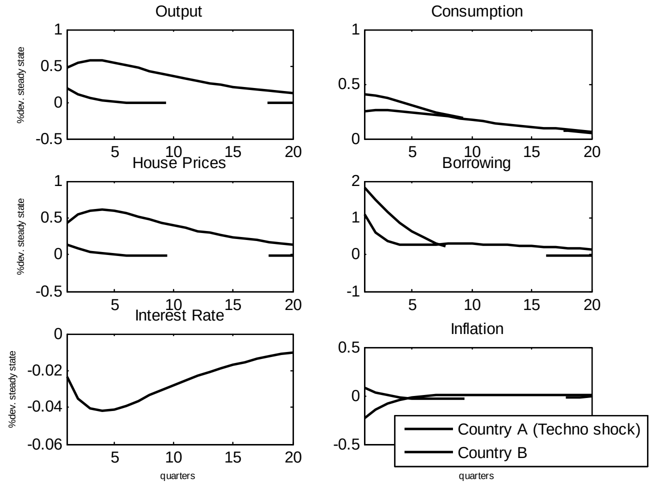

Figure 4: Impulse responses to a technology shock in Country A. No macroprudential policy. Country A versus Country B.

Table 3: 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	0.171	0.044	

Table 4 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 the Country B in which the volatility of borrowing is higher. Remember that given that the common interest rate was decreasing, inflation in Country B 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.

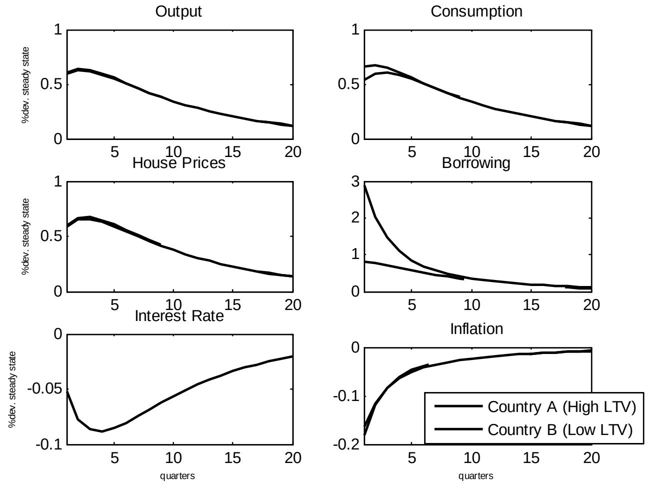

Figure 5: Impulse responses to a common technology shock. High LTV in Country A, low LTV in Country B

Table 4: 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

Looking at the impulse responses (Figures A3 and A4 in the Appendix), 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.

4.3 Different LTVs

Figure 5 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. 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 5, 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 5 displays the optimized parameters for the LTV rule. We can observe that, even though welfare gains are very similar for both cases, the centralized and the decentralized, the optimized parameters are different. 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.

Table 5: 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	0.334	0.343	

In Table 6, 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 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.

Table 6: 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

In figure A6 in the Appendix, 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

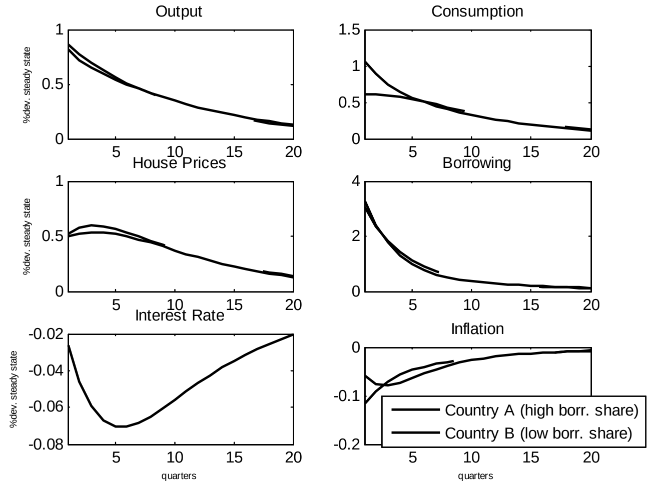

Figure 6: Impulse responses to a common technology shock. High proportion of borrowers in Country A, low proportion in Country B.

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 (See figure A5 in the Appendix).

4.4 Different proportion of borrowers

In this section, I consider that the two countries differ in their debt-to-GDP ratio. Although this is not an explicit parameter in the model, the borrower labor-income share can serve as a proxy. In a country where this share is high, the proportion of borrowers is also high and so it is the debt-to-GDP in consequence. I consider a common technology shock for two countries, A and B, in which the proportion of borrowers is 0.7 and 0.3, respectively.

Figure 6 shows how a common technology shock is transmitted differently across countries, when they differ in their proportion of borrowers. Consumption in Country A, the country with high borrowers share increases by more than in the other country, given the high proportion of borrowers. However, this makes inflation decrease less than in Country B. As a consequence, given the common interest rate, real rates in Country B are lower. Thus, borrowing in Country B increases by more. Finally, house prices and output increase slightly by more in Country B, the country with a low proportion of borrowers. Nevertheless, in aggregate terms, effects on output and borrowing are similar across countries.

When looking at the optimal macroprudential policy, decentralized and centralized policies show similar results in terms of welfare. The optimal rule is similar for all cases, one that responds slightly to deviations in output and more strongly to deviations in house prices. Welfare gains do not differ much when policies are implemented at national or union levels (See Table 7).

Table 7: Optimal Macroprudential Policy, given TR. High proportion borrowers in A.

	Centralized	Decentralized	
		Country A	Country B
ϕ_y^{k*}	0.02	0.02	0.02
ϕ_q^{k*}	0.29	0.3	0.3
Welfare Gain	3.336	3.271	

In Table 8 we clearly see why the optimal macroprudential policy is so similar for the centralized and the decentralized case. This source of asymmetry does not generate different volatilities, neither macroeconomic nor financial. Therefore, the macroprudential policy, both centralized and decentralized, is very similar to the symmetric case, that is, a low output response and a relatively higher house price response.

Table 8: Volatilities. High proportion borrowers A

	Country A			Country B		
	Baseline	MP Cent	MP Dec	Baseline	MP Cent	MP Dec
stdev (y)	1.9252	1.7774	1.7721	1.9697	1.7679	1.7628
stdev (π)	0.1877	0.2666	0.2695	0.1991	0.2678	0.2700
stdev (b)	4.9073	1.6390	1.5616	4.9122	1.6952	1.5863

Figure A7 in the Appendix displays the impulse responses for the baseline and the macroprudential case. We see how the macroprudential rule cuts borrowing in both countries. However, there is not much difference between the centralized and the decentralized rule since, even if there are differences in the LTV response (See figure A8 in the Appendix), they are not very large. For this shock, the effects seem to be more distributional than aggregate and this is why the centralized and the decentralized case do not display large differences.

4.5 Different mortgage contracts

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. Figure 7 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

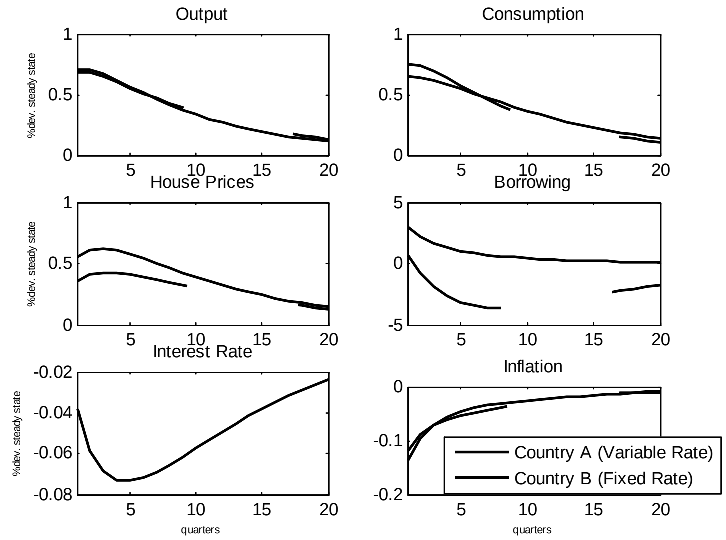

Figure 7: Impulse responses to a common technology shock. Variable rates in Country A, fixed rates in Country B.

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.

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.

Table 9: 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	0.857	7.757	

With fixed-rate mortgages, monetary policy is less efficient to stabilize the macroeconomy.[37] An aggressive macroprudential policy compensates the lack of effectiveness of monetary policy. The optimal

[37] See Rubio (2011) for a detailed discussion on this issue.

macroprudential policy responds more strongly to house prices than in the previous cases. In the centralized case because there are fixed-rates in half of the union. In the decentralized, for the country that has fixed rates. The decentralized case is preferred.

Table 10 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.

Table 10: 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

Figure A10 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 (See figure A9)

5 Concluding Remarks

In this paper, 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 settings; one in which they are implemented at a national level and a second one in which they are set at a union level.

As a benchmark, I consider a monetary union in which members are symmetric and shocks are synchronized. Then, I consider four sources of asymmetries across countries: the first one comes from non-synchronized business cycles, in the spirit of studies that analyzed 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 the labor income shares of borrowers. Finally, I consider mortgage contract asymmetries, in the sense that in one of the countries borrowers own variable-rate mortgages while fixed-rate in the other one.

Results show that, for the benchmark case, introducing an LTV rule is unambiguously welfare enhancing for the economy. Although at the expense of the savers, borrowers benefit from a more stable financial system that help them smooth consumption. Furthermore, the optimal rule is one that responds more strongly to house prices than to output deviations.

When introducing asymmetries, we see that they matter for the conduct of macroprudential policies, especially when heterogeneity results in differences in aggregate volatility. When there is an asymmetric shock, centralized policies are preferred, since they help balancing out the asymmetric effects of the shock. If the rule is decentralized, the optimal policy is one in which the macroprudential regulation is more aggressive in the country that does not receive the shock. For different LTVs, a rule that fights more aggressively against output fluctuations helps equalize the financial accelerator effects. However, welfare gains for the centralized and the decentralized policy are similar. For the case of different proportion of borrowers, the economy also benefits if there are macroprudential policies, however, there is no difference between the centralized and the decentralized case, since the shock causes distributional effects but not differences in aggregate volatility. Finally, when the asymmetry comes from different mortgage contracts, the decentralized policy is better, being more aggressive for the fixed-rate country, to compensate for the lack of effectiveness of monetary policy in that case.

Appendix

Tables and Figures

Country	LTV	Residential Debt/GDP	Rate
BELGIUM	83	43,3	F
FINLAND	75	58	V
FRANCE	75	38	F
GERMANY	70	47,6	F
ITALY	50	21,7	V
IRELAND	70	90,3	F
NETHERLANDS	90	105,6	F
PORTUGAL	75	67,5	V
SPAIN	70	66,4	V

Table A1: Characteristics of mortgage markets. Source: IMF (2008)

Parameter Values		
β	.99	Discount Factor for Savers
$\widetilde{\beta}$	.98	Discount Factor for Savers
j	.1	Weight of Housing in Utility Function
η	2	Parameter associated with labor elasticity
k	0.9	Average loan-to-value ratio
γ	.70	Labor-Income share for savers
α	1	Degree of variability of interest rate
ε	6	Elasticity of substitution among intermediate goods
ρ	0.8	Interest-rate smoothing in Taylor rule
ϕ_π	.5	Inflation Parameter in Taylor rule
σ_ϵ	0.29	Monetary shock standard error
ρ_ξ	0.9	Technology shock persistence

Table A2: Parameter Values

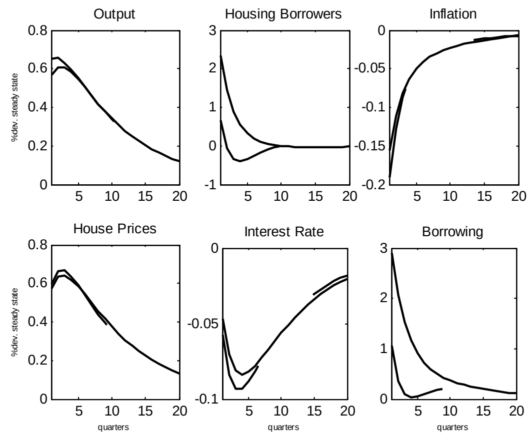

Figure A1: Impulse responses to a common technology shock. Symmetric countries. Optimized Macroprudential Rule.

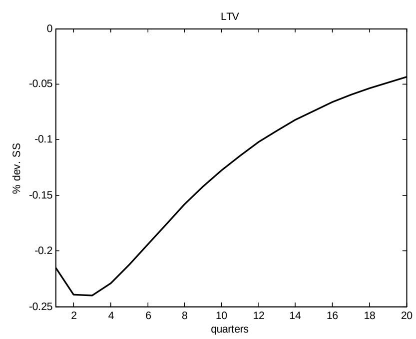

Figure A2: LTV response to a common technology shock. Symmetric countries. Optimized Macroprudential Rule.

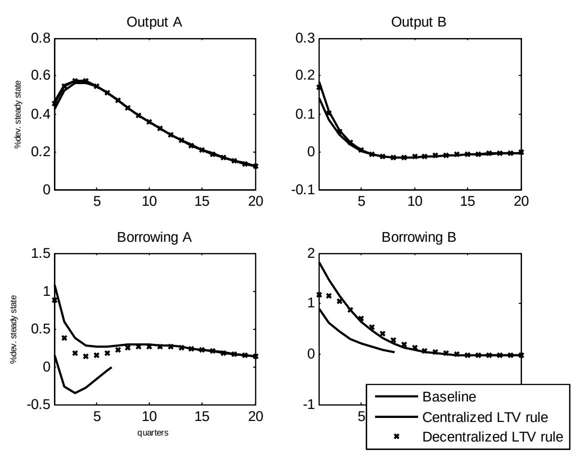

Figure A3: Impulse responses to a technology shock in Country A. Symmetric countries. Optimized Macroprudential Rule.

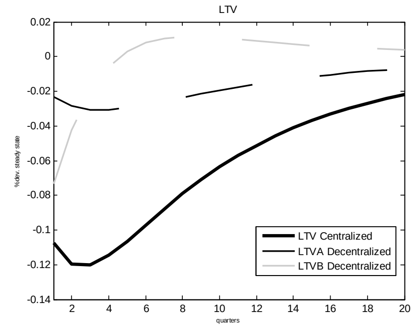

Figure A4: LTV response to a technology shock in Country A. Symmetric countries. Optimized Macroprudential Rule.

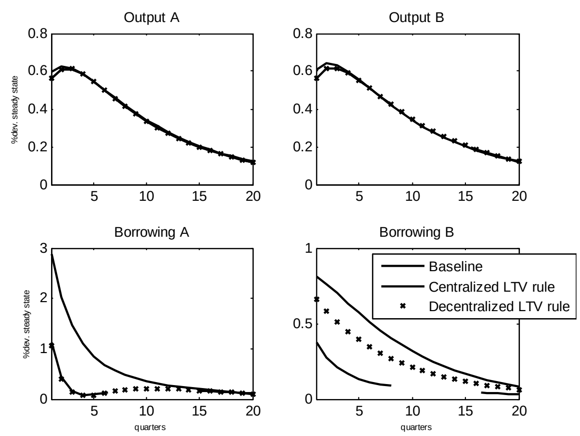

Figure A5: Impulse responses to a common technology shock. High LTV in Country A. Optimized Macroprudential Rule.

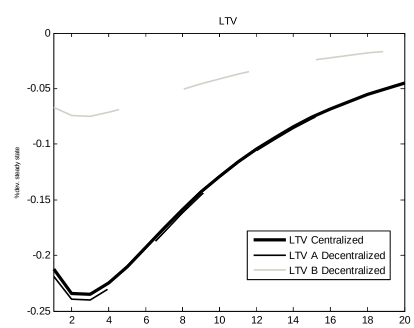

Figure A6: LTV response to a common technology shock. High LTV in Country A. Optimized Macroprudential Rule.

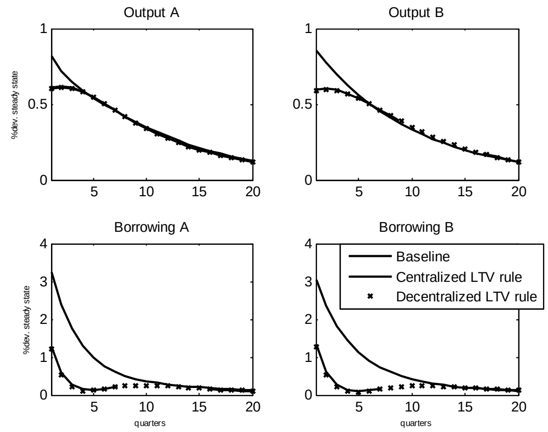

Figure A7: Impulse responses to a common technology shock. High proportion of borrowers in Country A. Optimized Macroprudential Rule.

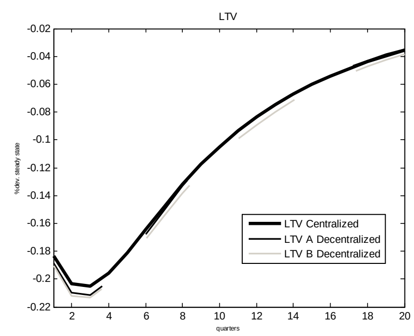

Figure A8: LTV response to a common technology shock. High proportion of borrowers in Country A. Optimized Macroprudential Rule.

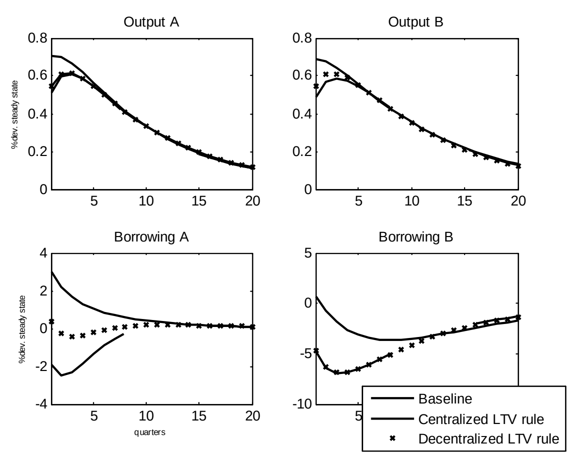

Figure A9: Impulse responses to a common technology shock. Variable rates in Country A. Optimized Macroprudential Rule.

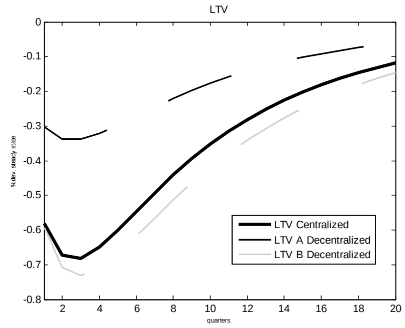

Figure A10: LTV response to a common technology shock. Variable rates in Country A. Optimized Macroprudential Rule.

Steady-state relationships

Relative prices in the steady state are derived from equations (10), (21) and their counterparts for Country B:

$$\frac{n}{1-n}\frac{P_B}{P_A} = \frac{C_A^u}{C_B^u} = \frac{C_A^c}{C_B^c} = \frac{C_A^{u*}}{C_B^{u*}} = \frac{C_A^{c*}}{C_B^{c*}}. \tag{A1}$$

Interest rates:

$$R_A = R = R_B = \overline{R} = \overline{R}^* = 1/\beta. \tag{A2}$$

We can find the consumption-to-housing ratio for savers and borrowers in Country A by using the first-order conditions for housing:

$$\frac{C_A^u}{qH^u} = \frac{n}{j}\left(1-\beta\right), \tag{A3}$$

$$\frac{C_A^c}{qH^c} = \frac{n}{j}\left[\left(1-\widetilde{\beta}\right) - k_A\left(\beta - \widetilde{\beta}\right)\right] = \frac{n}{j}\zeta. \tag{A4}$$

Similarly, for Country B:

$$\frac{C_B^{u*}}{q^*H^{u*}} = \frac{(1-n)}{j^*}\left(1-\beta\right), \tag{A5}$$

$$\frac{C_B^{c*}}{q^*H^{c*}} = \frac{(1-n)}{j^*}\left[\left(1-\widetilde{\beta}\right) - k_B\left(\beta - \widetilde{\beta}\right)\right] = \frac{(1-n)}{j^*}\zeta^*. \tag{A6}$$

Borrowing in the steady state is as follows:

$$b^c = \beta k_A q H^c, \tag{A7}$$

$$b^u + b^c = 0, \tag{A8}$$

$$b^{c*} = \beta k_B q^* H^{c*}, \tag{A9}$$

$$b^{u*} + b^{c*} = 0. \tag{A10}$$

From the firm problem, we have that in the steady state:

$$w^{u} = \frac{1}{X}\gamma\frac{Y_A}{L^u}, \tag{A11}$$

$$w^{c} = \frac{1}{X}\left(1-\gamma\right)\frac{Y_A}{L^c}, \tag{A12}$$

$$w^{u*} = \frac{1}{X^*}\gamma\frac{Y_B}{L^{u*}}, \tag{A13}$$

$$w^{c*} = \frac{1}{X^*}\left(1-\gamma\right)\frac{Y_B}{L^{c*}}, \tag{A14}$$

where $X = X^* = \dfrac{\varepsilon - 1}{\varepsilon}$.

Combining the steady-state budget constraint for unconstrained consumers in Country A with $(A3)$ and $(A11)$ we obtain:

$$\frac{C_A^u}{Y_A} = \frac{n\left(\gamma + X - 1\right)}{X\left(1 - jk_A\right)}. \tag{A15}$$

Similarly, for constrained consumers:

$$\frac{C_A^c}{Y_A} = \frac{1-\gamma}{X}\frac{\zeta n}{\zeta + jk_A\left(1-\beta\right)}. \tag{A16}$$

The market-clearing conditions for goods produced in Country A imply:

$$\frac{C_A^*}{Y_A} = \frac{n}{1-n}\left(1 - \frac{C_A^u}{Y_A} - \frac{C_A^c}{Y_A}\right). \tag{A17}$$

Using $(A3)$ and $(A15)$ we can find the housing-to-output ratio for savers in Country A:

$$\frac{H^u}{Y_A} = \frac{j\left(\gamma + X - 1\right)}{Xq\left(1 - jk_A\right)\left(1-\beta\right)}. \tag{A18}$$

Analogously, using $(A4)$ and $(A16)$ we can find the housing-to-output ratio for constrained consumers in Country A:

$$\frac{H^c}{Y_A} = \frac{(1-\gamma)\, j}{Xq} \frac{n}{\zeta + jk_A\,(1-\beta)}. \tag{A19}$$

Similarly, for Country B:

$$\frac{C_B^{u*}}{Y_B} = \frac{(1-n)\,(\gamma + X^* - 1)}{X^*\,(1 - j^* k_B)}, \tag{A20}$$

$$\frac{C_B^{c*}}{Y_B} = \frac{1-\gamma}{X^*} \frac{\zeta\,(1-n)}{\zeta^* + j^* k_B\,(1-\beta)}, \tag{A21}$$

$$\frac{H^{u*}}{Y_B} = \frac{j^*\,(\gamma + X^* - 1)}{X^* q^*\,(1 - j^* k_B)\,(1-\beta)}, \tag{A22}$$

$$\frac{H^{c*}}{Y_B} = \frac{(1-\gamma)\, j^*}{X^* q^*} \frac{(1-n)}{\zeta^* + j^* k_B\,(1-\beta)}. \tag{A23}$$

Log-linearized equations

Variables in deviations from the steady state are expressed in lower-case and with a hat.

Interest rates

$$\hat{r}_{At} = \hat{r}_{Bt} + E_t\,(\hat{e}_{t+1} - \hat{e}_t) + \psi, \tag{A24}$$

$$\widehat{\widehat{r}}_{At} = \widehat{\widehat{r}}_{Bt} = 0. \tag{A25}$$

Aggregate demand

$$\widehat{c}_{At}^{u} = E_t \widehat{c}_{At+1}^{u} - (\widehat{r}_{At} - E_t \widehat{\pi}_{At+1})\,, \tag{A26}$$

$$\widehat{c}_{Bt}^{u*} = E_t \widehat{c}_{Bt+1}^{u*} - (\widehat{r}_{Bt} - E_t \widehat{\pi}_{Bt+1})\,, \tag{A27}$$

$$\hat{c}^{c}_{At} = \left(\frac{\zeta + jk_A\left(1-\beta\right)}{\zeta}\right)\left(\hat{y}_{At} + \widehat{\xi}_t - \hat{x}_t\right) - \frac{j}{\zeta}\left(\hat{h}^c_t - \hat{h}^c_{t-1}\right)$$
$$+\frac{k_A j}{\zeta}\left(\beta\hat{b}^c_t - \hat{b}^c_{t-1}\right) - k_A j\left(\alpha_A \hat{r}_{At-1} - \hat{\pi}_{At}\right), \tag{A28}$$

$$\hat{b}^c_t = E_t\hat{q}_{t+1} + \hat{h}^c_t - \left(\alpha_A\hat{r}_{At} - E_t\hat{\pi}_{At+1}\right), \tag{A29}$$

$$\hat{c}^{c*}_{Bt} = \left(\frac{\zeta^* + j^*k_B\left(1-\beta\right)}{\zeta^*}\right)\left(\hat{y}_{Bt} + \widehat{\xi}^*_t - \hat{x}_t\right) - \frac{j^*}{\zeta^*}\left(\hat{h}^{c*}_t - \hat{h}^{c*}_{t-1}\right)$$
$$+\frac{k_B j^*}{\zeta^*}\left(\beta\hat{b}^{c*}_t - \hat{b}^{c*}_{t-1}\right) - k_B j^*\left(\alpha_B \hat{r}_{Bt-1} - \hat{\pi}_{Bt}\right), \tag{A30}$$

$$\hat{b}^{c*}_t = E_t\hat{q}^*_{t+1} + \hat{h}^{c*}_t - \left(\alpha_B\hat{r}_{Bt} - E_t\hat{\pi}_{Bt+1}\right), \tag{A31}$$

$$\hat{c}_{At} - \hat{c}_{Bt} = \hat{c}^*_{At} - \hat{c}^*_{Bt}. \tag{A32}$$

Housing equations

$$\widehat{h}^u_t = \frac{1}{1-\beta}\left(\widehat{c}^u_{At} - \widehat{q}_t\right) - \frac{\beta}{1-\beta}E_t\left(\widehat{c}^u_{At+1} - \widehat{q}_{t+1}\right), \tag{A33}$$

$$\widehat{h}^{u*}_t = \frac{1}{1-\beta}\left(\widehat{c}^{u*}_{Bt} - \widehat{q}^*_t\right) - \frac{\beta}{1-\beta}E_t\left(\widehat{c}^{u*}_{Bt+1} - \widehat{q}^*_{t+1}\right), \tag{A34}$$

$$\hat{h}^c_t = \frac{1-k_A\beta}{\zeta}\hat{c}^c_t - \frac{1}{\zeta}\hat{q}_t - \frac{k_A\beta}{\zeta}\left(\alpha_A\hat{r}_{At} - E_t\hat{\pi}_{At+1}\right) + \frac{\widetilde{\beta}}{\zeta}E_t\hat{q}_{t+1} - \frac{\widetilde{\beta}\left(1-k_A\right)}{\zeta}E_t\hat{c}^c_{t+1}, \tag{A35}$$

$$\hat{h}^{c*}_t = \frac{1-k_B\beta}{\zeta^*}\hat{c}^{c*}_t - \frac{1}{\zeta}\hat{q}^*_t - \frac{k_B\beta}{\zeta^*}\left(\alpha_B\hat{r}_{Bt} - E_t\hat{\pi}_{Bt+1}\right) + \frac{\widetilde{\beta}}{\zeta^*}E_t\hat{q}^*_{t+1} - \frac{\widetilde{\beta}\left(1-k_B\right)}{\zeta^*}E_t\hat{c}^{c*}_{t+1}. \tag{A36}$$

Aggregate supply

$$\hat{y}_{At} = \frac{\eta+1}{\eta-1}\widehat{\xi}_t - \frac{1}{\eta-1}\left(\gamma\hat{c}^u_{At} + (1-\gamma)\,\hat{c}^c_{At} + \hat{x}_t\right), \tag{A37}$$

$$\hat{y}_{At} = \left(\frac{C^u_A}{Y_A} + \frac{C^c_A}{Y_A}\right)\hat{c}_{At} + \left(1 - \frac{C^u_A}{Y_A} - \frac{C^c_A}{Y_A}\right)\hat{c}^*_{At}, \tag{A38}$$

$$\hat{y}_{Bt} = \frac{\eta+1}{\eta-1}\widehat{\xi}^*_t - \frac{1}{\eta-1}\left(\gamma\hat{c}^{u*}_{Bt} + (1-\gamma)\,\hat{c}^{c*}_{Bt} + \hat{x}^*_t\right), \tag{A39}$$

$$\hat{y}_{Bt} = \left(\frac{C^{u*}_B}{Y_B} + \frac{C^{c*}_B}{Y_B}\right)\hat{c}^*_{Bt} + \left(1 - \frac{C^{u*}_B}{Y_B} - \frac{C^{c*}_B}{Y_B}\right)\hat{c}_{Bt}, \tag{A40}$$

$$\hat{\pi}_{At} = \beta\hat{\pi}_{At+1} - \widetilde{k}\hat{x}_t + u_{At}, \tag{A41}$$

$$\hat{\pi}^*_{Bt} = \beta\hat{\pi}^*_{Bt+1} - \widetilde{k}\hat{x}^*_t + u_{Bt}, \tag{A42}$$

where $\widetilde{k} = \frac{(1-\theta)(1-\beta\theta)}{\theta}$ and u_{At} and u_{Bt} are cost-push shocks.

Monetary policy

$$\hat{r}_t = \rho\hat{r}_{t-1+}\,(1-\rho)\left\{(1+\phi_\pi)\left[n\hat{\pi}_{At} + (1-n)\,\hat{\pi}_{Bt}\right] + \log\left(1/\beta\right)\right\} + \widehat{\epsilon}_{R,t}. \tag{A43}$$

Macroprudential policy

Centralized

$$\widehat{k}_t = \log(k_{SS}) - \phi^k_y\left[n\hat{y}_{At} + (1-n)\,\hat{y}_{Bt}\right] - \phi^k_q\left[n\widehat{q}_{At} + (1-n)\,\widehat{q}_{Bt}\right]. \tag{A44}$$

Decentralized

$$\widehat{k}_{At} = \log(k_{SSA}) - \phi^k_y\hat{y}_{At} - \phi^k_q\widehat{q}_{At}, \tag{A45}$$

$$\widehat{k}_{Bt} = \log(k_{SSB}) - \phi^k_y\hat{y}_{Bt} - \phi^k_q\widehat{q}_{Bt}. \tag{A46}$$

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