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Macroprudential and monetary policies: Implications for financial stability and welfare

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ABSTRACT

In this paper, we analyze the implications of macroprudential and monetary policies for business cycles, welfare, and financial stability. We consider a dynamic stochastic general equilibrium (DSGE) model with housing and collateral constraints. A macroprudential rule for the loan-to-value ratio (LTV), which responds to credit growth, interacts with a traditional Taylor rule for monetary policy. We compute the optimal parameters of these rules both when monetary and macroprudential policies act in a coordinated and in a non-coordinated way. We find that both policies acting together unambiguously improves the stability of the system. In both cases, this interaction is welfare improving for the society, especially in the case of the non-coordinated game. There is though a trade-off between borrowers and savers. However, borrowers can compensate the saver's welfare loss *à la* Kaldor–Hicks to achieve a Pareto-superior outcome.

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> *"Normally, however, the policy rate is not the only available tool, and much better instruments are available for achieving and maintaining financial stability. Monetary policy should be the last line of defence of financial stability, not the first line."* Svensson (2012)

1. Introduction

The housing sector is key to understand how the recent financial crisis developed and, therefore, crucial for designing recovery and prevention policies. The financial crisis was born in the housing sector, grew in the financial sector and had its final consequences in the real sector. Financial innovations made the financial system increasingly complex and interconnected, leading to an expansion of systemic risk, especially through the mortgage market. In this context, when house prices collapsed, micro-prudential policies, those dedicated to prevent the risk from each company, had not managed to avoid the contagion to the real sector, and the crisis spread across the financial system to the real economy. Then, a great recession affected the whole economy, causing a high level of unemployment. Thus, from a policy perspective, traditional measures have not seemed to be sufficient to, first, avoid the crisis and, second, have a fast and effective recovery.

As a result, several institutions have implemented macroprudential tools in order to explicitly promote the stability of the financial system in a global sense, not just focusing on individual companies. The goal of this kind of regulation is to avoid the transmission of financial shocks to the broader economy. Some examples of macroprudential tools are asset-side tools (loan-to-value (LTV) and debt-to-income ratio caps), liquidity-based tools (countercyclical liquidity requirements), or capital-based tools (countercyclical capital buffers, sectorial capital requirements or dynamic provisions).

The LTV requirement is a limit on the value of a loan relative to the underlying collateral (e.g. residential property). Several studies have pointed out that higher LTV ratios combined with higher risk mortgages contributed to the mortgage crisis.[1] The LTV is nowa-

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[1] See, for instance, Abraham et al. (2008) and Duca et al. (2011).

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days described as one of the main macroprudential instruments to “mitigate and prevent excessive credit growth and leverage” by the European Systemic Risk Board.[2] Within the EU, LTV limits are available in the national prudential framework of 16 Member States.[3]

The aim of this paper is to evaluate the implications of a macroprudential LTV tool for business cycles, financial stability, and welfare, as well as its interaction with monetary policy. In order to do that, we use a dynamic stochastic general equilibrium (DSGE) model which features a housing market.

The modelling framework consists of an economy composed of borrowers and savers. In particular, our model imposes a limit on borrowing, that is, loans need to be collateralized by a proportion of the value of the assets that the borrower owns. This proportion can be interpreted as an LTV. The macroprudential tool we propose is a rule that automatically reduces loan-to-values when there is a credit boom, therefore limiting the expansion of credit. We assume that there exists a macroprudential Taylor-type rule for the LTV ratio, so that it responds to credit growth, in the spirit of the Basel III regulation which aims at avoiding episodes of excessive credit growth. The monetary policy literature has extensively shown that simple rules result in a good performance; therefore, it seems sensible to apply these kinds of rules to macroprudential supervision. This microfounded general equilibrium model allows us to explore all the interrelations that appear between the real economy and the credit market. Furthermore, such a model can deal with welfare-related issues.

In the context of this model, we address several research questions. First, we study the welfare gain for each agent and for the aggregate both for different levels of a static LTV and for different values of the reaction parameters of the macroprudential rule. In this way, we discuss the welfare trade-offs that may appear between borrowers and savers. Second, we analyze the combination of monetary and macroprudential policy parameters that maximize welfare when the macroprudential regulator and the central bank are coordinated and when they are not. Third, we discuss a Pareto-superior outcome to overcome this trade-off by a system of transfers *à la* Kaldor–Hicks. Then, we study the dynamics of the model under the optimal parameters. Finally, we graphically convey our results to highlight the effects on macroeconomic and financial stability of introducing a new macroprudential policy based on the LTV ratio.

The rest of the paper continues as follows: Section 1.1 reviews the literature. Section 2 describes the model. Section 3 presents the welfare analysis. Section 4 computes the optimal parameter combination of the different policies in a coordinated and in a non-coordinated situation. It also develops a rule to obtain a Pareto-superior outcome, presents results from simulations, and conveys the results graphically to show the effects of the macroprudential policy on financial and macroeconomic stability. Section 5 concludes.

1.1. Related literature

Our paper fits into the literature that introduces a macroprudential rule and studies its effects using a DSGE model. Other examples are, for instance, Antipa et al. (2010), who uses a DSGE model to show that macroprudential policies would have been effective in smoothing the past credit cycle and in reducing the intensity of the recession. Another example is Borio and Shim (2007), which emphasizes the complementary role of macroprudential policy to monetary policy and its supportive function as a built-in stabilizer. As well, N’Diaye (2009) shows that monetary policy can be supported by countercyclical prudential regulation. Angelini et al. (2012) uses a DSGE model with a banking sector and shows interactions between capital requirement ratios as a macroprudential tool and monetary policy; they find that macroprudential policies are most helpful to counter financial shocks that lead the credit and asset price booms. We find in our paper that macroprudential policies moderate credit booms. Furthermore, for housing demand shocks, the combination of the macroprudential and the monetary policies manages to control credit without moderating the real effects of the boom.

Since there is an extensive consensus that the origin of the last crisis is related to real estate booms and busts, we have focused on the effects of a macroprudential tool that has to do with the housing sector. However, while most papers in the field tend to analyze macroprudential policies through the lens of a countercyclical bank leverage rule (e.g. Angelini et al., 2012; Christensen et al, 2011), in our paper, we study how a key element of the real estate sector, namely the LTV, can serve as a macroprudential tool to improve financial stability.[4] With a macroprudential orientation, Kannan et al. (2012) also examines a monetary policy rule that reacts to prices, output and changes in collateral values with a macroprudential instrument based on the LTV; they remark on the importance of identifying the source of the shock of the housing price boom when assessing policy optimality. Funke and Paetz (2012) considerers a non-linear version of a macroprudential rule for the LTV. Following this literature, we propose a macroprudential policy based on a Taylor-type automatic rule.[5] By analogy with monetary policy, rule-based macroprudential tools – for example, automatic stabilizers – appear appealing (Goodhart, 2004).

One question that arises from the topic is what the objective of the macroprudential authority should be. In recent years, research on macroprudential issues has been wide and intense[6] and there is an increasing consensus among academics and policy makers that “the ultimate objective of macroprudential policy is to contribute to the safeguard of the stability of the financial system as a whole” (Recommendation of the European Systemic Risk Board, 2013). In this way, Almeida et al. (2006) has studied the effect on the amplitude of the credit cycle results from the mitigating impact of more stringent LTV ratios on the ‘financial accelerator’ mechanism. They find that when a positive income shock leads to an increase in housing prices, the increase in borrowing is expected to be lower in countries with lower LTV ratios. Gelain et al. (2013) evaluates different policy actions that might be used to dampen the resulting excess volatility, including a direct response to house-price growth or credit growth in the central bank’s interest rate rule, the imposition of a more restrictive loan-to-value ratio, and the use of a modified collateral constraint that takes into account the borrower’s wage income. We contribute to this line of research, finding that when we use the macroprudential policy based on the LTV, both the macroeconomy and the financial system become more stable. To illustrate that, we construct policy frontiers (Taylor curves) including not only the traditional objectives of monetary policy but also the objective of the macroprudential regulator: financial stability. As a measure of financial stability we propose the variability of borrowing. This three-dimensional policy frontier shows graphically that the macroprudential policy unambiguously helps to achieve a more stable financial and macroeconomic situation.

A central issue that we cover in our paper is the interaction between monetary and macroprudential policies. There is no consensus on whether both policies should act in a coordinated or in a

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[2] See Recommendation of the European Systemic Risk Board (2013).

[3] More world results are available in Lim et al. (2011).

[4] Borio et al. (2001) also evaluated limits on the LTV.

[5] See Borio and Shim (2007) for a distinction between rules and discretion in calibrating the tools of macroprudential policy.

[6] See Galati and Moessner (2013) for an extensive review.

non-coordinated way. For instance, Bean et al. (2010), with a DSGE model adapted from Gertler and Karadi (2011), studies how the use of a macroprudential policy tool based on a lump-sum levy or subsidy on the banking sector might affect the conduct of monetary policy. Their results suggest that monetary and macroprudential policies should be coordinated, since they are not merely substitutes, but they mention that the issue of coordination needs to be studied further. Beau et al. (2012) claims that it is preferable to have a combination of separate objectives for monetary and macroprudential policies, with monetary policy taking the macroeconomic effects of macroprudential policy into account in choosing interest rates, that is, the non-coordinated case would be preferable. Angelini et al. (2012) studies the coordination issue in a context in which the macroprudential regulator uses capital requirements as a tool to achieve financial stability. They find that lack of cooperation between a macroprudential authority and a central bank may actually generate conflicting policies and, therefore, cooperation is preferred. In our paper, we also distinguish between the cases of coordination and non-coordination to try to shed some light on this issue. As argued by Svensson (2012), we find that the non-coordination game delivers higher social welfare and then is preferable. When each authority focuses on its own objective, they are more effective in minimizing both macroeconomic and financial variability.

Finally, measuring the potential welfare improvement of macroprudential policies has deserved the special attention of academics. Some papers have found that the macroprudential reaction to exogenous shocks can make some people better off (typically borrowers), but not every type of household, or not in all cases. For instance, Lambertini et al. (2013) extends the Iacoviello and Neri (2010) model to incorporate news shocks and a macroprudential rule on the LTV. They find that an optimized LTV-ratio rule that responds to credit growth is a Pareto-improving policy compared to the use of a constant LTV ratio. Campbell and Hercowitz (2009) performes a welfare analysis in a DSGE model with borrowers and savers and determines that, although high LTV ratios have a direct positive effect on welfare through constraint relaxation, other indirect effects may dominate. Angelini et al. (2012) also discusses the issue and concludes that there is no regime that makes all agents better-off. They claim that the optimal (from a welfare perspective) monetary and macroprudential policies may depend on which agent's welfare is used as objective in the computation of the policies, and also on the type of shock considered. In our paper, we actively contribute to this discussion. We focus on highlighting the welfare trade-offs between agents in order to carefully characterize the conditions under which there is room for Pareto improvements. By analyzing welfare for a static LTV, we find an LTV threshold below which there is room for Pareto-improving solutions. However, for higher values the trade-off between borrowers and savers appears. Since a plausible value for the LTV tends to be higher than this value, we also observe this trade-off when calculating the optimal macroprudential rule. Thus, we propose a system of transfers *à la* Kaldor–Hicks in which borrowers would compensate savers so that they are indifferent between having the macroprudential policy or not. In this way, we obtain a Pareto-superior outcome.[7]

2. Model setup

The modelling framework is a DSGE model with a housing market, following Iacoviello (2005). The model is solved by log-linearizing the equilibrium equations around a well-defined steady state. The use of DSGE models for the study of macroprudential policies has some limitations and deserves some discussion. When using DSGE models for monetary policy evaluation, the dynamics of the model are matched with the monetary policy transmission mechanism found in the data. However, for macroprudential policies, empirical applications are rare. Furthermore, the macroprudential analysis often refers to the vulnerability of the financial system to exceptional events related to non-equilibrium, which cannot be captured by a DSGE model. At the same time, a drawback of DSGE models is that they are infinite horizon models and, therefore, are not well suited to incorporate state contingency in a meaningful way. As a result, DSGE models have problems of modelling financial intermediation and frictions (Bean, 2009). However, regardless of these limitations, DSGE models are often used for macroprudential analysis since they count with other advantages: First, they can be compared with a benchmark in which there is only monetary policy. Second, they include many sources of shocks that can be used to check for different economic trajectories. Moreover, they rely on general equilibrium analysis and are suitable for simulations to study the impact of new policy instruments. Also, calibrated parameters can be altered to test for alternative policy scenarios. And finally, since DSGE models are microfounded, they are suitable to study welfare issues.[8]

In our model, the economy features patient and impatient households, a final goods firm, and a central bank which conducts monetary policy. Households work and consume both consumption goods and housing. Patient and impatient households are savers and borrowers, respectively. Borrowers are credit constrained and need collateral to obtain loans. The representative firm converts household labor into the final good. The central bank follows a Taylor rule for the setting of interest rates. The macroprudential authority sets the LTV following a Taylor-type rule.

2.1. Savers

Savers maximize their utility function by choosing consumption, housing and labor hours:

$$\max_{C_{s,t},H_{s,t},N_{s,t}} E_0 \sum_{t=0}^{\infty} \beta_s^t \left[\log C_{s,t} + j_t \log H_{s,t} - \frac{(N_{s,t})^{\eta}}{\eta} \right],$$

where $\beta_s \in (0,1)$ is the patient discount factor, E_0 is the expectation operator and $C_{s,t}$, $H_{s,t}$ and $N_{s,t}$ represent consumption at time t, the housing stock and working hours, respectively. $1/(\eta-1)$ is the labor supply elasticity, $\eta > 0$. j_t represents the weight of housing in the utility function. We assume that $\log(j_t) = \log(j) + u_{Jt}$, where u_{Jt} follows an autoregressive process. A shock to j_t represents a shock to the marginal utility of housing.

Subject to the budget constraint:

$$C_{s,t} + b_t + q_t(H_{s,t} - H_{s,t-1}) = \frac{R_{t-1}b_{t-1}}{\pi_t} + w_{s,t}N_{s,t} + F_t, \tag{1}$$

where b_t denotes bank deposits, R_t is the gross return from deposits, q_t is the price of housing in units of consumption, and $w_{s,t}$ is the real wage rate. F_t are lump-sum profits received from the firms. The first order conditions for this optimization problem are as follows:

$$\frac{1}{C_{s,t}} = \beta_s E_t \left(\frac{R_t}{\pi_{t+1} C_{s,t+1}} \right), \tag{2}$$

$$w_t^s = (N_{s,t})^{\eta-1} C_{s,t}, \tag{3}$$

$$\frac{j_t}{H_{s,t}} = \frac{1}{C_{s,t}} q_t - \beta_s E_t \frac{1}{C_{s,t+1}} q_{t+1}. \tag{4}$$

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[7] This is the first time that this criterion has been applied in the macroprudential context, albeit it is widely used in regulatory analysis in Law and Economics. See for instance Posner (2007).

[8] See Brázdik et al. (2012) for further discussion.

Eq. (2) is the Euler equation, the intertemporal condition for consumption. Eq. (4) represents the intertemporal condition for housing, in which, at the margin, benefits for consuming housing equate costs in terms of consumption. Eq. (3) is the labor-supply condition.

2.2. Borrowers

Borrowers solve:

$$\max_{C_{b,t},H_{b,t},N_{b,t}} E_0\sum_{t=0}^{\infty}\beta_b^t\left[\log C_{b,t}+j_t\log H_{b,t}-\frac{(N_{b,t})^{\eta}}{\eta}\right],$$

where $\beta_b \in (0,1)$ is the impatient discount factor, subject to the budget constraint and the collateral constraint:

$$C_{b,t}+\frac{R_{t-1}b_{t-1}}{\pi_t}+q_t(H_{b,t}-H_{b,t-1})=b_t+W_{b,t}N_{b,t}, \tag{5}$$

$$E_t\frac{R_t}{\pi_{t+1}}b_t=k_tE_tq_{t+1}H_{b,t}, \tag{6}$$

where b_t denotes bank loans and R_t is the gross interest rate. k_t can be interpreted as a loan-to-value ratio. The borrowing constraint limits borrowing to the present discounted value of their housing holdings. The first order conditions are as follows:

$$\frac{1}{C_{b,t}}=\beta_bE_t\left(\frac{R_t}{\pi_{t+1}C_{b,t+1}}\right)+\lambda_tR_t, \tag{7}$$

$$w_{b,t}=(N_{b,t})^{\eta-1}C_{b,t}, \tag{8}$$

$$\frac{j_t}{H_{b,t}}=\frac{1}{C_{b,t}}q_t-\beta_bE_t\left(\frac{1}{C_{b,t+1}}q_{t+1}\right)-\lambda_tk_tE_t(q_{t+1}\pi_{t+1}), \tag{9}$$

where λ_t denotes the multiplier on the borrowing constraint.[9] These first order conditions can be interpreted analogously to those of savers.

2.3. Firms

2.3.1. Final goods producers

There is a continuum of identical final goods producers that operate under perfect competition and flexible prices. They aggregate intermediate goods according to the production function

$$Y_t=\left[\int_0^1 Y_t(z)^{\frac{\varepsilon-1}{\varepsilon}}\,dz\right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{10}$$

where $\varepsilon > 1$ is the elasticity of substitution between intermediate goods. The final good firm chooses $Y_t(z)$ to minimize its costs, resulting in demand of intermediate good z:

$$Y_t(z)=\left(\frac{P_t(z)}{P_t}\right)^{-\varepsilon}Y_t. \tag{11}$$

The price index is then given by:

$$P_t=\left[\int_0^1 P_t(z)^{1-\varepsilon}\,dz\right]^{\frac{1}{\varepsilon-1}}. \tag{12}$$

2.3.2. Intermediate goods producers

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

$$Y_t(z)=A_tN_{s,t}(z)^{\alpha}N_{b,t}(z)^{(1-\alpha)}, \tag{13}$$

where $\alpha \in [0,1]$ measures the relative size of each group in terms of labor.[10] This Cobb–Douglas production function implies that labor efforts of constrained and unconstrained consumers are not perfect substitutes. This specification is analytically tractable and allows for closed form solutions for the steady state of the model. This assumption can be economically justified by the fact that savers are the managers of the firms and their wage is higher than that of the borrowers.[11]

A_t represents technology and it follows the following autoregressive process:

$$\log\,(A_t)=\rho_A\log\,(A_{t-1})+u_{At}, \tag{14}$$

where ρ_A is the autoregressive coefficient and u_{At} is a normally distributed shock to technology. We normalize the steady-state value of technology to 1.

Labor demand is determined by:

$$w_{s,t}=\frac{1}{X_t}\alpha\frac{Y_t}{N_{s,t}}, \tag{15}$$

$$w_{b,t}=\frac{1}{X_t}(1-\alpha)\frac{Y_t}{N_{b,t}}, \tag{16}$$

where X_t is the markup, or the inverse of marginal cost.[12]

The price-setting problem for the intermediate good producers is a standard Calvo-Yun setting. An intermediate good producer sells its good at price $P_t(z)$, and $1-\theta, \in [0,1]$, is the probability of being able to change the sale price in every period. The optimal reset price $P_t^*(z)$ solves:

$$\sum_{k=0}^{\infty}(\theta\beta)^kE_t\left\{\Lambda_{t,k}\left[\frac{P_t^*(z)}{P_{t+k}}-\frac{\varepsilon/(\varepsilon-1)}{X_{t+k}}\right]Y_{t+k}^*(z)\right\}=0, \tag{17}$$

where $\varepsilon/(\varepsilon-1)$ is the steady-state markup.

The aggregate price level is then given by:

$$P_t=\left[\theta P_{t-1}^{1-\varepsilon}+(1-\theta)\left(P_t^*\right)^{1-\varepsilon}\right]^{1/(1-\varepsilon)}. \tag{18}$$

Using (17) and (18), and log-linearizing, we can obtain a standard forward-looking New Keynesian Phillips curve $\hat{\pi}_t=\beta E_t\hat{\pi}_{t+1}-\psi\hat{x}_t+u_{\pi t}$, that relates inflation positively to future inflation and negatively to the markup ($\psi\equiv(1-\theta)(1-\beta\theta)/\theta$). $u_{\pi t}$ is a normally distributed cost-push shock.[13]

2.4. Monetary policy

We consider a Taylor rule which responds to inflation and output growth:

$$R_t=(R_{t-1})^{\rho}\left((\pi_t)^{(1+\phi_\pi^R)}(Y_t/Y_{t-1})^{\phi_y^R}R\right)^{1-\rho}\varepsilon_{Rt}, \tag{19}$$

where $0\leqslant\rho\leq 1$ is the parameter associated with interest-rate inertia, $\phi_\pi^R\geqslant 0$ and $\phi_y^R\geqslant 0$ measure the response of interest rates to current inflation and output growth, respectively. ε_{Rt} is a white noise shock with zero mean and variance σ_ε^2.

2.5. A macroprudential rule for the LTV

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

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[9] Through simple algebra it can be shown that the Lagrange multiplier is positive in the steady state and thus the collateral constraint holds with equality.

[10] Notice that the absolute size of each group is one.

[11] It could also be interpreted as the savers being older than the borrowers, therefore more experienced.

[12] Symmetry across firms allows us to write the demands without the index z.

[13] Variables with a hat denote percent deviations from the steady state.

research on macroprudential policies has proposed Taylor-type rules for the LTV ratio so that it reacts inversely to variables such as the growth rates of GDP, credits, 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, we assume that there exists a macroprudential Taylor-type rule for the LTV ratio, so that it responds to credit growth, in the spirit of the Basel III regulation which aims at avoiding episodes of excessive credit growth[14]:

$$k_t = k_{SS}\left(\frac{b_t}{b_{t-1}}\right)^{-\phi_b^k}, \tag{20}$$

where k_{SS} is a steady state value for the loan-to-value ratio, and $\phi_b^k \geqslant 0$ measures the response of the loan-to-to value to the credit growth. This kind of rule would deliver a lower LTV ratio in booms, when there is excessive credit growth, therefore restricting the credit in the economy and avoiding a credit boom derived from good economic conditions (and symmetrically for recessions).[15]

2.6. Equilibrium

The market clearing conditions are as follows:

$$Y_t = C_{s,t} + C_{b,t}. \tag{21}$$

The total supply of housing is fixed and it is normalized to unity:

$$H_{s,t} + H_{b,t} = 1. \tag{22}$$

3. Welfare

3.1. Welfare measure

To assess the normative implications of macroprudential and monetary policies, we numerically evaluate the welfare derived in each case. 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), we take this latter approach to be able to evaluate the welfare of the two types of agents separately.[16] The individual welfare for savers and borrowers, respectively, as follows:

$$W_{s,t} \equiv E_t \sum_{m=0}^{\infty} \beta_s^m \left[\log C_{s,t+m} + j \log H_{s,t+m} - \frac{(N_{s,t+m})^{\eta}}{\eta}\right], \tag{23}$$

$$W_{b,t} \equiv E_t \sum_{m=0}^{\infty} \beta_b^m \left[\log C_{b,t+m} + j \log H_{b,t+m} - \frac{(N_{b,t+m})^{\eta}}{\eta}\right]. \tag{24}$$

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

$$W_t = (1-\beta_s)W_{s,t} + (1-\beta_b)W_{b,t}. \tag{25}$$

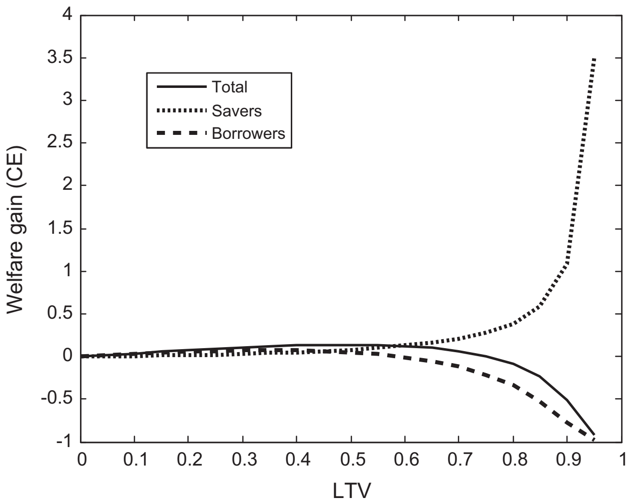

Fig. 1. Welfare gains from increasing the LTV ratio, everything else constant. Benchmark case: no macroprudential regulator.

Each agent's welfare is weighted by her discount factor, respectively, so that all the groups receive the same level of utility from a constant consumption stream.

However, in order to make the results more intuitive, we present welfare changes in terms of consumption equivalents. The consumption equivalent measure defines the constant fraction of consumption that households should give away in order to obtain the benefits of the macroprudential policy. A positive value means a welfare gain, that is, how much the consumer would be willing to pay to obtain the welfare improvement. Then, when there is a welfare gain, households would be willing to pay in consumption units for the measure to be implemented because it is welfare improving. We 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. The derivation of the welfare benefits in terms of consumption equivalent units is as follows:

$$CE_s = \exp\left[(1-\beta_s)\left(W_s^{MP} - W_s^{*}\right)\right] - 1, \tag{26}$$

$$CE_b = \exp\left[(1-\beta_b)\left(W_b^{MP} - W_b^{*}\right)\right] - 1, \tag{27}$$

where the superscripts in the welfare values denote the benchmark case when macroprudential policies are not introduced and the case in which they are, respectively.[17]

3.2. Welfare trade-offs

The literature typically finds that the macroprudential reaction to exogenous shocks can make some people better off (typically borrowers), but not every type of household, or not in all cases. This is why, welfare comparisons should not only be made on the basis of an *ad hoc* aggregate welfare function but disaggregating welfare between agents, to highlight the trade-offs that may appear between them.

In this section, we first compute welfare for each individual and for the aggregate, when we have a static LTV. Then, we numerically evaluate welfare gains when we introduce a macroprudential rule, given the Taylor rule.

Fig. 1 presents welfare gains, in consumption equivalents, for different values of the LTV, when there is no macroprudential rule in place. Here, we observe that up to a threshold LTV value, there is

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[14] See Kannan et al. (2012) for a similar specification.

[15] The feasibility of implementing an LTV rule at a quarterly frequency may be questionable in practice. However, as the Committee on the Global Financial System (2012) suggests, once the legal and operational infrastructure is in place, LTV changes can be implemented rather rapidly, given that many jurisdictions have ample experience with these tools at the practical level.

[16] We 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.

[17] We follow Ascari and Ropele (2009).

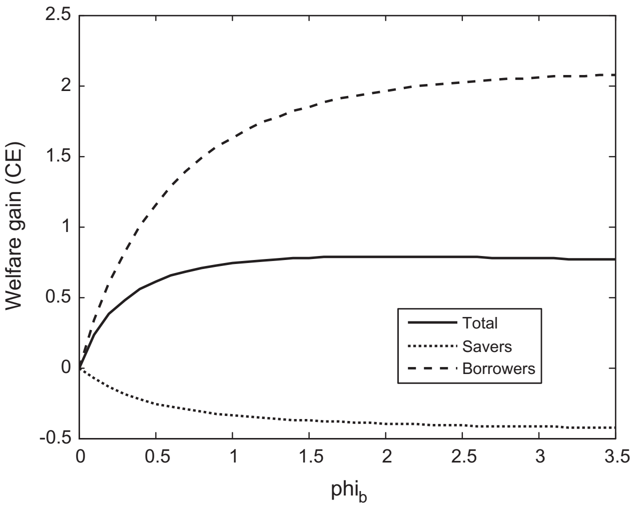

Fig. 2. Welfare gains from introducing the macroprudential rule, given monetary policy (different values of the reaction parameter for borrowing).

room for Pareto optimal policies. However, starting from a value of 0.55, there is a trade-off between borrowers and savers in terms of welfare when we keep increasing the LTV. Large values of the LTV harm borrowers while savers benefit from the increase. Social welfare decreases. This result is in line with that of Campbell and Hercowitz (2009), who performes a welfare analysis in a DSGE model with borrowers and savers and determined that although high LTV ratios have a direct positive effect on welfare through constraint relaxation, other indirect effects may dominate. Notice that k, the LTV ratio, is a parameter that strongly affects the collateral constraint. A small change in this parameter can cause very large changes in borrowing that can be excessive. Higher LTVs lead to higher consumption levels, because borrowing constraints are always binding: the more borrowers are offered, the more they take. But this in turn, as shown in Campbell and Hercowitz (2009), changes relative prices. In particular, higher consumption levels imply higher interest rates. This could lead to a situation of overindebtedness in the sense that high repayments could offset the positive effects on constraint relaxation. Then, higher interest rates imply higher returns on saving for savers. Smith (2009) shows that these results do not rely on the specific assumptions of Campbell and Hercowitz (2009); even in the simplest model with borrowers, savers, and collateral constraints, this effect takes place.[18]

Fig. 2 shows the welfare gains from introducing a macroprudential tool in the economy, given the Taylor rule. We use a steady-state value of the LTV of 0.9, as in Iacoviello (2005) and Iacoviello (2013). Therefore, we are in a region in which trade-offs should appear. Leaving fixed monetary policy, we present welfare for a continuum of values of the reaction parameters in the LTV rule, from a less to a more aggressive rule. The figure is very informative because it shows welfare gains for each agent in the economy and for the aggregate. The conclusions we can obtain from the figure are the following: using both policy measures at the same time is unambiguously welfare enhancing, as we can observe from the solid line. We can see that welfare increases by more, the larger the response of the LTV to credit growth is, but up to a point at which welfare stops increasing. The figure also shows the trade-off between borrowers' and savers' welfare, illustrated by the difference between the two dashed lines. Borrowers' welfare increases with the introduction of the macroprudential rule because tightening the collateral constraint avoids situations of overindebtedness in which debt repayments are a burden for them. Furthermore, borrowers can benefit from more financial stability in the economy, as we will show later on. Notice that borrowers have a collateral constraint which is always binding and this does not allow them to make consumption smoothing. They do not have an Euler equation to smooth consumption as savers do. A more stable financial system smooths their consumption path thus mitigating the negative effects of the collateral constraint. This welfare gain is at the expense of savers, who lose from having this measure in the economy, given that they are not financially constrained. However, the borrower's welfare gain compensates the loss of the savers and globally, the measure is welfare increasing.

The next section performs an optimal policy analysis in order to assess which are the combination of values of the reaction parameters which would maximize welfare and make policy recommendations on this issue.

4. Optimal policy analysis

4.1. Optimal parameters

In this section, we aim to find the optimal combination of policy parameters that maximizes welfare. For this purpose, we consider three different cases. A benchmark case in which there is only a monetary authority that acts in the traditional way, using the interest rate as an instrument. Then, we include a macroprudential authority that introduces an extra instrument, the LTV ratio. We study the interaction between the two authorities from two perspectives, when they act both in a coordinated and in a non-coordinated way.

The optimal policy analysis, in models with financial frictions, deserves some discussion. In the standard new Keynesian model, the central bank aims at minimizing the variability of output and inflation to reduce the distortion introduced by nominal rigidities and monopolistic competition. However, in models with collateral constraints, welfare analysis and the design of optimal policies involves a number of issues not considered in standard sticky-price models. In models with constrained individuals, there are two types of distortions: price rigidities and credit frictions. This creates conflicts and trade-offs between borrowers and savers. Savers may prefer policies that reduce the price stickiness distortion. However, borrowers may prefer a scenario in which the pervasive effect of the collateral constraint is softened. Borrowers operate in a second-best situation. They consume according to the borrowing constraint as opposed to savers that follow an Euler equation for consumption. Borrowers cannot smooth consumption by themselves, but a more stable financial system would provide them a setting in which their consumption pattern is smoother. Therefore, in order to assess the optimality of policies, factors that help borrowers smooth their consumption should be included. Studies show that, in these kind of models, financial variables should be included in the loss function that the policy maker aims at minimizing.[19]

In the standard sticky-price model, the Taylor rule of the central bank is consistent with a loss function that includes the variability of inflation and output. In order to rationalize the Taylor rule of the macroprudential regulator, we follow Angelini et al. (2012) in which they assume that the loss function in the economy also con-

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[18] Huggett (1997) also found a similar result, but in this case is the reduction in the precautionary motive for saving, driven by the looser borrowing constraints, what leads to the increase in the interest rate.

[19] Andres et al. (2013) find that optimal monetary policy may involve a trade-off between the stabilization of inflation, output gap, consumption gap and the distribution of the collateral asset between constrained and unconstrained consumers.

Table 1
Optimal macroprudential and monetary policy mix.

	Benchmark	Coordinated	Non-coordinated
ϕ_b^{k*}	–	0.8	0.7
$1+\phi_\pi^{R*}$	16.1	1.3	1.7
ϕ_y^{R*}	8.2	0.5	1
Social Welfare Gain	–	0.024	0.041
Borrowers Welfare Gain	–	0.22	0.31
Savers Welfare Gain	–	−0.16	−0.21
σ_b^2	1.4308	1.1861	1.1767
σ_π^2	0.2183	0.3481	0.3025
σ_y^2	1.9113	1.7877	1.8087

tains financial variables, namely borrowing variability, as a proxy for financial stability. Then, there would be a loss function for the economy that would include not only the variability of output and inflation but also the variability of borrowing: $L = \sigma_\pi^2 + \lambda_y \sigma_y^2 + \sigma_b^2$ where σ_π^2, σ_y^2 and σ_b^2 are the variances of inflation, output and borrowing. $\lambda_y \geqslant 0$, represents the relative weight of the central bank to the stabilization of output.[20]

If the central bank and the macroprudential regulator coordinate, they would aim at jointly minimizing the loss function each one with its own instrument. The problem becomes analogous to the Mundell's assignment rule in which each arm of policy concentrates on a single task, addressing the issue it cares most about, and making coordination of policy trivial.[21] Following this line of argument, we consider a case in which we jointly optimize the parameters of both rules.

However, Svensson (2012) argues that conducting monetary policy and financial stability policy in an integrated way may be inappropriate, since monetary policy and financial-stability policy are distinct and separate policies with different objectives and different instruments. Tinbergen (1952) put forth what we now call the 'Tinbergen principle,' that policymakers need at least one independent policy instrument for each policy objective. Since the policy interest rate is used by monetary policymakers to achieve the objective of price stability, at least one other instrument is required to achieve the additional objective of financial stability of macroprudential policy. Svensson (2012) suggests that monetary policy should be in charge of price stability while macroprudential policy needs to address financial stability. He argues that monetary policy should be conducted taking the macroprudential policy into account, and vice versa, as in a Nash equilibrium rather than a coordinated equilibrium. Therefore, we study a second case in which the central bank and the macroprudential regulator play a non-coordinated game. The central bank would find the optimal parameters in its policy rule, taking the macroprudential regulator behavior as given. Similarly, the macroprudential authority would find the best response given monetary policy. The intersection of these two best responses would give us the Nash equilibrium.

In order to contribute to the discussion and evaluate the welfare gains of introducing macroprudential polices, we first compute the optimal parameters of the Taylor rule for monetary policy, assuming that there is no macroprudential regulator. Then, we compute the optimal monetary and macroprudential policies for the coordinated and the non-coordinated game.

Table 1 shows the optimal parameter values and the welfare gains in consumption equivalents, taking as a benchmark the situation without macroprudential policy. We also present the implied volatilities.

As expected, when a macroprudential regulator does not exist, the central bank needs to act in a very aggressive way, given that it only counts with a single instrument to minimize the loss function.[22] We take this case as a benchmark, both for welfare and for macroeconomic and financial volatilities (presented in the first column).

The second column presents the case in which there is a macroprudential regulator that acts in a coordinated way with the central bank. We see that adding this extra instrument produces a welfare gain in the economy. In this case, monetary policy does not need to be as aggressive as in the benchmark case because it counts with the help of the macroprudential policy. However, as already pointed out, there is a trade-off between borrowers and savers and, while borrowers are better-off, savers are not. Furthermore, if we compare the volatilities that this combination of policies generates, with respect to the benchmark case, we observe that the standard deviation of borrowing decreases, which is what makes borrower's welfare increase. In terms of the macroeconomic volatilities, we see that the volatility of output decreases, but this comes at the expense of a higher inflation volatility.[23] This higher inflation volatility contributes to a decrease in savers' welfare.

Nevertheless, if both authorities act in a non-coordinated way, social welfare gains are even higher. As Svensson (2012) argues, letting each regulator focus on its own objective, leads to more effective results in reducing volatilities. In this case, monetary policy acts in a more aggressive way, favoring the reduction of the volatility of inflation. The macroprudential authority reaction parameter does not need to be as high as in the previous case to obtain a lower standard deviation of borrowing. As usual, we also observe the same trade-off between borrowers and savers.

4.2. Pareto-superior outcomes

Results from optimal policy analysis show that trade-offs between the two agents appear. However, if the welfare gain that borrowers obtain is large enough, there could be room for Pareto-superior outcomes.

In order to do that, we apply the concept of Kaldor–Hicks efficiency, also known as Kaldor–Hicks criterion.[24] Under this criterion, an outcome is considered more efficient if a Pareto-superior outcome can be reached by arranging sufficient compensation from those that are made better off to those that are made worse off so that all would end up no worse off than before. The Kaldor–Hicks criterion does not require the compensation actually being paid, merely that the possibility for compensation exists, and thus need not leave each at least as well off.

In our case, our measure for welfare presented in consumption equivalents is given by Eqs. (26) and (27). Since, there is a trade-off between savers and borrowers, introducing the macroprudential policy, both in coordination and non-coordination with monetary policy, produces $CE_b > 0$ and $CE_s < 0$.

Thus, a Kaldor–Hicks improvement to a obtain Pareto-superior outcome would be one in which:

$$CE_b - \varepsilon_b \geqslant 0$$

and

$$CE_s + \varepsilon_b = 0.$$

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[20] This loss function would be consistent with studies that make a second-order approximation of the utility of individuals and find that it differs from the standard case by including financial variables.

[21] See Mundell (1962).

[22] Notice that here, we are considering that the central bank acts in a traditional way, we are excluding the possibility that financial variables enter in the Taylor rule for the central bank. For further discussion on interactions between different rules, see Kannan et al. (2012) or Rubio and Carrasco-Gallego (2013).

[23] This result is consistent with other studies on macroprudential policies. See for instance, Mendicino et al. (2013).

[24] See Scitovsky (1941).

Then,

$$\varepsilon_b \geqslant 1 - \exp\left[(1-\beta_s)\left(W_s^{MP} - W_s^*\right)\right]. \tag{28}$$

That is, a system of transfers in which the borrowers would compensate the savers with at least the amount they are losing, so that they are at least indifferent between having the macroprudential policy or not. Then, the new outcome would be desirable for society and there would be no agent that would lose with the introduction of the new policy. Then, if Eq. (28) holds with equality, the borrower compensates the saver with the exact welfare that she is losing. Then, in our case, after the compensations are made, the final result is presented in Table 2.

Table 2
Optimal macroprudential and monetary policy mix (Kaldor–Hicks improvement).

	Benchmark	Coordinated	Non-coordinated
ϕ_b^{k*}	–	0.8	0.7
$1+\phi_\pi^{R*}$	16.1	1.3	1.7
ϕ_y^{R*}	8.2	0.5	1
Social Welfare Gain	–	0.024	0.041
Borrowers Welfare Gain	–	0.06	0.10
Savers Welfare Gain	–	0	0

4.3. Impulse responses

In order to understand the dynamics of the model and how the LTV rule interacts with monetary policy, in this section, we simulate the impulse responses of the model, using the optimized parameters we found in the previous section. We compare the benchmark (no macroprudential policy) with the case in which monetary and macroprudential policies coexist, both in a coordinated and in a non-coordinated game. We consider a technology shock and a housing demand shock.

The discount factor for savers, β_s, is set to 0.99 so that the annual interest rate is 4% in steady state. The discount factor for the borrowers 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, consistent with the US data. We set $\eta = 2$, implying a value of the labor supply elasticity of 1.[26] For the parameters controlling leverage, we set k_{SS} to 0.90, in line with the US data.[27] The labor income share for savers is set to 0.64, following the estimate in Iacoviello (2005). For the Taylor rule, we consider the optimized parameters found in the previous section. For ρ we use 0.8, which also reflects a realistic degree of interest rate smoothing.[28]

We assume that technology, A_t, follows an autoregressive process with 0.9 persistence and a normally distributed shock. We also assume that the weight of housing on the utility function is equal to its value in the steady state plus a shock which follows an autoregressive process with 0.95 persistence.[29] For the reactions parameter in the LTV rule, we use the optimized parameters both for the coordination and non-coordination with monetary policy. Table 3 presents a summary of the parameter values used:

Table 3
Parameter values.

β_s	.99	Discount factor for savers
β_b	.98	Discount factor for borrowers
j	.1	Weight of housing in utility function
η	2	Parameter associated with labor elasticity
k	.9	Loan-to-value ratio
α	.64	Labor share for savers
X	1.2	Steady-state markup
θ	.75	Probability of not changing prices
ρ_A	.9	Technology persistence
ρ_j	.95	Housing demand shock persistence
ρ	.8	Interest-rate-smoothing parameter in Taylor rule

4.3.1. Technology shock

Fig. 3 presents impulse responses to a 1% shock to technology. Given the technology shock, output increases and inflation decreases.

In the benchmark case, when there is only monetary policy, the interest rate increases, while the LTV remains at its steady state. Since output is increasing, monetary policy reacts in a contractive way. Given the expansion in the economy, borrowing and housing demand increase, leading to an increase in house prices.

However, when the macroprudential rule interacts with monetary policy, the reaction of the interest rate is not as strong, given that the optimal parameters of the Taylor rule are lower. The LTV ratio decreases to cut credit because borrowing is growing following the boom. Therefore, when the macroprudential rule is in place, borrowing does not increase as much as in the benchmark, and this mitigates the effects of the boom.

Concerning the difference between the coordinated and the non-coordinated case, the pattern of the impulse responses is very similar. Nevertheless, the non-coordinated case is always slightly closer to the benchmark. This is due to the fact that the reaction parameters in the Taylor rule are higher for the coordinated case and thus more similar to the benchmark.

Notice that, interestingly, when monetary and macroprudential policies coexist, the interest rate decreases, focusing on stabilizing inflation, while the LTV is cut, to reach the financial stability objective. The decrease in the interest rate contributes to increase borrowing while the decrease in the LTV cuts it.

4.3.2. Housing demand shock

In Fig. 4, we see the effects of a 25% housing demand shock. Given the increase in demand, house prices increase as well. This directly affects the collateral constraint and borrowers are able to borrow more out of their housing collateral, which is worth more now. The wealth effect permits them consume both more houses and consumption goods. The increase in house prices is, therefore, transmitted to the real economy and output increases.

The raise in output generates inflation and the Taylor rule responds with a higher interest rate. This is particularly true in the benchmark case in which monetary policy is more aggressive. On impact, this higher interest rate also dampens the increase in the price of the house, especially for the benchmark for the same reasons. Therefore, the initial shock is mitigated in the case in which monetary is the only policy in action.

When the macroprudential and the monetary policy interact, the LTV decreases to moderate the credit boom. This is the reason why, in this case, borrowing does not increase as much as in the benchmark. However, as we have seen, the increase in the interest rate is not as strong as in the benchmark and therefore the effects on real output of this demand shock are more noticeable. In the case of this shock, the combination of the macroprudential and the monetary policies manage to control credit without moderating the real effects of the boom.

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[25] Lawrance (1991) estimated discount factors for poor consumers at between 0.95 and 0.98 at quarterly frequency. We take the most conservative value.

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

[27] See Iacoviello (2013).

[28] As in McCallum (2001).

[29] The persistence of the shocks is consistent with the estimates in Iacoviello and Neri (2010).

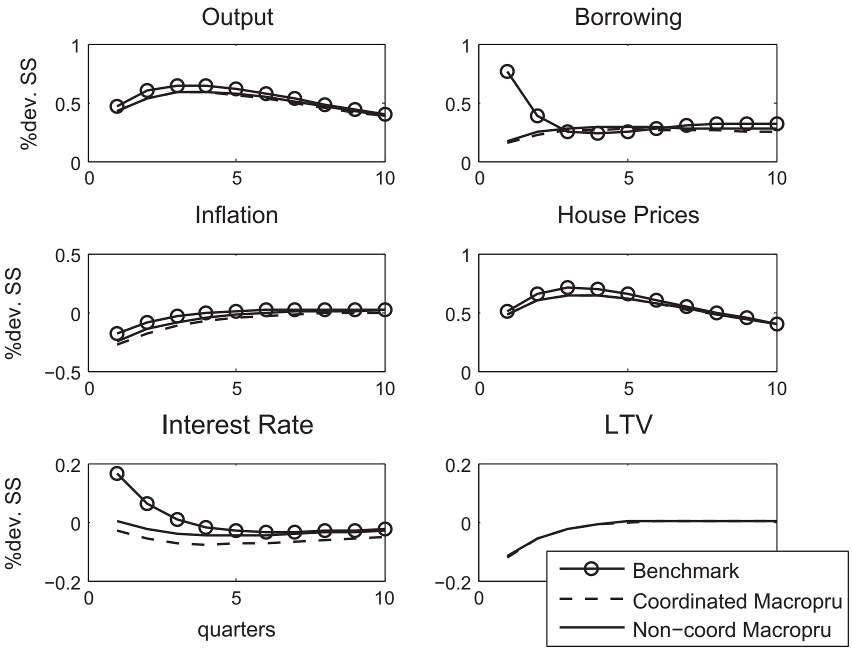

Fig. 3. Impulse responses to a technology shock. Optimized parameters.

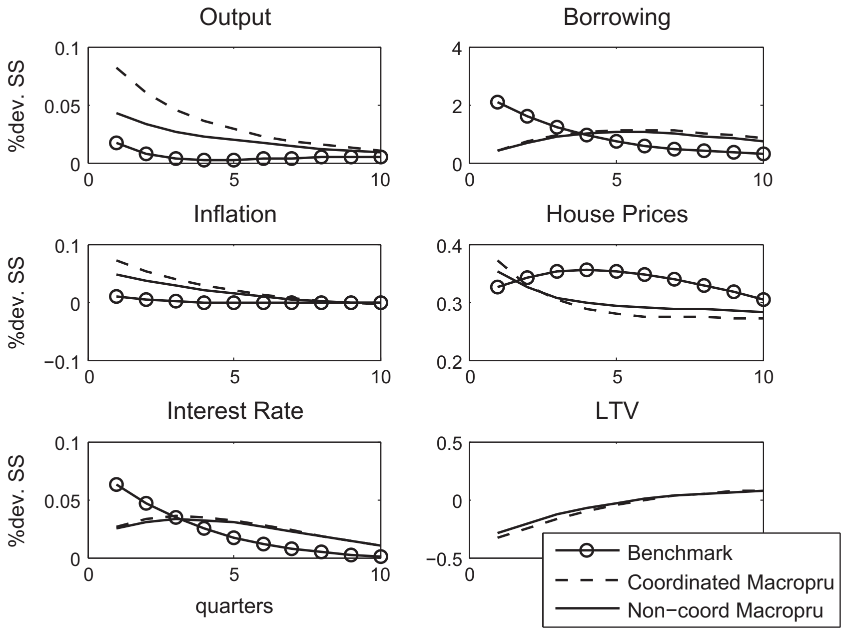

Fig. 4. Impulse responses to a housing demand shock. Optimized parameters.

As in the previous case, and for the same reasons, the non-coordinated situation is closer to the benchmark.

4.4. Financial and macroeconomic stability

Results from the optimal policy analysis have shown that the combination of macroprudential and monetary policies deliver a more stable financial and macroeconomic scenario. In order to show these results graphically, we plot an efficiency frontier that includes the three objectives that the policy makers aim at minimizing: variability of output, variability of inflation and variability of borrowing.

Policy analysis is usually done through policy frontiers, also known as Taylor curves or efficiency frontiers.[30] This curve shows, given different parameters of the Taylor rule, the combination that delivers the lower output and inflation variability. Therefore, a Taylor curve which is closer to the origin would be more efficient. In order to include the objective of the macroprudential regulator, we present an extended Taylor curve in which we include the variability of borrowing, as a measure to capture financial stability.

We are aware that there is not a widely accepted definition of financial stability or systemic risk. Those are difficult concepts to

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[30] See for instance Iacoviello (2005) that evaluates a Taylor rule responding to house prices with a policy frontier.

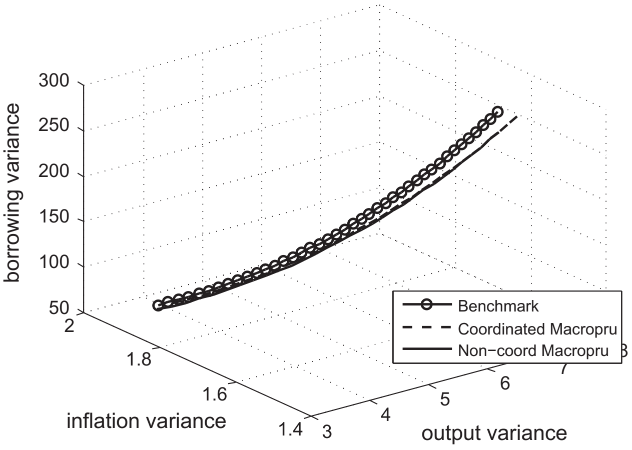

Fig. 5. Three dimensional efficiency frontier.

define and to measure. Many definitions include the interactions between the financial and the real sector.[31] In our model, we characterize the financial sector implicitly: borrowers take credits from savers and sign mortgages to buy houses, the asset of our model. Therefore, the financial system can be proxied by the amount of borrowing that takes place. Within this framework, we propose a measure for financial stability: a low variability of borrowing. In this sense, a lower variance of borrowing would imply a more stable financial system: if the variance of borrowing is lower, credit is smoother. A more stable financial system contributes to a lower systemic risk. Our model fits this idea. Borrowers do not have an Euler equation that allows them to smooth their consumption, as savers do. If the variability of the borrowing is lower then borrowers can sign mortgages in a smoother way and also can achieve a more stable consumption. The financial sector will be more stable and also the real sector. The economy can benefit from a more stable financial system and a lower systemic risk with a higher welfare, as we proved in previous sections. However, if the situation is the opposite and there is a high variability of borrowing, the financial system will be more unstable: with credit being more variable, consumption would also be more variable, the systemic risk will increase and, therefore, welfare will be lower.

Fig. 5 presents our augmented policy frontier which is three-dimensional, since it takes into account three policy objectives: output, inflation and financial stabilization. The first two correspond to the standard objectives of the central bank, while the third one would be the objective of the macroprudential regulator. As in previous cases, we are comparing the macroprudential (coordinated and non-coordinated) with the no macroprudential scenario (benchmark). Here, curves are preferable, the lower (less borrowing variance) and closer to the inflation and output variance origin (less inflation and output variability) they are. We see that when we take the three dimensions together, macroprudential and monetary policies interacting with each other manage to deliver a more stable scenario, which includes not only macroeconomic stability but also financial stability. These results represent a way to convey the findings in previous sections, that is, the introduction of the macroprudential policy is welfare enhancing because it is delivering a more stable system.

5. Concluding remarks

In this paper, we analyze the impact of macroprudential and monetary policies on business cycles, welfare, and financial stability. In particular, we consider a macroprudential rule for the LTV ratio that responds to credit growth.

We compute the optimal parameters of the macroprudential and monetary rule both when monetary and macroprudential policies act in a coordinated and in a non-coordinated way. We find that in both cases, this interaction is welfare improving for the society, especially in the case of the non-coordinated game. However, there is a trade-off between the agents of the model and savers lose from this new scenario. We find that by transfers *à la* Kaldor–Hicks, so that borrowers can compensate the saver's welfare loss, a Pareto-superior outcome can be obtained.

From a positive perspective, we show the dynamics of the model under the optimal parameters that maximize welfare. We find that, given a positive technology or housing demand shock, the macroprudential authority would decrease the LTV to moderate the credit boom. In this way, it can achieve its ultimate goal: financial stability.

We also show graphically, with a three dimensional policy frontier, that the interaction between monetary and macroprudential policies unambiguously enhances the stability of the economic system.

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Appendix A. Main equations

$$\frac{1}{C_{s,t}} = \beta^s E_t \left(\frac{R_t}{\pi_{t+1} C_{s,t+1}} \right), \tag{29}$$

$$w_t^s = (N_{s,t})^{\eta-1} C_{s,t}, \tag{30}$$

$$\frac{j}{H_{s,t}} = \frac{1}{C_{s,t}} q_t - \beta^s E_t \frac{1}{C_{s,t+1}} q_{t+1}, \tag{31}$$

$$\frac{1}{C_{b,t}} = \beta^b E_t \left(\frac{R_t}{\pi_{t+1} C_{b,t+1}} \right) + \lambda_t R_t, \tag{32}$$

$$w_{b,t} = (N_{b,t})^{\eta-1} C_{b,t}, \tag{33}$$

$$\frac{j}{H_{b,t}} = \frac{1}{C_{b,t}} q_t - \beta^b E_t \left(\frac{1}{C_{b,t+1}} q_{t+1} \right) - \lambda_t^b k_t E_t (q_{t+1} \pi_{t+1}), \tag{34}$$

$$E_t \frac{R_t}{\pi_{t+1}} b_t = k_t E_t q_{t+1} H_{b,t}, \tag{35}$$

$$C_{b,t} + q_t H_{b,t} + \frac{R_{t-1} b_{t-1}}{\pi_t} = q_t H_{b,t-1} + w_{b,t} L_{b,t} + b_t, \tag{36}$$

$$w_{s,t} = \frac{1}{X_t} \alpha \frac{Y_t}{N_{s,t}}, \tag{37}$$

$$w_{b,t} = \frac{1}{X_t} (1-\alpha) \frac{Y_t}{N_{b,t}}, \tag{38}$$

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[31] See Galvão and Owyang (2013) for a discussion on the topic.

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} - \psi \hat{x}_t + u_{\pi t}, \tag{39}$$

$$W_{s,t} \equiv E_t \sum_{m=0}^{\infty} \beta_s^m \left[\log C_{s,t+m} + j \log H_{s,t+m} - \frac{(N_{s,t+m})^{\eta}}{\eta} \right], \tag{40}$$

$$W_{b,t} \equiv E_t \sum_{m=0}^{\infty} \beta_b^m \left[\log C_{b,t+m} + j \log H_{b,t+m} - \frac{(N_{b,t+m})^{\eta}}{\eta} \right], \tag{41}$$

$$W_t = (1 - \beta_s) W_{s,t} + (1 - \beta_b) W_{b,t}. \tag{42}$$

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