Macroprudential Policy and Housing

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Abstract

Significant changes in house prices may merit changes in macroprudential policy. This work introduces land into a quantitative non-linear model of financial crises devised to study the design and effectiveness of optimal macroprudential policy. This framework is used to perform a comparative statics exercise and study how optimal macroprudential policy changes when an exogenous and permanent rise in external demand raises housing prices. Results show that, even in such a setting, macroprudential policy should lean against the wind in most circumstances. The role of both fundamentals news and the global liquidity regime is significantly strengthened by the rise in external demand.

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1 Introduction

Last few years housing prices have seen large real increases in the European Union, while there was a significant heterogeneity between countries (Eurostat, 2020). Additional heterogeneity may be found if one compares the price increases in rural areas with major urban centers: the latter having witnessed increases often more than three times higher than in the rest of the territory during this period (Claeys et al., 2019). This trend may be about to reverse.

While monetary policy may have played some role in this evolution, by increasing the value of assets vis-a-vis consumption goods (Alessi and Kerssenfischer, 2019), one may also find other reasons for this surge: the expansion of supply of low-cost flights (ICAO, 2020) and increase in international tourism (INWTO, 2020), the popularization of vacation rental online marketplace platforms (Ayouba et al., 2020; Chang, 2020) and other developments may all have played a role in the market evaluation of urban land. The COVID-19 pandemic, through its effect on tourism demand and travel in general (Gössling et al., 2021), may also have had an impact on urban land prices. The recent tightening of monetary policy and the Chinese property sector crisis may also be responsible for large price swings in the coming years.

All these fast and significant variations in market prices beg the question: how should macroprudential policy change? What should the macroprudential authority do to adapt macroprudential policy to changes in house prices, even when driven by exogenous non-monetary factors?

I introduce housing into a quantitative non-linear model of financial crises devised to study the design and effectiveness of optimal macroprudential policy. My results show that macroprudential policy should be strengthened when housing is accounted for, if collateral constraints are adequatlly modeled. They also show that, even when the increase in average land prices is exogenous and permanent, macroprudential policy should lean against the wind.

Since the financial crisis of 2008, Macroprudential policy has attracted considerable attention among researchers. One important approach to this matter looks back on Fisher's debt-deflation channel (Fisher, 1933): a *deflation spiral* may take place because, as financial intermediaries' net worth shrinks, liquidity constraints harm the economy, in turn leading to fire sales and consequent decreases in prices that further harm financial intermediaries' net worth. This strong non-linear amplification mechanism sets in when collateral constraints bind.

Building on Bernanke and Gertler (Bernanke and Gertler, 1989) and on the Kiyotaki–Moore framework (Kiyotaki and Moore, 2007) to study this impact of occasionally-binding collateral constraints on credit, Mendoza (2010) adds working capital constraints. In the same vein, Bianchi (2011) conduct a quantitative analysis to evaluate the macroeconomic and welfare effects of overborrowing in a dynamic stochastic general equilibrium (DSGE) model.

Overborrowing occurs because there is a pecuniary externality that drives a wedge between the competitive equilibrium and the social planner's equilibrium, since borrowers do not fully internalize the impact of their decision on the price of the collateral. The role of pecuniary externalities in financial stability had already been studied qualitatively by Auernheimer and Garcia-Saltos (2000), Caballero and Krishnamurthy (2001), Lorenzoni (2008) and Korinek (2011), but the quantitative nature of Bianchi and Mendoza's work sets it apart.

In incomplete markets, agents cannot perfectly insure against adverse shocks even when they are idiosyncratic, leading to precautionary savings and to a decrease in the equilibrium real interest rate, that fosters the accumulation of a large amount of debt in a given open economy. Assuming an occasionally binding credit constraint partially leveraged by the nontradable sector production (but denominated, in real terms, in tradable goods), the amplification mechanism is set. A typical adverse shock interacts with a debt level close to the constraint and makes agents lower their consumption abruptly, in turn devaluing nontradables and lowering their price. This tightens the credit constraint further and leads to additional decreases in consumption, in a mutually reinforcing mechanism. In spite of the fact that, in the model, private agents form rational expectations about the evolution of macroeconomic variables, those agents fail to internalize the general equilibrium effects of their borrowing decisions on prices: the pecuniary externality.

Empirical studies of credit cycles and financial crises have suggested that noisy news about future economic fundamentals (e.g. Schularick and Taylor, 2012; Borio and Zhu, 2012) and regime shifts in global liquidity (e.g. Calvo et al., 1996; Mendoza and Terrones, 2009; Shin, 2013; Bruno and Shin, 2015) are important macroeconomic drivers of the economy. However, in most studies that built on Bianchi and Mendoza's model (e.g. Bianchi et al., 2012; Benigno et al., 2013; Bengui and Bianchi, 2014) these features have been absent. Bianchi and Mendoza's 2016 paper (Bianchi et al., 2016) introduces these unconventional shocks, news shocks about future fundamentals and regime changes in global liquidity into a quantitative non-linear model of financial crises, and finds that both of them contribute to strengthen the amplification mechanism driving financial crisis dynamics.

In this framework, however, the housing market is absent or poorly modeled. Empirical work in the field of Household Finance (Guiso and Sodini, 2013; Zinman, 2015; Badarinza et al., 2016) shows that residential real estate represents the largest wealth component for the vast majority of households. In different OECD countries, the main residence accounts for more than half of real assets and a significant proportion of liabilities. Housing is, therefore, a key component of the Fisher's debt-deflation channel that is central to these models.

This is further reinforced by results shown in Atalay et al. (2016) and Aladangady (2017). Previous literature (Muellbauer and Murphy, 1990; Iacoviello, 2004; Campbell and Cocco, 2007; Attanasio et al., 2009) presented three causal mechanisms by which an increase in household wealth induced by higher house prices leads to higher consumption: unanticipated increases in wealth leading directly to increases in consumption; increases in house prices inducing higher consumption through the relaxation of credit constraints on borrowers (collateral effects); both housing wealth and consumption being affected by a common causal factor, such as productivity growth. Atalay, Whelan and Yates's results shed light on the underlying causal mechanism relating housing wealth to consumption, supporting the collateral channel as the main driver of that relation. More recently, Aladangady (2017) has shown that looser borrowing constraints are a primary driver of the marginal propensity to consume out of housing wealth. These results not only highlight the importance of credit constraints and pecuniary externalities, but also reinforce the close relation between them and housing.

Some previous work related to the pecuniary externality (see Boz and Mendoza (2014) and Bianchi et al., 2012) has incorporated land (crucial to housing), modeling it as capital. This approach, however, fails to distinguish between the consumption of housing services and other goods. It has been empirically shown that the joint behavior of the consumption of durable and nondurable goods is best explained assuming a finite elasticity of substitution between these goods (Bernanke, 1984) and this insight has been widely applied to housing as a durable good (see Fratantoni, 2001; Iacoviello, 2005; Lustig and Nieuwerburgh, 2005; Yogo, 2006 and Khorunzhina, 2021) in order to best explain consumption and prices. If the housing market is frequently at the heart of financial crisis, the adequate modelling of preferences regarding housing goods and other forms of consumption is critical.

Therefore, I extend Bianchi and Mendoza's model by introducing land in order to have a properly modeled housing sector. I show that the introduction of an endowment of housing services provided by land, by itself, has an effect akin to an increase in the elasticity of intertemporal substitution, thereby decreasing the effectiveness and importance of macroprudential policy. These results are reversed, however, when the impact of residential assets in the collateral constraint is adequately considered: land increases the debt level noticeably and therefore the role of the pecuniary externality. As a consequence, macroprudential policy becomes much more effective at dampening the effects of financial crises and its importance increases significantly.

This extension of the model also allows me to study how macroprudential policy should change with external demand for housing. Using data for Spain, I perform a comparative statics exercise in which the stochastic equilibrium of a reference scenario is compared to one with an increase in external demand associated with a 10% price surge.

My results show that, even when - by construction - the increase in average land prices was completely exogenous and permanent, macroprudential policy should lean against the wind in most relevant settings. This may appear in opposition to Schmitt-Grohé and Uribe (2017)'s results regarding optimal capital control policy (which we could generalize to macroprudential policy overall), according to which optimal policy should be countercyclical - stronger in *bad times* (short of a financial crisis), and weaker in *good times* - which could lead us to believe that an increase in land prices (an occurrence usually associated with *good times*) should demand a weaker macroprudential policy.

These results show instead that, if the macroprudential authority is not fine-tuning policy with regard to any conjunctural small change in land prices, but instead reacting to significant changes - regardless of whether they are caused by an anomalously fast surge or a long trend of increase in prices - then an increase in land prices should lead to a strengthening of macroprudential policy.

Furthermore, my results show that states with higher production or good news about the future are the ones that demand the higher strengthening of macroprudential policy.

The rest of the paper is organized as follows. Section 2 describes the model. Section 3 shows the calibration used, the solution method and results obtained, and section 4 provides conclusions.

2 Model

2.1 Assumptions

2.1.1 Overall setting

Household preferences are given by:

$$U_t = \mathbb{E}_t \left[\sum_{i=0}^{\infty} \beta^i \frac{c_{t+i}^{1-\sigma} - 1}{1-\sigma} \right]. \tag{1}$$

In this expression, $\mathbb{E}_t$ is the expectation operator, conditional on information at time t, and β is the discount factor. The period utility function is a constant relative risk aversion where the coefficient of relative risk aversion is σ. The consumption basket c is a CES aggregator with elasticity of substitution $1/(\eta_A + 1)$ between goods and services on the one hand and land on the other. Goods and services are themselves a CES aggregator with substitution $1/(\eta + 1)$ between tradable goods and non-tradable goods. The whole basket is given by:

$$c_t = \left(\alpha \left[\omega \left(c_t^T \right)^{-\eta} + (1-\omega) \left(c_t^N \right)^{-\eta} \right]^{\frac{\eta_A}{\eta}} + (1-\alpha) A_t^{-\eta_A} \right)^{-\frac{1}{\eta_A}}, \tag{2}$$

where c_t is the consumption basket at period t, c_t^T is the consumption of tradable goods at period t, c_t^N is the consumption of non-tradable goods at that same period, and A_t is the stock of land (to which the agent is endowed), assumed constant and non-depreciating. Land provides service flows indefinitely which are assumed to be linear in the stock of land.

In choosing that A_t represents land instead of housing, the assumption of a perfectly inelastic non-depreciating asset becomes more reasonable. Furthermore, there is not much to lose concerning the ability to explain housing prices: land prices, rather than replacement costs, are the key to understanding the trajectory of house prices (Knoll et al., 2017), to the point where the increase in land prices explains about 80 percent of the global house price boom that has taken place in the last seven decades.

Normalizing the price of tradable goods to 1 and denoting the relative price at period t of the nontradable consumable goods acquired c_t^N in that period by p_t^N and also the relative price of land in the same period by p_t^A, the agent's budget constraint is:

$$q_t b_{t+1} + c_t^T + p_t^N \, c_t^N + p_t^A \, A_t = b_t + y_t^T + p_t^N \, y_t^N + p_t^A \, A_t, \tag{3}$$

where b_t denotes holdings of one-period, non-state-contingent discount bonds at the beginning of period t, denominated in units of tradable goods. These bonds are sold at a price $q_t = 1/R_t$, where R_t is the exogenous world gross real interest rate.

Agents face a collateral constraint that limits their debt. For this constraint both the current income and total assets of the agent matter. The following condition holds:

$$q_t b_{t+1} \geq -\kappa_Y \left(y_t^T + p_t^N \, y_t^N \right) - \kappa_A \, p_t^A \, A_t. \tag{4}$$

As in Bianchi and Mendoza's work (Bianchi et al., 2012; Bianchi et al., 2016), the collateral constraint intends to capture observed practices in credit markets that limit international flows of capital. However, this model departs from Bianchi et al. (2016) in that to the DTI-kind restriction (here represented by the constant κ_Y) in that model, a LTV-kind restriction is also considered (κ_A). While limits to a country's international indebtedness are much more connected to its GDP than to the market value of its assets (and the calibration of κ_Y and κ_A makes this clear), it would be wrong to assume that the latter plays no role at all. Furthermore, the fact that the collateral channel is shown empirically to be the most important in determining the impact of house prices in household consumption (Atalay et al., 2016; Aladangady, 2017) means that the role of κ_A in these financial crises must not be ignored.

Later it will be considered that, as a consequence of external demand for land, a proportion $e \in [0, 1]$ will be rented to foreigners, which pay a value of $e \, \mathcal{P} \, A_t \, p_t^A$, where $\mathcal{P}$ is the rent-to-price ratio.

2.1.2 Exogenous stochastic Processes

The stochastic process for the production of tradables is a finite-state, stationary Markov process that models the following law of motion:

$$y_t^T = (1-\rho)\mu + \rho\, y_{t-1}^T + \epsilon_t^T, \tag{5}$$

where μ is the unconditional expected value of y_t^T, and ϵ_t is a shock to the production of tradables with a standard normal distribution.

Furthermore, this stochastic process for the production of tradables is associated with news shocks in the form of a noisy signal. As in Bianchi and Mendoza (2016), the specification proposed by Durdu et al. (2013) is followed. The form of the signal precision is:

$$p(s_t = i|y_{t+1}^T = l) = \begin{cases} \theta \quad , \quad i = l \\ \frac{1-\theta}{N-1} \quad , \quad i \neq l, \end{cases} \tag{6}$$

where s_t is the signal that the economy receives in period t, $p(s_t = i|y_{t+1}^T = l)$ is the probability of receiving a given signal in period t given the state of y^T in the following period. N is the number of possible realizations of y^T and θ is the signal precision parameter. Notice that $\theta = 1/N$ is a completely uninformative signal, whilst a $\theta = 1$ signal has perfect precision.

Conditional on the future state y_{t+1}^T, the current state for the tradable's endowment y_t^T does not change the probability of attaining a given signal:

$$p(s_t = i|y_{t+1}^T = l) = p(s_t = i|y_{t+1}^T = l, y_t^T = j). \tag{7}$$

Define the Markov chain for the joint evolution of y^T and s as:

$$\Pi(y_{t+1}^T, s_{t+1}, y_t^T, s_t) \equiv p(s_{t+1} = k, y_{t+1}^T = l|s_t = i, y_t^T = j). \tag{8}$$

To study regime changes in global liquidity, the interest rate is modelled by a stochastic regime-switching process that exhibits periods of high ($R = R^l$) and low global liquidity ($R = R^l$), with $R^h > R^l$.

The continuation transition probabilities are given by:

$$\begin{bmatrix} F_{hh} & F_{lh} \\ F_{hl} & F_{ll} \end{bmatrix} = \begin{bmatrix} p(R_{t+1} = R^h | R_t = R^h) & p(R_{t+1} = R^l | R_t = R^h) \\ p(R_{t+1} = R^h | R_t = R^l) & p(R_{t+1} = R^l | R_t = R^l) \end{bmatrix}. \tag{9}$$

For the numerical exercises presented in this paper it will be assumed, as in Bianchi et al. (2016), that nontradable production is constant. However, as is the case there, this is not a requirement of the model.

2.2 Competitive Equilibrium

Sequences of allocations for consumption (of tradables and nontradables), bond holdings and prices constitute a competitive equilibrium if the representative agent maximizes utility subject to the budget and collateral constraints taking prices as given and the market clears.

For the nontradables domestic market, market clearing implies:

$$c_t^N = y_t^N. \tag{10}$$

Conditions (10) and (3) together imply:

$$q_t b_{t+1} + c_t^T = b_t + y_t^T. \tag{11}$$

The representative agent chooses optimally the stochastic processes for consumption (of tradables and nontradables) and bond holdings to maximize expected lifetime utility (1), subject to condition (2) and sequences of budget constraints (11) and credit constraints (4), taking b_0, p_t^N and H_t as a given. This implies that the prices p_t^N and p_t^A are given by:

$$p_t^N = \left(\frac{1-\omega}{\omega}\right)\left(\frac{c_t^T}{c_t^N}\right)^{1+\eta}, \tag{12}$$

$$p_t^A = \frac{1}{\alpha\,\omega}\, c_t^{\sigma-1-\eta_A}\,(c_t^{NA})^{\eta_A-\eta}\left(\frac{\partial U_t}{\partial A_t}\right), \tag{13}$$

with $c_t^{NA} \equiv \left[\omega\,(c_t^T)^{-\eta} + (1-\omega)\,c_t^N)^{-\eta}\right]^{\frac{1}{\eta}}$.

The optimal choice of stochastic processes for consumption under condition (2) and sequences of budget constraints (11) and credit constraints (4) also implies:

$$\frac{\partial\left(\frac{c_t^{1-\sigma}-1}{1-\sigma}\right)}{\partial c_t^T} = \frac{\beta}{q_t}\mathbb{E}_t\left[\frac{\partial\left(\frac{c_{t+1}^{1-\sigma}-1}{1-\sigma}\right)}{\partial c_{t+1}^T}\right] + \mu_t, \tag{14}$$

$$q_t b_{t+1} + \kappa_Y \left(y_t^T + p_t^N\, y_t^N\right) + \kappa_A\, p_t^A\, A_t \geq 0\,, \quad \text{with equality if } \mu_t \geq 0. \tag{15}$$

Regarding the Markov transition probability matrix for the joint evolution of y^T and s, $\Pi(y_{t+1}^T, s_{t+1}, y_t^T, s_t)$, as defined in (8), it is given by:

$$\Pi(y_{t+1}^T, s_{t+1}, y_t^T, s_t) = p(y_{t+1}^T = l|s_t = i, y_t^T = j) \sum_{m=1}^{N} p(y_{t+2}^T = m|y_{t+1}^T = l).p(s_{t+1} = k|y_{t+2}^T = m), \tag{16}$$

where Bayes' theorem allows for the derivation of $P(y_{t+1}^T = l|s_t = i, y_t^T = j)$ as:

$$P(y_{t+1}^T = l|s_t = i, y_t^T = j) = \frac{p(s_t = i|y_{i+1}^T = l).P(y_{t+1}^T = l|y_t^T = j)}{\sum_{n=1}^{N} P(s_t = i|y_{t+1}^T = n).P(y_{t+1}^T = n|y_t^T = j)}. \tag{17}$$

With respect to the continuation transition probabilities related to liquidity regimes, it is possible to derive the long-run probabilities of each regime as:

$$p(R_t = R^h) = \frac{F_{lh}}{F_{lh} + F_{hl}}, \tag{18}$$

$$p(R_t = R^l) = \frac{F_{hl}}{F_{lh} + F_{hl}}. \tag{19}$$

The mean durations of the low and high liquidity regime are, respectively, $1/F_{hl}$ and $1/F_{lh}$. The values of the Markov transition probability matrix also imply, for the unconditional mean, variance and first-order autocorrelation of R, the following:

$$\mathbb{E}\left[R\right] = \frac{F_{lh}R^h + F_{hl}R^l}{F_{lh} + F_{hl}}, \tag{20}$$

$$Var\left[R\right] = \frac{F_{lh}(R^h)^2 + F_{hl}(R^l)^2}{F_{lh} + F_{hl}} - \left(\frac{F_{lh}R^h + F_{hl}R^l}{F_{lh} + F_{hl}}\right)^2, \tag{21}$$

$$\rho_R = F_{ll} - F_{hl} = F_{hh} - F_{lh}. \tag{22}$$

2.3 Macroprudential Policy

Consider a social planner who maximizes the representative agent's utility subject to the same budget and credit constraints, whilst letting all other markets clear competitively. Nevertheless, the social planner internalizes the effects of its borrowing decisions on the market prices of nontradable goods and land. The financial regulator is presented with this same problem, and constrained by the collateral constraint. Then, the financial regulator's dynamic programming problem in recursive form does not take prices on land and nontradable goods as a given, but instead includes equations (12) and (13) as constraints. The planner's dynamic programming problem also includes the CES aggregator for consumption (2), the budget constraint (11), the market-clearing condition for nontradable goods (10), and the collateral constraint (4):

$$V(b_t, A_t, y_t^T, y_t^N, s_t, q_t) = \max_{c_t^T, c_t^N, A_t, b_{t+1}} \left[\frac{(c(c_t^T, c_t^N, A_t))^{1-\sigma} - 1}{1-\sigma} + \beta \mathbb{E}_t V(b_{t+1}, A_{t+1}, y_{t+1}^T, y_{t+1}^N, s_{t+1}, q_{t+1}) \right], \tag{23}$$

where:

$$c(c_t^T, c_t^N, A_t) = \left(\alpha \left[\omega \, (c_t^T)^{-\eta} + (1-\omega) \, c_t^N)^{-\eta} \right]^{\frac{\eta_A}{\eta}} + (1-\alpha) A_t^{-\eta_A} \right)^{-\frac{1}{\eta_A}},$$

and subject to:

$$p_t^N = \left(\frac{1-\omega}{\omega} \right) \left(\frac{c_t^T}{c_t^N} \right)^{1+\eta},$$

$$p_t^A = \frac{1}{\alpha \, \omega} \, c_t^{\sigma - 1 - \eta_A} \, (c_t^{NA})^{\eta_A - \eta} \left(\frac{\partial U_t}{\partial A_t} \right),$$

$$q_t b_{t+1} + c_t^T = b_t + y_t^T,$$

$$c_t^N = y_t^N,$$

$$q_t b_{t+1} \geq -\kappa_Y \left(y_t^T + p_t^N\, y_t^N \right) - \kappa_A\, p_t^A\, A_t,$$

$$A_{t+1} = A_t.$$

The markov process exogenously determines the evolution of the states for production of tradables y_t^T and nontradables y_t^N, the signal s_t and the price of bonds q_t, and whereas land is constant and current bond holdings b_t are endogenously determined.

The first-order conditions of the problem imply the following relations:

$$\frac{\partial \left(\frac{c_t^{1-\sigma} - 1}{1-\sigma} \right)}{\partial c_t^T} + \mu_t\, \psi_t = \frac{\beta}{q_t} \mathbb{E}_t \left[\frac{\partial \left(\frac{c_{t+1}^{1-\sigma} - 1}{1-\sigma} \right)}{\partial c_{t+1}^T} + \mu_{t+1}\, \psi_{t+1} \right] + \mu_t, \tag{24}$$

$$\psi_t = \kappa_Y\, \frac{\partial p_t^N}{\partial c_t^T} + \kappa_A\, \frac{\partial p_t^A}{\partial c_t^T}, \tag{25}$$

$$q_t\, b_{t+1} + \kappa_Y \left(y_t^T + p_t^N\, y_t^N \right) + \kappa_A\, p_t^A\, A_t \geq 0\,, \quad \text{with equality if } \mu_t \geq 0. \tag{26}$$

The term ψ_t represents the effect of an additional unit of tradables consumption on the borrowing capacity via general equilibrium effects on the price of nontradables, and the product $\mu_t\, \psi_t$ internalizes the effect that tradables consumption has on the expected consequences of a binding credit constraint on the agent's consumption decision.

From a macroprudential perspective, most care should be taken regarding a scenario where credit constraints do not bind in the current period, but might bind in the next one. That is:

$$\frac{\partial \left(\frac{c_t^{1-\sigma} - 1}{1-\sigma} \right)}{\partial c_t^T} = \frac{\beta}{q_t} \mathbb{E}_t \left[\frac{\partial \left(\frac{c_{t+1}^{1-\sigma} - 1}{1-\sigma} \right)}{\partial c_{t+1}^T} + \mu_{t+1}\, \psi_{t+1} \right]. \tag{27}$$

This means that the social planner faces a strictly higher marginal cost of borrowing than the representative agent, the difference of both costs being the pecuniary externality.

There are several policy instruments that may be used, so that agents in a decentralized competitive equilibrium internalize the pecuniary externality such as taxes on debt, loan-to-value ratios, capital requirements or reserve requirements (Stein, 2012; Claessens, 2015). A straightforward solution (from a theoretical perspective) is a tax on borrowing that depends on the state variables (and may thus vary across time). There is no tax in the states where the credit constraint binds. For the remaining states, the optimal tax τ_t is given by:

$$\tau_t = \frac{\mathbb{E}_t\left[\mu_{t+1}\,\psi_{t+1}\right]}{\mathbb{E}_t\left[\frac{\partial\left(\frac{c_{t+1}^{1-\sigma}-1}{1-\sigma}\right)}{\partial c_{t+1}^T}\right]}. \tag{28}$$

Under this optimal tax, the new optimal value q_t^o for the cost of bonds in period t becomes:

$$q_t^o = \frac{q_t}{1+\tau_t}. \tag{29}$$

While it is true that LTVs, DTIs and other macroprudential instruments have similar implications to the debt tax (they increase the marginal cost of borrowing overall, while at the same time increasing the equilibrium marginal returns on capital and therefore decreasing investment), there are important differences and Bianchi and Mendoza (2020) have shown that an equilibrium supported by a given debt-tax policy τ_t cannot be supported by some LTV regulation κ_A. One difference is that the direct effects of the macroprudential instruments on the marginal cost of borrowing and capital returns are exogenous in the case of the debt tax, but partially endogenous in the case of some other instruments like LTV. The other difference regards implementation: the debt tax can help agents internalize costs even when constraints are far from binding, which is not the case for other instruments.

This being said, the aggregate effect of LTVs, DTIs and other instruments over a population of agents with heterogeneous debt levels may be more closely mirrored by the effects of a debt tax on a representative agent. The qualitative similarities between the effects of a given mix of macroprudential instruments over a heterogeneous population and the the tax on debt over the representative agent make this last instrument ideal to characterize the strength of macroprudential policy overall under such a setting.

2.4 External demand for land

I will consider a scenario where, as a consequence of external demand for land, a proportion e of it will be rented at price $\mathcal{P}\, p_t^A$. External demand could, of course, result in the whole sale of land, not just its rental. However, in the comparative statics exercise between a scenario where some additional land has been sold as a result of a spike in external demand and a reference scenario, the main features would be the same as in a scenario where land is rented, only starker. The most conservative option would be to consider the rental.

Furthermore, the question of what has been done with the sales revenue would limit the analysis: either the comparison is made with a stochastic equilibrium immediately after the sale, or it is made with the long-term steady-state stochastic equilibrium after the sale. The latter option is the only compatible one with the numerical procedure used to obtain the unconditional moments of the economy and moments conditional on sudden stops, and also to perform event analysis of sudden stops. However, the assumption that the equilibrium takes place long after the price surge limits its interest. Assuming instead that the land is rented avoids these problems whilst being more cautious. Hence, I adopt this option.

As a consequence of the rental of land, the agent's basket of consumption and their budget constraint change to:

$$c_t = \left(\alpha \left[\omega \left(c_t^T \right)^{-\eta} + (1-\omega)\, c_t^N \right)^{-\eta} \right]^{\frac{\eta_A}{\eta}} + (1-\alpha)\left((1-e)A_t\right)^{-\eta_A} \right)^{-\frac{1}{\eta_A}}, \tag{30}$$

$$q_t b_{t+1} + c_t^T + p_t^N\, c_t^N + (1-e)\, p_t^A\, A_t = b_t + y_t^T + p_t^N\, y_t^N + (1 + (\mathcal{P} - 1)e)\; p_t^A\, A_t, \tag{31}$$

and thus, equation 11 becomes:

$$q_t b_{t+1} + c_t^T = b_t + y_t^T + e\, \mathcal{P}\, p_t^A\, A_t. \tag{32}$$

Finally, the collateral constraint would also change by increasing the income of the agent:

$$q_t b_{t+1} \geq -\kappa_Y \left(y_t^T + p_t^N\, y_t^N + e\, \mathcal{P}\, p_t^A\, A_t \right) - \kappa_A\, p_t^A\, A_t. \tag{33}$$

The social planner problem also changes accordingly:

$$V(b_t, A_t, y_t^T, y_t^N, s_t, q_t) = \max_{c_t^T, c_t^N, A_t, b_{t+1}} \left[\frac{(c(c_t^T, c_t^N, A_t))^{1-\sigma} - 1}{1-\sigma} + \beta \mathbb{E}_t V(b_{t+1}, A_{t+1}, y_{t+1}^T, y_{t+1}^N, s_{t+1}, q_{t+1}) \right], \quad (34)$$

where:

$$c(c_t^T, c_t^N, A_t) = \left(\alpha \left[\omega \, (c_t^T)^{-\eta} + (1-\omega) \, c_t^N)^{-\eta} \right]^{\frac{\eta_A}{\eta}} + (1-\alpha) \, ((1-e)A_t)^{-\eta_A} \right)^{-\frac{1}{\eta_A}},$$

and subject to:

$$p_t^N = \left(\frac{1-\omega}{\omega} \right) \left(\frac{c_t^T}{c_t^N} \right)^{1+\eta},$$

$$p_t^A = \frac{1}{\alpha \, \omega} \, c_t^{\sigma - 1 - \eta_A} \, (c_t^{NA})^{\eta_A - \eta} \left(\frac{\partial U_t}{\partial A_t} \right),$$

$$q_t b_{t+1} + c_t^T = b_t + y_t^T + e \, \mathcal{P} \, p_t^A \, A_t,$$

$$c_t^N = y_t^N,$$

$$q_t b_{t+1} \geq -\kappa_Y \left(y_t^T + p_t^N \, y_t^N + e \, \mathcal{P} \, p_t^A \, A_t \right) - \kappa_A \, p_t^A \, A_t.$$

3 Results

To address the question of how should macroprudential policy change with house price changes driven by exogenous changes in demand, it is best to first understand how does the introduction of the housing sector change the results from Bianchi et al. (2016). In order to do so, I changed the model just enough to introduce the housing sector and calibrated it maintaining as many parameters as possible, so as to highlight the differences in the results as consequences of the changes in the model. This calibration had Argentina as a reference, the name of the next subsection. However, to address the initial question, which I do in the following subsection, I found more useful to calibrate using data from Spain, an example of an eurozone economy where housing prices played a key role in its financial crisis. I first considered a baseline scenario, without external demand for land, and then a "price surge" scenario where an increase in exogenous external demand is enough to increase average house prices by 10%. A comparative statics exercise allows me to find how should optimal macroprudential policy change with the surge in prices.

3.1 Argentina

3.1.1 Calibration

To highlight the effects of the introduction of land in the model, almost all parameters used in Bianchi et al. (2016) were maintained, while the introduction of some new parameters is required by the new model. Firstly, the collateral condition in Bianchi et al. (2016) is maintained without any LTV-kind constraints, i.e., with $\kappa_A = 0$. I performed an exercise showing the effects of introducing land in this setting. Then, motivated by the empirical results highlighting the importance of the housing-collateral channel, I relaxed the condition $\kappa_A = 0$, which requires additional values to perform moment matching: I used a discount factor more in line with the literature. In this new setting, I also compared results with and without housing.

Table 1 shows the list of parameter values used across all simulations, taken directly from Bianchi et al. (2016). Table 2 shows additional parameters for the comparison when the housing-collateral channel is absent ($\kappa_A = 0$), and table 3 shows parameters for the comparison when the housing-collateral channel is at play.

Regarding the exogenous processes y_t^N and y_t^T, as in Bianchi et al. (2016), the deterministic nontradables endowment and the mean endowment of tradables are all normalized to 1 for simplicity. The Markov process for y_t^T is set using the Tauchen-Hussey quadrature algorithm, which uses calibrated parameters $\rho_y^T = 0.54$ and $Var\left[y^T\right] = 0.059$ set to match the first-order autocorrelation and standard deviation of tradables GDP in Argentina in the

Table 1: Previous baseline model parameters

Parameter	Values
y^N	1
$\mathbb{E}\left[y^T\right]$	1
ρ_y^T	0.540
$Var\left[y^T\right]$	0.059
N_y^T	3
γ	2
η	0.205
ω	0.310
R^h	1.0145
R^l	0.9672
F^{hh}	0.9833
F^{ll}	0.90
θ	0.66

period from 1965 to 2007. The process presents three realizations ($N = 3$).

Regarding σ, the coefficient of relative risk aversion, its value corresponds to the standard value in the DSGE literature, $\sigma = 2$. As previously mentioned, the elasticity of substitution in consumption of tradables and nontradables relates to the η parameter in the CES aggregator expression by $1/(\eta + 1)$. Bianchi and Mendoza use a 0.83 estimate for the elasticity of substitution (they choose the upper bound of empirical estimates to establish a conservative benchmark), rendering the value of η as $\eta = 0.205$.

Argentina's data regarding the share of tradables consumption in the CES aggregator and the average ratio between the net foreign asset position and GDP allows to set values of ω and κ as $\omega = 0.31$ and $\kappa = 0.32$ as used in Bianchi (2011) and maintained in Bianchi et al. (2016).

Bianchi et al. (2016) calibrated the stochastic process for the world interest rate so as

Table 2: Parameters for the baseline-housing comparison when $\kappa_A = 0$

Parameter	Baseline setting	Housing setting
α	1	0.595
η_D	0.282	0.282
β	0.910	0.910
κ_Y	0.320	0.320
κ_A	0	0

Table 3: Parameters for the full baseline-housing comparison

Parameter	Baseline setting	Housing setting
α	1	0.595
η_D	0.282	0.282
β	0.9375	0.9375
κ_Y	0.29	0.29
κ_A	0.03	0.03

to capture the global liquidity phases identified in Calvo et al. (1996) and Shin (2013). The value R_l for the high liquidity regime was set to $R_l = 0.9672$, and the value R_h for the low liquidity regime was set to $Rh = 1.0145$. Furthermore, values F_{hh} and F_{ll} were set as $F_{hh} = 0.9833$ and $F_{ll} = 0.9$, and both $F_{hl} = 1 - F_{hh}$ and $F_{lh} = 1 - F_{ll}$ hold. These values F_{hh} and F_{ll} are set for quarterly data, whereas the simulation considers each period to be one year, and thus the values $F_{hh} = 0.9333$ and $F_{ll} = 0.6$ should have been used instead. To ease the comparison with results from Bianchi et al. (2016), I maintained the (quarterly) values for F_{hh} and F_{ll}. There are no qualitative changes in the results if I use the yearly values instead.

The signal s_t has the same number (N) of realizations as y_t^T. Bianchi et al. (2016) decided to set the parameter θ as the mid-point between a perfect predictor of y_t^T $(\theta = 1)$ and a completely uninformative signal $(\theta = 1/N)$. Therefore, I set θ to $\theta = 2/3$.

Regarding the values absent in Bianchi et al. (2016), to obtain η_D, I used the estimate in Khorunzhina (2021) for the elasticity of substitution between housing and non-housing goods. The elasticity is estimated as $1/(\eta_D + 1) = 0.78$ where $1/(\eta_D + 1)$ is the elasticity of substitution and $\eta_D = 0.282$ the corresponding parameter in the CES specification presented.

The value for the price-to-income ratio was also published by Banco Central de la República Argentina (it was evaluated by the Central Bank considering the cost of a typical housing unit of 100 square meters), and it is equal to 29.29. To convert from the ratio between the price of land and income per capita in the simulations to the price-to-income ratio in the data, the land leverage (the ratio between land value and house value) is necessary:

$$p^A = \chi p^H, \tag{35}$$

where p^A is the price of land, p^H is the housing price and χ the land leverage. I obtained the value of $\chi = 0.43$ from the data in Kajuth (2021). With these two values, it is possible to set α in order to match the average price-to-income ratio. Doing so, I obtained the value $\alpha = 0.595$.

In Bianchi et al. (2016) β was set at $\beta = 0.91$ by matching three long-run moments of the decentralized equilibrium of the economy with Argentina's data regarding the frequency of financial crises, the share of tradables consumption in the CES aggregator and the average ratio between the net foreign asset position and GDP. For $\kappa_A = 0$, I used the same approach, and in that setting κ_Y is kept at $\kappa_Y = 0.32$ as well.

When relaxing the condition $\kappa_A = 0$, however, it is necessary to use another estimate for β. Schmitt-Grohé and Uribe (2015) estimate β as $\beta = 0.9375$, closer to values typical in the literature. I used this value for β allowing the moment matching exercise to obtain $\kappa_Y = 0.29$ and $\kappa_A = 0.03$.

3.1.2 Solution Method

An analytical solution of the model presented is impossible and thus I followed a numerical approach instead. The code utilized to obtain the results presented solves the decentralized equilibrium using the policy-function iteration method: the model is solved by backward recursive-substitution of the model's optimality conditions written in recursive form, thus computing the policy function, and the value function as well. To obtain additional accuracy, this method is augmented by interpolated decision rules (linear interpolation). The same method is used to solve the Social Planner's problem (this time with the externality term in the Euler equation). The welfare gain is then calculated. These results allow the computation of the optimal macro-prudential tax.

The current state is defined not only by the realization of y_t^T, s_t and R_t (for a total of $3 \times 3 \times 2 = 18$ possibilities), but also by current bond holdings - a 500 point grid ($N_B = 500$) is used. Instead of using a uniform grid, it has higher density closer to the lower bound to increase accuracy. It is obtained as:

$$B_1 = B_l, \tag{36}$$

$$B_i = B_{i-1} + \frac{B_h - B_{i-1}}{(N_B - i + 1)^{\varrho}}, \tag{37}$$

Where B_l and B_h are, respectively, the lower and upper bounds for b_t, and ϱ is set to $\varrho = 1.05$.

To obtain land prices, however, I used two additional states: one with $A = 1 + \epsilon_A$ and another with $A = 1 - \epsilon_A$. These states mirror the states with $A = 1$ in all regards, and there is no possible transition between states with different values for A. The value function of these states is used in order to obtain $\left(\frac{\partial U_t}{\partial A_t}\right)$ according to:

$$\left(\frac{\partial U_t}{\partial A_t}\right)(b_t, A_t, y_t^T, y_t^N, s_t, q_t) \approx \frac{V(b_t, A_t + \epsilon_A, y_t^T, y_t^N, s_t, q_t) - V(b_t, A_t - \epsilon_A, y_t^T, y_t^N, s_t, q_t)}{2\,\epsilon_A}. \tag{38}$$

With the policy function obtained, I used a code that simulates the economy recursively in order to estimate the unconditional moments of the economy and moments conditional on sudden stops, and also to perform event analysis of sudden stops. The code simulates 1 001 000 periods, but the first 1000 are discarded (to guarantee results do not depend on an arbitrary initial state). The code uses the policy functions obtained previously and simulates a Markov chain given the transition matrix and an initial state, and then creates the simulated time-series data by means of a recursive loop that reads the exogenous state and the current debt to obtain, using the policy function, all the endogenous variables including the debt in the next period. With those values, the code calculates aggregate moments in the economy, and defines sudden stops as periods when both the borrowing constraint binds and the current account is more than two standard deviations above mean, in order to obtain moments conditional on sudden stops.

The size of the sample, even when restricted to the sudden-stop episodes (about forty thousand sudden-stops in the decentralized equilibrium) is large enough that, even with a confidence interval of 99%, the confidence band for the average deviations is always narrower than the thickness of the lines used on the graphs to represent the results.

3.1.3 Impact of housing trough DTI-kind constraint

Table 4 shows a subset of the moments that characterize the decentralized equilibrium without any kind of macroprudential policy intervention (denoted by the subscript DE) and the social planner's equilibrium that incorporates optimal macroprudential policy (denoted by the subscript SP). It shows the probability of crisis (with and without macroprudential policy), the probability of attaining states where the optimal tax τ_t is different from zero, the mean net foreign asset position-GDP ratio (with and without macroprudential policy), the standard deviation of the current account-output ratio ($\sigma_{CA/Y} = \sqrt{Var\left[\frac{y^T - c^T}{y^T + y^N p^N}\right]}$) with and without macroprudential policy, the depreciation in the real exchange rate, the decrease in GDP and in consumption during the sudden-stop event (with and without macroprudential policy) and finally the average tax on debt. Values in the first column are shown for the model in Bianchi et al. (2016), that is with $\alpha = 1$, meaning abstracting from a housing sector. Values in the second column are shown for $\alpha = 0.595$, with an important housing sector. Both results assume $\kappa_A = 0$.

As in Bianchi et al. (2016), macroprudential policy barely changes the mean debt ratio, and this does not change with the introduction of housing. Changes in the distribution of net foreign assets, however, are quite consequentional as one may observe in the first column of table 5 showing the effects of macroprudential policy in the default setting: macroprudential policy not only decreases significantly the probability of a crisis, but it also has a large role in dampening its effects with respect to the decrease in consumption, GDP, the depreciation of the real exchange rate and the decrease in the volatility of the current account.

Short of a sudden-stop episode, the introduction of housing does not lead to significant changes in the decentralized equilibrium: there is a slight decrease in the probability of crises

Table 4: Comparison between model moments ($\kappa_A = 0$)

Moment	Without housing	With housing
$P_{DE}(SS)$	3.649 %	3.641 %
$P_{SP}(SS)$	2.649 %	2.703 %
$P(\tau \neq 0)$	87.66 %	83.35 %
$\bar{B/Y}_{DE}$	−29.37 %	−29.46 %
$\bar{B/Y}_{SP}$	−29.26 %	−29.35 %
$\sigma_{CA/Y\,DE}$	3.19 %	3.54 %
$\sigma_{CA/Y\,SP}$	2.02 %	2.26 %
$\Delta\epsilon_{DE}$	−47.48 %	−52.22 %
$\Delta\epsilon_{SP}$	−31.58 %	−34.74 %
ΔY_{DE}	−33.27 %	−35.06 %
ΔY_{SP}	−25.86 %	−27.37 %
Δc_{DE}	−14.21 %	−15.34 %
Δc_{SP}	−10.07 %	−10.90 %
$\bar{\tau}$	3.028 %	2.827 %

(a tenuous 0.2% reduction) and a slight increase in the absolute value of the average debt level (a tenuous 0.3% increase). However, the effects of introducing land during crises are noticeable as compared to the effects of crises in the original Bianchi et al. (2016) model: they may be observed in the volatility of sudden-stops (11.0% increase), the real exchange rate depreciation (10.0% increase), the decrease in GDP (5.4% increase) and in consumption (8.0% increase). In spite of the fact that crises have stronger effects, macroprudential policy proves slightly less effective in this setting. The effects of macroprudential policy when the model does not abstract from the housing sector are shown in the second column of table 5, and the third column presents a comparison between the effectiveness of macroprudential policy in both settings. The difference in effectiveness is very small for dampening the decrease in consumption and the depreciation of the real exchange rate, and small for dampening both the decrease in GDP and the volatility of the current account, and also for decreasing the probability of a sudden-stop.

Figures 1, 2 plot seven-year event analysis windows that help understand the dynamics around financial crisis events for the current account-output ratio (CA/Y), the net foreign

Table 5: Macroprudential policy effects ($\kappa_A = 0$)

Moment	Without housing	With housing	Variation
$P(SS)$	−27.40 %	−25.76 %	−5.78 %
$\sigma_{CA/Y}$	−36.68 %	−36.16 %	−1.42 %
$\Delta\epsilon$	−33.49 %	−33.47 %	−0.06 %
ΔY	−22.27 %	−21.93 %	−1.51 %
Δc	−29.13 %	−28.94 %	−0.64 %

asset position (B), the consumption of tradable goods (c^T), non-tradable prices (P_n) and GDP (Y) when the model does not include land (figure 1) and when it does (figure 2). The latter also includes the plot of a seven-year event analysis window regarding the price of land. These plots show the dynamics under both a decentralized equilibrium and social planner settings, and demonstrate again the effectiveness of the optimal macroprudential policy at reducing the severity of financial crises.

Figure 3 shows the role of the three exogenous shocks in the seven periods covered in the event windows. As expected, financial crises are periods that largely coincide with low income realizations and high interest rates. In the periods before a crisis, however, the income realization is much more likely to be average. Furthermore, most crises follow good or average news and only seldom bad news, showing that the discrepancy between expectations and realizations is an important driver of financial crises. These results have not changed significantly with the introduction of land in the model, as can be seen in figure 4.

The instrument used for macroprudential policy, as stated in the previous section, is a state-dependent tax on debt. Figures 5 and 6 present the optimal tax schedule as a function of the current value for net foreign assets (denominated in tradable goods) for a high liquidity and low liquidity regime respectively. In both panels, the nine plots present all possible states regarding tradable income (bad, average and good) and news about the future (bad, average and good) and in each the tax schedule for the model without land is contrasted with that for the model that incorporates land.

The tax profiles are remarkably similar, increasing as bond holdings decrease up to the point where the collateral constraint binds and the optimal tax becomes zero (the corner solution), which happens almost at the same level of debt, regardless of the inclusion of land.

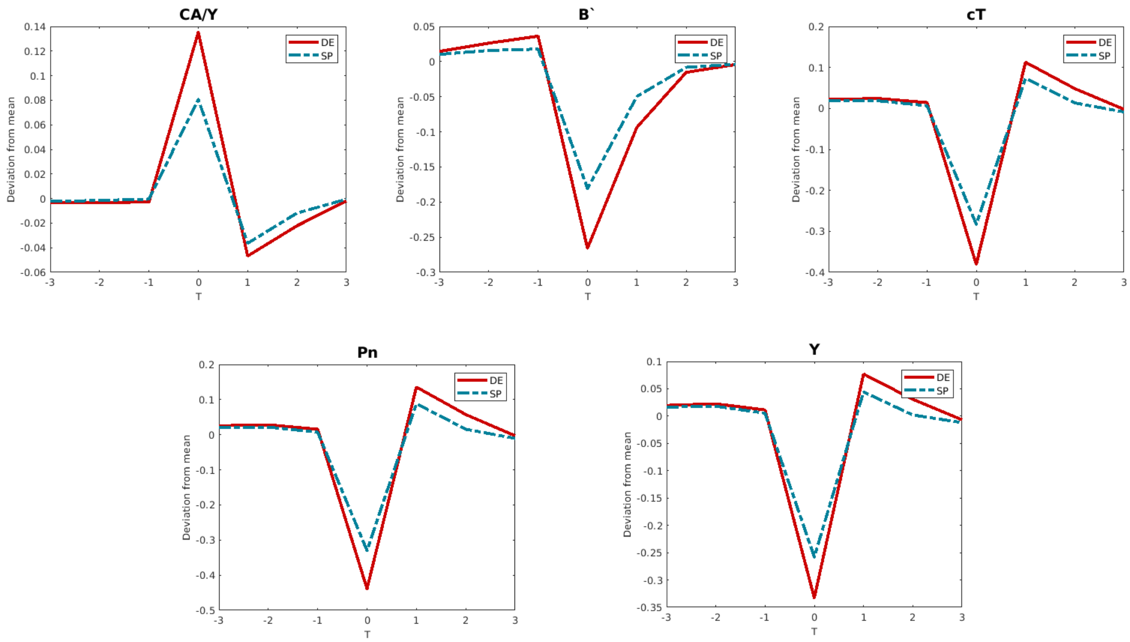

Figure 1: Average deviations from the mean around a sudden-stop event in the baseline scenario with $\kappa_A = 0$. The solid line represents the Decentralized Equilibrium (DE) allocations for (up, left to right) the current account-output ratio (CA/Y), the net foreign asset position (B), the consumption of tradable goods(c^T), and (down, left to right) non-tradable prices (P_n) and GDP (Y). The dashed line represents the Social Planner (SP) allocations for those same variables.

Generally, housing softens the profile, the tax being slightly higher with housing than without it for lower values of debt, and then becoming slightly lower as the debt level approaches the limit set by the collateral condition, roughly at the same value. The computation of the integral of the optimal tax with respect to the bond holdings for each exogenous state regarding the production of tradables, the interest rate and the news regarding the next period shows that, in general, the value is similar or smaller when the model includes housing. An exception are those states where, regardless of the interest rate, the level of production is average but news regarding the next period are good. An average of the change in the integral of optimal tax profile weighted to the unconditional probability of each state renders the value -0.91%. The reduction in the average tax, however, is higher: -6.64%. This means

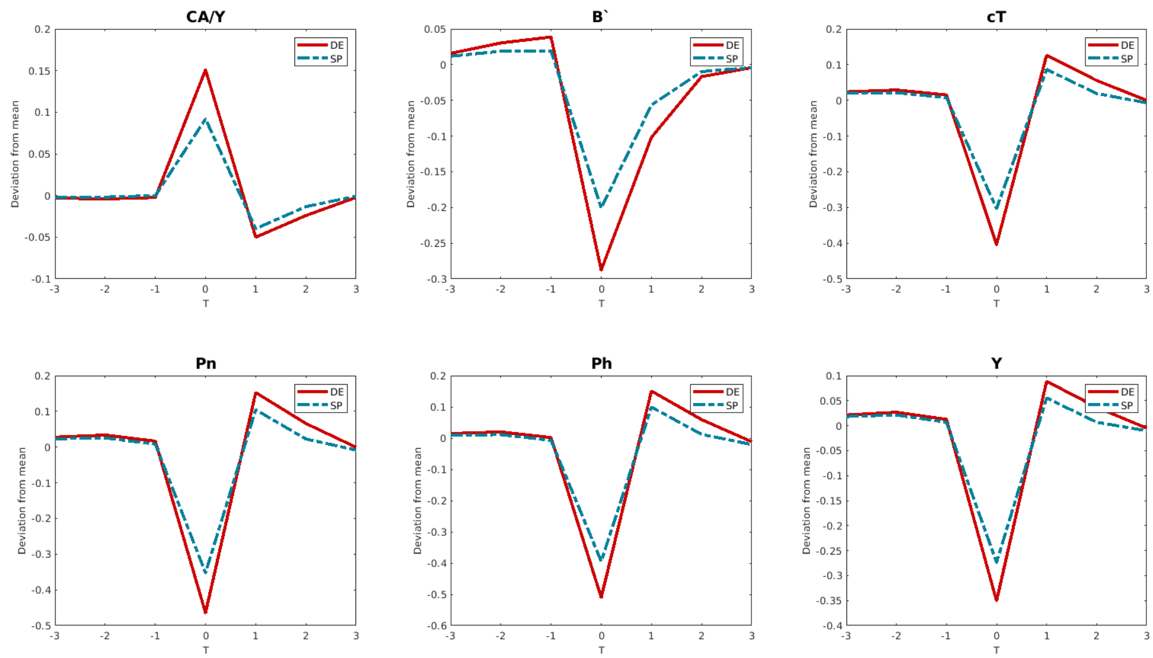

Figure 2: Average deviations from the mean around a sudden-stop event when the model includes land and $\kappa_A = 0$. The solid line represents the Decentralized Equilibrium (DE) allocations for (up, left to right) the current account-output ratio (CA/Y), the net foreign asset position (B), the consumption of tradable goods(c^T), and (down, left to right) non-tradable prices (P_n), land prices (P_h) and GDP (Y). The dashed line represents the Social Planner (SP) allocations for those same variables.

that when the model includes housing, the agent is, on average, slightly closer to the limit established by the collateral constraint.

All these results - the slight increase in the average debt level, the significant increase in the effects of financial crises, the decrease in the average value of optimal taxes - are the same effects that one would expect from an increase in the elasticity of intertemporal substitution, and in fact those are the results that a simulation with a 0.1 decrease on the value of σ presents. The similarity between these results is not fortuitous: once an endowment of land is introduced on the basket of consumption of the agent, temporary changes in the consumption of tradable goods become less impactful on the utility function, just as if the

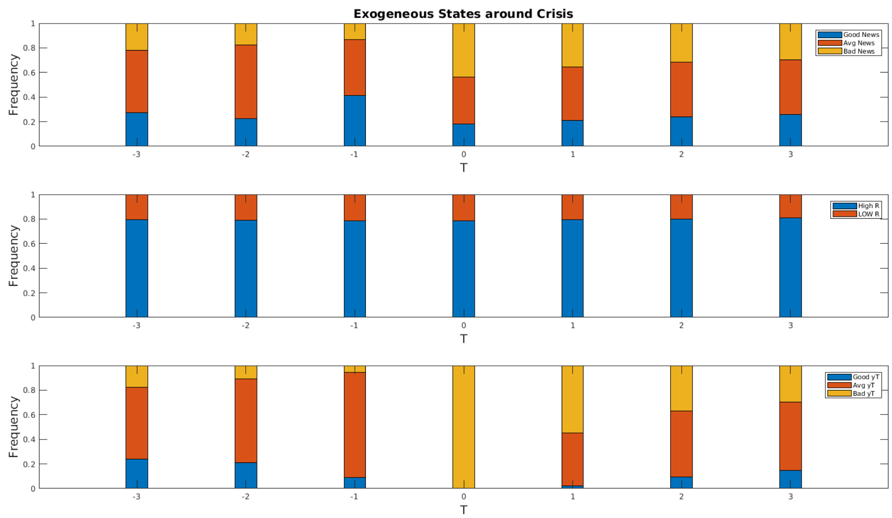

Figure 3: Baseline Exogenous States around Crisis ($\kappa_A = 0$).

elasticity of intertemporal substitution had increased. The land *shields* the agent from abrupt changes in the consumption of tradable goods, leading to a smaller incentive for prudential savings and thus a higher debt level, and, consequently, crises with stronger decreases in consumption, GDP and real exchange rate. However, precisely because the land endowment softens the blow that smaller tradable goods consumption may create on the whole basket, it becomes less important to prevent and dampen financial crises, which explains why the optimal tax is lower on average.

3.1.4 Overall impact of housing

Previous results assume the collateral constraint to be a function of the income of the agent ($\kappa_Y \neq 0$) but not of the assets of the agent ($\kappa_A = 0$). However, when introducing the housing sector into this model, empirical results suggest that this channel is critical. As mentioned before, Atalay, Whelan and Yates (2016) show that the collateral channel is the main driver of the relation between housing prices and consumption. More recently, Aladangady (2017)

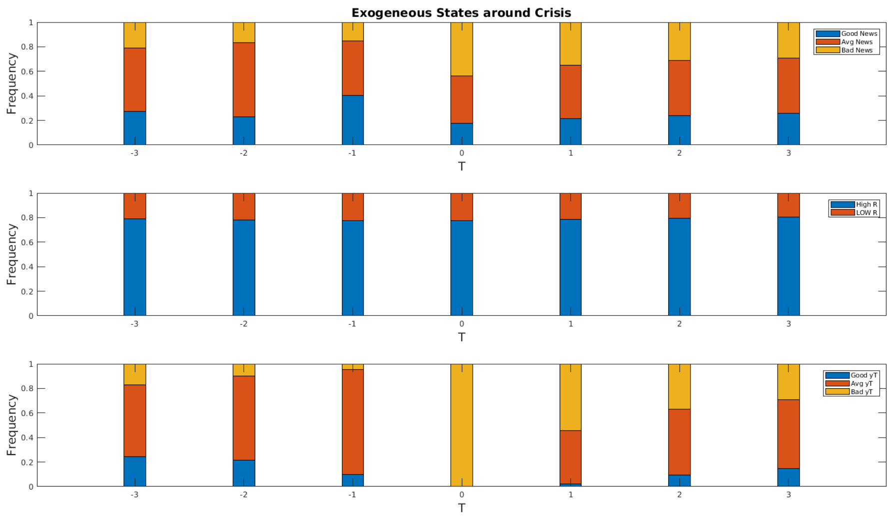

Figure 4: Exogenous States around Crisis when the model accounts for land ($\kappa_A = 0$).

has shown that, when house prices rise, credit constrained households present the largest increase in consumption, which means that looser borrowing constraints are a primary driver of the marginal propensity to consume out of housing wealth for households in general.

When introducing a new parameter, however, the moment-matching exercise has to be performed again, this time imposing a value for the discount factor in Argentina from the literature instead of matching it. Once the matching is complete, the housing sector may be shut off by making $\alpha = 0$. In spite of the fact that matching was performed for a setting where housing plays a role, to ease the comparison and interpretation, the setting without the housing sector will still be considered the baseline scenario, so that our attention is focused on changes that take place when housing is introduced in the simulation.

Table 6 shows a subset of the moments that characterize the decentralized equilibrium without any kind of macroprudential policy intervention (denoted by the subscript DE) and the social planner's equilibrium that incorporates optimal macroprudential policy (denoted by the subscript SP). It shows the probability of crisis (with and without macroprudential

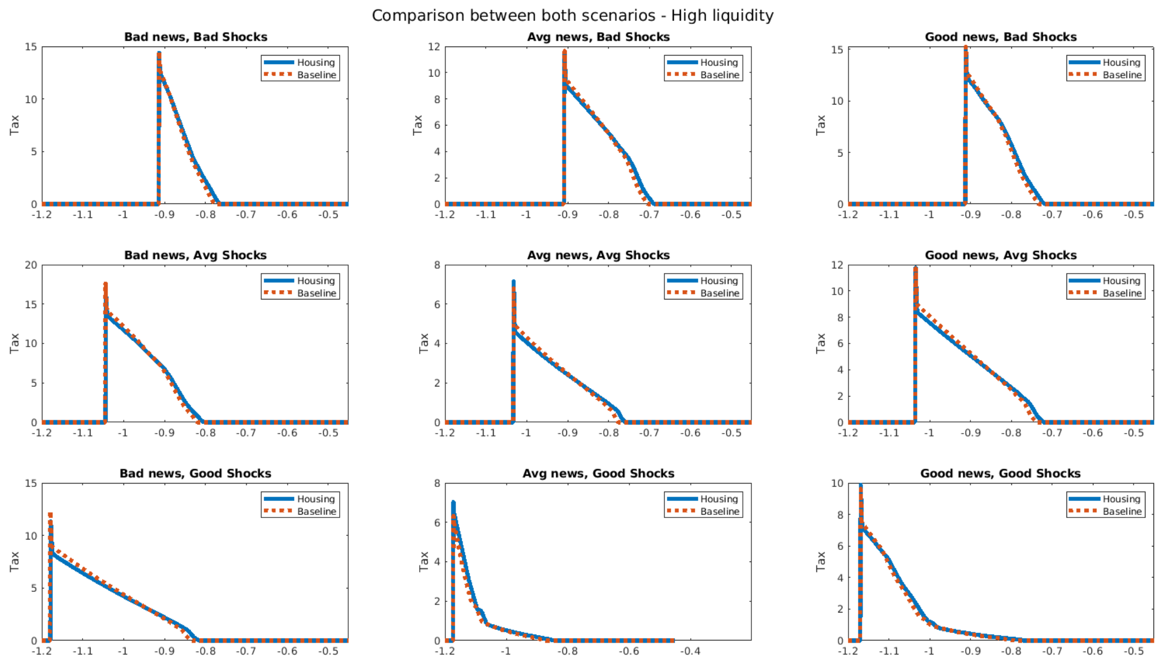

Figure 5: Optimal debt tax as a function of bond holdings, in a high liquidity (low interest) setting, when housing is considered (blue line) and not considered (dashed line) for $\kappa_A = 0$.

policy), the probability of attaining states where the optimal tax τ_t is different from zero, the mean net foreign asset position-GDP ratio (with and without macroprudential policy), the standard deviation of the current account-output ratio ($\sigma_{CA/Y} = \sqrt{Var\left[\frac{y^T - c^T}{y^T + y^N p^N}\right]}$) with and without macroprudential policy, the depreciation in the real exchange rate, the decrease in GDP and in consumption during the sudden-stop event (with and without macroprudential policy) and finally the average tax on debt. Values in the first column are shown for $\alpha = 1$ or abstracting from a housing sector. Values in the second column are shown for $\alpha = 0.595$, with an important housing sector.

Results change considerably in this setting. While macroprudential policy continues not to lead to strong changes in the average value of bond holdings, again it changes the distribution so that the effects of macroprudential policy are quite effective both at preventing crises and

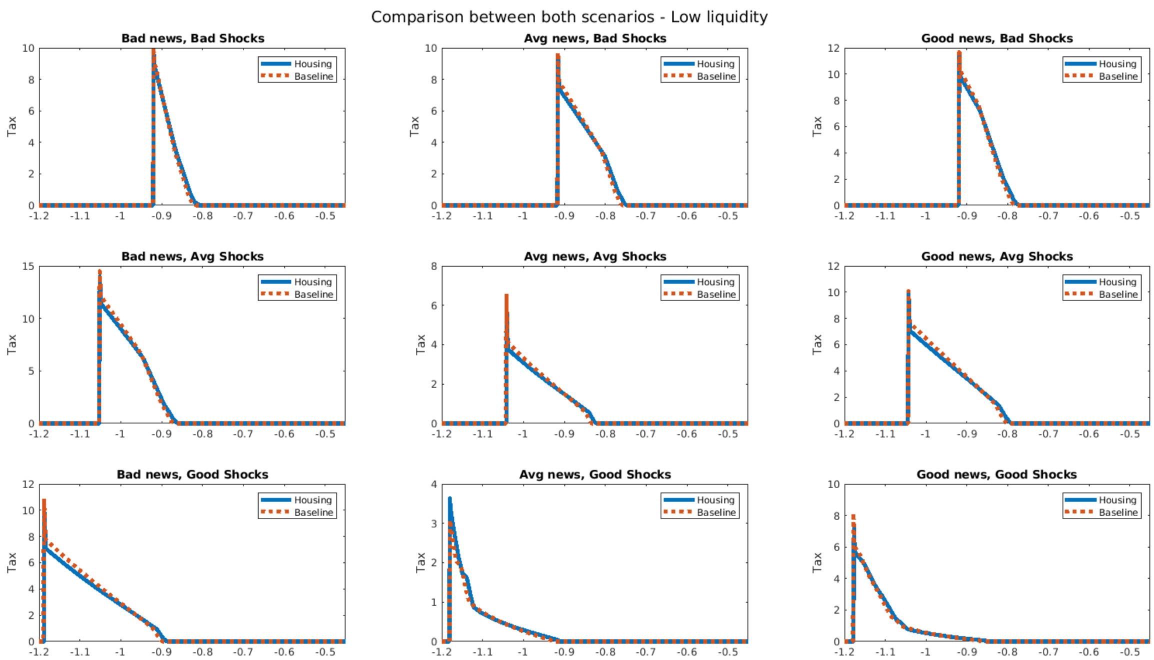

Figure 6: Optimal debt tax as a function of bond holdings, in a low liquidity (high interest) setting, when housing is considered (blue line) and not considered (dashed line) for $\kappa_A = 0$.

dampening their effects. However, differently from the previous setting, the introduction of housing changes the debt level considerably. It increases it by 10.26% in the centralized equilibrium and 10.96% when macroprudential policy is at play, which contrasts with much less than one percent increases when $\kappa = 0$.

As before, macroprudential policy is quite consequential as one may observe in the first column of table 7: it not only decreases significantly the probability of a crisis (by about 40% both with and without land in the model), but it also has a large role in dampening its effects with respect to the decrease in consumption, GDP, the depreciation of the real exchange rate and the decrease in the volatility of the current account.

Contrarily to the previous setting, the introduction of land changes the decentralized equilibrium regarding the probability of crises (this time showing a 3.53% increase). The

Table 6: Comparison between model moments ($\kappa_A > 0$)

Moment	Without housing	With housing
$P_{DE}(SS)$	3.764 %	3.897 %
$P_{SP}(SS)$	2.160 %	2.341 %
$P(\tau \neq 0)$	75.89 %	82.54 %
$\bar{B/Y}_{DE}$	−26.61 %	−29.34 %
$\bar{B/Y}_{SP}$	−26.46 %	−29.36 %
$\sigma_{CA/Y\,DE}$	2.03 %	2.49 %
$\sigma_{CA/Y\,SP}$	1.32 %	1.54 %
$\Delta\epsilon_{DE}$	−31.29 %	−38.29 %
$\Delta\epsilon_{SP}$	−21.62 %	−23.72 %
ΔY_{DE}	−25.91 %	−29.30 %
ΔY_{SP}	−20.27 %	−21.46 %
Δc_{DE}	−10.04 %	−11.89 %
Δc_{SP}	−7.23 %	−7.83 %
$\bar{\tau}$	1.550 %	2.150 %

effects introducing land during crises continue to be noticeable, and are now even stronger: they may be observed in the volatility of sudden-stops (22.7% increase), the real exchange rate depreciation (22.4% increase), the decrease in GDP (13.1% increase) and in consumption (18.4% increase) when comparing with the effects of crises when land is not at play (the increases were 11.0%, 10.0%, 5.4% and 8.0% respectively).

The introduction of land leads to considerable changes in the effectiveness of macroprudential policy. On the one hand, the probability of preventing crises decreases by 6%; on the other hand, the capacity to dampen the effects of a sudden-stop episode becomes much stronger (as opposed to the previous setting when the introduction of land made it weaker): this may be observed with respect to the dampening of the volatility of sudden-stops (9.1% increase), the real exchange rate depreciation (23.1% increase), the decrease in GDP (22.9% increase) and in consumption (22.0% increase).

When comparing these results with those from table 5, it becomes clear that macroprudential policy becomes considerably more effective at preventing financial crises. If we account for the housing sector, macroprudential policy becomes more effective at dampening

Table 7: Macroprudential policy effects ($\kappa_A = 0$)

Moment	Without housing	With housing	Variation
$P(SS)$	−42.61 %	−39.93 %	−6.29 %
$\sigma_{CA/Y}$	−34.98 %	−38.15 %	9.06 %
$\Delta\epsilon$	−30.90 %	−38.05 %	23.14 %
ΔY	−21.77 %	−26.76 %	22.92 %
Δc	−27.99 %	−34.15 %	22.01 %

the effects of crises as well.

Figure 7 plots seven-year event analysis windows that help understand the dynamics around financial crises events for the current account-output ratio (CA/Y), the net foreign asset position (B), the consumption of tradable goods(c^T), non-tradable prices (P_n), land prices (P_h) and GDP (Y), assuming $\kappa_A > 0$ and the housing sector is at play. The plot shows both the dynamics of the decentralized equilibrium and social planner settings and demonstrates again the effectiveness of the optimal macroprudential policy at reducing the severity of financial crises.

Figure 8 shows the role of the three exogenous shocks in the seven periods covered in the event windows for when $\kappa_A > 0$ both with and without land in the model. As before, financial crises are periods that largely coincide with low income realizations and high interest rates, whereas in periods before the crisis the income realization is much more likely to be average. As before, most crises follow good or average news and only seldom bad news, showing that the discrepancy between expectations and realizations continues to be an important driver of financial crises. Like previously, these results do not change significantly with the introduction of land in the model.

Regarding macroprudential policy, figures 9 and 10 present the optimal tax schedule as a function of the current value for net foreign assets (denominated in tradable goods) for a high liquidity and low liquidity regime respectively. In both panels, the tax schedule for the model without land is contrasted with that for the model that incorporates land.

In all exogenous states, we see a very similar shape for the debt tax, apart from a difference in scale and a shift in the horizontal axis.

A result is immediately apparent when observing both graphs: whatever the state where

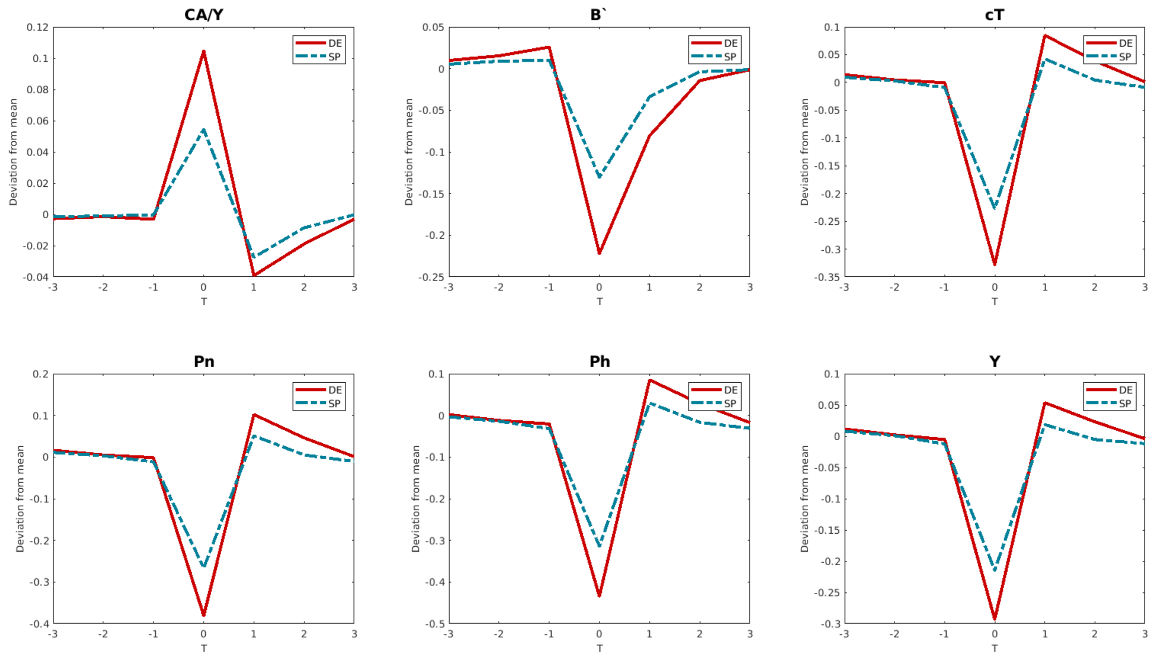

Figure 7: Average deviations from the mean around a sudden-stop event when the model includes land and $\kappa_A > 0$. The solid line represents the Decentralized Equilibrium (DE) allocations for (up, left to right) the current account-output ratio (CA/Y), the net foreign asset position (B), the consumption of tradable goods(c^T), and (down, left to right) non-tradable prices (P_n), land prices (P_h) and GDP (Y). The dashed line represents the Social Planner (SP) allocations for those same variables.

the optimal tax for the baseline setting is not zero, it is higher than the corresponding tax when land is at play. There is nothing mysterious in the higher average tax for the setting where land is at play (38.7% higher), once we account for the fact that the average debt is also higher, such that the agent ends up at roughly the same distance from the collateral constraint (the fundamentals determining the size of the prudential buffer created would barely have changed with the introduction of land, according to results in the previous section), and therefore we would expect the rise in the average tax to be determined by the rise in scale from one shape of the debt tax profile to the other, as if there was no shift.

To evaluate this change in scale, I integrated all debt taxes with respect to debt for every

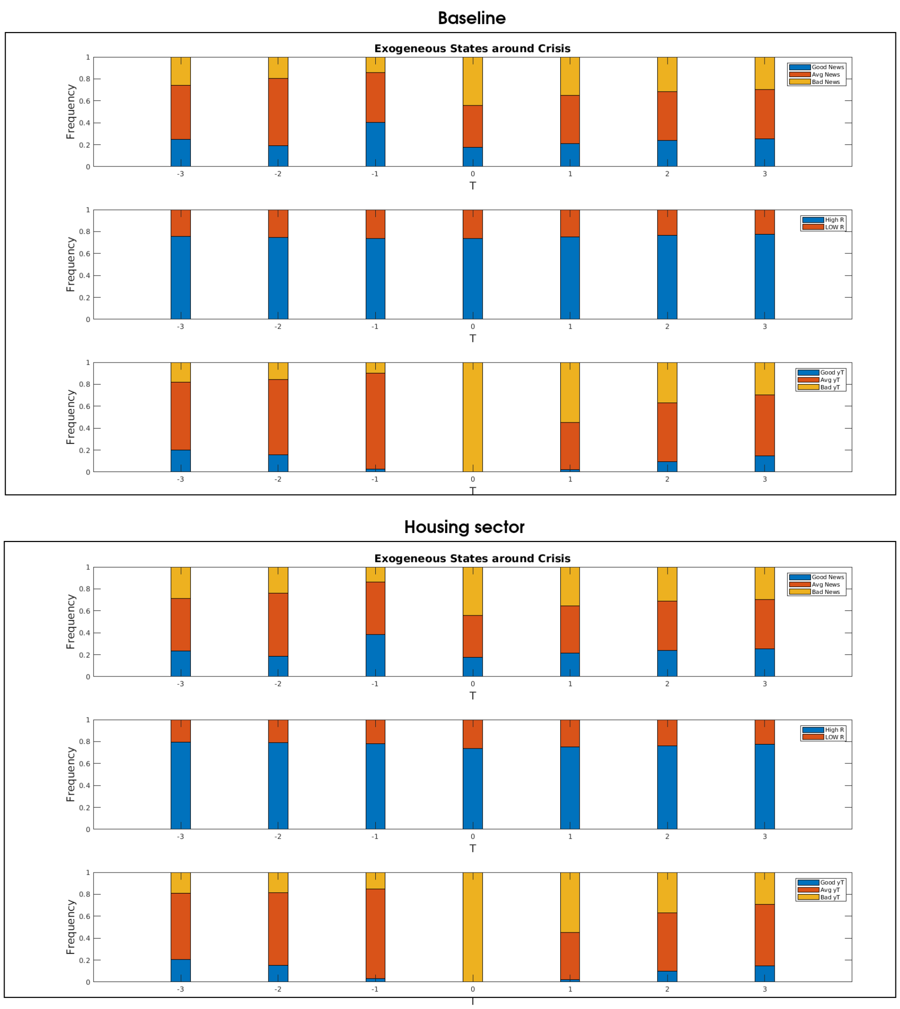

Figure 8: Exogenous States around Crisis with $\kappa_A > 0$, both withot land in the model (above) and with land included in the model (bellow).

given exogenous state and compared the values in both settings. These results are shown in table 15. A weighted average of the increase in any given state to the unconditional probability

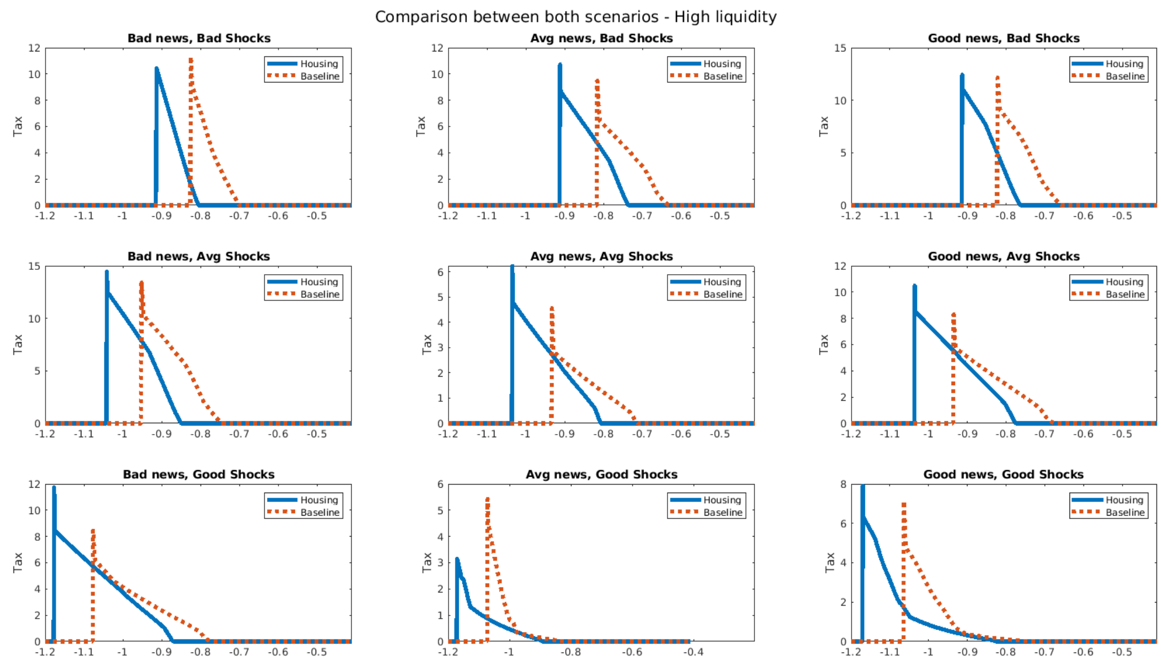

Figure 9: Optimal debt tax as a function of bond holdings, in a high liquidity (low interest) setting, when housing is considered (blue line) and not considered (dashed line) for $\kappa_A > 0$.

of that state renders the value 74.46%, a value that almost doubles the average increase in taxes of 38.7%, showing that the shift in the optimal tax schedule is larger than the shift in the distribution of the debt value. This shows that, through κ_A, land considerably strengthens the amplification of the debt deflation mechanism, both increasing the individual prudential buffer between the debt level of the agent and the maximum affordable (the opposite of what happens when $\kappa_A = 0$) and also the pecuniary externality.

These results change noticeably with the liquidity regime, however: with low liquidity the tax profile integral increases, on average (weighted by the probability of each state) by 78.8% whereas with high liquidity the increase is only 48.7%. With one single exception (high liquidity, and a *good state* regarding the production of tradable goods), for each state regarding the production of tradable goods, average news are those that lead to higher in-

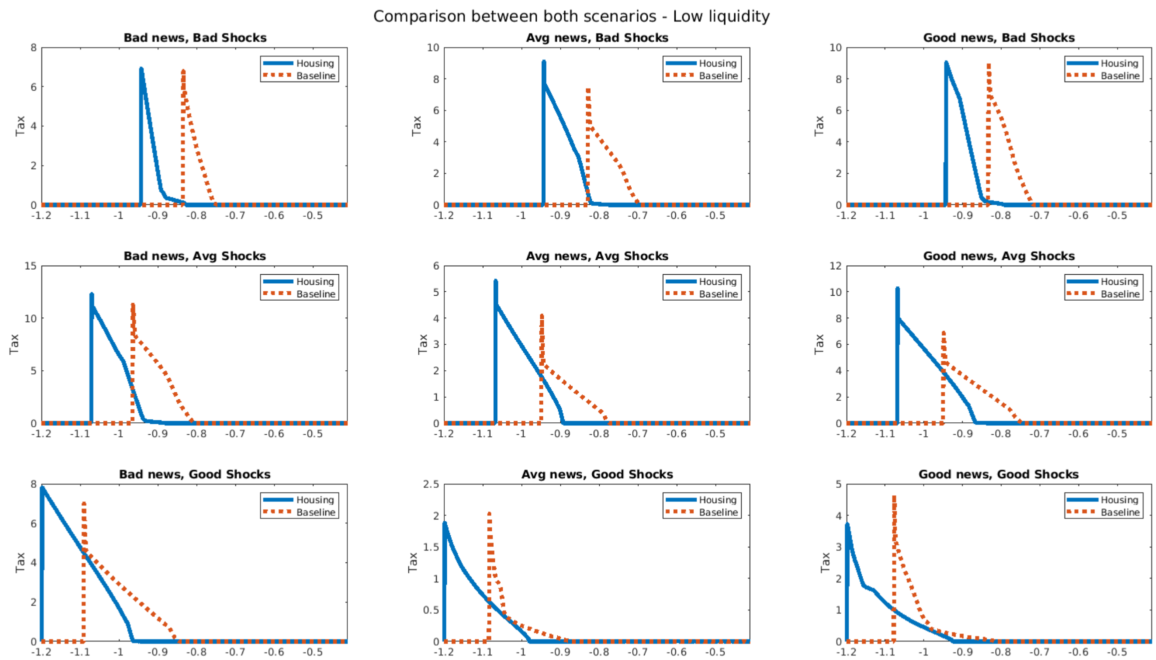

Figure 10: Optimal debt tax as a function of bond holdings, in a low liquidity (high interest) setting, when housing is considered (blue line) and not considered (dashed line) for $\kappa_A > 0$.

creases in the optimal tax profile (the opposite was the case when $\kappa_A = 0$) which means that the mismatch between expectations and realizations is not what is driving the increase in optimal tax profile when land is at play. It is also possible to observe that *good states* lead to higher increases than *bad states* for the same signal regarding the next period (with one single exception for high liquidity and *average news*), and in general to higher increases than in the respective *average state*.

Overall these results represent good news for implementation. The states where increases are higher are those where taxes are lower - with respect to liquidity, the production of tradable goods and news regarding next period - and thus the optimal tax when land is considered presents a smaller dependence on the current exogenous state. The opposite happens if the analysis assumes the housing-collateral channel is turned off ($\kappa_A = 0$): implementation would

Table 8: Increase in taxes as a result of the high external demand

Liquidity Regime	Shock to y^T	News	Increase (%)
Low liquidity	Bad Shock	Bad News	7.30
		Avg News	57.31
		Good news	28.06
	Avg Shock	Bad News	28.60
		Avg News	117.79
		Good news	89.84
	Good Shock	Bad News	81.77
		Avg News	151.65
		Good news	67.23
High liquidity	Bad Shock	Bad News	12.90
		Avg News	41.24
		Good news	25.43
	Avg Shock	Bad News	24.07
		Avg News	84.21
		Good news	61.50
	Good Shock	Bad News	61.89
		Avg News	7.32
		Good news	43.93

become even harder. However, even with these changes, the optimal tax schedule has a strong state-dependence, which means that implementation of the optimal policy is still very hard.

When $\kappa_A = 0$ the introduction of land in the model is akin to a small increase in the elasticity of intertemporal substitution, leading to a slight increase in the average debt level and a decrease in the importance of consumption smoothing and, therefore, a decrease in the necessity of macroprudential policy. The -6.64% decrease in the average tax value is therefore to be expected. When $\kappa_A > 0$, however, the amplification mechanism operates in an additional channel: the housing-collateral channel. This allows the agent to increase the debt level, even if the average buffer between the current debt level and the maximum debt allowed is also enlarged, as the agent already anticipates the stronger amplification caused by the housing market. The agent does not, however, internalize the general equilibrium effects of the consumption decisions on prices, and thus the introduction of land ends up increasing the pecuniary externality. That is why, when the housing-collateral channel is accounted for, the average optimal tax value increases by 38.7% with the introduction of land, showing that macroprudential policy becomes more necessary in economies where the role of the housing market cannot be ignored.

The welfare impact of macroprudential policy is presented in table 9. Since all prices are denoted in tradable goods, as well as the GDP of this economy, the welfare of macroprudential policy is measured as the increase in tradable goods required for the agent to attain the same utility in the decentralized equilibrium as the one attained in the social planner's equilibrium. Overall, values are similar to the ones presented in Bianchi et al. (2016). With the DTI-kind constraint alone, one finds that results change little with the introduction of housing, and in fact the welfare impact of macroprudential policy decreases slightly (which seems consistent with the fact that optimal policy is weaker). With both collateral constraints, however, changes in welfare with the introduction of housing are unnoticeable, which contrasts with the fact that optimal macroprudential policy is much stronger when we consider the housing sector.

Table 9: Welfare impacts (Δc^T) of Macroprudential Policy

Scenario	Without housing	With housing
$\kappa_A = 0$	0.46 %	0.43 %
$\kappa_A > 0$	0.25 %	0.25 %

One should take notice of the assumptions behind these results. As stated above, by assuming rational expectations, the agent already fully anticipates the possibility of a fast and strong devaluation of housing assets without ever evaluating housing prices irrationally - the market inefficiency coming fully from the pecuniary externality. Given the critical importance of belief-driven boom and bust cycles in general (Adam et al., 2016) and of real estate bubbles in particular (Adam et al., 2012), this approach avoids all uncertainty regarding how beliefs are formed (Fuster et al., 2010) by presenting what could be considered a lower bound for macroprudential policy. Even under these adversarial assumptions, macroprudential policy is important and the proper inclusion of the housing sector enhances its importance further.

3.2 Spain

3.2.1 Calibration

The parameter values used to calibrate the model are shown in tables 10 and 11. For the baseline calibration, I use data from Spain, an example of an eurozone economy where housing prices played a key role in its financial crisis.

Table 10: Baseline model parameters

Parameter	Values
y^N	1
$\mathbb{E}\left[y^T\right]$	1
ρ_y^T	0.3478
$Var\left[y^T\right]$	1.369×10^{-2}
N_y^T	3
σ	2
η	0.205
η_D	0.282
β	0.9617
ω	0.3213
R^h	1.00194
R^l	0.98406
F^{hh}	0.7465
F^{ll}	0.7755
θ	0.76

Regarding σ, the coefficient of relative risk aversion, its value corresponds to the standard value in the DSGE literature, $\sigma = 2$. As previously mentioned, the elasticity of substitution in consumption of tradables and nontradables relates to the η parameter in the CES aggregator expression by $1/(\eta + 1)$. Bianchi and Mendoza used a 0.83 estimate for the elasticity of substitution (they chose the upper bound of empirical estimates to establish a conservative

Table 11: Parameters matched

Parameter	Values
κ_Y	0.011
κ_A	0.010
α	0.69

benchmark), rendering the value of η as $\eta = 0.205$. I follow the same approach.

A CES utility function with housing and other consumption goods has been presented in the literature as a way to explain wealth and expenditure puzzles (Fernández-Villaverde and Krueger, 2011; Martin and Gruber, 2004) and also to make sense of the time-series data on consumption (Fratantoni, 2001). It has also been used to explain the equity premium puzzle (Lustig and Nieuwerburgh, 2005; Piazzesi et al., 2007). Khorunzhina (2021) estimatimates the elasticity of substitution between housing and non-housing goods as $1/(\eta_D + 1) = 0.78$ where $1/(\eta_D + 1)$ is the elasticity of subtitution and η_D the corresponding parameter in the CES specification presented. I use the same value.

As in Bianchi et al. (2016), I set the parameter ω considering the primary and secondary sectors. Data for the Spanish economy was obtained using IMF data[1], and thus $\omega = 0.3213$.

Regarding the exogenous processes y_t^N and y_t^T, as in Bianchi et al. (2016), the deterministic nontradables endowment and the mean endowment of tradables are all normalized to 1 for simplicity. The Markov process for y_t^T is set using the Tauchen-Hussey quadrature algorithm, which uses calibrated parameters $\rho_y^T = 0.3478$ and $Var\left[y^T\right] = 0.01369$ set to match the first-order autocorrelation and standard deviation of tradables GDP in Spain in the period from 1970 to 2008 (Martín-Moreno et al., 2014). The process presents three realizations ($N = 3$). I obtained the value for the discount parameter $\beta = 0.9617$ from Martín-Moreno et al. (2014).

Bianchi et al. (2016) calibrated the stochastic process for the world interest rate so as to capture the global liquidity phases identified in Calvo et al. (1996) and Shin (2013). This was adapted to use the ECB's interest rate minus inflation as an input instead. I set the value R_l for the high liquidity regime to $R_l = 0.98406$, and the value R_h for the low liquidity regime

[1] IMF (2020)

to $Rh = 1.00194$. Furthermore, I set values F_{hh} and F_{ll} as $F_{hh} = 0.7465$ and $F_{ll} = 0.7755$, and both $F_{hl} = 1 - F_{hh}$ and $F_{lh} = 1 - F_{ll}$ hold.

The signal s_t has the same number (N) of realizations as y_t^T. Bianchi et al. (2016) decided to set the parameter θ as the mid-point between a perfect predictor of y_t^T ($\theta = 1$) and a completely uninformative signal ($\theta = 1/N$). Therefore, θ was set to $\theta = 2/3$ whenever the effects of the news shocks were being studied. To shut the signal off, θ was set to $\theta = 1/3$. To obtain an empirical estimation for θ, I used one-year ECB forecasts of real GDP growth (regarding 2001-2021), as well as the values for real GDP growth itself (from 2000 to 2021, according to the ECB). Although an estimation of the level of tradables production is not the same as an estimation of overall GDP growth, the effective meaning of the signal precision (the probability of foreseeing "good(bad) times" given that "good(bad) times" come to be) makes this an effective way of estimating its value. The value obtained for ECB's precision was $\theta = 0.75$.

Finally, to obtain the remaining parameters, κ_Y, κ_A and α, I set them by matching the long-run moments of the decentralized equilibrium of the economy to Spain's data regarding the probability of a financial crisis, the housing rent-to-price ratio and the price-to-income ratio.

Regarding the probability of a financial crisis, Betrán et al. (2012) study 150 years of data, starting in 1850, and determine objective criteria to identify currency crisis, banking crisis, and stock market crashes. They also identify instances where both of these criteria are met simultaneously (which they call *twin crisis*), and instances where all the criteria are met simultaneously (which they call *triple crisis*). They present the probability of a *triple crisis* starting in four different time periods and by computing a weighted average of those values, I set the unconditional probability of crisis at $p(C_{DE}) = 2.5\%$.

I obtained the expected value of the rent-to-price ratio by simulating the economy and, for every attained state, computing the price of the rent (denoted in tradable goods) and dividing it by the land price. Notice that the rent being calculated is also the rent of land, the assumption being that the average rent-to-price ratio of a house is the same as the rent-to-price ratio of land. The price of the rent is calculated according to:

$$p_t^{rA} = \frac{\frac{\partial u(c^N, c_t^T, A)}{\partial A}}{\frac{\partial u(c^N, c_t^T, A)}{\partial c^T}}. \quad (39)$$

By computing $E[\frac{p_t^A}{p_t^{rA}}]$ one obtains the average rent-to-price ratio. I matched this value to the one published by Banco de España, the Spanish Central Bank (a price-to-rent value of 25).

The value for the price-to-income ratio was also published by Banco de España (it was evaluated by the Central Bank considering the cost of a typical housing unit of 100 square meters) and equal to 23.24. To convert from the ratio between the price of land and income per capita in the simulations to the price-to-income ratio in the data I used the relation 35. The value of $\chi = 0.43$ was obtained from the data in Kajuth (2021). In the absence of a high quality estimation for Spain, I used the best estimation for a European economy, since the population density in Europe is considerably higher than that of the USA.

The solution method is the same as the one described in section 3.1.2.

3.2.2 The baseline scenario

Table 12 shows a subset of the moments that characterize the decentralized equilibrium without any kind of macroprudential policy intervention (denoted by the subscript DE) and the social planner's equilibrium that incorporates optimal macroprudential policy (denoted by the subscript SP). It shows the probability of crisis (with and without macroprudential policy), the probability of attaining states where the optimal tax τ_t is different from zero, the mean net foreign asset-GDP ratio (with and without macroprudential policy), the standard deviation of the current account-output ratio ($\sigma_{CA/Y} = \sqrt{Var\left[\frac{y^T - c^T}{y^T + y^N p^N}\right]}$) with and without macroprudential policy, the depreciation in the real exchange rate, the decrease in GDP and in consumption during the sudden-stop event (with and without macroprudential policy) and finally the average tax on debt.

Results for the decentralized equilibrium show that financial amplification in this model is powerful, resulting in significant declines in consumption and in the real exchange rate, in addition to large current-account reversals.

As in Bianchi et al. (2016), macroprudential policy barely changes the mean debt ratio,

Table 12: Baseline Model Moments

Moment	Value
$P_{DE}(SS)$	2.525 %
$P_{SP}(SS)$	0.315 %
$P(\tau \neq 0)$	54.37 %
$\bar{B/Y}_{DE}$	−10.85 %
$\bar{B/Y}_{SP}$	−10.82 %
$\sigma_{CA/Y\,DE}$	0.52 %
$\sigma_{CA/Y\,SP}$	0.41 %
$\Delta\epsilon_{DE}$	−4.64 %
$\Delta\epsilon_{SP}$	−3.98 %
ΔY_{DE}	−5.01 %
ΔY_{SP}	−4.40 %
Δc_{DE}	−1.78 %
Δc_{SP}	−1.53 %
$\bar{\tau}$	0.6211 %

greatly reducing the volatility of capital flows instead. As compared to Bianchi et al. (2016), macroprudential policy proves much more effective in decreasing the probability of a sudden stop (an 87.5 % reduction), but less effective in dampening its effects (a 14.0 % reduction in the drop of overall consumption). This happens in spite of the fact that the discount factor is much higher in Spain that in Argentina ($\beta_S = 0.9617 > 0.91 = \beta_A$) and the probability of crisis somewhat lower ($P_S(SS) = 2.51\% < 3.67\% = P_A(SS)$) decreases the importance and effectiveness of macroprudential policy, and also that once the Bianchi et al. (2016) is extended to include housing, macoprudential policy is shown to be less effective (as seen in section 3.1.4) in preventing financial crises (and more effective at softening their effects). The smaller $Var\left[y^T\right]$ is driving this result and increasing the effectiveness of macroprudential policy at preventing financial crises.

The International Monetary Fund (IMF) has data for Spain's net foreign assets from 2000 to 2020, and the average value of the series is equal to -6.7%. The IMF defines net foreign assets as the sum of foreign assets held by monetary authorities and deposit money banks, less their foreign liabilities. A time-series from 1994 to 2021 for the spanish net international investment position, however, leads to an average of -64.47%. None of these values was used to calibrate the model. On the one hand, both time-series are shorter than would be desirable. On the other hand, the value for net foreign assets in the model should be closer to the IMF's value for net foreign assets (as the model does not include other types of assets), but should stand between this value and the value for the net international investment position, as the latter represents the acummulation of current accounts. Indeed, results show average net foreign assets equal to -10.8%. Interestingly, even though the changes of macroprudential policy to the distribution of net foreign assets in the simulation are so consequential, they barely change this first moment of that distribution. The average fall in GDP both in the decentralized equilibrium (5.01%) and under the social planner (4.40%) are also on the ballpark of the actual fall in GDP in 2009 (3.76%) on the outset of the "Spanish property bubble".

Panel 11 shows seven-year event analysis windows that help understand the dynamics around a sudden-stop event. All graphics show, in the horizontal axis, up to three periods before the sudden-stop, the sudden-stop, and up to three periods after. The average deviation from the mean is plotted for the current account-output ratio (CA/Y), net foreign assets, the consumption of tradable goods, non-tradable prices, land prices, and GDP, both in the decentralized equilibrium (DE) and the social-planner (SP) allocations. Again, due to the large size of the sample (23873 sudden-stops in the decentralized equilibrium), even with a confidence interval of 99%, the confidence band for the average deviations is always narrower than the thickness of the lines.

The changes that occur when financial crises hit highlight the non-linear nature of the fluctuations relative to the pre and post-crises patterns. The plots show both the dynamics of the decentralized equilibrium and social planner settings and demonstrate again that optimal macroprudential policy reduces the severity of financial crises. These results also show that, in spite of the considerably different role these goods play in the model, the dynamics regarding the evolution of prices of nontradables and land are remarkably similar, apart from a scale factor.

Figure 12 shows optimal time-consistent macroprudential policy for every possible state of the system. The instrument used for macroprudential policy, as stated in the previous section,

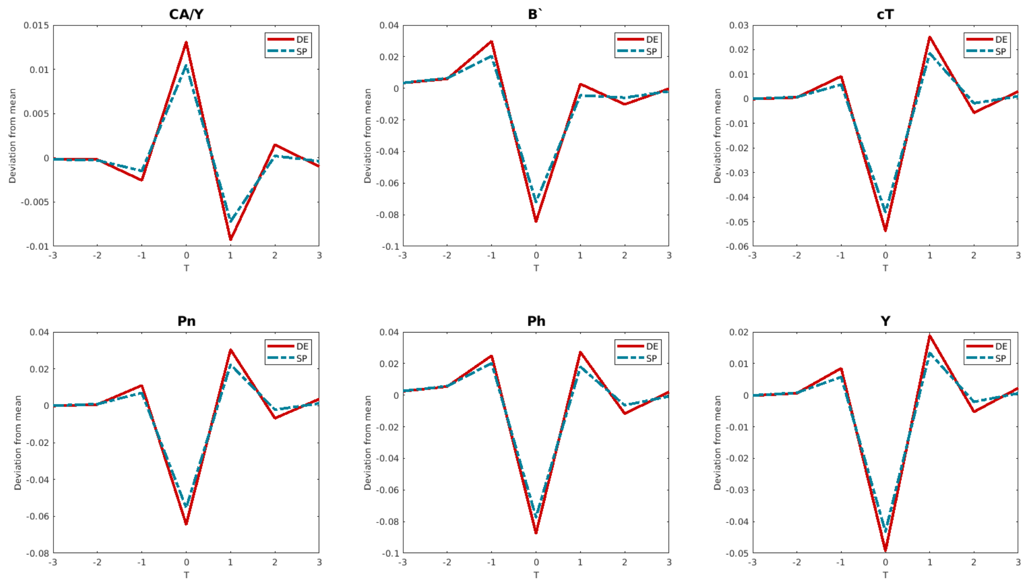

Figure 11: Average deviations from the mean around a sudden-stop event in the baseline scenario. The solid line represents the Decentralized Equilibrium (DE) allocations for (up, left to right) the current account-output ratio (CA/Y), net foreign asset (B), the consumption of tradable goods(c^T), and (down, left to right) non-tradable prices (P_n), land prices (P_h) and GDP (Y). The dashed line represents the Social Planner (SP) allocations for those same variables.

is a state-dependent tax on debt and the horizontal axis is the nominal debt b denoted in tradable goods. The nine plots present all possible states regarding tradable income (bad, average and good) and news about the future (bad, average and good) and the lines represent the two liquidity regimes (low interest rates for higher liquidity and high interest rates for lower liquidity).

In all settings, quite intuitively, macroprudential policy should strengthen as the debt level increases, up to the point where the constraint binds, in which case there is no pecuniary externality in play and therefore no optimal macroprudential tax. In general, as in Bianchi et al. (2016), for both liquidity regimes, debt taxes tend to be the highest when news about the future are bad, and they fall as the news turn average or good. For a bad state

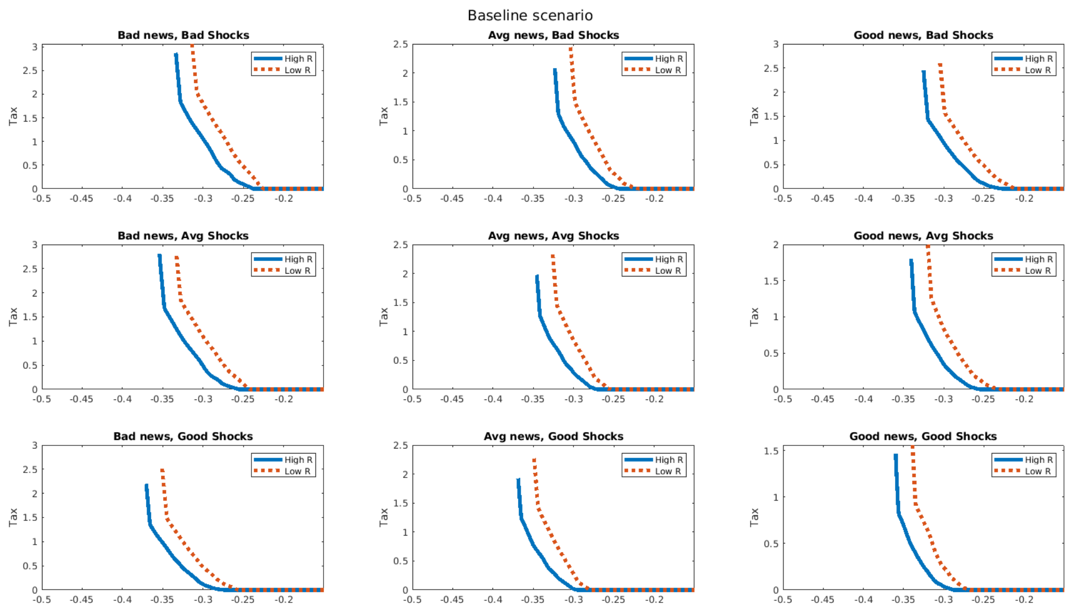

Figure 12: Optimal macroprudential policy in the baseline scenario. The horizontal axis is the value of net foreign assets and the vertical axis is the percentage value for the tax on debt.

regarding y^T, however, average news are the ones that demand a weaker macroprudential policy. On the one hand we could expect better news to be associated with a lower pecuniary externality, as they are associated with a lower probability of a sudden stop; on the other hand, average news give less of a margin for a difference between expectations and realizations in the following period. These results show that this second factor becomes more important when the agent has less of a margin to adjust the buffer between the debt value and the debt constraint, but less important in other states.

Not surprisingly, optimal taxes are higher when interest rates are lower: if the market inefficiency is a pecuniary externality that leads to overborrowing, higher real interest rates decrease the difference between the decentralized equilibrium and the social planner's allocations. Overall, optimal values for the tax are much lower than those for Argentina (Bianchi et al., 2016) but they are still very relevant.

As in section 3.1.4, the role of news shocks (as compared to a framework without land) and liquidity regimes is enhanced, meaning: the relative increase or decrease in the debt taxes as we change the exogenous state of the system is higher once land is introduced in the model.

3.2.3 The price surge

I set the value of e for external demand at $e = 0.07$ in order to attain an increase in land prices equal to 10%. Table 13 shows a subset of the moments that characterize the decentralized equilibrium without any kind of macroprudential policy intervention (denoted by the subscript DE) and the social planner's equilibrium that incorporates optimal macroprudential policy (denoted by the subscript SP). As before, it shows the probability of crises (with and without macroprudential policy), the probability of attaining states where the optimal tax τ_t is different from zero, the mean net foreign asset-GDP ratio (with and without macroprudential policy), the standard deviation of the current account-output ratio with and without macroprudential policy, the depreciation in the real exchange rate, the decrease in GDP and in consumption during the sudden-stop event (with and without macroprudential policy) and finally the average tax on debt. Table 14 compares the effect of macroprudential policy in the baseline scenario with the one in the price-surge scenario.

Results for the decentralized equilibrium show that financial amplification in this model remains powerful under this price surge setting, resulting in declines in consumption, GDP and real exchange rate, which are even larger than in the baseline scenario (42.7%, 37.7% and 44.2% more, respectively), and larger current-account reversals as well.

Again, macroprudential policy barely changes the average debt level, but it changes the distribution just enough to noticeably decrease the probability of a sudden stop: a 64.0% decrease. To be sure, macroprudential policy is less effective under this price surge setting: the probability of crisis in a decentralized equilibrium is (26.9%) lower than in the baseline scenario, but for a social planner it is (111%) higher than in the baseline scenario. That is why macroprudential policy after the price surge gives rise to a 64.0% decrease in the probability of a sudden stop instead of the 87.5% reduction of the previous setting. These results show that the extra source of income dampens the role of the pecuniary externality,

Table 13: Model Moments for the high external demand setting

Moment	Value
$P_{DE}(SS)$	1.845 %
$P_{SP}(SS)$	0.664 %
$P(\tau \neq 0)$	62.43 %
$\bar{B/Y}_{DE}$	−11.01 %
$\bar{B/Y}_{SP}$	−11.01 %
$\sigma_{CA/Y\,DE}$	0.77 %
$\sigma_{CA/Y\,SP}$	0.63 %
$\Delta\epsilon_{DE}$	−6.69 %
$\Delta\epsilon_{SP}$	−5.54 %
ΔY_{DE}	−6.90 %
ΔY_{SP}	−5.87 %
Δc_{DE}	−2.54 %
Δc_{SP}	−2.11 %
$\bar{\tau}$	0.9032 %

but that it remains nonetheless quite relevant.

While the effectiveness of macroprudential policy in decreasing the probability of crises is lower under the price surge setting, its effectiveness at decreasing the drop in consumption is higher. The average decrease of consumption in a decentralized equilibrium is 42.7% higher after the price surge than in the baseline scenario, and macroprudential policy may dampen this drop by -16.9% instead of -14.0% as in the baseline scenario (a 20.7% increase in efficacy).

Regarding the volatility of the current account-output ratio, it increases after the price surge both with and without macroprudential policy (by 53.7% and 48.1%). However, even if the surge in prices increases volatility, the ability of macroprudential policy to reduce it decreases (from a 21.2% reduction in the baseline scenario to a 18.2% after the surge in prices).

Since all prices are denoted in tradable goods, as well as the GDP of this economy, the welfare impact of macroprudential policy is measured as the increase in tradable goods required for the agent to attain the same utility in the decentralized equilibrium as the one attained in the social planner's equilibrium. Overall, values are low, but the surge in house

Table 14: Comparison between the effect of macroprudential policy in both settings

Effect of policy	Baseline	Price Surge
$\Delta P(SS)$	87.5 %	64.0 %
$\Delta\sigma_{CA/Y}$	21.2 %	18.2 %
$\Delta(\Delta\epsilon)$	14.2 %	17.2 %
$\Delta(\Delta Y)$	12.2 %	14.9 %
$\Delta(\Delta c)$	14.0 %	16.9 %
ΔU	0.04 %	0.14 %

prices increases the welfare impact by about 350% (from 0.04% to 0.14%), stressing how significant may be these swings driven by external demand.

Panel 13 shows seven-year event analysis windows that help understand the dynamics around a sudden-stop event for the current account-output ratio (CA/Y), net foreign assets, the consumption of tradable goods, non-tradable prices, land prices, and GDP, both in the decentralized equilibrium (DE) and the social-planner (SP) allocations. When comparing to the values in 11, one may notice a larger difference between the decentralized equilibrium allocation and the social planner allocations.

Overall, optimal macroprudential policy is more stringent in this setting: the probability of being in a state where the tax applied is higher (a 14.8% increase), and, crucially, the average tax is higher (a 45.4% increase). This is a key result. In spite of the assumption that the increase in average prices is exogenous, permanent and that the agent's expectations and choices are fully rational, this surge in prices still demands a stronger response from the macroprudential authority. Furthermore, these results show that, overall, the strengthening of optimal macroprudential policy (45.4%) is commensurate with the average increase in prices (10%).

This may seem to contradict Schmitt-Grohé and Uribe (2017)'s results regarding optimal capital control policy (which we could generalize to macroprudential policy overall). Using Bianchi (2011)'s model, Schmitt-Grohé and Uribe challenge the conventional view according to which policymakers should strengthen macroprudential policy during economic booms and loosen it during contractions. Their results show that, short of a financial crisis, macroprudential authorities should do the opposite. While for small conjunctural changes this may be

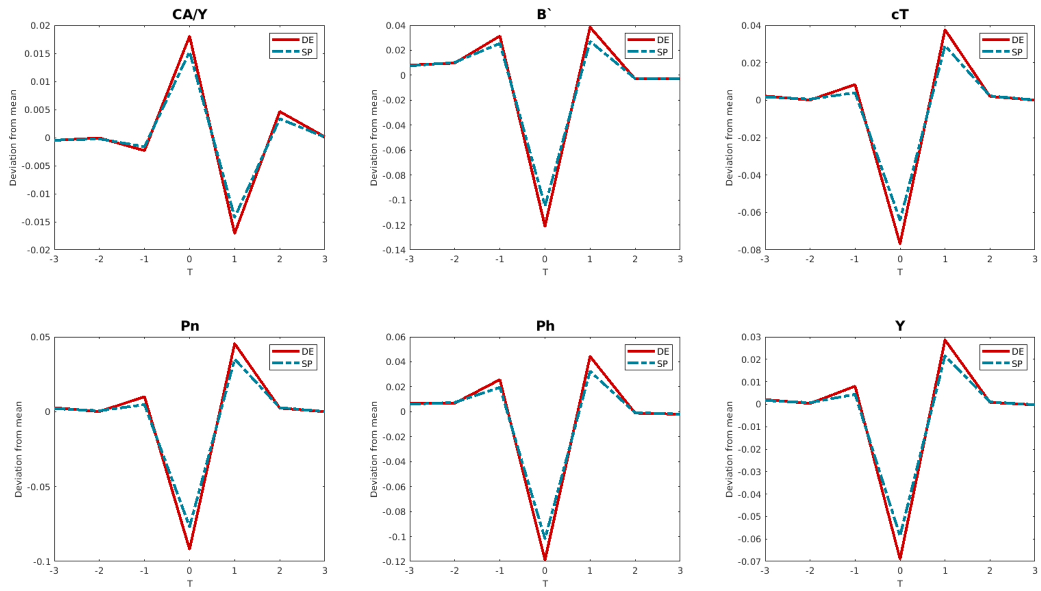

Figure 13: Average deviations from the mean around a sudden-stop event in the price-surge scenario. The solid line represents the Decentralized Equilibrium (DE) allocations for (up, left to right) the current account-output ratio (CA/Y), net foreign assets (B), the consumption of tradable goods(c^T), and (down, left to right) non-tradable prices (P_n), land prices (P_h) and GDP (Y). The dashed line represents the Social Planner (SP) allocations for those same variables.

seen as an inconsequential debate, as the dangers of fine-tuning policy are well known, one could believe that with a fast and wide surge in land prices, or a long-term trend increase in land prices, macroprudential authorities should avoid strengthening macroprudential policy, if not weakening it altogether. When introducing land in this model and performing a comparative statics exercise assuming a permanent change in external demand for land, one may instead retrieve the conventional view that, at least in regard to wide changes in land prices, macroprudential authorities should indeed lean against the wind. Additionally, the strengthening of macroprudential policy should be commensurate with the increase in prices.

Figure 14 shows the role of the three exogenous shocks in the seven periods covered in the event windows. When comparing to values for the simulations in section 3.1.4 there seems to be almost no noticeable qualitative changes.

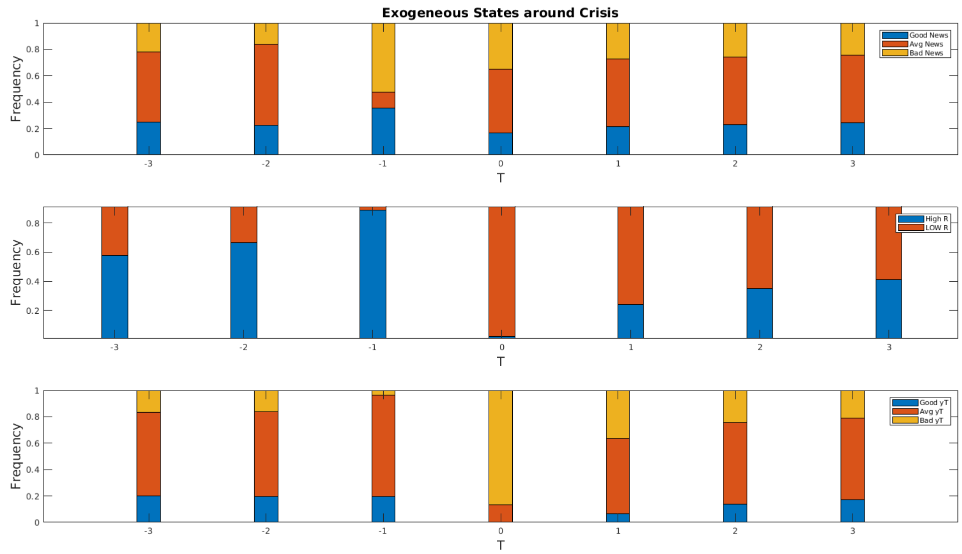

Figure 14: Exogenous States around Crisis in the price-surge scenario.

Figure 15 and 16 show, for a high liquidity setting (the states where the interest rate is low) and a low liquidity setting (the sates where the interest rate is high) respectively, a comparison between the optimal macroprudential policy under the baseline scenario presented in the previous subsection and the price surge scenario.

In all exogenous states, we see a very similar shape for the debt tax, apart from a difference in scale and a shift in the horizontal axis.

A result is immediately apparent when observing both graphs: whatever the state where the optimal tax for the baseline setting is not zero, it is higher than the corresponding tax in the price surge scenario. There is nothing mysterious in the higher average tax for the price surge scenario, once we account for the fact that the average debt is also higher, such that the agent ends up at roughly the same distance from the collateral constraint (the fundamentals determining the size of the prudential buffer he wants to create have barely changed with the rise in demand), and therefore we would expect the rise in the average tax to be determined by the rise in scale from one shape of the debt tax profile to the other, as if there was no shift. To evaluate this change in scale, one may integrate all debt taxes with respect to debt for every given exogenous state and compare the values in both settings. These results are shown in table 15. A weighted average of the increase in any given state to the unconditional

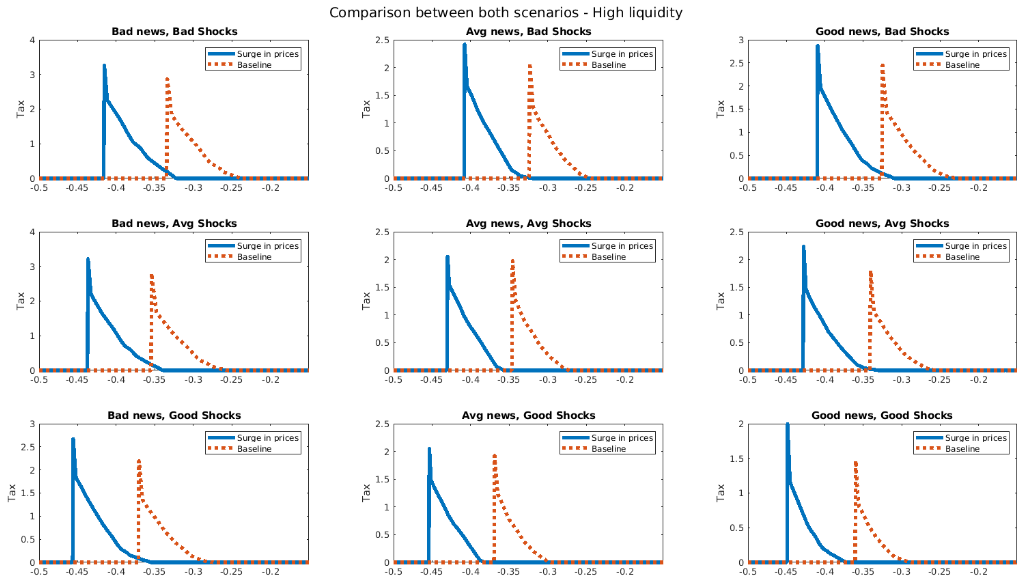

Figure 15: Optimal macroprudential policy in the high liquidity regime.

probability of that state renders the value 45.27%, a value almost identical to the average increase in taxes of 45.42%, confirming that the shift in the optimal tax schedule is the same as the shift in the debt value.

One may notice that, whatever the liquidity regime, states where there are good news about the future are associated with a higher increase in taxes, considerably above average (45.27%), the increases being stronger the higher the production of tradable goods (and the higher GDP) is. On the other hand, bad news are generally associated with increases lower than average, except when in *Good Shocks*, in which case they are not only higher than average, but also higher than the increases for average news about the future. Average news are generally associated with below-average increases in taxes. Low liquidity heightens the increase in taxes in those states where the increase is above average (*Good News*, *Good Shocks*), and dampens the increase in taxes when news about the future are bad.

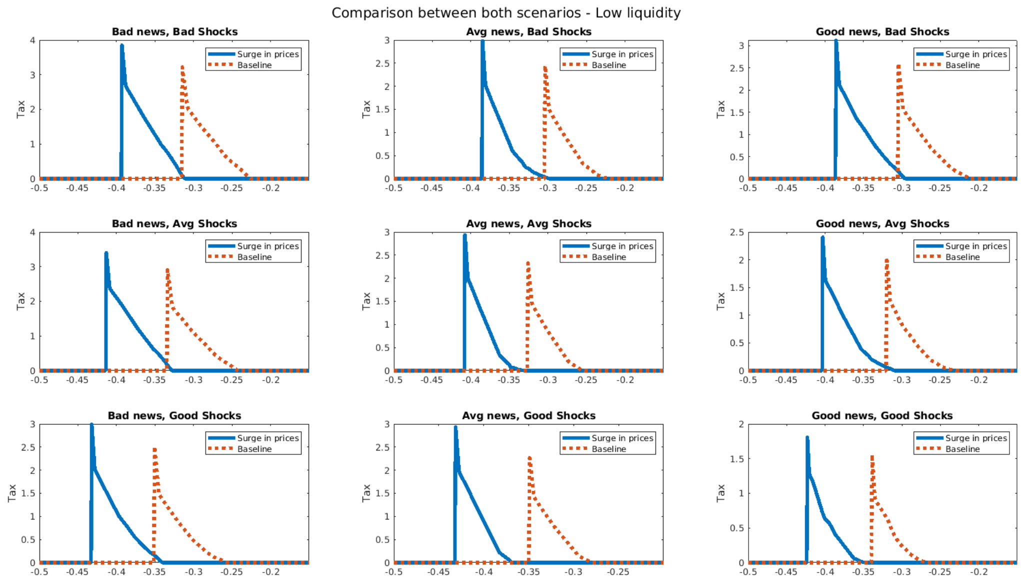

Figure 16: Optimal macroprudential policy in the low liquidity regime.

A good signal that fails to accurately predict the shock in the next period becomes more dangerous when the space of the agent to act based on that false information is enhanced by the increase in land prices, as part of the risk associated is not internalized. The effect of the tradable's production in the agent's income also increases in the price-surge setting due to the addition of a second channel: the rent increase as a result of higher land prices. However, because the states where higher increases are observed are those where the taxes were lower to begin with, the surge in house prices actually decreases the role of information about future periods as well as the the production level. This is also the case when it comes to the liquidity regime. The weighted average (by the unconditional probabilities of each exogenous state) of increases is 46.59% for the low liquidity regime (the one with lower values for τ) and only 44.12% for the high liquidity regime. The role of all exogenous states is dampened.

These are great news for implementation if the housing prices surge; conversely, if housing

Table 15: Increase in taxes as a result of the high external demand

Liquidity Regime	Shock to y^T	News	Increase (%)
Low liquidity	Bad Shock	Bad News	35.88
		Avg News	48.81
		Good news	49.45
	Avg Shock	Bad News	38.72
		Avg News	42.67
		Good news	59.59
	Good Shock	Bad News	52.88
		Avg News	41.91
		Good news	66.16
High liquidity	Bad Shock	Bad News	39.08
		Avg News	40.30
		Good news	49.18
	Avg Shock	Bad News	41.87
		Avg News	40.69
		Good news	55.11
	Good Shock	Bad News	47.10
		Avg News	43.62
		Good news	48.83

prices colapse, implementation may become more challenging.

Consequently, these results show the complexity of the optimal tax schedule: it is very hard to establish a simple rule that comes near this state-dependent optimal policy. Since the role of news shocks and liquidity regimes may be strengthened or weakened, the changes in external demand make it even harder to come close to the optimal macroprudential policy.

As such, the results presented show how fundamental macroprudential policy is, with its potential to decrease the probability of crises by more than half and also to dampen their effects, as well as to decrease the volatility of the current account and real exchange rate. However, results also highlight how hard it is to make it right. The findings of this paper show that the implementation challenges may become easier when house prices rise, but become even harder when they decrease.

4 Conclusions

This paper studied financial crises and optimal policy to prevent them or mitigate their effects, and how the latter changes when the housing sector is at play. It did so by introducing land into a quantitative non-linear model of financial crises designed to study optimal macroprudential policy under a framework with news shocks about future fundamentals and regime changes in global liquidity. In this framework, overborrowing leading to avoidable financial crises occurs because there is a pecuniary externality that drives a wedge between the competitive equilibrium and the social optimal, since borrowers do not fully internalize the impact of their borrowing decision on the price of the collateral. However, considering housing is a key component of the Fisher's debt-deflation channel that is central to these models (either through price or collateral amount), the proper modeling of the housing sector in this framework is essential for a welfare-based quantitative evaluation of macroprudential policy based on it. Using data from Argentina, the implications of the introduction of housing were studied. This extension of the model allowed to study how macroprudential policy should change with external demand for housing. Using data for Spain, I performed a comparative statics exercise where the stochastic equilibrium of a reference scenario was compared to one with an increase in external demand associated to a 10% price surge.

The baseline model moments obtained show that, if housing is considered without the introduction of a channel for it to impact the collateral constraint, macroprudential policy becomes less effective both at preventing crises and softening their effects. When lenders care about residential assets, the amplification mechanism is enhanced by the introduction of land and thus the pecuniary externality increases. Macroprudential policy continues to be less effective at preventing crises than it would be in a setting without land, but it becomes much more effective at dampening their effects. Overall, there is a significant increase in the average tax (38.7% higher). As opposed to the previous setting without the housing-collateral channel, implementation becomes slightly easier, as the differences in state-contingent tax from state to state are softened.

Results regarding the price surge showed that, even when - by construction - the increase in average land prices is completely exogenous and permanent, macroprudential policy should lean against the wind in most relevant settings. This challenges previous results in the literature according to which optimal capital controls under these models are, short of a financial crisis, countercyclical. Not only do results show that macroprudential authorities should instead strengthen macroprudential policies when land prices increase significantly and vice-versa, but also that the strengthening of optimal macroprudential policy should be commensurate with the average increase in prices (a 45.4% increase in the tax for a 10% increase in prices).

However, while results encourage an active approach on the part of macroprudential authorities, they also highlight the complexity of the optimal tax schedule and show that the implementation challenges may be even harder than previously thought. Surges in housing prices ease those challenges, but the reverse is also true.

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