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OPTIMAL MONETARY POLICY RULES AND HOUSE PRICES: THE ROLE OF FINANCIAL FRICTIONS

by Alessandro Notarpietro† and Stefano Siviero†

Abstract

We probe the scope for reacting to house prices in simple and implementable monetary policy rules, using a New Keynesian model with a housing sector and financial frictions on the household side. We show that the social welfare maximizing monetary policy rule features a reaction to house price variations, when the latter are generated by housing demand or financial shocks. The sign and size of the reaction crucially depend on the degree of financial frictions in the economy. When the share of constrained agents is relatively small, the optimal reaction is negative, implying that the central bank must move the policy rate in the opposite direction with respect to house prices. However, when the economy is characterized by a sufficiently high average loan-to-value ratio, then it becomes optimal to counter house price increases by raising the policy rate.

JEL Classification: E20, E44, E52.
Keywords: Optimal simple interest rate rules; Housing; Credit frictions.

Contents

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1 Introduction[1]

For a number of years, consensus has been unanimous that no major role should be played by asset prices in monetary policy-making (see, e.g., Bernanke and Gertler (2001) and Mishkin (2007)). The fate of asset prices as a possible ingredient of monetary policy has long seemed set and sealed. The events of the last few years, with repeated crises accompanied by, and often stemming from, violent swings in asset prices, have prompted the economic profession to reconsider whether asset prices should not play a role of sort in monetary policy-making after all. Asset booms and busts had been a systematic feature of the world economy for a number of decades. However, never before the financial crisis that started in 2007 had their contribution to an economic downturn been so sharp, sizeable and extended, as it was between 2008 and 2009. Those dramatic events have left many wondering whether there might not be good reasons why central banks should actually respond to asset prices in general, and to house prices in particular, given the prominent role played by housing sector developments in precipitating that crisis.

In this paper we investigate whether the effectiveness of monetary policy may be enhanced by the inclusion of house prices among the objectives of the central bank, when the economy is characterized by the presence of financial frictions. In particular, we consider the case of collateral constraints that link the maximum amount that (a fraction of) households can borrow to the value of existing collateral. To this end, we lay out a simple two-sector New Keynesian model with a non-durable consumption sector and a housing sector. Households are divided into patients and impatients according to their discount factor. The impatient agents face a perpetually binding collateral constraints, along the lines of Kiyotaki and Moore (1997). The model closely follows Iacoviello (2005) and Monacelli (2009);[2] we abstract from capital accumulation and introduce nominal rigidities in the non-durable consumption sector only. The model is kept as simple as

[1]We wish to thank our discussant Zheng Liu, an anonymous referee and conference participants at the Dallas Fed-IMF-JMCB Conference on Housing, Stability and the Macroeconomy: International Perspectives for useful comments and discussions. We thank Giovanni Lombardo for help with his Matlab codes, and Giuseppe Ferrero, Andrea Gerali, Stefano Neri, Francesco Nucci, Massimiliano Pisani, Tiziano Ropele and conference and seminar participants at Banca d'Italia, Bogaziçi University (Istanbul), Computing in Economics and Finance 2013, Money, Macro and Finance 2013, Texas A&M University and Universidad del País Vasco (Bilbao) for useful suggestions and comments. All errors are ours. The usual disclaimers apply.

[2]Recent contributions that introduce a housing sector in DSGE models for monetary policy analysis include among others Andrés, Arce, and Thomas (2011), Aspachs-Bracons and Rabanal (2011), Darracq Pariès and Notarpietro (2008), Forlati and Lambertini (2011), Finocchiaro and Von Heideken (2013), Jeske and Liu (2013), Iacoviello and Neri (2010), Lambertini, Mendicino, and Punzi (2013), Monacelli (2009) and Rubio (2011).

possible, in order to highlight the transmission mechanism and the amplification effect related to the borrowing constraint and to illustrate the main features of the optimal monetary policy.

In the context of this model, we perform a normative analysis and look for optimal monetary policy within the class of *simple* and *operational* interest rate rules, according to the definition of Schmitt-Grohe and Uribe (2007). Namely, we restrict our attention to policy rules that (i) respond to variables that can be easily observed and (ii) deliver equilibrium determinacy. We are particularly interested in understanding if and how monetary policy must react to house price fluctuations, when the objective is the welfare maximization.[3] Our contribution is twofold.

First, we characterize the optimal simple rule. Simple rules are ranked in terms of welfare levels, which are computed, following a common practice in the literature, using a second-order approximation to the model solution. We also solve the Ramsey problem of a social planner that maximizes the social welfare function subject to the competitive equilibrium conditions and provide the relative welfare losses entailed by the optimal simple rule compared to the Ramsey optimal monetary policy. The social-welfare maximizing rule displays two prominent features. First, the response to inflation is not as aggressive as it would be in a frictionless model, so that inflation is not fully stabilized under the optimal rule. Such result reflects the existence of a transfer of wealth between borrowers and savers resulting from unexpected variations in the inflation rate. Second, the optimal rule features a negative response to house price inflation, implying that the policy rate should be lowered in response to an increase in house price inflation. Such feature mainly reflects, as shown below, a welfare-enhancing choice from the borrower's welfare perspective.

Second, we look deeper into the contribution of financial frictions - as captured by the average loan-to-value (LTV) ratio and the share of borrowers in the economy - in shaping the optimal response to house price fluctuations. We show that for a sufficiently small fraction of borrowers, the optimal response is negative, irrespective of the LTV ratio. As the share of borrowers increases, the value of the LTV ratio becomes crucial in determining the sign of of the response, which becomes positive in the neighbourhood of a 90% LTV or more. Such result reflects the fact that the amplification effect generated by the collateral constraint becomes larger as the

[3]We note in passing that, as in previous literature, also in our model reacting to house prices does not help the central bank if its objective is business cycle stabilization.

average LTV ratio increases. The socially optimal rule must take into account not only the potential benefit for the borrower of a relaxation of the collateral constraint (generated via a negative response to house price fluctuations) but also the potential loss for the saver stemming from higher volatility. The latter component tends to prevail as the leverage increases.

Our work relates to a number of previous contributions in the literature.

In terms of modelling structure, Iacoviello and Neri (2010) provide a much richer model estimated on U.S. data, with housing and non-housing goods, household heterogeneity and collateral constraints; the model includes a large number of structural shocks, to capture cyclical dynamics of the main macroeconomic variables. Compared to Iacoviello and Neri (2010), our model setup is less data-oriented and more stylized. We introduce two exogenous shocks that directly influence housing market dynamics: a housing demand shock and a financial shock (which hits the loan-to-value ratio). Estimated DSGE models with housing and financial frictions (see Iacoviello and Neri (2010) and Liu, Wang, and Zha (2013)) show that housing demand shocks drive most of the cyclical fluctuations in house prices. Ludvigson, Nieuwerburgh, and Favilukis (2013) argue that shocks to the loan-to-value ratio (LTV), which can be interpreted as changes in financial regulation, are relevant to generate fluctuations in house prices. Moreover, as illustrated in Liu, Wang, and Zha (2013), credit constraints can amplify and propagate exogenous shocks only when such shocks generate fluctuations in the collateral value. This is clearly the case with housing demand and LTV shocks, but not, for instance, with TFP shocks, which leads us to exclude the latter from our experiments. Importantly and different from previous studies (see e.g. Rubio (2011)) we do not consider cost-push shocks either. The latter are known to be a source of policy tradeoff in a standard New Keynesian model. Such tradeoff is however distinct and independent from housing dynamics and financial frictions. In short, we focus only on the sources of disturbance that are peculiar to our setup.

About the optimal monetary policy analysis, Iacoviello (2005) using a similar model considers the case of a central bank that minimizes the weighted sum of the unconditional variances of inflation and output under technology, housing preference and inflation shocks. He finds that no stabilization gains arise from a positive systematic response to house price changes. Finocchiaro and Von Heideken (2013) estimate the model of Iacoviello (2005) using quarterly data for the U.S., U.K. and Japan and show that a non-negligible response to house prices is empirically plausible.

They also show that, when the central bank minimizes a standard quadratic loss function, it is optimal to respond to house price movements, even though the corresponding gains are very small. Jeske and Liu (2013), use a two-sector DSGE model calibrated on U.S. data show to analyze the optimal response to rental prices. Their model does not include credit constraints, nor any other type of financial frictions. They show that, although rental prices are sticky and should therefore be stabilized under the optimal monetary policy rule, asymmetries in factor intensities across sectors imply that the optimal response to rental inflation is actually smaller than what theory would predict in the case of symmetric sectors.[4] More closely related to our study are Mendicino and Pescatori (2008) and Rubio (2011), that analyse welfare-maximizing monetary rules in the presence of housing and borrowing constraints. The latter focuses in particular on the role of fixed and variable rate mortgages. Different from our paper, both contributions include a large set of shocks, among which cost-push shocks, that provide a source of monetary policy tradeoff in a standard New Keynesian model. We limit our analysis to the case of shocks that directly affect the housing market. Both studies conclude that the aggressiveness of a central bank towards non-durable price inflation is reduced with respect to a standard New Keynesian model, because of the presence of collateral constraints. Monacelli (2008) also reaches similar conclusions, performing a fully-fledged Ramsey optimal monetary policy exercise, which however abstracts from welfare considerations.

Finally, in a recent contribution, Lambertini, Mendicino, and Punzi (2013) (LMP henceforth) document the welfare gains obtained by letting the central bank react to fluctuations in housing and credit markets that are driven by expectations of future developments. Their paper is the closest to our work and the differences between their contribution and ours thus deserve further elaboration. In terms of modeling choices, LMP use the model developed and estimated in Iacoviello and Neri (2010), which, as already mentioned, includes a very rich specification of nominal and real rigidities and a large number of shocks. LMP introduce news shocks in order to generate boom-bust cycles in credit and housing markets. Our modeling choice is much more parsimonious: we abstract from capital accumulation and real rigidities and simply introduce a

[4]Several contributions (see Aoki (2001), Benigno (2004), Mankiw and Reis (2003) and Woodford (2003)) have established that, in the presence of multiple sources of nominal rigidities, the optimal rule should target the sectoral inflation indices using different weights, which are increasing functions of the degree of price stickiness in each sector and of the share of each good in the final consumption basket.

housing sector in a two-agent model with collateral constraints. Moreover, the two shocks that we include (housing demand and financial shocks) generate cyclical fluctuations in the housing market, but cannot give rise to boom-bust episodes. Our analysis aims at characterizing the optimal monetary policy response to house price movements under "normal" circumstances, i.e., regular business cycle fluctuations. In terms of policy analysis, LMP consider both monetary and macro-prudential optimal policy rules. Our purpose is more limited: we abstract from macro-prudential considerations and focus our attention on the optimal monetary policy, analyzing in detail the role played by financial frictions in shaping the results. Moreover, in their analysis of optimal simple monetary policy rules, LMP consider both a rule in which the policy rate reacts to house price movements and one in which it reacts to credit market developments. We limit our analysis to the case of house price fluctuations only. Finally, and most importantly, different from LMP and the other above-mentioned contributions, we expand the analysis to investigate the contribution of the magnitude of financial frictions in shaping the optimal monetary policy decisions. In this way, we characterize the relationship between financial frictions and monetary policy.

The rest of the paper is organized as follows. Section 2 describes the model. Section 3 illustrates the calibration of the structural parameters. Section 4 discusses our welfare measure and reports the main results. Section 5 analyzes the role of financial frictions in shaping the results. Section 6 reports the results of sensitivity analysis. Section 7 concludes.

2 The model

The economy is populated by two groups of households, labelled patient and impatient, with discount factors β^s and β^b, respectively, with $\beta^b < \beta^s$. Impatient households have size ω; patient households have size $(1-\omega)$. The former face a perpetually binding collateral constraint, which links the amount of borrowing to the value of a house (the existing collateral). As in Kiyotaki and Moore (1997) and Iacoviello (2005), all impatient agents behave as net borrowers and all patient agents as savers in equilibrium, so we use the terms impatient/borrower and patient/saver interchangeably in the following. Firms in the economy produce two final goods: a non-durable consumption good and a (durable) housing good. Both goods are produced using labor, which is supplied by households. Monopolistic competition is introduced in the production of intermediate goods in both sectors, along the lines of the standard New Keynesian model.

2.1 Impatient households

The impatient agent (denoted with a superscript b) maximizes the following stream of discounted utility:

$$E_0 \sum_{t=0}^{\infty} \left(\beta^b\right)^t \left\{ \frac{1}{1-\sigma} \left(X_t^b\right)^{1-\sigma} - \frac{1}{1+\varphi_C} \left(N_{C,t}^b\right)^{1+\varphi_C} - \frac{1}{1+\varphi_H} \left(N_{H,t}^b\right)^{1+\varphi_H} \right\} \tag{1}$$

where X_t^b is an index of consumption services derived from non-durable consumption $\left(C^b\right)$ and the stock of housing goods $\left(H^b\right)$, as follows:

$$X_t^b \equiv \left[\left(1-\varepsilon_t^H \omega_H\right)^{\frac{1}{\eta_H}} \left(C_t^b\right)^{\frac{\eta-1}{\eta}} + \varepsilon_t^H \omega_H^{\frac{1}{\eta}} \left(H_t^b\right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{2}$$

and $N_{C,t}^b$, $N_{H,t}^b$ denote the impatient agent's hours worked in each sector. A housing preference shock is introduced, ε_t^H, which affects the marginal rate of substitution between non-durable and housing consumption.[5]

Impatient agents have limited access to the credit market and face a collateral constraint which, in real terms, reads as follows:

$$b_t^b \leq \varepsilon_t^{LTV} (1-\chi) E_t \left\{ q_{t+1} H_t^b \frac{\pi_{t+1}}{R_t} \right\} \tag{3}$$

where $b_t^b \equiv \frac{B_t^b}{P_t}$ denotes real private debt, $\pi_{t+1} \equiv \frac{P_{t+1}}{P_t}$ is the gross inflation rate, R_t is the (gross) short-term nominal interest rate, q_t is the relative price of housing goods in terms of non-durable goods and $\chi \in (0,1)$ is the down-payment rate, so that $(1-\chi)$ is the loan-to-value ratio. The term ε_t^{LTV} denotes an exogenous shock to the loan-to-value ratio, which follows a stationary AR(1) process. Impatient households thus maximize (1) subject to the collateral constraint (3) and the following sequence of real budget constraints:

[5] The shock is assumed to follow a stationary AR(1) process.

$$C_t^b + q_t(H_t^b - (1-\delta)H_{t-1}^b) + \frac{R_{t-1}}{\pi_t} b_{t-1}^b = b_t^b + \frac{A_t^b}{P_t} + \frac{W_{C,t}^b N_{c,t}^b + W_{H,t}^b N_{H,t}^b}{P_t} \tag{4}$$

where δ is the depreciation rate of the housing good, $W_{C,t}^b$ and $W_{D,t}^b$ denote the nominal wages received by the borrower in the two sectors and A_t^b is the stream of income derived from state-contingent securities, which allow the borrowers to hedge against wage income risk.[6]

2.2 Patient households

Patient agents, indexed with a superscript s, maximize the same type of function as the impatient agents:

$$E_0 \sum_{t=0}^{\infty} (\beta^s)^t \left\{ \frac{1}{1-\sigma} (X_t^s)^{1-\sigma} - \frac{1}{1+\varphi_C} \left(N_{C,t}^s\right)^{1+\varphi_C} - \frac{1}{1+\varphi_H} \left(N_{H,t}^s\right)^{1+\varphi_H} \right\} \tag{5}$$

and

$$X_t^s \equiv \left[\left(1 - \varepsilon_t^H \omega_H\right)^{\frac{1}{\eta_H}} (C_t^s)^{\frac{\eta-1}{\eta}} + \varepsilon_t^H \omega_H^{\frac{1}{\eta}} (H_t^s)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{6}$$

where ε_t^H is the same housing preference shock introduced above.[7] The saver's real budget constraint reads:

$$\begin{aligned} C_t^s + q_t \left(H_t^s - (1-\delta) H_{t-1}^s\right) + b_t^s &= \frac{R_{t-1}}{\pi_t} b_{t-1}^s + \frac{W_{C,t}^s N_{C,t}^s + W_{H,t}^s N_{H,t}^s}{P_t} \\ &+ \frac{A_t^s + \Pi_t^s}{P_t} \end{aligned} \tag{7}$$

where Π_t^s are distributed profits (see below). Similarly to the case of the borrowers, it is assumed that state-contingent assets are traded among the savers, in order to hedge against wage income. The corresponding stream of income is denoted A_t^s. As a result, all savers have identical consumption plans in equilibrium.

[6] We assume that the borrowers can trade such securities within their group, although they face financial frictions when borrowing from savers. Under separable preferences, trading such assets ensures that all borrowers have identical consumption plans in equilibrium.

[7] It is assumed that a common housing preference shock contemporaneously hits both agents, in order to capture a generalized increase in housing demand.

2.3 Firms

Final producers of the non-residential good operate in perfect competition and aggregate a continuum of differentiated intermediate goods. The elementary differentiated goods, indexed with $h \in [0,1]$, are imperfect substitutes with an elasticity of substitution denoted $\frac{\mu_C}{\mu_C - 1}$. Final goods are produced with the following technology $Y_{C,t} = \left[\int_0^1 Y_{C,t}(h)^{\frac{1}{\mu_C}} \mathrm{d}h\right]^{\mu_C}$. The corresponding demand-based price index is $P_t = \left[\int_0^1 p_t(h)^{\frac{1}{1-\mu_C}} \mathrm{d}h\right]^{1-\mu_C}$. As a result, individual demand for each good is defined as:

$$Y_{C,t}(h) = \left(\frac{p_t(h)}{P_t}\right)^{-\frac{\mu_C}{\mu_C - 1}} Y_{C,t}$$

Intermediate-goods producers operate in monopolistic competition and produce differentiated products using a linear technology:

$$Y_{C,t}(h) = L_t^C(h) - \Omega_C \qquad \forall h \in [0,1]$$

where Ω_C is a fixed cost. The term $L_t^C(h)$ aggregates individual labor supply as follows:

$$L_C \equiv \omega^{\omega}(1-\omega)^{(1-\omega)} \left(N_{C,t}^S\right)^{(1-\omega)} \left(N_{C,t}^B\right)^{\omega}$$

Firms set prices on a staggered basis *à la* Calvo (1983): at any time t, a firm h faces a constant probability θ_C of not being able to re-optimize its nominal price. The average duration between price changes is therefore $\frac{1}{1-\theta_C}$. Under these assumptions, in a symmetric equilibrium (with $p_t(h) = p_t \ \forall h$) the aggregate price index evolves as follows:

$$P_t^{\frac{1}{1-\mu_C}} = \theta_C \left(P_{t-1}\right)^{\frac{1}{1-\mu_C}} + (1-\theta_C)\widetilde{p}_t^{\frac{1}{1-\mu_C}}$$

where $\widetilde{p}_t$ is the price chosen by firm h to maximize its intertemporal profit.

The housing sector is perfectly symmetric to the non-residential goods sectors. The elasticity of substitution among differentiated goods is denoted $\frac{\mu_H}{\mu_H - 1}$. Final goods are produced with the following technology $Y_{H,t} = \left[\int_0^1 Y_{H,t}(h)^{\frac{1}{\mu_H}} dh\right]^{\mu_H}$. The linear production technology for intermediate goods is:

$$Y_{H,t}(h) = L_t^H(h) - \Omega_H \qquad \forall h \in [0,1]$$

In our baseline calibration we assume that housing prices are perfectly flexible, in line with what often assumed in the literature.[8] The probability that a firm is not able to re-optimize its nominal price is accordingly set equal to zero (θ_H=0). We relax this assumption in Section 6, where we also briefly discuss contributions that provide empirical evidence that house prices are not fully flexible and analyse the resulting implications.

2.4 Monetary policy

Monetary policy is specified in terms of an interest rate rule as follows:

$$\frac{R_t}{\overline{R}} = \left(\frac{R_{t-1}}{\overline{R}}\right)^{\rho} \left(\left(\frac{\pi_t}{\overline{\pi}}\right)^{\phi_\pi} \left(\frac{Y_t}{Y_{t-1}}\right)^{\phi_{\Delta y}} \left(\frac{\pi_{H,t}}{\overline{\pi_H}}\right)^{\phi_{\pi_H}}\right)^{1-\rho} \tag{8}$$

where Y_t denotes GDP, defined as $Y_{C,t} + q_t Y_{H,t}$, $\pi_{H,t} \equiv \frac{q_t}{q_{t-1}}$ is the housing inflation rate and an upperbar denotes the steady-state value of a given variable. This general specification allows for a systematic reaction of the policy instrument to fluctuations in the relative price of the housing good.

2.5 Market clearing

Equilibrium in the non-residential and housing goods market requires the allocation of total production of the final good to total households' expenditure:

$$Y_t = \omega C_t^b + (1-\omega) C_t^s \tag{9}$$

and:

$$Y_t^S = \omega(H_t^b - (1-\delta)H_{t-1}^b) + (1-\omega)(H_t^s - (1-\delta)H_{t-1}^s) \tag{10}$$

Equilibrium in the debt market requires:

$$\omega B_t^b = (1-\omega) B_t^s \tag{11}$$

[8] See Aspachs-Bracons and Rabanal (2011) and Iacoviello and Neri (2010).

3 Calibration

The savers' discount rate is set to 0.99, implying a steady-state interest rate of 4%; the borrowers' discount rate is equal to 0.96. We assume log utility for both type of agents by setting $\sigma = 1$, as in Monacelli (2009). Labor supply elasticities φ_C and φ_H are equal to 2, a standard value in the macroeconomic literature. The share of impatient agents, ω, is equal to 0.2, close to the estimates of Iacoviello and Neri (2010) for the U.S. and Darracq Pariès and Notarpietro (2008) for the euro area. The intratemporal elasticity of substitution between durable and non-durable goods, η, is equal to one, implying a Cobb-Douglas specification for the final consumption bundle, in line with the evidence reported in Davis and Ortalo-Magne (2011). The share of housing services in the utility function, ω_H, is set to 0.1, which helps obtaining a steady-state ratio of residential investment to GDP similar to the U.S. and euro area long-run averages. The depreciation rate of housing, δ, is set to 0.01, corresponding to an annual rate of 4%, as in Monacelli (2009). The down-payment ratio, χ, is set to 0.2, implying a loan-to-value ratio of 80%, in line with the average for the U.S. and the euro area.[9] Elasticities of substitution across varieties in the goods markets are set to 4.33, in order to obtain a gross markup of 1.3. About nominal rigidities, we set the Calvo parameter $\theta_C = 0.75$, corresponding to an average duration of price contracts of four quarters. We assume perfectly flexible prices in the residential sector, as mentioned above.

As to the sources of exogenous variations, we focus only on those that are peculiar to our setup, viz. housing demand and loan-to-value ratio shocks, which have been found to be the main source of fluctuation in house prices. Specifically, estimated DSGE models with housing and financial frictions (see Iacoviello and Neri (2010) and Liu, Wang, and Zha (2013)) show that housing demand shocks drive most of the cyclical fluctuations in house prices. Ludvigson, Nieuwerburgh, and Favilukis (2013) argue that shocks to the loan-to-value ratio (LTV), which can be interpreted as changes in financial regulation, are also important for generating fluctuations in house prices. Moreover, as illustrated in Liu, Wang, and Zha (2013), credit constraints can amplify and propagate exogenous shocks only when such shocks generate fluctuations in the collateral value. This is clearly the case for housing demand and LTV shocks, but not, for instance, with TFP shocks. We therefore exclude the latter from our experiments. We also do

[9]See Iacoviello and Neri (2010) and Calza, Monacelli, and Stracca (2013) for the U.S. and the euro area, respectively.

not consider cost-push shocks either. The latter are known to be a source of policy tradeoff in a standard New Keynesian model. Such tradeoff is however distinct and independent from housing dynamics and financial frictions. We set the persistence parameters of the exogenous shocks to 0.95, close to the estimated values reported in Iacoviello and Neri (2010) and Darracq Pariès and Notarpietro (2008). The standard deviation of housing demand and financial shocks are chosen to obtain a 1% increase on impact in house prices and the loan-to-value ratio, respectively, under a standard calibration of the monetary policy rule.

4 Welfare evaluation

In our normative analysis we look for the optimal monetary policy within the class of *simple* and *operational* interest rate rules, according to the definition of Schmitt-Grohe and Uribe (2007). Namely, we restrict our attention to policy rules that (i) respond to variables that can be easily observed and (ii) deliver equilibrium determinacy. For the sake of simplicity, we do not include a measure of the output gap in the monetary policy rule. Apart from operational difficulties in estimating such measure in real time, it would be particularly troublesome to define an efficient level of output in our setup, which is characterized by monopolistic competition and financial frictions. Rather, we focus on real GDP growth as a measure of real activity. To fulfil the requirement that rules be operational, we discard all combinations of parameters that give rise to indeterminacy.

4.1 The individual and social welfare measures

In order to assess the relative performance of alternative monetary policy rules, we follow a common practice in the literature and compute a second-order approximation to the model solution.[10] We compare the welfare levels achieved under alternative monetary policy rules by assuming that the initial state of the system coincides with the deterministic steady state.[11] The

[10] More precisely, we solve the model at second order and provide an approximation of welfare. As is well known, a first-order approximation would be insufficient since all the alternative monetary policy rules would imply the same deterministic steady state for the endogenous variables (see e.g. Kim and Kim (2003), Schmitt-Grohe and Uribe (2007)). In addition, since the steady state is distorted, a first order approximation to the policy rules would give rise to incorrect welfare rankings even under a second-order approximation to welfare (see Fendoglu (2014)).

[11] The same approach is followed in Lambertini, Mendicino, and Punzi (2013) to compute optimal monetary and macro-prudential policy rules, in a similar model.

performance of each simple rule is evaluated in terms of both individual and social welfare, to take into account households' heterogeneity. The welfare measure is computed by augmenting the model structure with equations (1) and (5) , which in recursive form read:

$$\mathcal{W}_t^j = U(X_t^j, N_{C,t}^j, N_{H,t}^j) + \beta^j E_t \mathcal{W}_{t+1}^j \tag{12}$$

Because of agents' heterogeneity, individual welfare functions must be aggregated into a social welfare function. We follow Lambertini, Mendicino, and Punzi (2013), Mendicino and Pescatori (2008) and Rubio (2011) and define the social welfare function as a weighted average of individual welfare as follows:

$$\mathcal{W}_t \equiv \phi^s \mathcal{W}_t^s + \phi^b \mathcal{W}_t^b \tag{13}$$

where $\phi^s = (1-\omega)(1-\beta^s)$ and $\phi^b = \omega(1-\beta^b)$, so that given a constant stream of final consumption X, the two agents receive the same level of utility. In the following we focus on the simple rule that achieves the highest social welfare, but we also analyze the properties of rules that independently maximize borrowers' and savers' individual welfare.

The individual and social welfare levels achieved under each alternative rule provide an ordinal measure, which is sufficient for our purpose of selecting the optimal simple rule. However, in order to provide a quantitative characterization of the losses (or gains) entailed by each rule with respect to a benchmark policy, we also compute a consumption-equivalent measure, defined as the percentage change in final consumption that is required to make individual welfare under each rule equal to the individual welfare level achieved under the Ramsey optimal monetary policy (to be discussed below). Formally, let the welfare of each agent $j = b, s$ under the Ramsey allocation be defined as follows:

$$\mathcal{W}_t^{j,R} \equiv E_0 \sum_{t=0}^{\infty} \left(\beta^{j,R}\right)^t \left\{ \frac{1}{1-\sigma}\left(X_t^{j,R}\right)^{1-\sigma} - \frac{1}{1+\varphi_C}\left(N_{C,t}^{j,R}\right)^{1+\varphi_C} - \frac{1}{1+\varphi_H}\left(N_{H,t}^{j,R}\right)^{1+\varphi_H} \right\}$$

Analogously, under any alternative regime a, we have:

$$\mathcal{W}_t^{j,a} \equiv E_0 \sum_{t=0}^{\infty} \left(\beta^{j,a}\right)^t \left\{ \frac{1}{1-\sigma}\left(X_t^{j,a}\right)^{1-\sigma} - \frac{1}{1+\varphi_C}\left(N_{C,t}^{j,a}\right)^{1+\varphi_C} - \frac{1}{1+\varphi_H}\left(N_{H,t}^{j,a}\right)^{1+\varphi_H} \right\}$$

Let Δ_j denote the welfare loss attained under policy a relative to the Ramsey allocation. Such loss corresponds to the percentage increase in final consumption (X) under regime a that makes each agent indifferent between living under that regime and under the benchmark regime. That is, Δ_j solves the following equation:

$$E_0 \sum_{t=0}^{\infty} \left(\beta^{j,R}\right)^t \left\{ \frac{1}{1-\sigma} \left(X_t^{j,R}(1+\Delta_j) \right)^{1-\sigma} - \frac{1}{1+\varphi_C} \left(N_{C,t}^{j,R} \right)^{1+\varphi_C} - \frac{1}{1+\varphi_H} \left(N_{H,t}^{j,R} \right)^{1+\varphi_H} \right\} = \mathcal{W}_{j,t}^R$$

4.2 The Ramsey optimal monetary policy

Before illustrating the properties of the optimal simple monetary policy rule in our model, we briefly discuss the Ramsey optimal monetary policy. Let us consider the problem of a social planner that maximizes a social welfare function (defined above) under the private-sector optimality conditions that characterize the (imperfectly) competitive equilibrium.[12] The Ramsey planner chooses state-contingent allocations and prices to maximize (13) taking the equilibrium conditions (except the monetary policy rule) as given. We compute a second-order approximation to the solution of the Ramsey problem.[13] A few observations are in order. First, we assume that the Ramsey planner does not have access to subsidies and transfers to undo the distortions due to monopolistic competition and financial frictions. Therefore, the social planner cannot achieve the first-best equilibrium allocation. Moreover, the deterministic steady state under the Ramsey optimal plan is distorted and coincides with the decentralized equilibrium in the absence of exogenous shocks. Second, as already pointed out, a criterion must be chosen to aggregate individual utilities into a social welfare function, due to agents' discount factors heterogeneity. The aggregation scheme illustrated in the previous section guarantees that agents receive the same level of utility, for a given a stream of final consumption. We use (13) as our social welfare function also in the Ramsey problem.[14] However, as noted also in Mendicino and

[12]Monacelli (2008) solves a Ramsey problem in a model with heterogeneous households and collateral constraints, in the presence of technology shocks only. His analysis is limited to a first-order approximation in order to study local dynamics and abstracts from welfare considerations.

[13]We compute the first-order conditions of the welfare maximisation problem of the policy maker using Giovanni Lombardo's *lq solution* routine. We then compute a second-order approximation of all the model equations using Dynare.

[14]Lambertini, Mendicino, and Punzi (2013) propose also an alternative criterion, in which individual welfare functions are equally weighted. Monacelli (2008) uses yet a different aggregation in the definition of the Ramsey planner's objective function, where individual weights coincide with the relative shares of patient and impatient households in the economy.

Pescatori (2008), the Ramsey optimal policy is not suited for an analysis of the effects of alternative monetary policy regimes on the welfare of borrowers and savers separately. Therefore, when computing individual welfare in terms of consumption equivalent units, we aim at providing a complementary quantitative indicator of the size of the losses achieved by each agent under alternative monetary policy regimes. It is understood that the Ramsey problem only maximizes aggregate welfare. Third, the solution to the Ramsey problem crucially depends on the definition of the social planner's intertemporal discount factor in equation (13). In particular, while the period social welfare function $\mathcal{W}_t$ reflects the differences in the individual discount factors, computing the Ramsey planner's optimality conditions requires an appropriate definition of the planner's discount factor. In the following we assume that the social planner discounts future utility with the saver's intertemporal discount factor β^s. This assumption is motivated by the observation that in the deterministic steady state of the decentralized economy (which coincides with the Ramsey deterministic steady state) it is the saver's discount factor β^s that determines the nominal interest rate. As such, it would be inappropriate to use the borrower's discount factor to discount social welfare.

4.3 Welfare maximizing rules

In order to compute the welfare-maximizing monetary policy rule, a search is performed in the following intervals: $\rho \in [0, 1]$, $\phi_{\Delta y} \in [0, 2]$, $\phi_{\pi} \in [1.1, 5]$ and $\phi_{\pi_H} \in [-1, 3]$. The choice of the intervals is based on several consideration. The smoothing parameter ρ is allowed to be in the unit interval in order to facilitate the interpretation of the results.[15] The boundaries for the response to GDP fluctuations reflect existing estimates of this parameter in the literature. The response to inflation is bounded below by the requirement that the rule guarantees determinacy (in the absence of a response to house prices). The upper bound is arbitrary, but, as suggested in Schmitt-Grohe and Uribe (2007), larger policy coefficients would be difficult to communicate to policymakers or the public. Finally, the parameter capturing the response to house price fluctuations is allowed to assume both negative and positive values.

[15] Previous contributions in the literature on optimal monetary policy rules have highlighted the presence of *superinertia*, namely $\rho > 1$, in optimized monetary policy rules for DSGE models (see, e.g., Adalid, Coenen, McAdam, and Siviero (2005)). We do not consider such issue here, in order to simplify the interpretation and to focus the analysis on the optimal responses to inflation and house price fluctuations.

Table 1 reports the results.

The first row reports the parameters of the optimal rule and the corresponding social and individual welfare levels, with the corresponding welfare losses (relative to the Ramsey optimal monetary policy) in parenthesis. The second and third row report the rules that directly maximize the saver's and borrower's individual welfare, respectively.

The optimal simple rule features a relatively high degree of inertia (0.9) and no response to GDP variations. The latter result is in line with the findings of Schmitt-Grohe and Uribe (2007) in a standard New Keynesian model without financial frictions. The presence of a collateral constraint thus does not result in a prominent role being played by the direct stabilization of real activity. The response to consumer price inflation is large, although well below the upper bound. Such result is consistent with previous contributions that have analyzed the optimal response to inflation in DSGE models with credit constraints and housing. Lambertini, Mendicino, and Punzi (2013) find that, under news shocks, complete inflation stabilization is suboptimal in the presence of agents' heterogeneity, a feature shared by our model. The suboptimality of full inflation stabilization in our setup has to do with the implied unintended transfers of wealth between borrowers and savers. As debt contracts are fixed in nominal terms, any increase in the inflation rate reduces the real value of existing debt and induces a fall in the real interest rate, ceteris paribus (the opposite holds true in the presence of a negative inflation shock). Such effect reflects the well-known debt-deflation mechanism.[16] As a result, an unexpected rise in the inflation rate is equivalent to a transfer of wealth from the saver to the borrower (and viceversa in the case of an unexpected fall in inflation). The optimal rule takes into account such mechanism and avoids a complete neutralization of inflation volatility. Finally and most importantly, under the baseline calibration, the optimal simple rule features a negative response to house price fluctuations (-0.7), implying that the nominal interest rate should fall in response to a rise in house prices.

Looking at the second and third row of Table 1 helps clarifying the results.

On the one hand, the best rule from the saver's viewpoint (second row) resembles an inflation targeting regime. While the smoothing coefficient has a value of 0.5, the response to inflation

[16] See Fisher (1933).

takes the largest possible value in the range.[17] Conversely, the response to house price fluctuations is very small, although in the positive range. Hence, from the saver's perspective the presence of financial frictions slightly alters the prescriptions of optimal monetary policy in a multi-sector economy with different degrees of nominal price rigidity. The optimal rule should counteract movements in non-durable price inflation by sufficiently raising the nominal interest rate. However, the absence of nominal rigidities in the housing sector does not imply that fluctuations in house prices be completely neglected. The optimal coefficient attached to house price fluctuations is in fact positive, suggesting that the central bank should mildly contrast movements in house prices related to either a change in the demand for housing or a relaxation/tightening of borrowing limits. In both cases, in fact, the financial accelerator mechanism generated by the collateral constraint entails an increase in volatility of real variables, which is disliked by risk-averse consumers. As shown in Table 2, the saver's preferred rule almost perfectly stabilizes the volatility of inflation and, as a result, the real interest rate.

The rule that maximizes the borrower's welfare is very different (see Table 1, third row). The smoothing parameter is high (0.9), while the response to inflation is positive, although well below the upper bound. This reflects the above-mentioned benign effect of a positive inflation rate on the borrower's welfare. Most importantly, the optimal response to house price fluctuations from the borrower's viewpoint is negative, requiring a fall in the nominal interest rate in response to an exogenous increase in house prices. Through this reduction, the central bank can alleviate the distortion related to credit frictions, i.e. the existence of a borrowing limit. Consider a positive housing demand shock. By definition, the shock raises the marginal rate of substitution (MRS) between housing and non-durable consumption. Each agent thus would like to consume more housing services. In the case of the borrowers, however, the perpetually binding collateral constraints limits their ability to consume as much housing as desired. In fact, from the borrower's first order optimality condition we have:

$$\frac{U_{H,t}}{U_{C,t}} = q_t - \beta(1-\delta)E_t\left\{\frac{U_{C,t+1}q_{t+1}}{U_{C,t}}\right\} - \varepsilon_t^{LTV}(1-\chi)\psi_t E_t\left\{\frac{q_{t+1}\pi_{t+1}}{R_t}\right\} \tag{14}$$

[17] We have experimented with a higher upper bound and results are qualitatively unchanged. The rule that maximizes the saver's welfare attaches the largest possible coefficient to consumer price inflation. We have decided to keep the upper bound at the value of 5 for the reasons explained in the text.

where ψ_t is the Lagrange multiplier attached to the collateral constraint. The equation implies that the borrowers equate the marginal rate of substitution between housing and non-durable consumption to the user cost of durables. The latter depends on three components: the house price, the expected future utility derived from re-selling a housing unit in the future and a term that reflects the marginal utility of relaxing the borrowing constraint. The latter is proportional to the Lagrange multiplier associated to the collateral constraint. Importantly, since the constraint is assumed to bind at all times, the borrowers always need to buy one additional unit of housing (collateral) to obtain one additional unit of debt. A positive housing demand shock increases the MRS and therefore requires that the right-hand-side of equation (14) adjusts accordingly. If the central bank aims at maximizing borrowers' utility using the interest rate as an instrument, the best response is a decrease in the policy rate. In this way, in fact, the collateral constraint is relaxed, which is reflected in a rise in the third component of the user cost. In other words, the central bank allows the borrowers to expand their consumption of housing more than they would with a constant monetary policy rate. As such, borrowers' utility is maximized. Consider now a negative housing demand shock, which decreases the MRS between housing and non-durable consumption. The marginal utility of an extra unit of housing falls. Consequently, the borrowers would like to reduce housing services. However, the assumption of a perpetually binding collateral constraint limits their ability to do so, since the borrowers' demand for housing must exactly match the available amount of debt, for given LTV ratio, nominal interest rate and inflation rate. In other words, absent a monetary policy intervention, the borrowers would not be able to reduce housing services as much as desired. Then, a central bank that directly maximizes the borrowers' utility would increase the nominal interest rate, in order to tighten the collateral constraint. By doing so, it implicitly reduces the optimal amount of housing that the borrowers must demand for the constraint to bind. As a result, it allows the borrowers to cut on housing consumption, increasing their utility. A similar line of argument holds in the case of LTV ratio shocks. All in all, the best policy response from the borrower's viewpoint maximizes borrower's welfare by counteracting the presence of financial market imperfections. Notably, the implied volatilities of inflation and the real interest rate are larger compared to those generated under the saver's preferred rule (see Table 2).

The social-welfare maximizing rule thus results from "compromising" between the markedly different welfare maximizing rules for borrowers and savers. First, the response to inflation is not as aggressive as it would be in a frictionless model. Inflation is not fully stabilized under the optimal rule (see Table 2), reflecting the existence of a transfer of wealth between borrowers and savers resulting from unexpected variations in the inflation rate. Second, it features a non-zero response to house prices, again departing from the optimal monetary policy prescriptions in a model with perfect credit markets.

Figures 1-3 show the social and individual welfare surfaces around the optimal rule.[18] The social welfare function displays a marked concavity around the optimized coefficients. In particular, a smaller response to inflation would imply extremely large losses from a social perspective. As shown in Figure 2, the saver's welfare is relatively flat when π is sufficiently large, and declines when π is small. To the opposite, the borrower's welfare surface is monotonically decreasing in ϕ_π, reflecting the preference for less inflation stabilization, and increasing in ϕ_{π_H} (see Figure 3).

Interestingly, the socially optimal rule does not imply a Pareto improvement with respect to the Ramsey policy. In fact, while the borrower is better off under the simple rule, the saver is worse off. A few observations are in order. First, the socially optimal rule implies an individual gain for the borrower, compared to the Ramsey allocation. The fact that a simple rule can attain a larger individual welfare level than the Ramsey optimal policy should not be regarded as surprising. As already noted, the social planner discounts future utility is assumed to be discounted by the social planner with the saver's intertemporal discount factor β^s, which is likely to distort the borrowers' consumption plans if compared to a competitive equilibrium. Second, it is interesting to note that only in one case it is possible to obtain a Pareto improvement compared to the Ramsey allocation, namely under the saver's preferred rule, which closely approximates an inflation targeting regime.

4.4 Impulse response functions

In order to highlight the main features of the transmission mechanism, this section illustrates the dynamic responses of the model economy to the two shocks. Figures 4 and 5 report the impulse responses of the main variables after a housing demand shock and a financial shock,

[18]In the figures we only let ϕ_π and ϕ_{π_H} vary around their respective optimal values, fixing ρ and $\phi_{\Delta y}$ at their optimal values reported in Table 1.

respectively. Each panel reports the responses under the optimal rule (solid black line), the saver's and borrower's preferred rule (dotted blue and dashed red lines, respectively) and the Ramsey optimal policy (solid light blue line with diamonds).

4.4.1 Housing demand shock

Since the optimal simple rule features a negative response to house prices, the initial increase in housing demand drives house prices up without prompting a counteracting response by the central bank. In fact, the nominal interest rate initially falls and, due to the high inertia, remains below its baseline value for a significant amount of time. The dynamics of the main real variables follows from the differences in individual responses of the two types of agents. The positive valuation effect on existing collateral of higher house prices represents a positive income shock for the borrowers, who, being impatient, use all of the extra-amount of income to finance current consumption of both goods. Indeed, as Figure 4 shows, the borrowers increase both non-durable consumption and housing, under each of the three simple rules. Private debt also increases (not reported), reflecting the more favourable borrowing conditions. To the opposite, the initial increase in house prices generated by the positive demand shock only represents a relative price increase for the savers, whose response is thus a substitution away from the more expensive housing good to non-durable consumption. In fact, the savers' consumption of both goods falls, reflecting the complementarity of non-durables and housing in final consumption. As a result, the inflation rate falls, driving the nominal and real interest rate down. GDP gradually falls and remains below its steady-state value for a prolonged period of time. Interestingly, under the saver's preferred rule (which approximates an inflation targeting regime), the initial increase in house prices is partly counteracted by the (small) increase in the policy rate, which in turn raises the real interest rate too, depressing saver's consumption of both goods. Nevertheless, the expansion in borrowing capacity brought about by the initial increase in house prices is sufficient to sustain an increase in the borrower's consumption of both goods. Finally, under the Ramsey optimal monetary policy the initial increase in the policy rate is larger compared to all the simple rules, inducing a much larger initial fall in GDP. Importantly, under the Ramsey-optimal policy, the inflation rate is not completely stabilized. The presence of a financial imperfection (the collateral constraint) alters the traditional optimal monetary policy prescription and makes pure inflation targeting a suboptimal strategy. Previous contributions in the literature[19] have highlighted that in the presence of collateral constraints the monetary policymaker faces a tradeoff between stabilizing inflation (which would make the savers better off) and relaxing the collateral constraint, by tolerating a higher initial increase in house prices and consequently a higher inflation rate (which would make the borrower better off). The extent to which the policymaker relaxes the borrowing constraint can be measured by the dynamics of the Lagrange multiplier associated to the collateral constraint (3).[20] Under all policy regimes, including the Ramsey policy, the multiplier falls below its baseline value, testifying a relaxation of the constraint, which makes the borrower better off. Clearly, the largest drop is observed under the policy rule that directly maximizes borrower's welfare.

4.4.2 Financial shock

The qualitative behaviour of the main macroeconomic variables is similar to the one observed after a housing demand shock. The larger loan-to-value ratio allows the borrower to obtain more funds, everything else equal, so that its consumption of both goods increases, financed with the extra amount of borrowing. Both the nominal and the real interest rate barely move in response to the shock. As a result, GDP is virtually unaffected, also reflecting the muted response of the saver's consumption. As a result, the amplification and propagation effect that it generates is smaller, too. The dynamics under the three simple rules are overall very similar and hardly distinguishable.

5 The role of financial frictions

This section discusses in detail the role of financial frictions, as captured by two model parameters: the share of borrowers, ω, and the loan-to-value ratio, $(1-\chi)$. Under the baseline calibration, we have shown that the social-welfare maximizing monetary policy rule inherits the borrower's preference for a fall in the nominal interest rate in response to an appreciation in

[19]See e.g. Monacelli (2009)

[20]In the deterministic steady state the collateral constaint binds and, consequently, the Lagrange multiplier has a positive value (see e.g. Iacoviello (2005) and Iacoviello and Neri (2010)). As noted in Monacelli (2009), even though the constraint holds with equality in a neighbourhood of the deterministic steady state, variations in its tightness are still measurable in terms of the corresponding shadow value, i.e. the Lagrange multiplier.

house prices due to higher demand, or to a loosening of credit standards. As a result, the optimal coefficient ϕ_{π_H} assumes negative values, if allowed to do so.

We start our analysis of the role of financial frictions by comparing the behaviour of the economy to the one observed in the absence of financial imperfections. More precisely, suppose that the economy is populated by a representative agent (the saver) so that there is no private borrowing and, accordingly, there are no borrowing limits. In this case, optimal monetary policy theory would prescribe to focus on non-durable price inflation - which is affected by the presence of nominal rigidities and the inherent inefficiency stemming from price dispersion - and ignore house price fluctuations.[21] In other words, inflation targeting would approximate the optimal policy. Results reported in Table 3 confirm such guess. Importantly and different from the case of a borrower/saver economy, the optimal inflation volatility is zero (not reported).

Having established that the presence of financial frictions does alter the optimal choice of an instrument rule, a natural question is then: How much do the results depend on the pervasiveness of financial frictions in the economy? Or, equivalently: How would the optimal simple rule modify in the presence of more (less) impatient agents and/or a higher (lower) average loan-to-value ratio? In order to answer these questions we repeat the search analysis of the previous section by considering a number of combinations of the two crucial parameters. In particular, we consider $\omega \in [0.1, 0.5]$ and $(1-\chi) \in [0.8, 0.95]$. Figure 6 provides a graphical illustration of the results by reporting the regions where the implied optimized value for ϕ_{π_H} is negative (red area) or positive (grey area). The circle corresponds to the baseline calibration. For $\omega < 0.2$ the social-welfare maximizing rule always features a negative response to house prices, irrespective of the value assumed by the average LTV ratio. As the share of borrowers increases, the value of the LTV ratio becomes crucial in determining the sign of ϕ_{π_H}. For $0.2 < \omega < 0.4$, the optimal response to house prices becomes positive when the LTV ratio reaches high levels, in the neighbourhood of 90% or more. Such threshold level decreases as ω approaches 0.5. In other words, with a larger LTV ratio, a smaller fraction of borrwers is sufficient to induce the central bank to lean against house price fluctuations. In the limiting case of a 95% average LTV ratio, a positive coefficient is observed with ω=0.2. This result reflects the fact that the amplification effect generated by the collateral constraint becomes larger as the average LTV ratio increases. Intuitively, an economy

[21] See e.g. Aoki (2001) or Benigno (2004).

with a larger LTV ratio will provide the borrowers with more funds in response to the same shock, thus generating more volatile responses in real variables. As a result, the socially optimal rule must take into account not only the potential benefit for the borrower of a relaxation of the collateral constraint (generated via a negative response to house price fluctuations) but also the potential loss for the saver stemming from higher volatility. The latter component tends to prevail as the leverage increases. Therefore, for a given proportion of borrowers in the economy, the optimal rule features an optimal response to house prices which is increasing in the LTV ratio.

An interesting implication of our results concerns the ability of the central bank to correctly identify and estimate the degree of financial frictions in the economy. Suppose the policymaker acts as if the correct description of the economy was the one delivered by our baseline calibration and implements the corresponding optimal simple rule, which features, among other things, a negative reaction to house price movements. If the true degree of financial frictions in the economy turns out to be larger, it is likely that the optimal response to house prices becomes positive. Clearly, the enacted monetary policy rule would be suboptimal in this case, generating unintended losses. Therefore, in our setup the estimation of the ("true") degree of financial frictions is thus crucial for the robustness, or lack thereof, of monetary policy rules. The analysis of such issue is beyond the scope of this paper and is left to future research.

6 Sensitivity analysis

This section provides two sensitivity analyses: first, we assess if and how the features of welfare-maximizing simple rules change under alternative assumptions on the degree of nominal price rigidity in the housing sector; second, considering the stochastic structure of the model, we modify the persistence of the housing demand shock.

6.1 Sticky house prices

The assumption of sticky house prices is used in Kannan, Rabanal, and Scott (2012) to overcome the so-called "comovement" problem, i.e. the fact that a monetary contraction leads to an expansion in residential investment in models with collateral constraints, a fact at odds with the data (see Monacelli (2009)). The assumption can be rationalized on the basis of existing empirical evidence: e.g., Case (2008) documents that house prices are subject to inertia and are sticky downward. We test the robustness of our optimal simple rule under the assumption that the Calvo parameter governing the frequency of price adjustments in the housing sector (θ_H) takes the following values: 0.25, 0.5, 0.75 and 0.9, corresponding to an average duration of a price of, respectively, 1, 2, 4 and 10 quarters. Table 4 reports the results. The optimal simple rule consistently features a negative response to house prices, irrespective of the degree of nominal price rigidity. This reflects the preferences of the borrowers, who always prefer the largest possible reaction. Notably, in the savers' preferred rule the response to inflation and house prices are monotonically decreasing and increasing, respectively, in the degree of house price stickiness. Such pattern reflects the traditional optimal monetary policy prescription in a two-sector model with perfect financial markets, according to which the relative weight assigned to each sectoral inflation index is increasing in the degree of price rigidity (and in the weight of the corresponding good in the final consumption basket).

6.2 Persistence of housing demand shocks

Table 5 reports the results of the optimization exercise for a lower degree of persistence of the housing demand shock ($\rho_H = 0.5$), which is the main driver of cyclical fluctuations in house prices in our setup. It is quite natural to conjecture that the persistence of this shock may have an impact on the dynamics of house prices and real variables in general. A more persistent shock implies in fact a higher predictability of future house prices, under the assumption of a stationary AR(1) process for the shock. In a recent contribution, Xiao (2013) uses the model of Iacoviello (2005) and shows that responding to house prices, in addition to output and inflation, helps stabilizing the economy (namely, it expands the determinacy region of the model) only if both private agents and the central bank do not possess current data on inflation and output and must forecast them, but do observe current housing prices. We explore the effects of changing the persistence of the housing demand shock, which, according to the stochastic structure of the model, should directly influence the forecastability of future house prices. As reported in the last column of Table 5, the optimal response to house prices is virtually unaffected by the assumption of a much lower persistence of the housing demand shock.

7 Conclusions

We develop a New Keynesian model with a housing sector and financial frictions on the household side, to analyse the scope for including house prices in the set of variables that the monetary policymaker targets and/or reacts to. Our main findings can be summarized as follows. The social welfare maximizing monetary policy rule may feature a reaction to house price variations, when the latter are generated by housing demand or financial shocks. The sign and size of the reaction crucially depend on the degree of financial frictions in the economy. When the share of constrained agents is relatively small, the optimal reaction is negative, implying that the central bank must move the policy rate in the opposite direction with respect to house prices. Moreover, the response to inflation is not as aggressive as it would be in a frictionless model, so that inflation is not fully stabilized under the optimal rule. However, when the economy is characterized by a sufficiently high average loan-to-value ratio, then it becomes optimal to counter house price increases by raising the policy rate.

Our results suggest that modelling financial imperfections, possibly also on the firms' side, seems of crucial relevance for the evaluation of monetary policy rules. Also, the implications for the construction of robust monetary policy rules - those whose performance is less severely affected by incorrect measurement of financial imperfections - seems worth probing. We leave these investigations to future research.

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Table 1. Optimized simple rules.

	ρ	$\phi_{\Delta y}$	ϕ_{π}	$\phi_{\pi H}$	Social welfare	Saver's welf.	Borrower's welf.
Social welfare maximization	0.9	0.0	1.9	-0.7	7.44795	587.3066	344.2120
						(0.0411)	(-1.0000)
Saver's welfare maximization	0.5	0.0	5.0	0.1	6.2215	669.5614	108.2928
						(-0.5426)	(-0.9787)
Borrower's welfare maximization	0.9	0.0	2.1	-1.0	6.9779	455.1524	417.7268
						(2.9032)	(-1.0000)

Note: Conditional welfare values. In parenthesis, individual welfare losses relative to the Ramsey monetary policy. Negative losses indicate gains.

Table 2. Optimized simple rules. Standard deviations

	π	GDP	q	RR	C^s	D^s	C^b	D^b
Social welfare maximization	0.18	0.17	3.47	0.22	0.33	1.42	0.23	4.96
Saver's welfare maximization	0.01	0.19	3.45	0.06	0.36	1.28	0.18	4.41
Borrower's welfare maximization	0.30	0.19	3.44	0.34	0.34	1.38	0.23	4.88
Ramsey optimal monetary policy	0.11	0.46	3.45	0.76	0.60	0.73	0.18	2.13

Note: Unconditional standard deviations. RR denotes the ex-ante real interest rate

Table 3. Optimized simple rule. Frictionless model

	ρ	$\phi_{\Delta y}$	ϕ_{π}	$\phi_{\pi H}$	Welfare
Welfare maximization	0.8	0.0	4.6	0	547.6305
					(2.0044)

Note: Conditional welfare values. In parenthesis, welfare losses relative to the Ramsey monetary policy. Negative losses indicate gains.

Table 4. Sensitivity analysis: nominal house price rigidity

		ρ	$\phi_{\Delta y}$	ϕ_{π}	ϕ_{π_H}
$\theta_H = 0.25$	Social welfare maximization	0.9	0.0	2.0	-0.8
	Saver's welfare maximization	0.5	0.0	5.0	0.1
	Borrower's welfare maximization	0.9	0.0	2.1	-1.0
$\theta_H = 0.50$	Social welfare maximization	0.9	0.0	2.1	-0.9
	Saver's welfare maximization	0.0	0.0	5.0	0.3
	Borrower's welfare maximization	0.9	0.0	2.1	-1.0
$\theta_H = 0.75$	Social welfare maximization	0.9	0.0	2.1	-1.0
	Saver's welfare maximization	0.0	0.0	2.5	0.9
	Borrower's welfare maximization	0.0	0.0	2.1	-1.0
$\theta_H = 0.90$	Social welfare maximization	0.0	0.0	2.1	-1.0
	Saver's welfare maximization	0.0	0.0	1.1	2.6
	Borrower's welfare maximization	0.0	0.0	2.1	-1.0

Table 5. Sensitivity analysis: lower persistence of housing demand shocks

		ρ	$\phi_{\Delta y}$	ϕ_{π}	ϕ_{π_H}
$\theta_H = 0.25$	Social welfare maximization	0.9	0.0	2.1	-1.0
	Saver's welfare maximization	0.0	2.0	5.0	0.7
	Borrower's welfare maximization	0.9	0.0	2.1	-1.0

Figure 1: Social welfare surface. Social welfare-maximizing rule

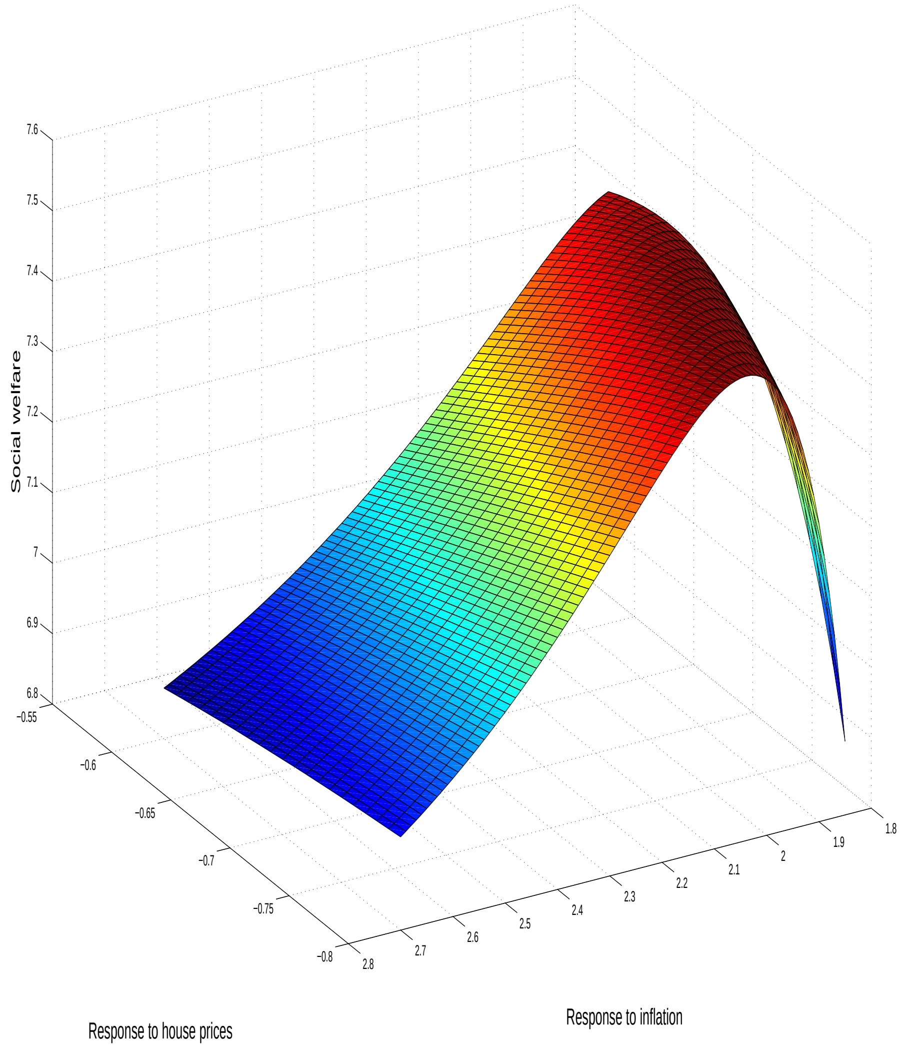


Figure 2: Saver's welfare surface. Social welfare-maximizing rule

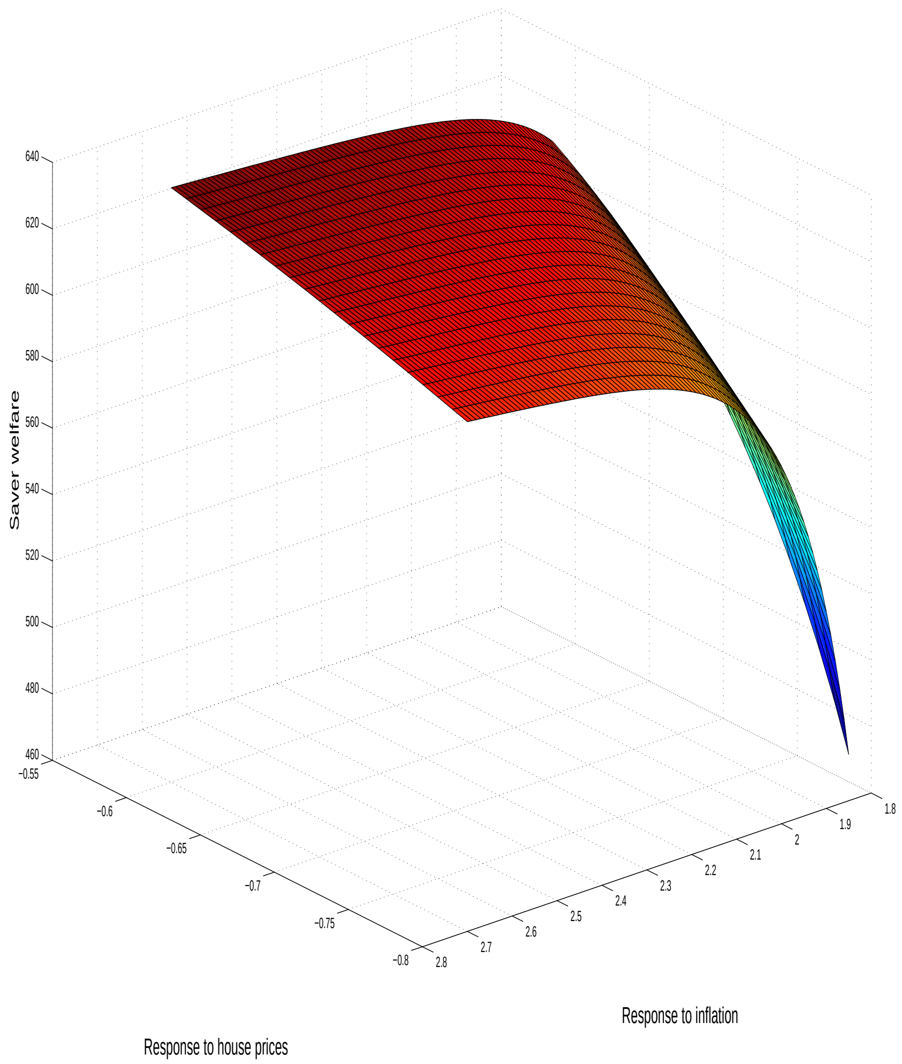


Figure 3: Borrower's welfare surface. Social welfare-maximizing rule

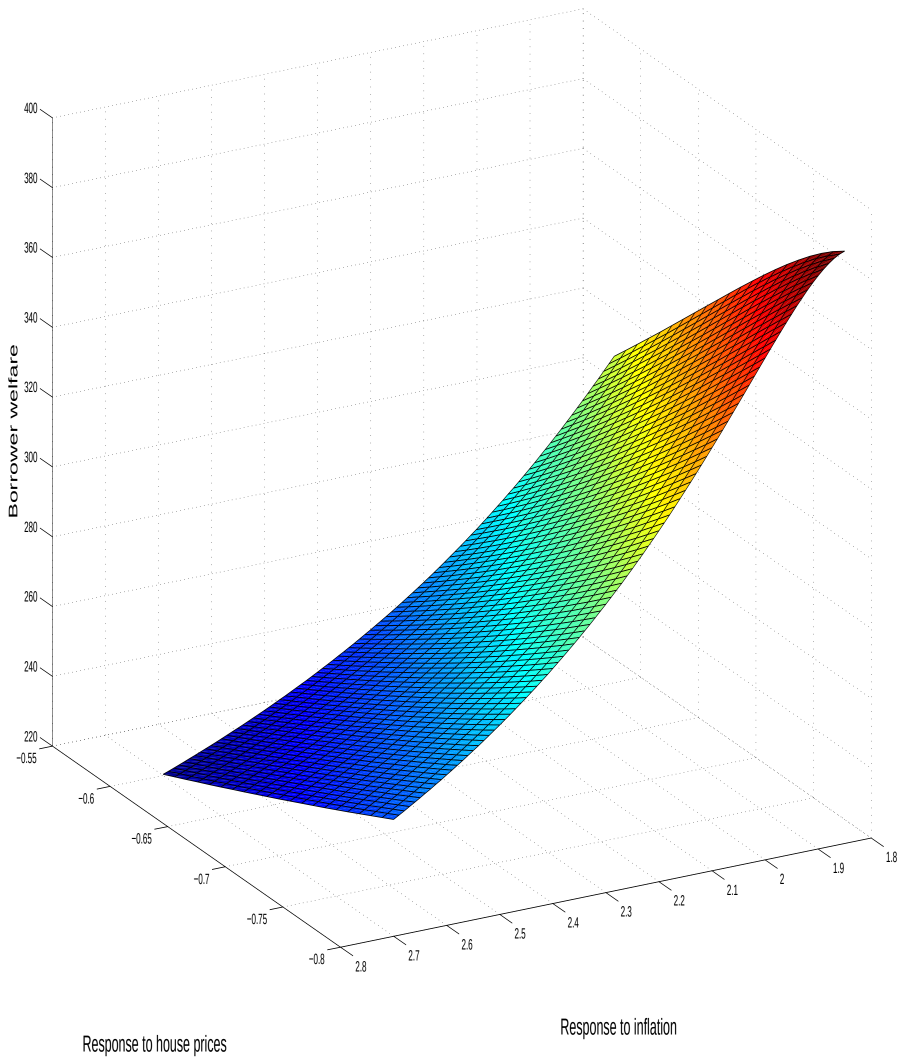


Figure 4: Housing demand shock

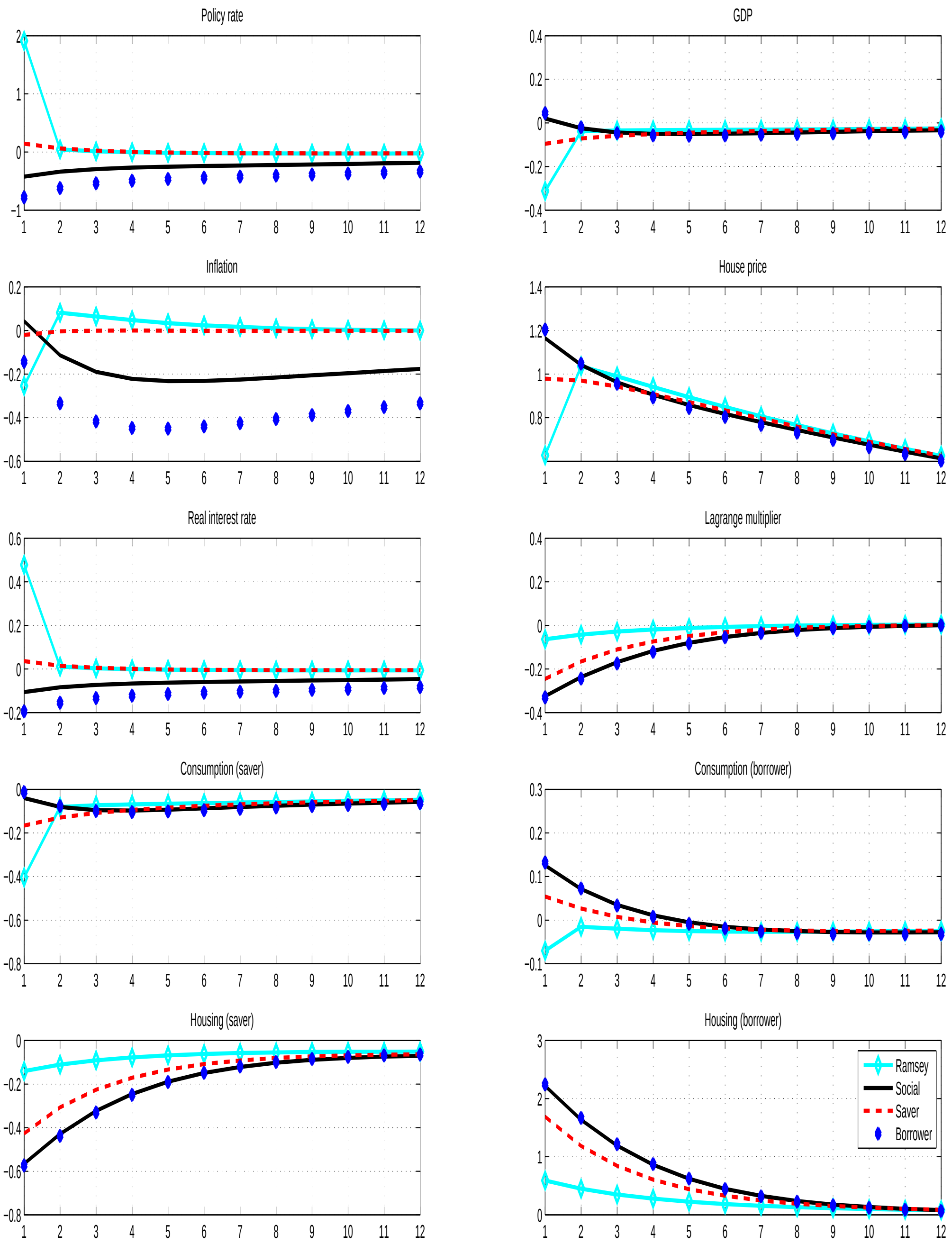


Figure 5: Loan-to-value ratio shock

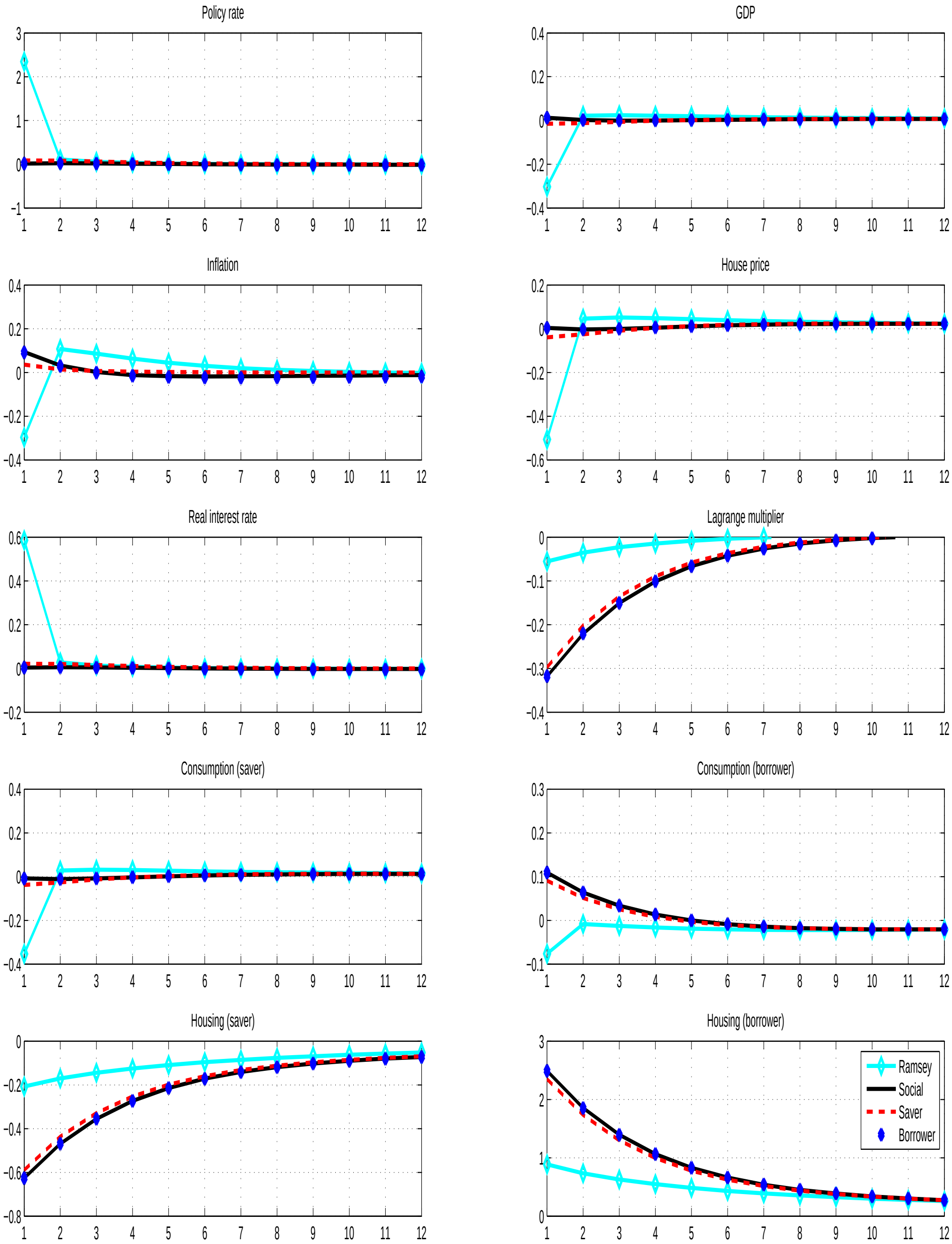
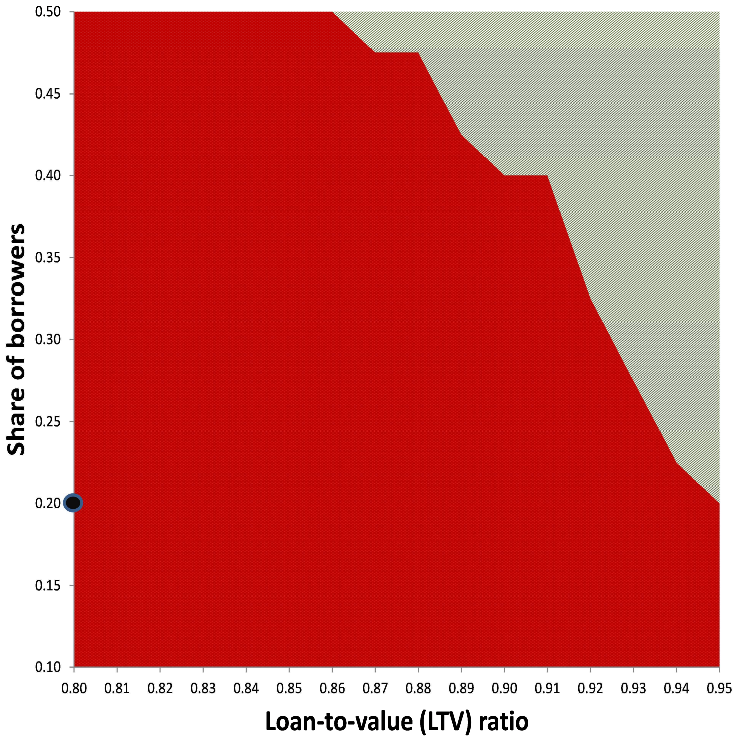


Figure 6: Optimal response to house prices. The role of financial frictions



Note: the red area indicates a negative coefficient; the grey area indicates a positive coefficient. The circle represents the baseline calibration.

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