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# Housing boom-bust cycles and asymmetric macroprudential policy

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## Abstract

Macroprudential policy is pre-emptive, aimed at preventing crises. An interpretation of this definition is a policy of tightening credit strongly during the boom phase of a cycle, but potentially unwinding slowly thereafter. Empirical evidence indeed hints at the existence of such asymmetric policy. I use a New Keynesian model with a financial friction on mortgage borrowing and collateral to show what implications this asymmetry might have on the economy. The main source of fluctuations is a bubble in the housing market, which causes house prices and credit to deviate from their fundamental values, leading to a boom and bust cycle. The main macroprudential tool is the regulatory loan to value (LTV) ratio. I find that while the asymmetric policy dampens the boom phase, it introduces more volatility in the economy by exacerbating the correction that follows. The higher the asymmetry in the policy response, the more volatile the economy is relative to one in which policy reacts symmetrically. Although both savers' and borrowers' consumption become more volatile, that of borrowers is especially sensitive as they are credit constrained and cannot smoothen consumption. Furthermore, the increased inflation volatility can create tensions between the goals of monetary and macroprudential policies. In this regard, policymakers are advised to unwind macroprudential policy just as strongly during the recovery phase of a cycle, such that the economy can exit the recession quicker, and credit, output and inflation are stabilised better.

**Keywords:** *asymmetric macroprudential policy, house price expectations, news shocks, credit booms, time-varying LTV ratio*

**JEL codes:** C61, E32, E44, E61, R21

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*“I would argue that, yes, bubbles do exist, but that it is very hard to identify them with certainty and almost impossible to reach a consensus about whether a particular asset price boom period should be considered a bubble or not.”*

Jean-Claude Trichet  
President of the ECB  
June 2005

## 1 Introduction

Writing in 2004, Ben Bernanke, then a member of the Board of Governors of the Federal Reserve System, noted how structural changes, better macroeconomic policies but also ‘good luck’ contributed to the macroeconomic stability witnessed over a period now referred to as the Great Moderation.<sup>1</sup> Yet, the build-up and eventual bursting of the housing bubble and the financial crisis that ensued a few years later, notably in the US, the UK and Spain, suggest that there is much further improvement to be made. While structural reforms are feasible, they are long term measures which do little to stabilize short to medium term fluctuations until they take full effect. Luck, by definition, is random. This leads to a focus on better macroeconomic policies which can stabilize business cycles driven by financial factors. In this paper I analyse the role that macroprudential policy can play in this regard when it is asymmetric; that is, used mainly during the boom phase of the cycle.

### 1.1 Asset price bubbles

Monetary policy has been effective in stabilizing inflation by anchoring inflationary expectations in many advanced economies, however it has been less successful in taming asset price swings. Gradual changes to the nominal interest rate do little to stabilize asset price boom-bust cycles, and nowadays there is widespread recognition that monetary policy is a blunt tool to address asset price booms (Trichet, 2005; Bernanke, 2010). Such policy, dubbed ‘leaning against the wind’, induces costs which are greater than the benefits (Svensson, 2017) and moreover seemingly violates the Tinbergen Principle since the nominal interest rate is a tool dedicated to promoting price stability, not financial stability (Galati and Moessner, 2013; Jordà et al., 2015a).

Asset price booms are frequently associated with an increase in credit through collateral (net worth) effects, and a booming literature on debt-fuelled crises unequivocally shows that highly leveraged economies develop a greater risk of experiencing heavy contractions and slow recoveries, often experienced as ‘financial crisis recessions’ (Reinhart and Rogoff, 2009, 2013; Schularick and Taylor, 2012; Jordà et al., 2015b, 2017). Two seemingly different narrations can explain this correlation. One is an exogenous increase in credit which leads to strong demand for assets, raising relative prices. This would support the hypothesis that in some countries asset price booms were driven by an increase in credit supply, brought about by changes to credit conditions (Mian and Sufi, 2009; Justiniano et al., 2017), deregulation (Favara and Imbs, 2015) or international capital inflows (Cesa-Bianchi et al., 2017). Another hypothesis reflects an endogenous process generated by collateralized borrowing, where any expected changes to the value of the underlying asset drives up borrowing, which further boosts the asset’s price, and so on (Kiyotaki and Moore, 1997; Iacoviello, 2005; Liu et al., 2013). These two hypothesis are complementary, as the initial change can be brought about by credit supply factors or expected

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<sup>1</sup> Bernanke (2004).

asset price changes, setting off the endogenous process. Indeed, while [Jordà et al. \(2015a\)](#) find a causal relationship flowing from loose monetary conditions to house price booms, [Case and Shiller \(2003\)](#) find that expectations of future house price appreciation in a number of US states were highest in 1988 and 2003, periods during which house prices and the credit to GDP ratio were at or close to peak levels around that time (Figure 1).

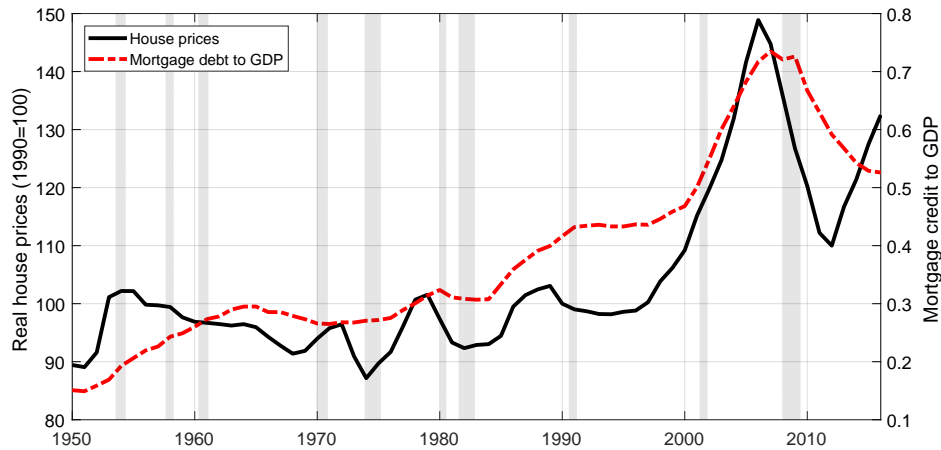


Figure 1: House prices and mortgage debt to GDP in the US

Notes: House prices are deflated using the CPI. Data are sourced the FRED database and extended backwards using the data in [Jordà et al. \(2017\)](#) and [Knoll et al. \(2017\)](#). Data codes and further details are available in Appendix A. Shaded regions represent recessions as dated by the NBER.

## 1.2 Macroprudential policy

Despite several rounds of monetary tightening, credit to GDP ratios have generally maintained an upward trend in several advanced economies, driven by financial liberalization in the 1980s and peaking around the onset of the financial crisis of 2007/8 (Figures 1 and 2). [Goodhart \(2009\)](#) notes that many major central banks and the Bank for International Settlements had been flagging the underpricing of risk and the build-up in excessive leverage several years prior to the crisis. However, at that time policymakers in these economies were lacking the regulatory framework to use macroprudential instruments suitable to counter the housing bubble and lax lending practices that led to the crisis. [Gambacorta and Murcia \(2017\)](#) show that a range of macroprudential tools, used mostly in emerging and developing economies, indeed are effective in dampening credit cycles. In addition, [Boar et al. \(2017\)](#) find that countries which routinely use macroprudential policies tend to experience stronger and less volatile GDP growth. Such tools, such as caps on loan to value (LTV) ratios, reserve requirements and countercyclical capital adequacy requirement ratios, indeed seem like the way forward to promote financial stability and hence more stable business cycles. Macroprudential policies targeting real estate booms have been used in countries such as China, Hong Kong (SAR), Korea, Sweden, Canada and New Zealand ([Crowe et al., 2011](#); [Krznar and Morsink, 2014](#); [Rogers, 2014](#)). However, experience with macroprudential policy in most advanced economies is relatively sparse ([Cerutti et al., 2017](#)), and debates are still being had on what the macroprudential policy reaction function should look like.<sup>2</sup>

<sup>2</sup> See [Haldane \(2017\)](#) and the references therein.

The use of any policy instrument raises an important consideration on the potential for policy biases and mistakes. This is especially so when experience with such tools is limited.<sup>3</sup> For example, a number of authors find that the conduct of monetary policy has been shaped by a particular preference to avoid a certain outcome, such as a stronger preference to avoid a negative output gap.<sup>4</sup> In that case, such an asymmetry causes an inflation bias (Nobay and Peel, 2003; Surico, 2008).

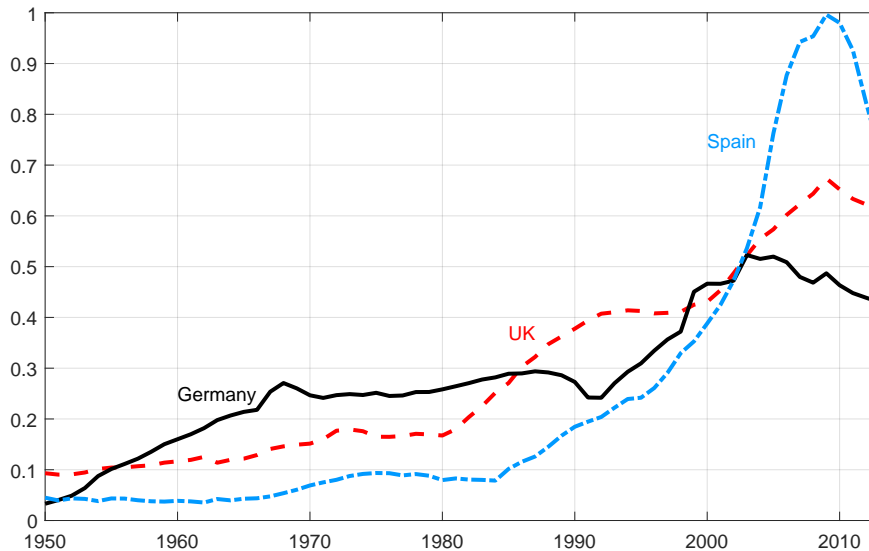


Figure 2: Mortgage debt to GDP in selected advanced economies

Note: Data are sourced from Jordà et al. (2017).

The same phenomenon can be extended to the conduct of macroprudential policy. Since the inherent task of macroprudential policy is to limit, *pre-emptively*, the build-up of systemic risk (Bank of England, 2009), it is reasonable to argue that there might be an implicit, stronger focus on the part of policymakers on the boom phase and associated tightening of credit conditions. This is especially the case since, as discussed above, high leverage increases the probability of a financial crisis, making policymakers generally averse to credit booms.

Indeed, as discussed in Rogers (2014), this line of thought is reflected in the Reserve Bank of New Zealand’s implementation of macroprudential policy: LTV policies are not routinely used to smoothen cycles, but “to limit the extreme peaks in house price and housing credit cycles.” (p.5; emphasis added). Similar reasoning is discussed in Cerutti et al. (2017, p.215), who argue that “macroprudential policies are meant to be mostly *ex-ante* rules, that is, they should help reduce the boom part of the financial cycle”. Using a large database of macroprudential policies from 119 countries for the period 2000-2013, they find that macroprudential policies tend to have an effect on real credit growth mostly during a boom. This result is derived from a reduced form regression and is open to at least two interpretations. The first could be that other factors, such

<sup>3</sup> Crowe et al. (2011) chronicle how some early LTV ratio policies were circumvented using clever tricks.

<sup>4</sup>Cukierman and Muscatelli (2008) show that prior to the shift to inflation targeting in the early 1990s, the Bank of England tended to want to avoid recessions rather than booms, and since the start of inflation targeting, had a stronger preference to avoid inflation overshooting rather than undershooting. Dolado et al. (2005) find that some of the major European central banks tended to place more weight on positive inflation and output gaps relative to negative gaps. More recently, Paloviita et al. (2017) show that the ECB’s monetary policy reaction function was not symmetric, but that reactions to overshooting inflation were typically stronger, which could in part reflect the “below, but close to, two percent” emphasis in its definition of price stability. See also Surico (2003, 2008); Nobay and Peel (2003) and Dolado et al. (2004).

as consumer and business confidence, are more important during busts. Another interpretation is that macroprudential policy loosening is typically weak during busts, possibly out of fear of re-igniting the boom before enough correction has taken place. In this paper I focus on the latter interpretation, as well as the implied strategy behind the definition for macroprudential policy, which I label as asymmetric macroprudential policy. I contribute to the literature by studying the macroeconomic implications of following asymmetric policy, focusing on two aspects. The first is the role it plays in output stabilization through a boom-bust cycle. The second is whether this policy impacts savers and borrowers differently.

I answer these questions using a DSGE model with representative saver and borrower households and housing, as in [Iacoviello \(2005\)](#) and [Rubio and Carrasco-Gallego \(2014\)](#).<sup>5</sup> Housing is an important factor behind macroeconomic fluctuations; [Iacoviello \(2015\)](#) finds that housing demand shocks explain about a third of the decline in output in the US during the financial crisis. [Jordà et al. \(2017\)](#) find that a significant proportion of credit growth is typically channelled to the housing sector, and financial liberalization and rising LTV ratios have increased the length and amplitude of financial cycles.<sup>6</sup> The financial friction in the model originates from collateralized borrowing, giving rise to a financial accelerator which amplifies the effect of a shock to net worth on economic activity ([Kiyotaki and Moore, 1997](#); [Bernanke et al., 1999](#)). This constraint motivates the use and effectiveness of macroprudential policy which controls leverage countercyclically through adjustments to the maximum LTV ratio. These adjustments tame credit booms by weakening the financial accelerator, thus dampening boom-bust cycles when these are driven by inefficient or strong asset price and credit growth. Such policy is not micro-founded but taken as given in accordance with regulation.

In this paper the driver of boom-bust cycles are unrealized *news shocks*, which give rise to the formation of asset price bubbles through expectations which are *ex-ante* rational but revealed *ex-post* to be disconnected from fundamentals. Such shocks have been recently included in models with a housing market as an additional driver of cycles ([Lambertini et al., 2013b](#); [Kaplan et al., 2017](#)). The reaction to the news shock follows the literature on herd behaviour and information cascades in financial markets ([Banerjee, 1992](#); [Bikhchandani et al., 1992](#); [Shiller, 2000](#), p. 151). It also follows [Bernanke and Gertler \(1999\)](#), who include asset price bubbles as a source of volatility in the celebrated BGG model<sup>7</sup> and [Christiano et al. \(2008, 2010\)](#) who add unrealized news shocks to technology in a standard New Keynesian model. More recently, [Bruneau et al. \(2016\)](#) estimate a model with both unanticipated and anticipated housing demand shocks, and [Burlon et al. \(2016\)](#) include a non-fundamental shock to house prices in a similar modelling framework.

I find that conducting macroprudential policy asymmetrically introduces more volatility in the economy, compared to a scenario in which the borrowing limit is revised symmetrically. This stems from the fact that collateral constraints are kept relatively tighter during the bust phase, affecting mainly borrower households whose consumption dynamics are strongly influenced by their leverage. A greater drop in borrowers' consumption then further exacerbates the correction in output. These findings lend support to a policy prescription laid in a 2017 speech by Alex Brazier, who argues that “[m]acroprudential policy must be fully countercyclical; not only tightening as risks build, but also loosening as downturn threatens.” ([Brazier, 2017](#)).<sup>8</sup>

<sup>5</sup> Although heterogeneous agent models with idiosyncratic shocks are more appropriate for studying distributional effects, the setup in this paper can be taken as the limiting case in which all idiosyncratic uncertainty can be insured.

<sup>6</sup> See also [Drehmann et al. \(2014\)](#) and [Borio \(2014\)](#).

<sup>7</sup> [Bernanke et al. \(1999\)](#).

<sup>8</sup> It also echoes the suggestion made by Jean-Claude Trichet in 2005, speaking in the context of monetary

I show that this increased volatility in output rises monotonically with the degree of asymmetry in the policy response, defined as the strength of the response during credit booms relative to that during credit busts. In addition, I find that since borrowers have a high marginal propensity to consume, they are hit particularly hard by such policy. Their consumption volatility is higher than that of savers and rises relatively faster as the degree of policy asymmetry intensifies. This paper therefore contributes to the debate on how macroprudential rules should be implemented, showing that it is equally important to consider the role of such policy during the *bust* phase of the cycle. This tends to receive less attention in the literature on macroprudential policy rules. I also contribute to the literature on the interaction between monetary and macroprudential policies, noting that while macroprudential policy reduces the strain on monetary policy during asset price driven booms, there are possibly negative spillovers from (asymmetric) macroprudential policy to monetary policy.

The rest of the paper is structured as follows. Section 2 describes the model, defines a competitive equilibrium and derives key steady state relationships. Section 3 emphasises the theoretical importance and empirical relevance of news shocks as driving forces in DSGE models, and explains the stochastic process of the key shock in the model. Section 4 discusses the benchmark calibration, while section 5 defines an asymmetric macroprudential rule and discusses how the model is solved. Section 6 presents impulse response analysis and compares symmetric and asymmetric macroprudential policy, and section 7 presents robustness checks and generalizes the result over varying degrees of asymmetry. Section 8 touches on policy issues related to the use of macroprudential policies. Section 9 concludes.

## 2 The model

I derive a New Keynesian model with financial frictions originating from borrowing constraints. The setup is very similar to that in [Rubio and Carrasco-Gallego \(2014, 2016\)](#), who build on [Iacoviello \(2005\)](#). It is also very similar to [Liu et al. \(2013\)](#), apart from the fact that in their model the financial friction is faced solely by the productive sector. There are six types of infinitely-lived agents in the model: patient households, impatient households, intermediate and final goods firms, the central bank and the financial regulator. The numeraire is the price of the final good, therefore wages and house prices are expressed in units of consumption goods.

Households consume the final good, hold housing as a durable good and supply labour to intermediate goods firms. Housing is fixed in supply and does not depreciate.<sup>9</sup> Intermediate goods firms use labour to produce differentiated goods, which are packaged and sold as a final homogeneous good by the final good firm.<sup>10</sup> Intermediate goods firms are subject to a price setting friction, which introduces nominal rigidities in the model, giving rise to real effects of monetary disturbances. This allows the study of macroprudential policy in the presence of monetary policy. Impatient households face a borrowing constraint. As this is binding, it introduces amplification of real disturbances via a financial accelerator effect through changes in net wealth ([Bernanke et al., 1999](#)). Given the presence of these two distortions, the central bank and the financial regulator are tasked with maintaining price and financial stability respectively using

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policy which ‘leans against the wind’: *“By reacting more symmetrically - i.e. being tighter in booms as well as looser in busts - the central bank would discourage excessive risk-taking and thereby reduce over-investment already during the boom. This in turn would lead to a lower level of indebtedness and less severe consequences of a possible future bust.”* ([Trichet, 2005](#)).

<sup>9</sup> This is a simplification to guide intuition; see [Iacoviello and Neri \(2010\)](#) who allow for depreciation and model investment in the housing supply.

<sup>10</sup> To simplify the model I abstract from capital accumulation in the economy.



appropriate policy tools.

## 2.1 Households

There are two household types in the model, each of size one, having almost identical preferences. The source of heterogeneity between them is the rate at which they discount the future, which is the fundamental requirement for a distinction between savers and borrowers. As is standard in the literature, households with the higher discount factor are termed patient and hence will in equilibrium save and receive interest on resources (Kiyotaki and Moore, 1997). On the other hand, households with the lower discount factor will in equilibrium want to consume more than their budget, and hence will borrow and pay interest on resources to finance spending. Both household types derive utility from consumption, housing and leisure, and take wages and the interest rate as given. On the basis of the behaviour type, household variables are denoted with a subscript  $i \in \{s, b\}$  for savers and borrowers respectively. It is assumed that credit flows from savers to borrowers efficiently, so the presence of a financial intermediary is redundant.<sup>11</sup>

### 2.1.1 Patient households - savers

Savers aim to maximise lifetime utility subject to their per-period budget constraint, discounting future utility streams at  $\beta_s \in (0, 1)$ . They choose consumption  $C_{s,t}$ , housing  $H_{s,t}$  and labour supply in hours  $N_{s,t}$ , and form external habits in consumption governed by the parameter  $\varrho \in (0, 1)$ . Preferences are given by

$$U_s = \max_{C_s, H_s, N_s} \mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta_s^t \left( (1 - \varrho) \log(C_{s,t} - \varrho C_{s,t-1}) + j_t \log H_{s,t} - \tau \frac{N_{s,t}^{1+\varphi}}{1+\varphi} \right) \right\}$$

where  $\tau > 0$  is a preference parameter which shifts the labour supply schedule, and  $\varphi > 0$  is the inverse of the Frisch elasticity of labour supply. The process  $j_t$  is a shock to the marginal utility of housing, which is typically referred to as a housing demand shock in the literature, and is discussed further below.<sup>12</sup>

Patient households consume the final good, change their stock of housing at the current market price and save via a one-period loan instrument  $B_t$ . They earn labour income, and accrue savings from the previous period with interest. Furthermore, savers are assumed to own the production sector and hence receive lump-sum profits from intermediate goods firms. Their budget constraint is:

$$C_{s,t} + q_t(H_{s,t} - H_{s,t-1}) + B_t = w_{s,t}N_{s,t} + \frac{R_{t-1}B_{t-1}}{\pi_t} + \Pi_t \quad (1)$$

where  $q_t$  is the relative price of housing to consumption goods,  $w_{s,t}$  is the real hourly wage rate,  $R_t$  is the gross nominal interest rate and  $\pi_t \equiv \frac{P_t}{P_{t-1}}$  is the gross inflation rate for goods prices. Savers are assumed to lend in real terms in time  $t$  and receive back a nominal amount in time  $t + 1$ , such that debt is not indexed, as in Iacoviello (2005).<sup>13</sup> The term  $\Pi_t$  represents profits from intermediate goods producers, defined below.<sup>14</sup>

<sup>11</sup> See Gerali et al. (2010) and Iacoviello (2015) for models with frictions in the banking sector.

<sup>12</sup> See Iacoviello and Neri (2010) for a discussion and possible interpretations of this shock.

<sup>13</sup> This implies that an increase in prices between period  $t - 1$  and  $t$  lowers the real return on saving.

<sup>14</sup> Profits in real terms are equal to the difference between price and marginal cost of output;  $\Pi_t = (1 - MC_t)Y_t$ .

The first-order conditions for this problem are:

$$\frac{1 - \varrho}{C_{s,t} - \varrho C_{s,t-1}} = \beta_s \mathbb{E}_t \left\{ \left( \frac{1 - \varrho}{C_{s,t+1} - \varrho C_{s,t}} \right) \frac{R_t}{\pi_{t+1}} \right\} \quad (2)$$

$$q_t \left( \frac{1 - \varrho}{C_{s,t} - \varrho C_{s,t-1}} \right) = \frac{j_t}{H_{s,t}} + \beta_s \mathbb{E}_t \left\{ q_{t+1} \left( \frac{1 - \varrho}{C_{s,t+1} - \varrho C_{s,t}} \right) \right\} \quad (3)$$

$$w_{s,t} \left( \frac{1 - \varrho}{C_{s,t} - \varrho C_{s,t-1}} \right) = \tau N_{s,t}^\varphi \quad (4)$$

Equation (2) is the typical Euler equation over lending and equation (3) is the Euler equation specifying demand for housing. Savers aim to smoothen consumption by matching the return on saving to the cost of foregone consumption. Given that housing is a durable good, it not only increases utility in the current period but it also increases the amount of resources available in the next period, through its resale value. Equation (4) defines labour supply by equating marginal utilities over consumption and leisure.

### 2.1.2 Impatient households - borrowers

Impatient households have similar preferences as savers, with the exception of the discount factor  $\beta_b \in (0, 1)$ , where by assumption  $\beta_b < \beta_s$ :

$$U_b = \max_{C_b, N_b, H_b} \mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta_b^t \left( (1 - \varrho) \log(C_{b,t} - \varrho C_{b,t-1}) + j_t \log H_{b,t} - \tau \frac{N_{b,t}^{1+\varphi}}{1 + \varphi} \right) \right\}$$

They receive labour income and supplement their budget by obtaining an amount of borrowing  $B_t$  as a one-period loan at the gross rate  $R_t$ . These inflows finance the purchase of the consumption good and housing, and the repayment of the previous period's loan:

$$C_{b,t} + q_t(H_{b,t} - H_{b,t-1}) + \frac{R_{t-1}B_{t-1}}{\pi_t} = w_{b,t}N_{b,t} + B_t \quad (5)$$

taking the wage and interest rate as given. Note that the loan is written on the right hand side of the budget constraint. This implies a market clearing condition in every period such that the total saving by patient households through this loan instrument is equal to the total borrowing by impatient households.<sup>15</sup>

Following [Kiyotaki and Moore \(1997\)](#), savers can only enforce repayment of the loans by securing them against collateral. In this model housing is a durable good which can be pledged as collateral, and the fraction of borrowing relative to housing wealth is the LTV ratio. Therefore the maximum borrowing for impatient households is limited by a collateral constraint, written in terms of a time-varying LTV ratio  $m_t$  of their expected value of housing wealth in the next period:

$$R_t B_t \leq m_t \mathbb{E}_t \{ q_{t+1} \pi_{t+1} \} H_{b,t} \quad (6)$$

Section (2.5) discusses how  $m_t$ , the LTV ratio, is used as a policy tool by the financial regulator to actively relax or tighten the collateral constraint to boost or reduce credit flows. Since house prices respond to economic conditions, the collateral constraint is endogenous and thus can generate a strong financial accelerator, leading to amplified responses of output to exogenous disturbances. Note that the borrowing limit can rise if either (a.) the value of housing

<sup>15</sup> I use the terms loan, borrowing, credit and mortgage debt interchangeably in this paper since the latter is the only liability that borrowers hold.

wealth rises, (b.) the LTV ratio  $m_t$  rises, or (c.) the expected real interest rate  $\tilde{R}_t = \mathbb{E}_t \left\{ \frac{R_t}{\pi_{t+1}} \right\}$  falls.

The FOCs for this problem are:

$$\frac{1 - \varrho}{C_{b,t} - \varrho C_{b,t-1}} = \beta_b \mathbb{E}_t \left\{ \left( \frac{1 - \varrho}{C_{b,t+1} - \varrho C_{b,t}} \right) \frac{R_t}{\pi_{t+1}} \right\} + R_t \mu_t \quad (7)$$

$$q_t \left( \frac{1 - \varrho}{C_{b,t} - \varrho C_{b,t-1}} \right) = \frac{j_t}{H_{b,t}} + \beta_b \mathbb{E}_t \left\{ q_{t+1} \left( \frac{1 - \varrho}{C_{b,t+1} - \varrho C_{b,t}} \right) \right\} + \mu_t \mathbb{E}_t \{ m_t q_{t+1} \pi_{t+1} \} \quad (8)$$

$$w_{b,t} \left( \frac{1 - \varrho}{C_{b,t} - \varrho C_{b,t-1}} \right) = \tau N_{b,t}^\varphi \quad (9)$$

where  $\mu_t > 0$  is the Lagrange multiplier on the borrowing constraint. Equations (7)-(9) are the Euler equations over borrowing and housing demand respectively and the intratemporal labour supply equation. It can be seen that the borrowing constraint introduces a wedge between the marginal benefit and marginal cost of decisions. Borrowers are constrained by their borrowing limit and are therefore not able to fully smoothen consumption, making them unable to adjust fully in the wake of shocks. This implies that they have a higher marginal propensity to consume out of current income than savers. Note that shocks to housing preferences  $j_t$  generate an immediate response in housing demand and house prices, for both household types.<sup>16</sup>

## 2.2 Firms

The supply side of the model is standard as in the New Keynesian model, featuring Dixit-Stiglitz monopolistic competition with price setting frictions. Production of the final consumption good involves two stages: the manufacture of intermediate goods by a continuum of firms and the packaging of all these intermediate goods into a final good by another. Both firms are owned by savers and thus use the corresponding stochastic discount factor in intertemporal decisions.

### 2.2.1 Final goods firm

The final consumption good is produced by a competitive firm that takes as inputs a continuum of intermediate goods  $y_{j,t}$ , where  $j \in (0, 1)$ , and aggregates them using Dixit-Stiglitz CES technology with elasticity of substitution between varieties  $\sigma > 1$ :

$$Y_t = \left[ \int_0^1 y_{j,t}^{\frac{\sigma-1}{\sigma}} dj \right]^{\frac{\sigma}{\sigma-1}} \quad (10)$$

The firm aims to minimize the cost of a bundle  $\int_0^1 p_{j,t} y_{j,t} dj$  in each period, subject to the

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<sup>16</sup> Solving for  $H_s$  in (3), we get:

$$H_{s,t} = j_t \left( \frac{\widehat{C}_{s,t}}{q_t} - \beta_s \mathbb{E}_t \left\{ \frac{\widehat{C}_{s,t+1}}{q_{t+1}} \right\} \right)$$

where  $\widehat{C}_{s,t} = \frac{C_{s,t} - \varrho C_{s,t-1}}{1 - \varrho}$ . Housing demand  $H_{s,t}$  increases as the preference term  $j_t$  rises. The same holds for borrowers, although their housing demand function also includes the shadow cost of the borrowing constraint. In that case an increase in the LTV ratio  $m_t$  or an increase in inflation  $\pi_t$  also increases housing demand by borrowers, as both of these variables relax the borrowing constraint. The former directly, by increasing outright the borrowing limit, and the latter by reducing the real burden of debt.

technology described above. Demand for intermediate good  $y_{j,t}$  is given by:

$$y_{j,t} = \left( \frac{p_{j,t}}{P_t} \right)^{-\sigma} Y_t \quad (11)$$

where the aggregate price  $P_t$  for the final good is a weighted average over the set of intermediate goods prices:

$$P_t = \left( \int_0^1 p_{j,t}^{1-\sigma} dj \right)^{\frac{1}{1-\sigma}} \quad (12)$$

### 2.2.2 Intermediate goods firms

A continuum of intermediate goods firms indexed by  $j \in (0, 1)$  operate in a monopolistically-competitive market, and each firm faces the downward sloping demand curve (11) with an elasticity depending on the substitutability across goods. Production of each firm is based on constant returns to scale technology using labour from both household types. All firms are subject to an aggregate technology shock  $A_t$ , which evolves as  $\log(A_t) = \rho_A \log(A_{t-1}) + (1 - \rho_A) \log(\bar{A}) + \epsilon_{A,t}$ , where  $\epsilon_{A,t} \sim N(0, \sigma_A^2)$  is an i.i.d. shock. Each firms' production technology delivers constant returns to scale:

$$y_{j,t} = A_t n_{s,j,t}^\alpha n_{b,j,t}^{1-\alpha}$$

where  $n_{s,j,t}$  and  $n_{b,j,t}$  are labour input from savers and borrowers respectively and  $\alpha \in (0, 1)$  is the share of income from production of savers. Cobb-Douglas technology has some desirable features; it allows for an analytical solution for the steady state of the model, and yields an interpretation for  $\alpha$  and  $1 - \alpha$  as the relative economic size of saver and borrower households respectively.<sup>17</sup> Each firm  $j$  faces two optimization problems; a static choice over labour to minimize production costs in each period, and a dynamic choice for the price which maximises present and future discounted profits. Firms take wages as given in both these problems. Cost minimization by any firm  $j$  is given by

$$\min_{n_{s,j,t}, n_{b,j,t}} w_{s,t} n_{s,j,t} + w_{b,t} n_{b,j,t} + MC_{j,t} \left( y_{j,t} - A_t n_{s,j,t}^\alpha n_{b,j,t}^{1-\alpha} \right)$$

where  $MC_t$  are real marginal costs. The first order conditions characterising optimal labour demand are:

$$n_{s,j,t} = \alpha \frac{MC_{j,t} y_{j,t}}{w_{s,t}} \quad (13)$$

$$n_{b,j,t} = (1 - \alpha) \frac{MC_{j,t} y_{j,t}}{w_{b,t}} \quad (14)$$

Using these optimality conditions, we can define marginal costs as

$$MC_t = \frac{1}{A_t} \left( \frac{w_{s,t}}{\alpha} \right)^\alpha \left( \frac{w_{b,t}}{1 - \alpha} \right)^{1-\alpha} \quad (15)$$

As marginal costs of production do not depend on characteristics of any firm  $j$ , and since technology is symmetric across all firms, we can drop the subscript  $j$  in (13) and (14) to ease notation.

Intermediate goods firms are subject to the Calvo-Yun price setting friction in their profit maximisation. In any given period a random fraction of firms  $\omega$  are not able to change prices.

<sup>17</sup> Iacoviello and Neri (2010) find that changing the substitutability between saver and borrower labour hours yields similar results but complicates the analysis unnecessarily, since it introduces a feedback loop between labour supply decisions and borrowing constraints.

With this knowledge, the remaining  $1 - \omega$  of firms set prices such that they maximise present and expected future discounted profits:

$$\max_{p_{j,t}} \mathbb{E}_t \left\{ \sum_{i=0}^{\infty} \omega^i \Lambda_{i,t+i} \left[ \frac{p_{j,t}}{P_{t+i}} y_{j,t+i} - MC_{t+i} y_{j,t+i} \right] \right\}$$

where  $\Lambda_{i,t+i} = \beta_s^i \frac{C_{s,t+i} - \rho C_{s,t+i-1}}{C_{s,t} - \rho C_{s,t-1}} = \beta_s \frac{\tilde{C}_{s,t+i}}{\tilde{C}_{s,t}}$  is the relevant stochastic discount factor and the term in square brackets is equal to profit in period  $t + i$ , which is rebated to savers. Using the demand curve faced by each firm  $y_{j,t} = \left( \frac{p_{j,t}}{P_t} \right)^{-\sigma} Y_t$ , we can write the above problem as:

$$\max_{p_{j,t}} \mathbb{E}_t \left\{ \sum_{i=0}^{\infty} \omega^i \Lambda_{i,t+i} Y_{t+i} \left[ \left( \frac{p_{j,t}}{P_{t+i}} \right)^{1-\sigma} - MC_{t+i} \left( \frac{p_{j,t}}{P_{t+i}} \right)^{-\sigma} \right] \right\}$$

As shown in [Christiano et al. \(2011\)](#), the solution to this problem leads to the following system of equations:

$$\Upsilon_t = \left( \frac{\sigma - 1}{\sigma} \right) \left( \frac{1 - \omega}{1 - \omega \pi_t^{\sigma-1}} \right)^{\frac{1}{\sigma-1}} \Phi_t \quad (16)$$

$$\Upsilon_t = \frac{Y_t}{\tilde{C}_{s,t}} MC_t + \omega \beta_s \mathbb{E}_t \{ \pi_{t+1}^{\sigma} \Upsilon_{t+1} \} \quad (17)$$

$$\Phi_t = \frac{Y_t}{\tilde{C}_{s,t}} + \omega \beta_s \mathbb{E}_t \{ \pi_{t+1}^{\sigma-1} \Phi_{t+1} \} \quad (18)$$

which characterise the non-linear formulation of the New Keynesian Phillips curve and jointly determine price dynamics.<sup>18,19</sup> See Appendix B for further details. Log-linearization of these conditions around a zero net inflation rate, combined with the dynamics of aggregate prices, yields the familiar New Keynesian Phillips curve:

$$\hat{\pi}_t = \beta_s \mathbb{E}_t \{ \hat{\pi}_{t+1} \} + \frac{(1 - \omega)(1 - \omega \beta_s)}{\omega} \widehat{MC}_t$$

where variables with a hat denote percentage deviations from steady state.

### 2.3 Market clearing

The market for labour employed by intermediate goods firms clears:

$$N_{s,t} = \int_0^1 n_{s,j,t} dj = \alpha \frac{MC_t Y_t}{w_{s,t}} \quad (19)$$

$$N_{b,t} = \int_0^1 n_{b,j,t} dj = (1 - \alpha) \frac{MC_t Y_t}{w_{b,t}} \quad (20)$$

I keep the housing supply ( $H$ ) fixed and normalized to 1, and the following housing market clearing condition holds in each period:

$$H_{s,t} + H_{b,t} = 1 \quad (21)$$

<sup>18</sup> This specification nests the familiar log-linearized version but has the advantage that it can be used to study dynamics based on higher order perturbations ([Schmitt-Grohé and Uribe, 2006](#)) or simulations around a non-zero steady state inflation rate ([Ascari and Sbordone, 2014](#)).

<sup>19</sup> When there is no nominal rigidity ( $\omega = 0$ ) we get the standard result that marginal costs are always constant ( $MC_t = \frac{\sigma-1}{\sigma}$ ).

Following Yun (1996) and Christiano et al. (2011), let  $Y_t^*$  be the unweighed sum of output from intermediate goods firms. Since all firms use labour in the same proportions, this can be written as

$$Y_t^* = \int_0^1 y_{j,t} dj = A_t \int_0^1 n_{s,j,t}^\alpha n_{b,j,t}^{1-\alpha} dj = A_t N_{s,t}^\alpha N_{b,t}^{1-\alpha}$$

Alternatively, summing over the demand across all intermediate firms and equating  $Y_t^*$ :

$$\begin{aligned} Y_t^* &= \int_0^1 y_{j,t} dj = Y_t \int_0^1 \left( \frac{p_{j,t}}{P_t} \right)^{-\sigma} dj \\ \Rightarrow Y_t &= \frac{Y_t^*}{s_t} = \frac{A_t}{s_t} N_{s,t}^\alpha N_{b,t}^{1-\alpha} \end{aligned} \quad (22)$$

where  $s_t = \int_0^1 \left( \frac{p_{j,t}}{P_t} \right)^{-\sigma} dj > 1$  is the measure of output cost of price dispersion, which reduces aggregate output compared with an economy with flexible prices (Yun, 1996).<sup>20</sup> This measure can be written recursively as:

$$\begin{aligned} s_t &= (1 - \omega) \left( \frac{p_t^*}{P_t} \right)^{-\sigma} + \omega \pi_t^\sigma s_{t-1} \\ &= (1 - \omega) \left( \frac{1 - \omega \pi_t^{\sigma-1}}{1 - \omega} \right)^{\frac{\sigma}{\sigma-1}} + \omega \pi_t^\sigma s_{t-1} \end{aligned} \quad (23)$$

The goods market clearing condition can therefore be written as:

$$Y_t = C_{s,t} + C_{b,t} = \frac{A_t}{s_t} N_{s,t}^\alpha N_{b,t}^{1-\alpha} \quad (24)$$

such that all output produced is consumed.

## 2.4 The central bank

The central bank implements monetary policy to ensure price stability. It steers the nominal interest rate in accordance with a standard Taylor rule, reacting to the deviations of inflation and output from their steady state values. The interest rate response is sluggish, reflecting the central bank's aversion to large rate revisions within a period. The interest rate evolves according to:

$$R_t = \bar{R}^{(1-\rho_R)} \left( \frac{\pi_t}{\bar{\pi}} \right)^{\delta_\pi (1-\rho_R)} \left( \frac{Y_t}{\bar{Y}} \right)^{\delta_Y (1-\rho_R)} R_{t-1}^{\rho_R} \exp(\epsilon_t^R) \quad (25)$$

The parameters  $\delta_\pi, \delta_Y > 0$  control the sensitivity of the interest rate to the deviation of gross inflation  $\pi_t$  and output from their steady state values ( $\bar{\pi}$  and  $\bar{Y}$  respectively).  $\bar{R}$  is the interest rate in the steady state and  $\rho_R$  controls the smoothness of changes in the interest rate over a given period.  $\epsilon_t^R \sim N(0, \sigma_R^2)$  is an i.i.d. monetary policy shock.

## 2.5 The financial regulator

Macroprudential policy is the prerogative of the financial regulator, with an objective of maintaining financial stability by taming excessive credit, or by supporting credit when it is anaemic. Some authors adopt a 'hybrid' approach to meet this objective, where a single institution implements monetary policy to maintain both price and financial stability (Gelain et al., 2013; Notarpietro and Siviero, 2015). However, using monetary policy to address financial stability

<sup>20</sup> Note that this variable drops out from any linear approximations of the model around a point, as the variance of prices has only second-order effects on output.

concerns has been questioned by [Svensson \(2012, 2017\)](#). He argues that just as the monetary and the fiscal authorities operate taking each others' actions as given, the conduct of financial stability should follow in an analogous way. The hybrid approach can otherwise place a heavy burden on the central bank by requiring that it addresses two distortions using a single rule. This can be argued to go against the Tinbergen principle of using one tool to meet one policy objective ([Galati and Moessner, 2013](#); [Rubio and Carrasco-Gallego, 2014](#)). Furthermore, monetary policy is relatively ineffective at controlling asset prices, necessitating large increases in the policy rate which would be highly contractionary ([Gilchrist and Leahy, 2002](#); [Trichet, 2005](#); [Bernanke, 2010](#)).

In view of the above, several studies have embedded a macroprudential reaction function acting as an additional policy response. As discussed in [Weidmann \(2017\)](#), there may also be conflict between the objectives of price and financial stability, which could put undue pressure on the central bank if it were also responsible for financial stability. Therefore in this model the macroprudential tool is administered by a separate authority - a financial regulator - which operates independently of the central bank.

Typically a macroprudential tool is tailored specifically to control leverage countercyclically by reacting to credit growth as in [Rubio and Carrasco-Gallego \(2014, 2016\)](#) and [Kannan et al. \(2012\)](#) or to measures of credit gaps, such as the deviation of the credit to GDP ratio from its long term trend or equilibrium, as in [Angelini et al. \(2014\)](#). The latter argue that macroprudential policy can be considered a reaction to abnormal developments in credit, that is, credit growing faster than output. The credit to GDP ratio has been identified as a good early warning indicator for excessive growth in credit, and is also the reference indicator used in practice to operate the Countercyclical Capital Buffer for banks ([Basel Committee, 2010](#)).

I specify a benchmark macroprudential policy rule and later I compare it to an alternate rule which reacts to credit conditions asymmetrically. The benchmark rule sets a time-varying LTV ratio  $m_t$ , which alters impatient households' borrowing constraint (6). The LTV ratio is pushed away from its steady state value  $\bar{m}$  countercyclically in response to the deviation of the credit to GDP ratio  $\Omega_t \equiv \frac{B_t}{Y_t}$  from its value in the steady state  $\bar{\Omega} \equiv \frac{\bar{B}}{\bar{Y}}$ . As for monetary policy, it is assumed that the financial regulator is averse to making sharp changes to the LTV ratio, so it revises  $m_t$  progressively. The benchmark LTV rule is:

$$m_t = \bar{m}^{(1-\rho_m)} \left( \frac{\Omega_t}{\bar{\Omega}} \right)^{-\delta_m(1-\rho_m)} m_{t-1}^{\rho_m} \quad (26)$$

where  $\bar{m}$  is the LTV ratio in steady state,  $\delta_m > 0$  is the sensitivity of the LTV ratio to deviations in the credit ratio, and  $\rho_m$  is the smoothing parameter over changes to the LTV ratio.

## 2.6 Equilibrium

A competitive equilibrium is defined as a sequence of prices  $\{q, R, w_s, w_b, \pi\}$  and quantities  $\{C_s, H_s, B, N_s, j, C_b, H_b, N_b, m, \mu, Y, MC, A, \Upsilon, \Phi, s\}$  that satisfy the dynamic system given by equations (1)–(9), (15)–(21), (23), (25), (26) and the shock processes for  $j$  (defined below) and  $A$ .<sup>21</sup> The difference in discount factors between savers and borrowers implies that the Lagrange multiplier on the borrowing constraint is positive and hence the borrowing limit binds both in the steady state and in small deviations from it. The borrowing constraint for impatient households (6) is therefore written as an equality. Monetary and macroprudential policies are implemented

<sup>21</sup> Explosive paths in credit and house prices are ruled out through relevant transversality conditions.

in an uncoordinated fashion, with either authority taking the actions of the other as given.<sup>22</sup>

## 2.7 The steady state

The analytic solutions for some variables and great ratios can be easily derived. Using the Euler equation for savers (2) we obtain the standard result for the equilibrium interest rate:

$$\bar{R} = \frac{1}{\beta_s}$$

Plugging this result in the borrowing constraint (6), the level of credit in steady state is a proportion of housing wealth held by borrowers:

$$B = \bar{m}\beta_s qH_b$$

The Euler equations over credit supply and demand yield the value of the Lagrange multiplier on the borrowing constraint, which is a function of the difference between the discount factors of savers and borrowers:

$$\mu = \frac{\beta_s - \beta_b}{C_b}$$

Since  $\beta_s > \beta_b$  by assumption, and  $C_b > 0$ , the constraint is binding in steady state. The Euler equation for housing for savers (3) yields consumption for savers to be a proportion of their housing wealth:

$$C_s = \frac{1 - \beta_s}{\bar{j}} qH_s$$

Using the definition for  $\mu$ , the corresponding equation for borrowers is:

$$C_b = \frac{1 - \tilde{\beta}_b}{\bar{j}} qH_b$$

where  $\tilde{\beta}_b = \bar{m}\beta_s + (1 - \bar{m})\beta_b$ . Since  $\tilde{\beta}_b > \beta_s$ , borrower households have a higher propensity to consume out of their housing wealth than savers, and this propensity is a function of the LTV ratio. As  $\bar{m} \rightarrow 1$ , borrowers' propensity to consume falls, approaching that of savers.<sup>23</sup>

Using these results, we get, after some algebra, key great ratios for credit to GDP, borrowers' consumption and housing shares, and borrowers' and total housing wealth to GDP:

$$\begin{aligned} \frac{B}{Y} &= \frac{\bar{j}\bar{m}\beta_s(1 - \alpha)\overline{MC}}{\iota} \\ \frac{C_b}{Y} &= \frac{(1 - \tilde{\beta}_b)(1 - \alpha)\overline{MC}}{\iota} \\ \frac{H_b}{H} &= \frac{(1 - \beta_s)(1 - \alpha)\overline{MC}}{\iota - \overline{MC}(\beta_s - \tilde{\beta}_b)(1 - \alpha)} \\ \frac{qH_b}{Y} &= \frac{\bar{j}(1 - \alpha)\overline{MC}}{\iota} \\ \frac{qH}{Y} &= \frac{\bar{j}(\iota - \overline{MC}(\beta_s - \tilde{\beta}_b)(1 - \alpha))}{\iota(1 - \beta_s)} \end{aligned}$$

where  $\overline{MC} = \frac{\sigma - 1}{\sigma}$  from the equations characterising price dynamics and  $\iota = 1 - \tilde{\beta}_b + \bar{j}\bar{m}(1 - \beta_s)$ . As the steady state LTV ratio increases, so does the maximum borrowing allowed for impatient

<sup>22</sup> For a discussion and comparison of the performance of coordinated and uncoordinated policy actions see [Rubio and Carrasco-Gallego \(2014\)](#).

<sup>23</sup> However note that the model has no stable solution for values of  $\bar{m}$  very close to 1.



households.<sup>24</sup> Borrowers use this additional credit to increase their holdings of housing, which pushes up house prices relative to consumption goods. This pushes up the borrowing limit further. The final effect is a rise in credit, a fall in borrowers' consumption share and a rise in their housing share and in their housing wealth relative to output.

Gross inflation in the steady state ( $\bar{\pi}$ ) is 1, so net inflation is 0. The steady state level of technology  $\bar{A}$  is normalized to 1.

### 3 News shocks

The standard driving forces in DSGE models are unanticipated shocks hitting technology, preferences or costs, which account for all of the variation in macroeconomic variables. However there exists evidence that *anticipated* shocks, that is, shocks expected to hit at some future period, are also equally important. [Beaudry and Portier \(2006\)](#) find that expectations about changes to future technology explain a significant proportion of consumption, investment and labour hours. More recently [Schmitt-Grohé and Uribe \(2012\)](#) extend the sources of uncertainty beyond future technology and find that anticipated shocks to productivity, government spending, the wage markup and preferences explain about half the variance in output, consumption, labour hours and inflation. Information about future changes in fundamentals is referred to as a *news shock*.<sup>25</sup>

The possibility that changes in expectations about future fundamentals affect the economy today dates back to [Pigou \(1927\)](#), who argues that excessive optimism about the future which turns out to be false can cause households and firms to scale back on their expenditure, tipping the economy into recession. This process, termed a 'Pigou cycle', is consistent with rational expectations as optimism or pessimism is *ex-ante* an optimal reaction to a possibly imprecise signal ([Beaudry and Portier, 2004](#)).

Asset prices respond directly to perceived changes to fundamentals in the future. Notable studies on the effect of expectations on asset prices include those by [Cochrane \(1994\)](#), [Bernanke and Gertler \(1999\)](#), [Gilchrist and Leahy \(2002\)](#), [Dupor \(2005\)](#), [Christiano et al. \(2010\)](#), [Lambertini et al. \(2013a\)](#), [Gomes and Mendicino \(2015\)](#) and more recently [Lambertini et al. \(2017\)](#) and [Kaplan et al. \(2017\)](#). The mechanism in this literature is through optimistic expectations about the future state of technology, policy, cost shocks and preferences, fuelling an asset price bubble. When this eventually bursts, it causes a recession. Meanwhile, it is generally assumed that policymakers do not have superior information about the economy, and therefore cannot distinguish excessive optimism or pessimism from a true shock to fundamentals in some future date.<sup>26</sup>

Are house prices driven by news shocks? [Wheaton and Nechayev \(2008\)](#) find that growth in US house prices during 1998-2005 was significantly higher than what time series models of the

<sup>24</sup> Note that as  $\bar{m}$  rises,  $\bar{\beta}_b$  rises and  $\iota$  falls.

<sup>25</sup> [Beaudry and Portier \(2004, 2007\)](#) show that news about a future improvement in technology actually triggers a recession in a model with household preferences given by standard constant relative risk aversion. This arises due to a strong wealth effect on labour supply, as households reduce their labour effort, which reduces output. [Jaimovich and Rebelo \(2009\)](#) show how this can be overcome by using different preference and technology specifications. [Cochrane \(1994\)](#) anticipates the literature by noting that a number of standard, observed shocks fail to properly account for economic fluctuations, and suggests the importance of *unobserved* 'consumption shocks' in setting off a chain of events which drive a business cycle. See the review in [Lorenzoni \(2011\)](#) for further discussion. News shocks have also been applied to understand the effects of anticipated changes to labour and capital taxes on business cycle volatility ([Mertens and Ravn, 2011](#); [Born et al., 2013](#)).

<sup>26</sup> [Lorenzoni \(2009\)](#) on the other hand assumes that agents receive imperfect signals about the current (and therefore future) state of technology, that is, 'noise shocks' rather than news of some event happening in time  $t + n$ . A positive noise shock causes expectations to temporarily stray off from fundamentals, leading to a boom. Agents solve a signal extraction problem, learn about the noise over the passage of time, correct their expectations and revise their allocations.

housing market could predict on the basis of fundamentals. [Iacoviello and Neri \(2010\)](#) back-out the sequence of housing preference shocks from an estimated DSGE model of the US economy and find that other relevant observables not included in their structural model, such as mortgage transactions costs, the share of population aged 25-39 and the share of subprime mortgages in total mortgage lending can only explain about 15% of the the variation in these shocks during the period 1975-2006. While the rise in the share of subprime mortgages explains some of the increased housing demand during 2003-2006, observables alone cannot account for all of housing demand disturbances.<sup>27</sup> This evidence lends support to the hypothesis that waves of consumer sentiment, namely optimism or pessimism about the future, are important drivers of house price dynamics ([Piazzesi and Schneider, 2009](#)). [Lambertini et al. \(2013a\)](#) find that indeed this is the case in episodes of housing booms, where expectations of rising house prices explain an important share of of house prices.

On the basis of the above discussion, in this paper optimism relates to expected future demand for housing that move housing preferences  $j_t$ . Positive *unanticipated* housing preference shocks increase the marginal utility of housing, stimulating demand. Since housing supply is fixed, the increase in demand maps directly into an increase in house prices. This boosts net worth and relaxes borrowers' borrowing constraint, triggering a boom. This is also the case for an *anticipated* future increase in demand which is driven by news, since households are forward-looking and react immediately. When this news turns out to be false, households realise that high house prices are not supported by fundamentals, and therefore housing is in a bubble. The housing bubble bursts, house prices revert to their original level, borrowers de-leverage, and consumption and output drop. The drop in households' net worth then further amplifies the contraction, as the borrowing constraint tightens and consumption falls further, and so on.

The process  $j_t$  follows a first-order autoregressive process in logs around the steady state value  $\bar{j}$  with i.i.d shocks having zero mean and variance  $\sigma_j^2$ . In addition to unanticipated housing demand shocks  $\epsilon_{j,t}$ , households are hit with news about a housing demand shock  $n$  periods in advance  $\tilde{\epsilon}_{j,t-n}$ :

$$\log(j_t) = (1 - \rho_j) \log(\bar{j}) + \rho_j \log(j_{t-1}) + \epsilon_{j,t} + \tilde{\epsilon}_{j,t-n} \quad (27)$$

where  $\epsilon_{j,t} \sim N(0, \sigma_j^2)$  and  $\tilde{\epsilon}_{j,t-n} \sim N(0, \sigma_j^2)$  are uncorrelated i.i.d. shocks. The shock  $\tilde{\epsilon}_{j,t-n}$  represents a news (belief) shock, known at time  $t - n$ , about an event happening in time  $t$ . If this news shock, which is an expectation, turns out to be unfounded, then  $\epsilon_{j,t} = -\tilde{\epsilon}_{j,t-n}$  and the housing demand term  $j_t$  never actually moves. This mechanism captures the expectations-driven cycle described above. I assume that any news that arrives is about events 1 year into the future, so  $n = 4$ , as in [Lambertini et al. \(2013b, 2017\)](#).

Following [Lorenzoni \(2009, 2010\)](#), households, firms, the central bank and the financial regulator cannot distinguish between a true shock to fundamentals and a non-fundamental expectations shock. This also follows views shared by policymakers, as discussed by [Trichet \(2005\)](#). News about the future arrives exogenously, and there is no way ex-ante to verify the reliability of such news. From the point of view of policy, the non-fundamental housing demand shock is a distortion as it gives rise to an inefficient boom and bust cycle. In this context, there is scope for active macroprudential policy ([Lambertini et al., 2013b; Burlon et al., 2016](#)).

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<sup>27</sup> See Figure 7 and Web Appendix D in [Iacoviello and Neri \(2010\)](#).

## 4 Calibration

A period in the model is a quarter. Most of the parameters are set at values typically used or estimated in the literature. I set the discount factor  $\beta_s$  at 0.9901, such that in the steady state the annualised net interest rate is 4%, and  $\beta_b$  at 0.96, which is at the lower end of the range typically used in the literature, yet within empirical estimates.<sup>28</sup> I set both the inverse of the Frisch labour supply elasticity and the external habit persistence parameter  $\varrho$  at 0.5, as estimated in [Iacoviello and Neri \(2010\)](#).<sup>29</sup> The preference parameter on labour  $\tau$  is set at 0.845 such that steady state output is normalized at 1.

Table 1: Parameter values

$\beta_s$	0.9901	Discount factor – savers
$\beta_b$	0.96	Discount factor – borrowers
$\varphi$	0.5	Inverse of Frisch labour supply elasticity
$\tau$	0.845	Preference parameter on leisure
$\bar{j}$	0.06	Preference parameter on housing
$\varrho$	0.5	Habit persistence
$\bar{m}$	0.9	LTV ratio
$\sigma$	6	Elasticity of substitution
$\alpha$	0.64	Share of labour income (savers)
$\omega$	0.75	Calvo parameter
$\delta_\pi$	1.5	Taylor rule coefficient on inflation
$\delta_Y$	0.125	Taylor rule coefficient on output growth
$\delta_m$	1	Macroprudential rule coefficient on credit to output
$\rho_R$	0.8	Smoothness parameter for monetary policy
$\rho_m$	0.8	Smoothness parameter for macroprudential policy
$\rho_A$	0.95	Persistence parameter for technology shock
$\rho_j$	0.96	Persistence parameter for housing preference shock
$\sigma_A$	0.01	Standard deviation of technology shock
$\sigma_j$	0.054	Standard deviation of housing preference shock
$\sigma_R$	0.00115	Standard deviation of monetary policy shock

I set  $\bar{j}$  at 0.06 such that the steady state level of total housing wealth to annual output is at about 1.4, the long run average for the US ([Iacoviello and Neri, 2010](#)), and  $\bar{m}$  to 0.9, which is the same value used by [Rubio and Carrasco-Gallego \(2014\)](#) and [Iacoviello \(2015\)](#). This LTV ratio reflects borrower household leverage which is high but within ranges observed in the data.<sup>30</sup> The share of income from production accruing to savers  $\alpha$  is set at 0.64, as estimated in [Iacoviello \(2005\)](#). This implies that savers own about 75% of housing wealth.<sup>31</sup> This calibration ensures that the collateral effect is strong enough to generate a positive response of output to a house price shock as in [Iacoviello \(2005\)](#).

<sup>28</sup> See [Lawrance \(1991\)](#), [Carroll and Samwick \(1997\)](#) and [Samwick \(1998\)](#).

<sup>29</sup> Their estimates for  $\varrho$  differ between savers (0.33) and borrowers (0.58). I use a figure close to the latter for both households to limit differences between them.

<sup>30</sup> As at 2007, LTV ratios varied between 0.63 and 1.01 across 15 countries in the euro area, whereas at the beginning of 2016 this ratio amongst 8 such countries varied between 0.7 and 1.01 ([ECB, 2009, 2016](#)). In the US, [Iacoviello and Neri \(2010\)](#) report that in 2004 a significant share of new home buyers took loans with high LTV ratios, at an average of 0.94. More recently, [Zabai \(2017\)](#) documents a range of maximum LTV ratios between a minimum of 70% and a maximum of 125%.

<sup>31</sup> This calibration yields an implied steady state annualised Loan to Income (LTI) ratio of 1 for borrowers, which is on the lower end of the data. The macroeconomic effects over different levels of steady state leverage are discussed further below.

The parameters involving price setting are standard. I set the elasticity of substitution between intermediate good varieties  $\sigma$  at 6, which implies a steady state mark-up over marginal costs of 20%, and the Calvo parameter  $\omega$  at 0.75, which implies that on average intermediate goods firms can reset prices once every four quarters.<sup>32</sup>

The persistence parameter on the technology shock  $\rho_A$ , at 0.95, is standard in the literature, and the variance of the shock is set such that a positive 1 standard deviation shock increases productivity by 1%. The persistence parameter for the housing shock  $\rho_j$  is the same as the estimate in [Iacoviello and Neri \(2010\)](#) at 0.96.<sup>33</sup> The shock variance is calibrated such that a 1-standard deviation shock produces a 1% increase in house prices on impact. The news shock has the same variance.<sup>34</sup> The variance of the monetary policy shock is set such that a 1-standard deviation shock raises the annualized nominal interest rate by 25 basis points.

Turning to the policy reaction functions, the inertia in the Taylor rule on the interest rate  $\rho_R$  is set at 0.8 as in [McCallum \(2001\)](#), which reflects a strong preference for small changes in the policy rate from one period to another. The coefficients of the Taylor rule are also standard, where  $\delta_\pi$  is set at 1.5, and  $\delta_Y$  at 0.125 (a response of 0.5 to annualised output). The reaction parameter on the LTV rule  $\delta_m$  is set by following the Optimal Simple Rule (OSR) literature, and therefore deserves some discussion. The objective of macroprudential policy is to reduce systemic risk, but the latter is unobservable. Following [Kannan et al. \(2012\)](#), [Angelini et al. \(2014\)](#) and [Rubio and Yao \(2017\)](#), I assume that a suitable proxy for systemic risk is the variability of the credit to output ratio. Lower variability in this ratio would then be synonymous with reduced systemic risk. In principle it is possible to meet this objective quickly and effectively by triggering large movements in the LTV ratio, that is, setting a very high  $\delta_m$ . Yet in practice this behaviour is hardly observed and any regulatory authority in general would want to avoid drastic and unpalatable policy measures, so I assume that the second objective of policy concerns the variability of the instrument.

I therefore specify the macroprudential loss function as the sum of the variability in both the credit to output ratio and the LTV ratio:

$$L = \sigma_\Omega^2 + \sigma_m^2$$

This welfare criterion follows the “revealed-preferences” approach of [Angelini et al. \(2014\)](#) and is not microfounded but modelled on policy experience.<sup>35</sup> In contrast with the studies listed above, I do not include the variability of output as this could create some overlap between the goals of monetary and macroprudential policy, as discussed in section 2.5. I assign equal weight to the two arguments in the loss function, and find the parameter  $\delta_m^*$  in (26) which minimizes this loss:

$$\delta_m^* = \arg \min L(\delta_j) \tag{28}$$

This minimization is subject to the structure of the economy as described above. It is also subject to a fixed persistence parameter in the macroprudential rule  $\rho_m$  of 0.8, as in the Taylor

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<sup>32</sup> A higher degree of price rigidity, as estimated for example in [Iacoviello and Neri \(2010\)](#), would imply stronger responses of real variables to shocks.

<sup>33</sup> The corresponding estimate in [Liu et al. \(2013\)](#) is 0.9987, since land prices are very persistent. This is in line with the discussion in [Drehmann et al. \(2014\)](#), who find that financial cycles, which are driven by credit and asset prices, are longer than typical business cycles.

<sup>34</sup> This shock is small enough to keep the borrowing constraint binding. A 2-standard deviation shock, even in the absence of a time-varying countercyclical LTV ratio, is also not big enough to raise housing wealth such that the borrowing constraint becomes slack.

<sup>35</sup> See the discussion in [Paez-Farrell \(2014\)](#) and [Wieland and Wolters \(2013\)](#) on the use of ad hoc loss functions in analysis of policy.

rule, to reflect the fact that the LTV ratio is not changed frequently in practice, but once changed, is kept lower or higher for some time.<sup>36</sup> The solution to (28), obtained while taking monetary policy (that is, the reaction parameters of the Taylor rule) as given and fixed at the benchmark calibration, yields  $\delta_m^* = 0.99$ , which is rounded to 1. This value will be used in the benchmark calibration. Robustness checks presented in section 7 show that relaxing the assumption of equal weight on the two arguments in the loss function does not affect the results.

## 5 An asymmetric macroprudential rule

This section describes the conduct of macroprudential policy that is asymmetric; aggressive during credit booms but relatively weak during credit busts. As discussed in the introduction, this policy response is inherent in the pre-emptive character of macroprudential policy. Empirical evidence also suggests that macroprudential policy is typically more effective during credit booms (Cerutti et al., 2017), likely on account of more intense implementation during the build-up phase. Intuitively, a strong reaction to credit booms may represent a willingness to dampen the build-up phase of the credit cycle, such that in the wake of a bursting bubble, the economy experiences a more muted correction.<sup>37</sup>

### 5.1 Defining asymmetry

In order to capture this type of policy, I propose an asymmetric macroprudential reaction function which responds aggressively to an *increase* in economy-wide leverage ( $\Omega_t > \bar{\Omega}$ ) relative to a *decrease* in leverage ( $\Omega_t < \bar{\Omega}$ ).<sup>38</sup> As in the symmetric rule, I allow the policymaker to adjust the LTV ratio around its steady state value, subject to the same degree of persistence  $\rho_m$ :

$$m_t = \bar{m}^{(1-\rho_m)} \left( \frac{\Omega_t}{\bar{\Omega}} \right)^{-\tilde{\delta}_m(1-\rho_m)} m_{t-1}^{\rho_m} \quad (29)$$

where  $\tilde{\delta}_m = (1 - \mathbb{1}_H)\underline{\delta}_m + \mathbb{1}_H\bar{\delta}_m$ , with  $\bar{\delta}_m > \underline{\delta}_m$  and  $\mathbb{1}_H$  is an indicator function for periods of credit booms:

$$\mathbb{1}_H = \begin{cases} 1 & \text{if } \Omega_t > \bar{\Omega} \\ 0 & \text{otherwise} \end{cases}$$

I set the asymmetry in rule (29) around  $\delta_m^*$ , the optimal value of the reaction parameter in the case of the symmetric rule (26). Specifically, the reaction parameters  $\bar{\delta}_m$  and  $\underline{\delta}_m$  are defined such that their weighted average is  $\delta_m^*$ :

$$\lambda\bar{\delta}_m + (1 - \lambda)\underline{\delta}_m = \delta_m^* \quad (30)$$

<sup>36</sup> The variance of the LTV ratio  $m_t$  is also influenced by the persistence parameter in the macroprudential rule (26); higher persistence implies a higher variance. In fact a minimization involving a search over both  $\delta_m$  and  $\rho_m$  yielded negative values for  $\rho_m$ , which does not make practical sense. I therefore fix this at the same value as in the Taylor rule, which is consistent with values used in other studies. Rubio and Yao (2017) use the same value in their robustness analysis, while Burlon et al. (2016) set this parameter at 0.99.

<sup>37</sup> Røisland (2017) assumes that central bank preferences are asymmetric around asset prices, favouring minimum deviations from a target, but more concerned with asset prices rising above rather than falling below target.

<sup>38</sup> Burlon et al. (2016) assume a stricter version of this rule, in which the LTV is lowered during credit booms, but does not rise in response to a credit slump.

for  $\lambda \in (0, 1)$ .<sup>39</sup> This permits a clearer definition of asymmetry as a departure from the special case  $\bar{\delta}_m = \underline{\delta}_m = \delta_m^*$ , and allows a like-for-like comparison across policy implementation and economic performance. It is useful to define the strength of the asymmetry, the ‘kink’, as  $\kappa = \bar{\delta}_m / \underline{\delta}_m$ , where  $\kappa \in [1, \infty)$ , which is a measure of how strong the response is during a boom relative to a recession. In what follows I fix  $\lambda$  at 0.5 and assume a strong asymmetric motive, setting  $\kappa = 5$ . Values for  $\underline{\delta}_m$  and  $\bar{\delta}_m$  which satisfy restriction (30) at this asymmetry are 1/3 and 5/3 respectively. Thus, the unconditional ‘average’ response to credit gaps is 1, as in the symmetric rule. Section 7 generalizes the results over varying degrees of asymmetry.

## 5.2 Solution method

Since the asymmetric rule (29) is not differentiable at the kink, standard local solution approaches based on perturbation cannot be used to solve the model. Instead, by casting the asymmetric macroprudential rule as an occasionally-binding constraint (OBC), I use the method proposed by [Guerrieri and Iacoviello \(2015\)](#), who argue that OBCs can be thought of as defining two regimes of the same model. In one regime the constraint binds, and in the other it is slack. The solution is based on a piecewise linear approximation around the non-stochastic steady state of the model. This approach has also been used to simulate monetary policy at the zero lower bound.<sup>40</sup> To the best of my knowledge this is the first attempt at using this technique to solve and simulate a model in which the occasionally-binding constraint is a macroprudential policy reaction function.

As discussed in [Guerrieri and Iacoviello \(2015\)](#), this solution method is fast, it can handle models with several state variables and has been shown to be highly accurate in selected models, with very low Euler equation residuals compared to a global solution. Furthermore, even though the model is approximated at first order, the solution can deliver significant non-linearities as the coefficients of the decision rules are dependent on the time agents believe the economy will be in any particular regime, which in turn is a function of the state variables. The limitation of this approach is that, since it is nevertheless based on linear approximations, it cannot account for precautionary behaviour, and therefore is not suitable for welfare analysis, which requires at least second order perturbation.<sup>41</sup> Consistent with the temporary nature of a bubble in this model, the solution assumes a return to the reference regime in finite time.

In what follows, shocks are small enough to guarantee that the *borrowing* constraint faced by impatient households (inequality (6)) is always binding.<sup>42</sup> Therefore the regimes relevant for this solution relate to leverage relative to its steady state value; credit booms represent one regime and credit busts another. Each regime is associated with a unique value for the macroprudential reaction parameter  $\tilde{\delta}_m$ .

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<sup>39</sup> This parameterization is assumed and is not derived from microfoundations.

<sup>40</sup> In such case the reference regime operates a standard Taylor rule which regulates the nominal interest rate, while in the alternate regime, which is entered when the nominal rate tries to go below zero, the interest rate is held at 0%. See [Guerrieri and Iacoviello \(2017\)](#) and [Rubio and Yao \(2017\)](#).

<sup>41</sup> However, the authors argue the main difference between the piecewise linear solution and a global solution in a standard Real Business Cycle model, due to the precautionary behaviour of households, is very small. They also show that in the case of a New Keynesian model with non-zero inflation in the steady state, an additional source of approximation error is the non-linearity due to price dispersion. In this paper the steady state net inflation rate is zero, such that price dispersion is constant up to first order.

<sup>42</sup> [Jermann and Quadrini \(2012\)](#) follow a similar procedure in a model with an enforcement constraint on firms’ borrowing, and show that the local and global approximations are almost identical when the constraint is binding.

## 6 Housing demand shocks

I now study how the model economy reacts to exogenous disturbances. Section 6.1 below shows dynamic responses to housing preference shocks, both unanticipated and anticipated, under the presumption that macroprudential policy is not active. In this case the LTV ratio is fixed. In this way I go over the response of the economy while shutting off the part of the collateral channel that is influenced by policy. I then assess the role of macroprudential policy to these shocks in section 6.2, comparing different specifications of the reaction function.

### 6.1 Unanticipated shocks and news shocks

Shocks either hit in the first period and are thus unanticipated, or hit in the future with some anticipation. I refer to unanticipated shocks, which adopt the standard timing in the literature, as the benchmark shock in each case. I will then explore the response of the economy to a shock with a different timing profile. Next is a shock which is anticipated at time  $t$  to hit in a year's time ( $t + 4$ ), a news shock. The third type is the case when such anticipation is incorrect, such that expectations are overly optimistic or pessimistic. This is an unrealized news or bubble shock. The size of the shock is the same in all scenarios. I report similar analysis for technology and monetary policy shocks in Appendix C.1.1 to save space, where I show that neither disturbances are relevant for the analysis of boom-bust cycles in which asset prices also rise significantly.

Figure 3 shows the effect of a housing preference shock which pushes house prices up by 1% on impact. Refer first to the case of an unanticipated shock which hits at time  $t$  (red dotted line). This rise in house prices increases the collateral value against which borrowers obtain credit. Impatient households, who experience a strong collateral effect from this appreciation, increase both their consumption and their housing investment on account of higher borrowing. This stimulates output, and therefore labour demand, raising marginal costs of production and pushing up inflation, and the economy experiences a boom.<sup>43</sup> The increase in credit is higher than the rise in output, so the credit to output ratio rises. Since only monetary policy is active, a rise in output and inflation trigger a relatively strong increase in the nominal (and real) interest rate. Patient households react by lowering consumption and working more. The model predicts that by quarter 6, or a year and half from the shock, consumption and labour profiles for borrowers and savers reverse (not shown), reflecting a deleveraging process. The aggregate effect on output from this period on is positive but small, as different consumption profiles largely offset each other. Since the shock is highly persistent, house prices, credit and consumption for both households follow a slow return to their steady state values.

The figure also shows the effect of a housing demand shock that is anticipated at time  $t$  to hit one year into the future (solid black line). This anticipation leads to a slightly stronger boom as output and inflation rise marginally higher than in the case of an unanticipated shock which hits immediately, but is of the same magnitude. Credit rises immediately, even though house prices in the first few quarters do not rise as much as in the benchmark case, since borrowers front-load the wealth effect from the anticipated higher collateral value. The behaviour of the economy from the realization of the shock in quarter 5 onwards is very close to the case of an unanticipated shock.<sup>44</sup>

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<sup>43</sup> As shown in [Iacoviello and Neri \(2010\)](#), the response of the economy to a housing preference shock is more muted in the case of flexible wages, as is the case in this paper, compared to a model with both wage and price rigidity, since more adjustment has to be done by 'real' variable allocations.

<sup>44</sup> The fact that the impulses for most variables are in phase with those in the benchmark case implies that these two shocks may be observationally equivalent, and therefore hard to identify when such models are estimated.

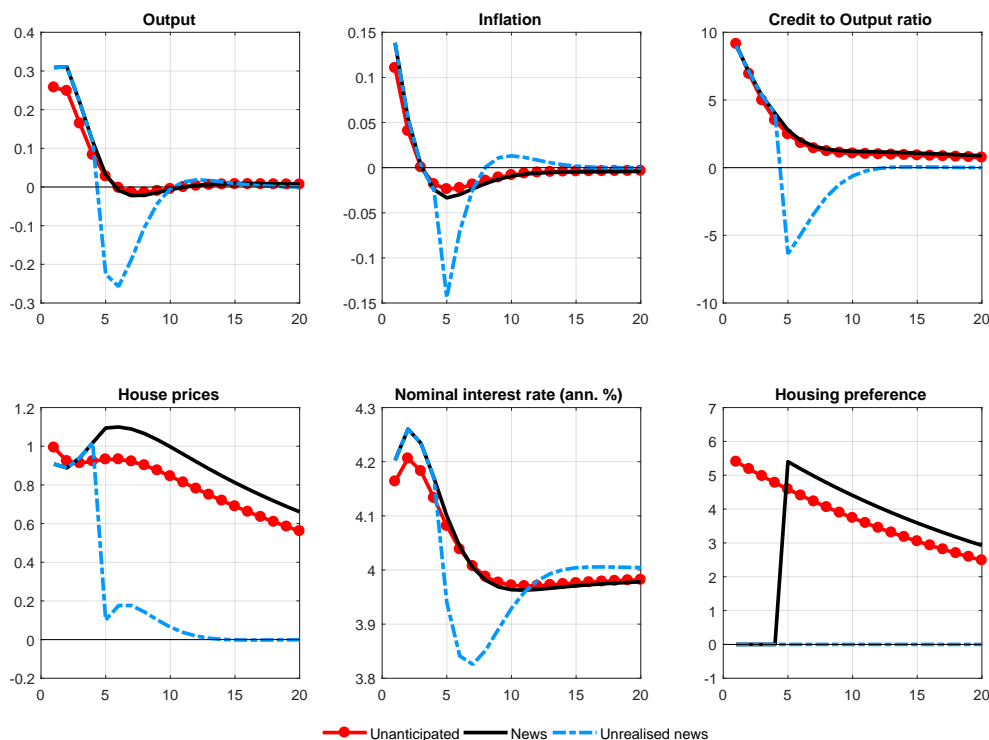


Figure 3: Impulse responses to housing preference shocks

Notes: Values on x-axis are time in quarters, on y-axis are percentage deviations from steady state, except for the interest rate.

The third shock analysed is the case of an unrealized news shock. As discussed above, this reflects a scenario of excessive optimism about the future that generates a boom, in which housing experiences a bubble since the price does not reflect underlying fundamentals. Note also that the reaction of the economy in the first year is identical to that of the realized news shock. This is followed by a strong correction when agents do not observe a true shift in preferences after  $t + 4$  and realise that house prices are overvalued. House prices fall sharply, triggering a drop in impatient households' borrowing, consumption and housing investment via the collateral effect, tipping the economy into a recession.<sup>45</sup> Since borrowers have a much higher marginal propensity to consume, the drop in borrowers' consumption is about 5 times larger than the increase in consumption from savers, and this dominates the effect on output. This scenario is similar to the boom-bust cycle studied in [Bernanke and Gertler \(1999\)](#), although the latter achieve this by adding a corresponding negative asset price bubble to capture financial market panic once the positive bubble bursts.

The bust occurs in the context of a sharp 0.44 basis point cut in the nominal rate from peak to trough by the central bank. In further analysis (not shown) I find that a higher coefficient on the output gap in the Taylor rule does not do much in dampening the boom and bust phase, illustrating how ineffective monetary policy is during an asset price bubble. These results highlight the importance of having an additional lever on the economy, one more suited to mitigate the financial amplification that results from collateral effects, especially in the case of house price bubbles.

<sup>45</sup> Note how the housing preference term  $j_t$  never deviates from its steady state value in this scenario (dashed blue line).



## 6.2 The role of macroprudential policy

Next I repeat the analysis above in the presence of an active macroprudential policy. I compare the outcomes under symmetric and asymmetric rules, and reference the case of a fixed LTV ratio as shown in Figure 3. The benchmark case in this sub-section relates to the use of a symmetric LTV rule.

### 6.2.1 Unanticipated shock to housing preferences

I start with an unanticipated shock to housing demand; Figure 4 clearly shows how the use of a time-varying LTV ratio can stabilize the economy during a boom driven by the housing market, a task not achievable by more aggressive monetary policy. In the benchmark case of a symmetric LTV rule, policy responds immediately by lowering  $m_t$ , working against the positive collateral effect of the increase in housing wealth brought about by higher prices. This restricts borrowing and as a result credit rises by only about a third relative to the case of no macroprudential policy. This dampens the increase in consumption from borrower households, and as a result the boom is dampened. The asymmetric rule, by construction, induces a larger drop in the LTV ratio for the same shock. The response parameters for the symmetric and asymmetric rules in this regime are 1 and 1.66 respectively, and as a result the boom is dampened slightly more in this latter case.<sup>46</sup>

Note how policy can take advantage of the financial accelerator to dampen activity by making small changes to the LTV ratio. This dampening also has an effect on the evolution of house prices and these return to the steady quicker, compared with the endogenous fluctuations in house prices that take place under no LTV rule. The presence of macroprudential policy also brings about positive spillovers to price stability. Since demand pressures are made weaker, inflation rises by less, and this in turn leads to a smaller reaction on the interest rate by the monetary authority.

### 6.2.2 News shock to housing preferences

A news shock leads to an immediate reaction which yields even stronger demand pressures on output in the time it is announced, relative to an unannounced shock of the same size. Figure 5 shows that, as in the previous case, active macroprudential policy leads to a weaker reaction since borrowing is tightened. House prices do not rise much, compared with some overshooting that is observed otherwise.<sup>47</sup> The corresponding figure for an anticipated *drop* in housing demand is shown in Appendix C.1.1. Since an asymmetric LTV rule implies a weaker response on the downward side, the impulses under this regime will be close to but higher than the impulses under the symmetric rule in absolute terms.

### 6.2.3 House price bubbles

As discussed in section 3, in this model bubbles are irrationally exuberant only *ex-post*, leading to inefficient responses. Moreover, these inefficiencies are amplified by the financial accelerator. In such a case the need for a tool powerful enough to limit these inefficiencies is especially warranted. Figure 6 illustrates the usefulness of a time-varying LTV ratio as a tool in managing

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<sup>46</sup> The opposite is true in the event of a negative demand shock, as in this case the credit ratio falls below its steady state value and the asymmetric rule would prescribe a smaller *increase* in the LTV ratio. The responses under passive and symmetric macroprudential policy are simply mirror images about the horizontal axis. In this regime, the blue crossed line would lie between the circled red and solid black line. The figure showing the response of the economy is shown in Appendix C.2 to save space.

<sup>47</sup> The size of the shock is such that it generates a 1% increase in prices on impact, when this is not anticipated.

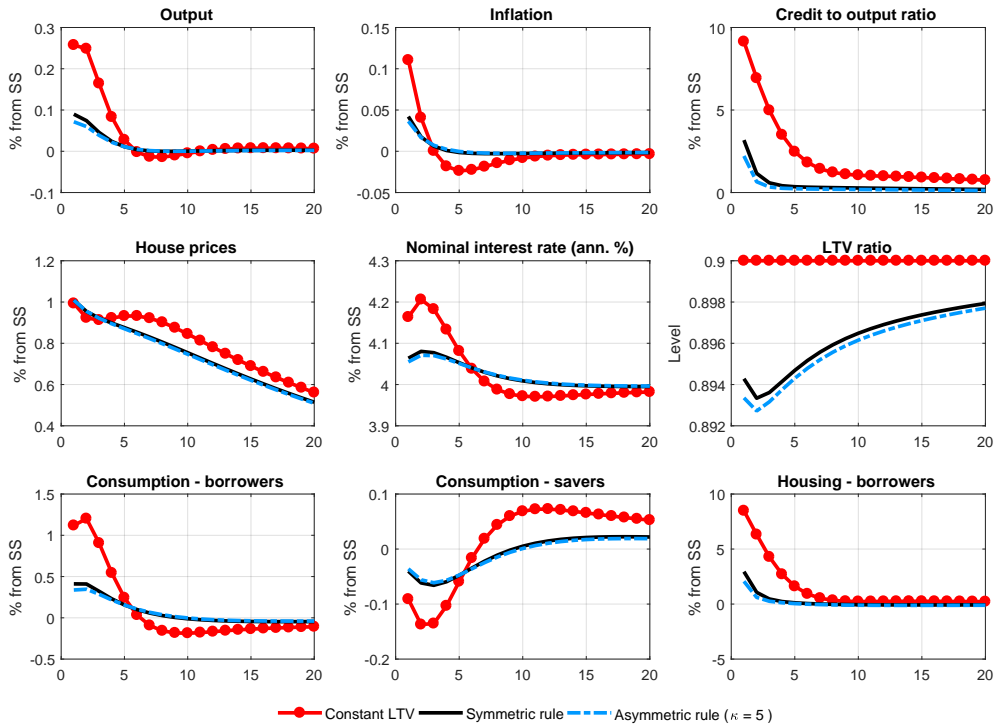


Figure 4: Impulse responses to an unanticipated housing demand shock

Notes: Values on x-axis are time in quarters, on y-axis are % deviations from steady state, except for the interest rate.

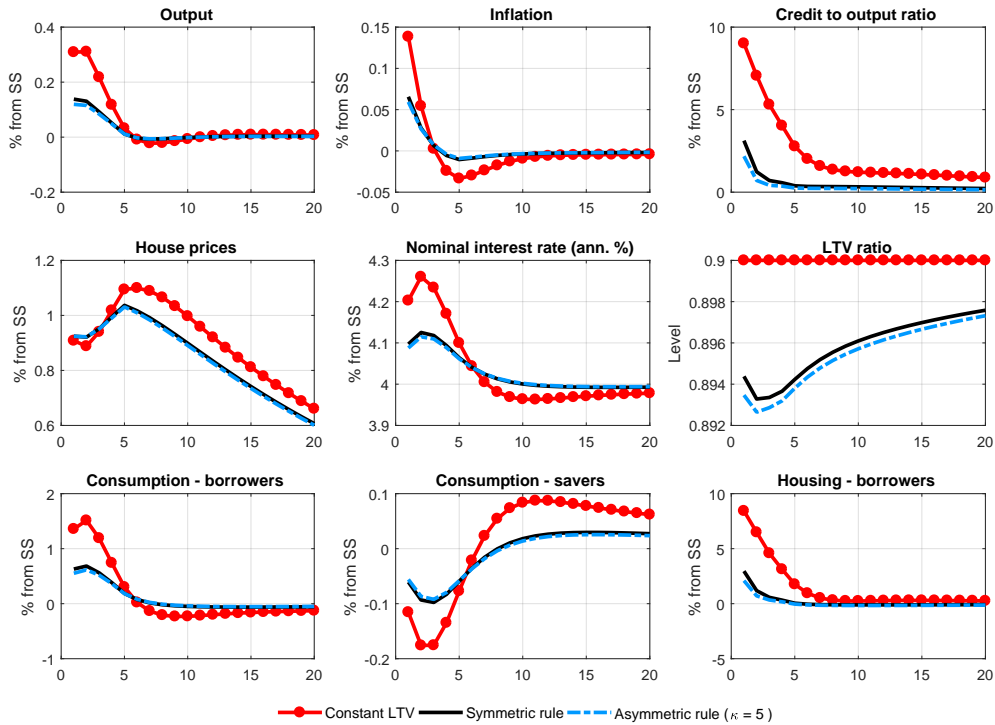


Figure 5: Impulse responses to a housing demand news shock

Notes: Values on x-axis are time in quarters, on y-axis are % deviations from steady state, except for the interest rate.

the economy during both boom and bust phases of the cycle. In the benchmark case, the peak and trough of the cycle are both dampened considerably by countercyclical movements in the LTV ratio. On the other hand an asymmetric countercyclical response to the same cycle reduces the build-up of credit and dampens the associated increase in demand that follows from the equity release of higher housing wealth. However, it can have undesirable side-effects during the bust that follows since policy remains tight by keeping the LTV ratio relatively lower during the correction, causing a relatively bigger drop in credit and output. Figure 7 zooms in on these two scenarios.

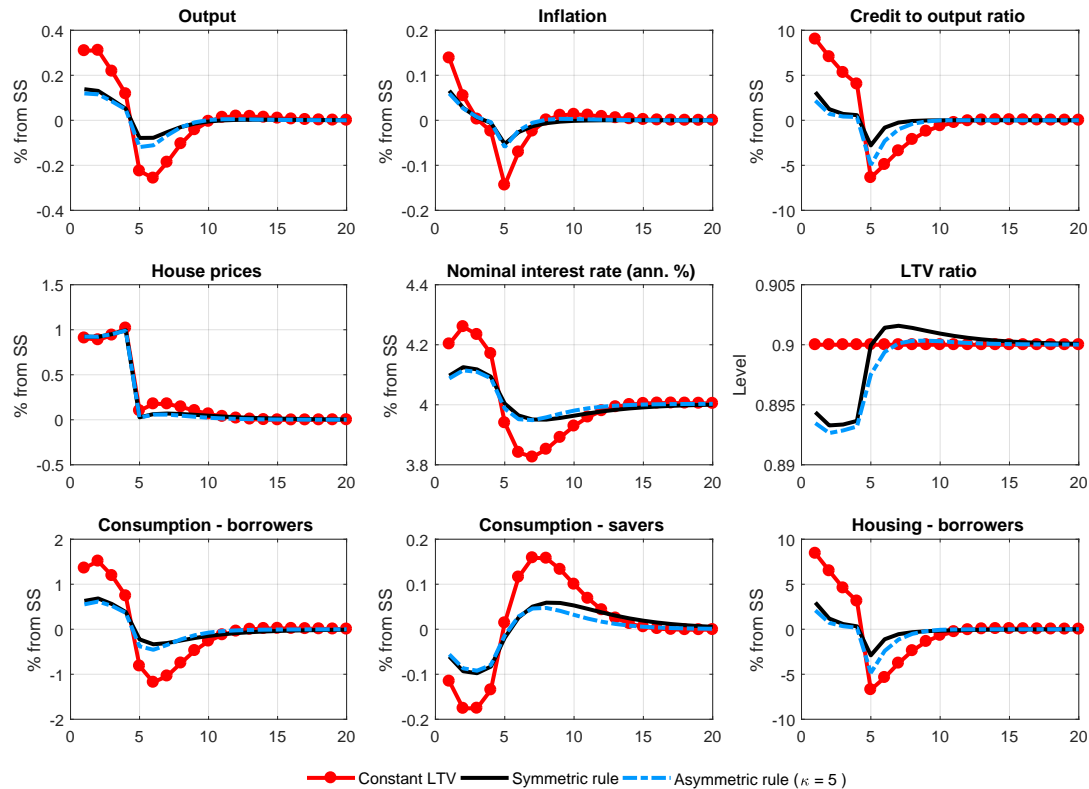


Figure 6: Impulse responses to an unrealized housing demand news shock

Notes: Values on x-axis are time in quarters, on y-axis are % deviations from steady state, except for the interest rate.

The lesson that can be drawn from this analysis is that although a time-varying LTV ratio can dampen an expectations-driven boom and bust cycle, it is important that macroprudential policy becomes accommodative as, and if, a bubble bursts. By *increasing* again the LTV ratio during the bust phase, the financial regulator can work against the collapse in housing wealth which tightens the borrowing limit. In contrast, by operating an asymmetric rule which is aggressive only during the build-up phase, the authority allows accelerator effects to worsen the bust. It is therefore more desirable that the authority exploits the collateral constraint and associated accelerator effects by relaxing  $m_t$  *just as aggressively*, as soon as the data indicate a correction.

Figure 7 shows that the implementation of asymmetric policy hits savers and borrowers differently. Since it affects the borrowing constraint unfavourably in the bust phase, borrowers' consumption falls by more than in the case of symmetric policy. Indeed it appears that while  $C_b$  rises by less during the boom, it falls by more during the bust phase, such that its volatility over repeated boom-bust episodes is higher. On the other hand, savers' consumption is less volatile in the case of asymmetric policy, during both boom and bust phases. This reflects the

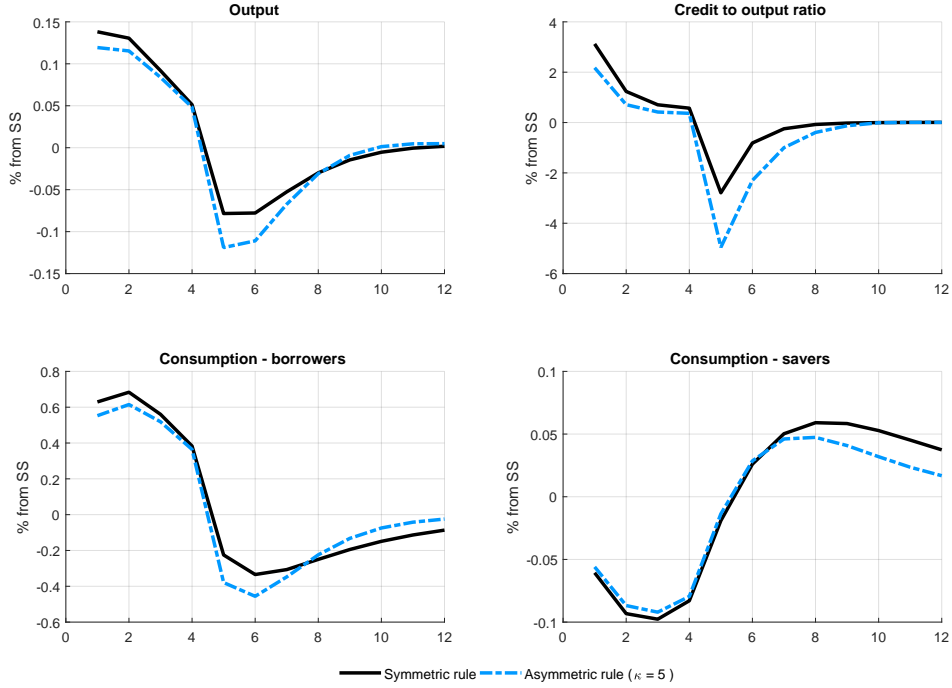


Figure 7: Responses across policy rules

Notes: Values on x-axis are time in quarters, on y-axis are % deviations from steady state.

dynamics of inflation and thus the nominal and real interest rate; in the presence of asymmetric macroprudential policy the real interest rate is slightly less volatile, leading to relatively less consumption variance for savers.

## 7 Robustness checks

### 7.1 The optimal simple macroprudential rule

In the benchmark calibration for the reaction parameter  $\delta_m$ , the weights in the loss function  $L = \sigma_\Omega^2 + \Theta\sigma_m^2$  on the variance of credit to output and on the variance of the LTV ratio are assumed to be equal ( $\Theta = 1$ ). The value which minimizes this loss is  $\delta_m^* = 1$ . Figure 8 shows the optimal value of the reaction parameter  $\delta_m^*$  for weights on the variance of the policy tool  $\Theta$  ranging between 0.2 to 2 ( $\Theta = 1$  is represented by the dashed red line). As the financial regulator becomes more concerned with the variance of the tool, the value of the reaction parameter that minimizes the loss falls. Note that the overall loss is minimized when no consideration is given to strong movements in  $m_t$ , yielding a very high reaction parameter. In this case policy would tighten the borrowing constraint significantly, minimizing the variance in credit.

Figure 9 compares the dynamics of output and credit following a housing bubble shock for optimal values of  $\delta_m$  that correspond to  $\Theta$  at 0.5 and 2 (2.22 and 0.434 respectively) with those under the benchmark assumption of  $\Theta = 1$  (the same responses as in Figure 7, shown in gray lines). Although the magnitudes of the responses of output and credit change with different macroprudential response parameters, the key conclusion that asymmetric policy exacerbates the recession holds. The stronger the weight on the LTV ratio in the loss function, the lower is the response parameter in the symmetric rule, over which the asymmetric rule is calibrated. A weaker response, under both symmetric and asymmetric policy, leads to a stronger (inefficient) boom but also a deeper bust. Moreover, the weaker is the response, the more pronounced is the

difference in the output drop between the two policy regimes.

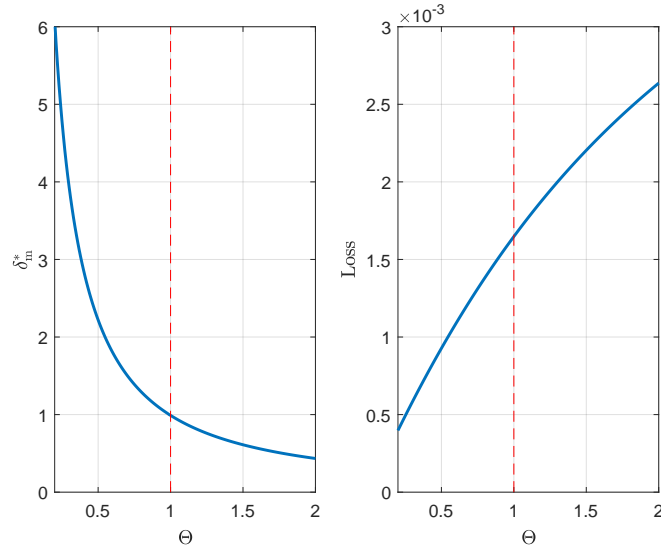


Figure 8: Optimal values of  $\delta_m$  and associated minimum loss

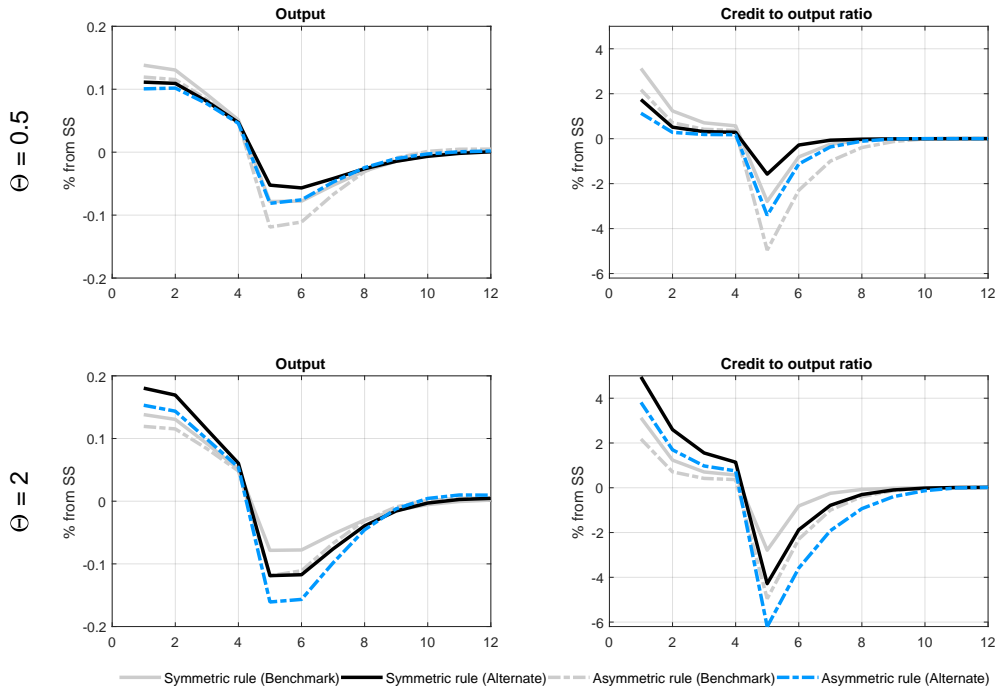


Figure 9: Responses across policy rules

Notes: Values on x-axis are time in quarters, on y-axis are % deviations from steady state.

## 7.2 The role of leverage

The economy described by the benchmark calibration is not highly leveraged when compared to the average levels observed in major advanced economies over the last 20 years. As shown in section 2.7, the steady-state LTV ratio  $\bar{m}$  and housing preference term  $\bar{j}$  control the aggregate housing wealth to output and the credit to output ratio. The simulations carried out above are conditional on housing wealth to (annualised) output  $\frac{qH}{4 \times Y} = 1.4$  and credit to (annualised)

output ratio  $\frac{B}{4 \times Y} = 0.3$  in the steady state. Such levels of mortgage debt to GDP were observed in the US, UK and Germany during the liberalization of financial markets in the mid-1980s (see Figures 1 and 2). The extent by which the impact of symmetric and asymmetric macroprudential policies on the economy differs is conceivably also affected by the level of steady state leverage since, as [Iacoviello \(2005\)](#) shows, financial amplification is a function of leverage. To examine these differences I repeat the boom-bust simulation above for an economy with both higher and lower steady state credit to output ratios. In the case of higher leverage, I set  $\bar{m}$  at 0.95 and  $\bar{j}$  at 0.08, which yield an annualised credit to output ratio of 46%, a scenario termed ‘High leverage’. This is a level observed in the US, UK, Germany and Spain in the early phase of the property price boom that preceded the crisis of 2007/2008. In the case of lower leverage, I set  $\bar{m}$  at 0.75 and  $\bar{j}$  at 0.04, yielding an annualised credit to output ratio of 13% (termed ‘Low leverage’). This is a level observed in the US and Germany in the mid-1950s and in the UK in the mid-1960s.<sup>48</sup> Table 2 and Figure 10 show comparative statics over these parameter configurations, and illustrate the non-linearity in the steady state debt to output ratio over high levels of the LTV ratio and housing preference term.

Table 2: Steady state ratios over  $\bar{m}$  and  $\bar{j}$

	$\bar{j}$	$\bar{m}$	$\frac{qH}{4 \times Y}$	$\frac{B}{4 \times Y}$
<b>Leverage</b>				
Low	0.04	0.75	0.88	0.13
Benchmark	0.06	0.90	1.41	0.30
High	0.08	0.95	1.93	0.46

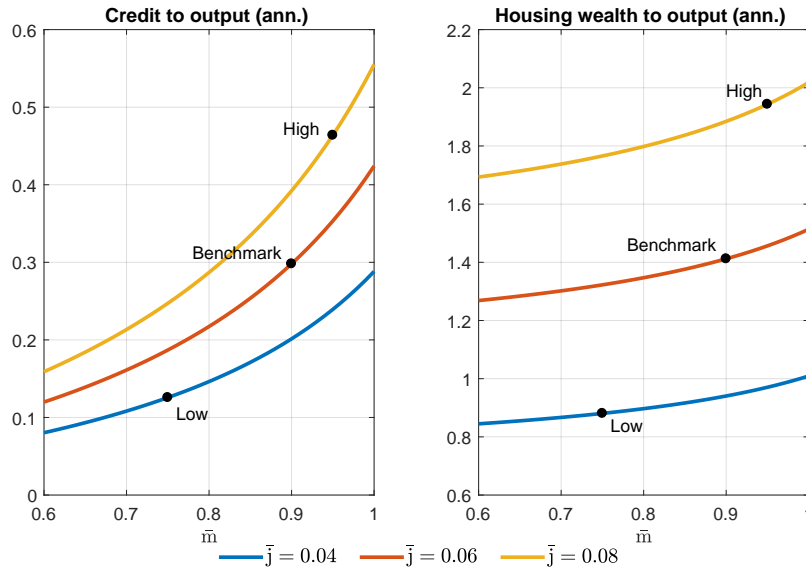


Figure 10: Steady state ratios over  $\bar{m}$  and  $\bar{j}$

The simulations under low and high leverage are shown in Figure 11, against the responses in the benchmark calibration. When leverage is low, the reaction of the economy to the bubble shock is muted, and the difference in the profile for output over symmetric and asymmetric policy

<sup>48</sup> These LTV ratios are very close to the ‘low’ and ‘high’ values used by [Iacoviello and Neri \(2010\)](#) when they estimate their model over two sub-samples, 1965–1982 and 1989–2006.

is minimal. This difference is noticeable at the benchmark calibration. At high levels of credit to output, the response of output is stronger due to higher amplification, and the implementation of asymmetric policy leads the economy into a deeper recession as the bubble bursts. In fact, the difference in the profile for output over the two policy regimes is positively related to the degree of leverage, as shown in Figure 12. Higher leverage leads to a stronger financial accelerator, causing the economy to react more strongly to the shock. These results confirm the main finding that asymmetric policy exacerbates a recession upon the bursting of a bubble, and the more leveraged the economy, the deeper the recession.

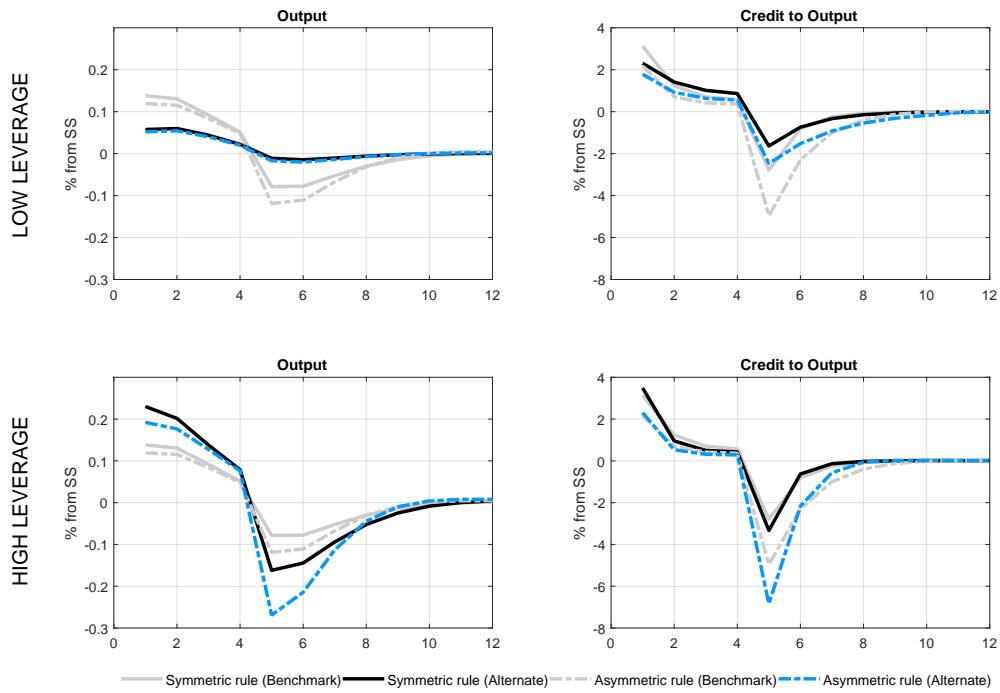


Figure 11: Responses across policy rules

Notes: Values on x-axis are time in quarters, on y-axis are % deviations from steady state.

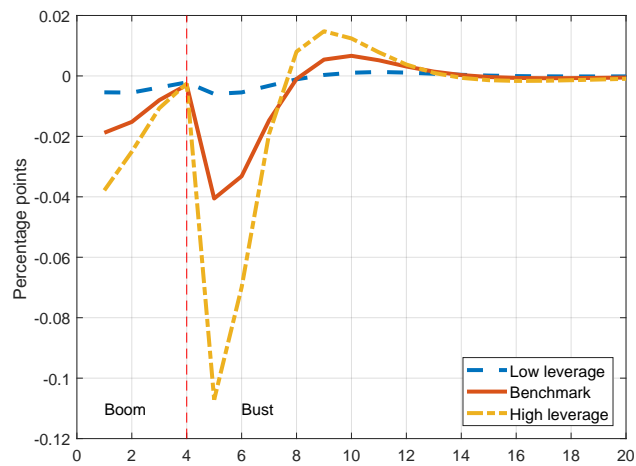


Figure 12: Difference in output responses across policy regimes

Notes: Values on x-axis are time in quarters, on y-axis the response of output under asymmetric policy less that under symmetric policy.

### 7.3 The relationship between asymmetry and volatility

All the preceding analysis is based on an arbitrary kink  $\kappa$  in the macroprudential rule of 5, that is, a response which is 5 times stronger during credit booms than during credit busts. In this section I illustrate the general implications of asymmetric policy using a wide range for  $\kappa$ , in a setting in which all types of housing demand shocks can hit the economy at random.

In a few instances all three shocks can be positive, big and hit at the same time – a housing demand shock that can be decomposed into an unanticipated component, an anticipated component, and a bubble component. When this happens their joint effect is strong and props house prices high enough such that the borrowing constraint becomes non-binding. To avoid this, I re-calibrate the variance of demand shocks  $\sigma_j^2$  at 0.027, which is half the value in the benchmark calibration. This ensures that, even in the case mentioned above, the increase in house prices does not render the borrowing constraint slack.<sup>49</sup> The re-sizing of the shock does not affect the results since under a first order perturbation the solution is in any case subject to certainty equivalence.

I simulate the model 1,000 times, for 100 years in each simulation, each time drawing random sequences of disturbances for the three housing shocks. This allows me to sample the average volatility of some variables within the model economy. I run these simulations for  $\kappa \in [1, 10]$  in increments of 0.5 and compare, for each  $\kappa$ , the variance of saver and borrower consumption, output, inflation and the credit to output ratio relative to the benchmark case of symmetry (when  $\kappa = 1$ ).<sup>50</sup> For comparability, I feed in the same sequence of shocks used over the 1,000 iterations for each value of  $\kappa$ .

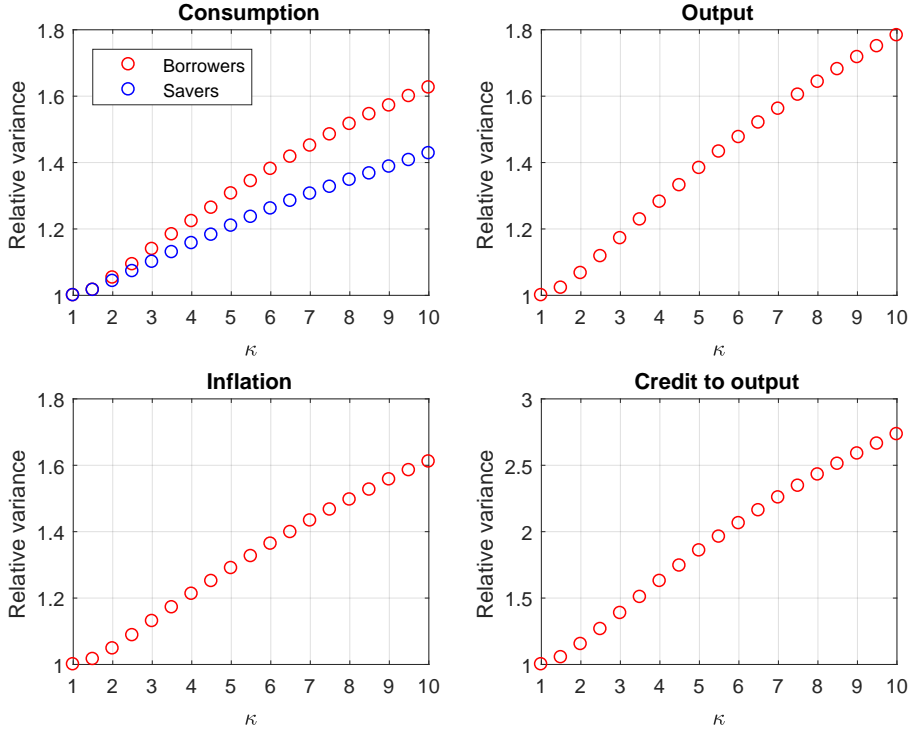


Figure 13: Relative volatility over the degree of asymmetry ( $\kappa = \bar{\delta}_m / \delta_m$ )

The results, in Figure 13, display a clear monotone relationship between the degree of asym-

<sup>49</sup> I check that the Lagrange multiplier on the borrowing constraint  $\mu_t$  is always strictly positive.

<sup>50</sup> The number of iterations, simulation length and increment in  $\kappa$  are influenced by the computational time required to complete one full round. The results indicate that these choices are sufficient to infer a clear pattern in the variance ratio.



metry in macroprudential policy and the relative variance of key variables. Stronger asymmetry on average leads to unequivocally higher output, inflation and credit volatility. The relationship between asymmetry and relative volatility is not linear; at low levels of  $\kappa$  the slope is high, falling over higher values. Asymmetric policy is never a superior policy to follow.

A secondary but important consideration is that the higher induced volatility in inflation (and to a lesser extent, output) creates an externality which may create tension between the goals of monetary and macroprudential policies. Asymmetric policy seems to partly undo the benefits that accrue under symmetric policy, in which small simultaneous movements in the nominal interest rate and the LTV ratio contribute collectively to greater macroeconomic stability.<sup>51</sup>

In addition, the results also generalise the result that borrowers are hit worse by asymmetric policy. Their consumption variance rises at a faster rate over  $\kappa$ , reflecting the increased variability in credit, since they are credit constrained. While savers' consumption variance also rises, it does so at a slower rate, since they can optimise their consumption path. Therefore, the implementation of asymmetric macroprudential policy not only leads to inferior business cycle stabilization and negative spillovers to monetary policy, but also generates non-trivial differentials between savers and borrowers in the economy. The policy recommendation is clear: policymakers are ill-advised to follow such a strategy.

## 8 Policy implications

There are a number of policy issues relating to the implementation of macroprudential policies, not covered above, which deserve further discussion. Firstly, I put aside social considerations related to housing, and in the model I assume that all households have access to a minimum unit of housing. Since financial amplification is a function of net wealth, I also assume that utility is derived from owning a house, ignoring the rental market. Therefore, macroprudential policy as described in this paper operates on households which already own a housing unit, that is, those which are non-first time buyers. While it is possible in practice to operate a time-varying LTV ratio that affects *all* households, for social and distributional considerations it may be more palatable either to lower borrowing limits faced by *non*-first time buyers first, to target households which are already highly indebted or to lower LTV ratios for first time buyers less severely.<sup>52</sup>

Secondly, in addition to an LTV limit, caps on debt to income (DTI) or debt service to income ratios (DSTI) can also be used as other complimentary tools to manage credit growth. Yet, [Cerutti et al. \(2017\)](#) document very poor use of DTI instruments in advanced economies in the early 2000s, rising only after the crisis. In this paper no constraints on credit supply are made since credit intermediation is assumed to be frictionless. In practice the implementation of the Countercyclical Capital Buffer as prescribed by Basel III in Europe is indeed another tool which can curb credit and asset price growth. Policymakers can therefore select from a range of tools and coordinate their implementation to contain risks stemming in the financial sector more effectively.

A third consideration is the celebrated discussion on rules versus discretion, applied to macroprudential policy. [Lim et al. \(2011\)](#) note that most countries prefer to operate macroprudential tools on a discretionary basis, subject to a routine review and judgement on the state of financial

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<sup>51</sup> See, for instance, Figure 4. The increased volatility in savers' consumption and inflation is more clearly seen in the case of negative demand shocks, which are shown in Appendix C.2.

<sup>52</sup> The Reserve Bank of New Zealand operates a 'speed limit' restriction on the *share* of loans with an LTV ratio higher than a threshold, that is, it allows banks to issue only a limited number of loans with a high LTV ratio ([Reserve Bank of New Zealand, 2013](#)). Such a policy seems to have first time buyers in mind.

risks. For instance, the Reserve Bank of New Zealand lists both the complexity of assessing risk that is not suitably captured by defining simple thresholds, and limited knowledge about the effectiveness of such policy, as key reasons to opt for discretion (Rogers, 2014). Although discretion gives policymakers flexibility in their decisions, it is likely to be less transparent than a rules-based approach and harder to communicate to the public. Discretion also implies that the public may engage in a guessing game of timing exit strategies.

Nonetheless, regulators should not operate macroprudential policy mechanically, disregarding any other relevant information about the state of the economy. Communication on macroprudential policy measures is particularly important in this regard because, besides guiding expectations, it also preserves accountability by relating revisions to policy to the state of the economy. Financial stability reports and related publications do exactly this. For example, in addition to the Macro Financial Review, the Central Bank of Ireland publishes a bi-annual ‘Systemic Risk Pack’ which shows a heatmap over a broad range of indicators of risk. This is an effective way of communicating potential build-up of risk in a relatively simple way.

However, referring to a single, observable variable as key indicator projects a strategy and therefore helps shape expectations about the start of both tightening and loosening phases. Especially when experience is limited, such an indicator also allows policymakers to learn about the strength of the link between the tool and the indicator and fine-tune their strategies over time. As in the conduct of monetary policy, macroprudential policy decisions which appear to be inconsistent with that indicator can then be substantiated and justified by referring to more extensive analysis. This policy prescription finds middle ground between rules and discretion, so-called ‘constrained discretion’ (Bernanke, 2003).

## 9 Conclusion

In this paper I argue that the character of macroprudential policy is such that it can give rise to asymmetric responses during the boom and bust phases of an asset price bubble. I use a New Keynesian DSGE model with financial frictions that require borrowing to be secured by housing collateral up to an LTV ratio. A housing bubble generates a boom-bust cycle in the real economy, due to the financial accelerator that is introduced by the financial friction. Policymakers intervene by varying the LTV ratio as a macroprudential tool to stabilize the cycle. Symmetric and asymmetric responses in the LTV ratio are compared.

While asymmetric policy helps to tame the increase in credit during the boom phase, relative to symmetric policy, it causes the economy to experience a deeper recession by not relaxing borrowing constraints at the same rate during the correction. I show that asymmetric policy hits borrowers proportionately harder since they are generally credit constrained and cannot smoothen consumption as efficiently as savers in the wake of shocks. The magnitude of both unfavourable outcomes also rises with the degree of asymmetry in the policy response. In this regard, policymakers are advised to unwind tight policy as soon as a bubble bursts, such that they work against and dampen the vicious downward collateral cycle, stabilizing business cycles. Ultimately, the predominant driver of leverage remains the value of housing as an asset. The evidence accumulated so far, namely that the debt ratio is the single most reliable early-warning indicator for financial crises, is convincing. While policymakers should not target asset prices directly, they should start using more the tools at their disposal to prevent over-indebtedness and excessive risk taking during a boom.

## References

- Angelini, P., Neri, S., and Panetta, F. (2014). The interaction between capital requirements and monetary policy. *Journal of Money, Credit and Banking*, 46(6):1073–1112.
- Ascari, G. and Sbordone, A. M. (2014). The macroeconomics of trend inflation. *Journal of Economic Literature*, 52(3):679–739.
- Banerjee, A. V. (1992). A simple model of herd behavior. *The Quarterly Journal of Economics*, 107(3):797–817.
- Bank of England (2009). The role of macroprudential policy. *Bank of England Discussion Paper*.
- Basel Committee (2010). Guidance for national authorities operating the countercyclical capital buffer. *Basel Switzerland*.
- Beaudry, P. and Portier, F. (2004). An exploration into Pigou’s theory of cycles. *Journal of Monetary Economics*, 51(6):1183–1216.
- Beaudry, P. and Portier, F. (2006). Stock prices, news, and economic fluctuations. *American Economic Review*, 96(4):1293–1307.
- Beaudry, P. and Portier, F. (2007). When can changes in expectations cause business cycle fluctuations in neo-classical settings? *Journal of Economic Theory*, 135(1):458–477.
- Bernanke, B. (2003). “Constrained Discretion” and Monetary Policy. *Speech delivered to the Money Marketeers of New York University, New York, 3 February 2003*, available at <https://www.federalreserve.gov/boarddocs/speeches/2003/20030203/> [accessed on 26 February 2018].
- Bernanke, B. (2004). The Great Moderation. *Speech delivered at the meetings of the Eastern Economic Association, Washington DC, 20 February 2004*, available at <https://www.federalreserve.gov/boarddocs/speeches/2004/20040220/> [accessed on 12 October 2017].
- Bernanke, B. (2010). Monetary policy and the housing bubble. *Speech at the Annual Meeting of the American Economic Association, Atlanta, Georgia, 3 January 2010*, available at <https://www.federalreserve.gov/newsevents/speech/bernanke20100103a.htm> [accessed on 12 October 2017].
- Bernanke, B. and Gertler, M. (1999). Monetary policy and asset price volatility. *Federal Reserve Bank of Kansas City Economic Review*, (Q IV):17–51.
- Bernanke, B. S., Gertler, M., and Gilchrist, S. (1999). The financial accelerator in a quantitative business cycle framework. In *Handbook of Macroeconomics*, volume 1, pages 1341–1393. Elsevier.
- Bikhchandani, S., Hirshleifer, D., and Welch, I. (1992). A theory of fads, fashion, custom, and cultural change as informational cascades. *Journal of Political Economy*, 100(5):992–1026.
- Binder, M., Lieberknecht, P., Quintana, J., and Wieland, V. (2017). Model uncertainty in macroeconomics: on the implications of financial frictions. *CEPR discussion paper DP 12013*.
- Boar, C., Gambacorta, L., Lombardo, G., da Silva, P., and Awazu, L. (2017). What are the effects of macroprudential policies on macroeconomic performance? *BIS Quarterly Review*, September 2017, pages 71–84.

- Borio, C. (2014). The financial cycle and macroeconomics: What have we learnt? *Journal of Banking & Finance*, 45:182–198.
- Born, B., Peter, A., and Pfeifer, J. (2013). Fiscal news and macroeconomic volatility. *Journal of Economic Dynamics and Control*, 37(12):2582–2601.
- Brazier, A. (2017). How to: MACROPRU. 5 principles for macroprudential policy. *Speech delivered at the Financial Regulation Seminar at the London School of Economics on Monday 13 February 2017*, available at <http://www.bankofengland.co.uk/publications/Documents/speeches/2017/speech960.pdf> [accessed on 20 February 2017].
- Bruneau, G., Christensen, I., and Meh, C. A. (2016). Housing market dynamics and macroprudential policy. *Staff Working Paper 2016-31, Bank of Canada*.
- Burlon, L., Gerali, A., Notarpietro, A., and Pisani, M. (2016). Non-standard monetary policy, asset prices and macroprudential policy in a monetary union. *Working Paper no. 1089, Bank of Italy*.
- Carroll, C. D. and Samwick, A. A. (1997). The nature of precautionary wealth. *Journal of Monetary Economics*, 40(1):41–71.
- Case, K. E. and Shiller, R. J. (2003). Is there a bubble in the housing market? *Brookings Papers on Economic Activity*, 2003(2):299–342.
- Cerutti, E., Claessens, S., and Laeven, L. (2017). The use and effectiveness of macroprudential policies: new evidence. *Journal of Financial Stability*, 28:203–224.
- Cesa-Bianchi, A., Ferrero, A., and Rebucci, A. (2017). International credit supply shocks. *Bank of England Staff Working Paper No. 680*.
- Christiano, L., Ilut, C., Motto, R., and Rostagno, M. (2008). Monetary policy and stock market boom-bust cycles. *ECB Working Paper Series no. 995*.
- Christiano, L., Ilut, C., Motto, R., and Rostagno, M. (2010). Monetary policy and stock market booms. In *Macroeconomic Challenges: The Decade Ahead*, pages 85–145. Federal Reserve Bank of Kansas City.
- Christiano, L. J., Trabandt, M., and Walentin, K. (2011). DSGE models for monetary policy analysis. *Handbook of Monetary Economics*, 3A:285–367.
- Cochrane, J. H. (1994). Shocks. In *Carnegie-Rochester Conference series on public policy*, volume 41, pages 295–364. Elsevier.
- Crowe, C., Dell’Ariccia, G., Igan, D., and Rabanal, P. (2011). Policies for macrofinancial stability: Options to deal with real estate booms. *IMF Staff Discussion Note: Policies for Macrofinancial Stability: Options to Deal with Real Estate Booms*, 11(33).
- Cukierman, A. and Muscatelli, A. (2008). Nonlinear Taylor rules and asymmetric preferences in central banking: Evidence from the United Kingdom and the United States. *The BE Journal of macroeconomics*, 8(1).
- Dolado, J., María-Dolores, R., and Ruge-Murcia, F. J. (2004). Nonlinear monetary policy rules: some new evidence for the US. *Studies in Nonlinear Dynamics & Econometrics*, 8(3).

- Dolado, J. J., María-Dolores, R., and Naveira, M. (2005). Are monetary policy reaction functions asymmetric? The role of nonlinearity in the Phillips curve. *European Economic Review*, 49(2):485–503.
- Drehmann, M., Borio, C., and Tsatsaronis, K. (2014). Can we identify the financial cycle? In *The Role of Central Banks in Financial Stability: How Has It Changed?*, pages 131–156. World Scientific.
- Dupor, B. (2005). Stabilizing non-fundamental asset price movements under discretion and limited information. *Journal of Monetary Economics*, 52:727–747.
- ECB (2009). Housing finance in the euro area. *Structural Issues Report, March 2009*.
- ECB (2016). Macroprudential Bulletin. *Issue 01/2016*.
- Favara, G. and Imbs, J. (2015). Credit supply and the price of housing. *American Economic Review*, 105(3):958–992.
- Galati, G. and Moessner, R. (2013). Macroprudential policy—a literature review. *Journal of Economic Surveys*, 27(5):846–878.
- Gambacorta, L. and Murcia, A. (2017). The impact of macroprudential policies and their interaction with monetary policy: an empirical analysis using credit registry data. *BIS Working Paper no. 636*.
- Gelain, P., Lansing, K., and Mendicino, C. (2013). House prices, credit growth, and excess volatility: Implications for monetary and macroprudential policy. *International Journal of Central Banking*, 9(2):219–276.
- Gerali, A., Neri, S., Sessa, L., and Signoretti, F. M. (2010). Credit and Banking in a DSGE Model of the Euro Area. *Journal of Money, Credit and Banking*, 42(s1):107–141.
- Gilchrist, S. and Leahy, J. V. (2002). Monetary policy and asset prices. *Journal of Monetary Economics*, 49(1):75–97.
- Gomes, S. and Mendicino, C. (2015). Housing market dynamics: any news? *ECB Working paper series no. 1775*.
- Goodhart, C. A. E. (2009). *The regulatory response to the financial crisis*. Edward Elgar, Cheltenham.
- Guerrieri, L. and Iacoviello, M. (2015). OccBin: A toolkit for solving dynamic models with occasionally binding constraints easily. *Journal of Monetary Economics*, 70:22–38.
- Guerrieri, L. and Iacoviello, M. (2017). Collateral constraints and macroeconomic asymmetries. *Journal of Monetary Economics*, 90:28–49.
- Haldane, A. G. (2017). Rethinking financial stability. *Speech at the conference on Rethinking Macroeconomic Policy IV, Washington DC, 12 October 2017*, available at <https://www.bankofengland.co.uk/speech/2017/rethinking-financial-stability> [accessed on 6 November 2017].
- Iacoviello, M. (2005). House prices, borrowing constraints, and monetary policy in the business cycle. *American Economic Review*, pages 739–764.

- Iacoviello, M. (2015). Financial business cycles. *Review of Economic Dynamics*, 18(1):140–163.
- Iacoviello, M. and Neri, S. (2010). Housing market spillovers: Evidence from an estimated DSGE model. *American Economic Journal: Macroeconomics*, 2(2):125–164.
- Jaimovich, N. and Rebelo, S. (2009). Can news about the future drive the business cycle? *American Economic Review*, 99(4):1097–1118.
- Jermann, U. and Quadrini, V. (2012). Macroeconomic effects of financial shocks. *American Economic Review*, 102(1):238–271.
- Jordà, Ò., Schularick, M., and Taylor, A. (2015a). Betting the house. *Journal of International Economics*, 96:S2–S18.
- Jordà, Ò., Schularick, M., and Taylor, A. (2015b). Leveraged bubbles. *Journal of Monetary Economics*, 76:S1–S20.
- Jordà, Ò., Schularick, M., and Taylor, A. M. (2017). Macrofinancial history and the new business cycle facts. In *NBER Macroeconomics Annual 2016, Volume 31*. University of Chicago Press. <http://www.macrohistory.net/data/>, [accessed on 21 March 2017].
- Justiniano, A., Primiceri, G. E., and Tambalotti, A. (2017). Credit supply and the housing boom. *Unpublished mimeo*.
- Kannan, P., Rabanal, P., and Scott, A. M. (2012). Monetary and macroprudential policy rules in a model with house price booms. *The BE Journal of Macroeconomics*, 12(1).
- Kaplan, G., Mitman, K., and Violante, G. L. (2017). The housing boom and bust: Model meets evidence. *NBER Working Paper no. 23694*.
- Kiyotaki, N. and Moore, J. (1997). Credit cycles. *The Journal of Political Economy*, 105(2):211–248.
- Knoll, K., Schularick, M., and Steger, T. (2017). No price like home: global house prices, 1870-2012. *American Economic Review*, 107(2):331–353.
- Krznar, I. and Morsink, J. (2014). With Great Power Comes Great Responsibility: Macroprudential Tools at Work in Canada. *IMF Working Paper, WP/14/83*.
- Lambertini, L., Mendicino, C., and Punzi, M. T. (2013a). Expectation-driven cycles in the housing market: Evidence from survey data. *Journal of Financial Stability*, 9(4):518–529.
- Lambertini, L., Mendicino, C., and Punzi, M. T. (2013b). Leaning against boom–bust cycles in credit and housing prices. *Journal of Economic Dynamics and Control*, 37(8):1500–1522.
- Lambertini, L., Mendicino, C., and Punzi, M. T. (2017). Expectations-driven cycles in the housing market. *Economic Modelling*, 60:297–312.
- Lawrance, E. C. (1991). Poverty and the rate of time preference: evidence from panel data. *Journal of Political Economy*, 99(1):54–77.
- Lim, C. H., Costa, A., Columba, F., Kongsamut, P., Otani, A., Saiyid, M., Wezel, T., and Wu, X. (2011). Macroprudential policy: what instruments and how to use them? Lessons from country experiences. *IMF Working Paper WP/11/238*.

- Liu, Z., Wang, P., and Zha, T. (2013). Land-price dynamics and macroeconomic fluctuations. *Econometrica*, 81(3):1147–1184.
- Lorenzoni, G. (2009). A theory of demand shocks. *American Economic Review*, 99(5):2050–2084.
- Lorenzoni, G. (2010). Optimal monetary policy with uncertain fundamentals and dispersed information. *Review of Economic Studies*, 77(1):305–338.
- Lorenzoni, G. (2011). News and aggregate demand shocks. *Annual Review of Economics*, 3(1):537–557.
- McCallum, B. T. (2001). Should monetary policy respond strongly to output gaps? *American Economic Review*, 91(2):258–262.
- Mertens, K. and Ravn, M. O. (2011). Understanding the aggregate effects of anticipated and unanticipated tax policy shocks. *Review of Economic Dynamics*, 14(1):27–54.
- Mian, A. and Sufi, A. (2009). The consequences of mortgage credit expansion: Evidence from the US mortgage default crisis. *Quarterly Journal of Economics*, 124(4):1449–1496.
- Nobay, R. A. and Peel, D. A. (2003). Optimal discretionary monetary policy in a model of asymmetric central bank preferences. *Economic Journal*, 113(489):657–665.
- Notarpietro, A. and Siviero, S. (2015). Optimal monetary policy rules and house prices: the role of financial frictions. *Journal of Money, Credit and Banking*, 47(S1):383–410.
- Paez-Farrell, J. (2014). Resuscitating the ad-hoc loss function for monetary policy analysis. *Economics Letters*, 123(3):313–317.
- Paloviita, M., Haavio, M., Jalasjoki, P., Kilponen, J., et al. (2017). What does “below, but close to, two percent” mean? Assessing the ECB’s reaction function with real time data. *Bank of Finland Research Discussion Paper 29/2017*.
- Piazzesi, M. and Schneider, M. (2009). Momentum traders in the housing market: survey evidence and a search model. *American Economic Review: Papers & Proceedings*, 99(2):406–411.
- Pigou, A. C. (1927). *Industrial fluctuations*. Macmillan.
- Reinhart, C. and Rogoff, K. (2009). *This time is different: eight centuries of financial folly*. Princeton University Press.
- Reinhart, C. and Rogoff, K. (2013). Banking crises: an equal opportunity menace. *Journal of Banking & Finance*, 37(11):4557–4573.
- Reserve Bank of New Zealand (2013). Limits for high-LVR mortgage lending. *Press release issued on 20 August 2013*. <https://www.rbnz.govt.nz/news/2013/08/limits-for-high-lvr-mortgage-lending>, [accessed 26 February 2018].
- Rogers, L. (2014). An A to Z of loan-to-value ratio (LVR) restrictions. *Reserve Bank of New Zealand Bulletin*, 77(1):3–14.
- Røisland, Ø. (2017). On the interplay between monetary policy and macroprudential policy: A simple analytical framework. *Norges Bank Working Paper no. 18-2017*.

- Rubio, M. and Carrasco-Gallego, J. A. (2014). Macprudential and monetary policies: Implications for financial stability and welfare. *Journal of Banking & Finance*, 49:326–336.
- Rubio, M. and Carrasco-Gallego, J. A. (2016). The new financial regulation in Basel III and monetary policy: A macroprudential approach. *Journal of Financial Stability*, 26:294–305.
- Rubio, M. and Yao, F. (2017). Macprudential policies in a low interest-rate environment. *Reserve Bank of New Zealand Discussion Paper Series 2017/04*.
- Samwick, A. A. (1998). Discount rate heterogeneity and social security reform. *Journal of Development Economics*, 57(1):117–146.
- Schmitt-Grohé, S. and Uribe, M. (2006). Optimal simple and implementable monetary and fiscal rules: Expanded version. *NBER Working Paper 12402*.
- Schmitt-Grohé, S. and Uribe, M. (2012). What’s news in business cycles. *Econometrica*, 80(6):2733–2764.
- Schularick, M. and Taylor, A. (2012). Credit booms gone bust: monetary policy, leverage cycles, and financial crises, 1870–2008. *American Economic Review*, 102(2):1029–1061.
- Shiller, R. (2000). *Irrational Exuberance*. Princeton University Press.
- Surico, P. (2003). Asymmetric reaction functions for the euro area. *Oxford Review of Economic Policy*, 19(1):44–57.
- Surico, P. (2008). Measuring the time inconsistency of US monetary policy. *Economica*, 75(297):22–38.
- Svensson, L. E. (2012). Comment on Michael Woodford, “Inflation Targeting and Financial Stability”. *Sveriges Riksbank Economic Review*, 1.
- Svensson, L. E. (2017). Cost-benefit analysis of leaning against the wind. *Journal of Monetary Economics*, forthcoming.
- Trichet, J. C. (2005). Asset price bubbles and monetary policy. *Speech delivered at the Mas lecture on 8 June 2005, Singapore*. <https://www.ecb.europa.eu/press/key/date/2005/html/sp050608.en.html>, [accessed 19 September 2017].
- Weidmann, J. (2017). Monetary policy after the crisis. *IMFS Distinguished Lecture, 14 September 2017, Frankfurt am Main*. <http://www.bis.org/review/r170919b.htm>, [accessed 19 September 2017].
- Wheaton, W. and Nechayev, G. (2008). The 1998-2005 housing “bubble” and the current “correction”: What’s different this time? *Journal of Real Estate Research*, 30(1):1–26.
- Wieland, V. and Wolters, M. (2013). Forecasting and policy making. In *Handbook of economic forecasting*, volume 2, pages 239–325. Elsevier.
- Yun, T. (1996). Nominal price rigidity, money supply endogeneity, and business cycles. *Journal of Monetary Economics*, 37(2):345–370.
- Zabai, A. (2017). Household debt: recent developments and challenges. *BIS Quarterly Review*, December 2017.



## Appendix A Data

The data used in Figure 1 are obtained from the FRED database. House prices are sourced from the U.S. Federal Housing Finance Agency (code: USSTHPI), and are deflated using the CPI sourced from the U.S. Bureau of Labour statistics (code: CPIAUCSL). Mortgage debt is sourced from the Board of Governors of the Federal Reserve System (code: HMLBSHNO). All annual series are end-of-period values. GDP is sourced from the U.S. Bureau of Economic Analysis (code: GDPA).

## Appendix B Price setting

The maximisation problem faced by price setting firms is:

$$\max_{p_{j,t}} \mathbb{E}_t \left\{ \sum_{i=0}^{\infty} \omega^i \Lambda_{i,t+i} Y_{t+i} \left[ \left( \frac{p_{j,t}}{P_{t+i}} \right)^{1-\sigma} - MC_{t+i} \left( \frac{p_{j,t}}{P_{t+i}} \right)^{-\sigma} \right] \right\}$$

Maximising with respect to  $p_{j,t}$ , and multiplying out all constants with respect to the sum:

$$\begin{aligned} \mathbb{E}_t \left\{ \sum_{i=0}^{\infty} \omega^i \Lambda_{i,t+i} Y_{t+i} (1-\sigma) \left( \frac{p_{j,t}}{P_{t+i}} \right)^{-\sigma} \left[ \left( \frac{p_{j,t}}{P_{t+i}} \right) - \frac{\sigma}{\sigma-1} MC_{t+i} \right] \right\} &= 0 \\ \Rightarrow \mathbb{E}_t \left\{ \sum_{i=0}^{\infty} \omega^i \Lambda_{i,t+i} Y_{t+i} P_{t+i}^{\sigma} \left[ \left( \frac{p_{j,t}}{P_{t+i}} \right) - \frac{\sigma}{\sigma-1} MC_{t+i} \right] \right\} &= 0 \end{aligned}$$

Using the definition for the stochastic discount factor, and noting that  $\tilde{C}_{s,t}$  is constant with respect to the problem, we get:

$$\mathbb{E}_t \left\{ \sum_{i=0}^{\infty} (\omega\beta)^i \frac{Y_{t+i}}{\tilde{C}_{s,t+i}} P_{t+i}^{\sigma} \left[ \left( \frac{p_{j,t}}{P_{t+i}} \right) - \frac{\sigma}{\sigma-1} MC_{t+i} \right] \right\} = 0$$

The price  $p_t^*$  which solves this can be written as:

$$p_t^* = \left( \frac{\sigma}{\sigma-1} \right) \frac{\mathbb{E}_t \left\{ \sum_{i=0}^{\infty} (\omega\beta_s)^i \frac{Y_{t+i}}{\tilde{C}_{s,t+i}} MC_{t+i} P_{t+i}^{\sigma} \right\}}{\mathbb{E}_t \left\{ \sum_{i=0}^{\infty} (\omega\beta_s)^i \frac{Y_{t+i}}{\tilde{C}_{s,t+i}} P_{t+i}^{\sigma-1} \right\}}$$

where the subscript  $j$  is dropped since all firms have the same technology and face the same demand curve, and hence will optimise in the same way. Multiplying both sides by  $P_t^{-1}$  we get relative prices.<sup>53</sup>

$$\frac{p_t^*}{P_t} = \left( \frac{\sigma}{\sigma-1} \right) \frac{\mathbb{E}_t \left\{ \sum_{i=0}^{\infty} (\omega\beta_s)^i \frac{Y_{t+i}}{\tilde{C}_{s,t+i}} MC_{t+i} \left( \frac{P_{t+i}}{P_t} \right)^{\sigma} \right\}}{\mathbb{E}_t \left\{ \sum_{i=0}^{\infty} (\omega\beta_s)^i \frac{Y_{t+i}}{\tilde{C}_{s,t+i}} \left( \frac{P_{t+i}}{P_t} \right)^{\sigma-1} \right\}}$$

Following [Christiano et al. \(2011\)](#) and [Ascari and Sbordone \(2014\)](#), it is useful to represent the New Keynesian Phillips curve as

$$\frac{p_t^*}{P_t} = \left( \frac{\sigma}{\sigma-1} \right) \frac{\mathbb{E}_t \left\{ \sum_{i=0}^{\infty} (\omega\beta_s)^i \frac{Y_{t+i}}{\tilde{C}_{s,t+i}} MC_{t+i} \Theta_{t,t+i}^{\sigma} \right\}}{\mathbb{E}_t \left\{ \sum_{i=0}^{\infty} (\omega\beta_s)^i \frac{Y_{t+i}}{\tilde{C}_{s,t+i}} \Theta_{t,t+i}^{\sigma-1} \right\}} = \left( \frac{\sigma}{\sigma-1} \right) \frac{\Upsilon_t}{\Phi_t} \quad (31)$$

<sup>53</sup>Use of the fact that  $P_t^{-1} \equiv P_t^{(-1+\sigma-\sigma)}$  has been made.

where  $\Theta_{t,t+i}$  represents cumulative gross inflation between two periods:

$$\Theta_{t,t+i} = \begin{cases} 1 & \text{if } j = 0 \\ \frac{P_{t+1}}{P_t} \times \dots \times \frac{P_{t+i}}{P_{t+i-1}} & \text{if } j \geq 1 \end{cases}$$

The numerator  $\Upsilon_t$  and denominator  $\Phi_t$  can be written in recursive form:

$$\Upsilon_t = \frac{Y_t}{\tilde{C}_{s,t}} MC_t + \omega \beta_s \mathbb{E}_t \{ \pi_{t+1}^\sigma \Upsilon_{t+1} \} \quad (32)$$

$$\Phi_t = \frac{Y_t}{\tilde{C}_{s,t}} + \omega \beta_s \mathbb{E}_t \{ \pi_{t+1}^{\sigma-1} \Phi_{t+1} \} \quad (33)$$

Since the probability of adjusting prices is independent of a firm's history, from the law of large numbers the aggregate price<sup>54</sup> is a weighted average of optimised prices and previous period prices:

$$P_t^{1-\sigma} = (1-\omega)(p_t^*)^{1-\sigma} + \omega P_{t-1}^{1-\sigma} \quad (34)$$

which can be used to solve for relative prices as a function of inflation:

$$\frac{p_t^*}{P_t} = \left( \frac{1-\omega}{1-\omega \pi_t^{\sigma-1}} \right)^{\frac{1}{\sigma-1}} \quad (35)$$

This can be used to eliminate  $p^*$ , and the optimal pricing equation can therefore be written as:

$$\Upsilon_t = \left( \frac{\sigma-1}{\sigma} \right) \left( \frac{1-\omega}{1-\omega \pi_t^{\sigma-1}} \right)^{\frac{1}{\sigma-1}} \Phi_t \quad (36)$$

Equations (32), (33) and (36) jointly determine price dynamics.

## Appendix C Other shocks

### C.1 Technology and monetary policy

#### C.1.1 Shocks to technology

Figure 14 shows the response to a positive technology shock. An unanticipated increase in productivity boosts output, demand and income, while inflation falls, due to the drop in marginal costs. Falling prices cause the monetary authority to cut the nominal interest rate. However, since the drop in inflation is more pronounced than in the benchmark case, the real interest rate rises strongly, increasing the cost of borrowing. Therefore impatient households do not increase their consumption initially, despite the increase in house prices, and actually reduce their holdings of debt and housing (not shown). Hence the increase in output is driven largely by savers in the first year of the boom. Subsequently the nominal interest rate falls further, while deflation slows down, lowering the real interest rate. Borrowers increase their consumption and borrowing in the second year following the shock. In sum, an unanticipated shock to technology raises output and house prices but does not generate a strong increase in credit. There is then

<sup>54</sup>The aggregate price is a CES aggregate of prices over the continuum of firms:

$$P_t = \left( \int_0^1 p_{j,t}^{1-\sigma} dj \right)^{\frac{1}{1-\sigma}}$$

little scope for macroprudential policies in this case, which is the conclusion reached by [Kannan et al. \(2012\)](#) in the wake of productivity shocks.<sup>55</sup>

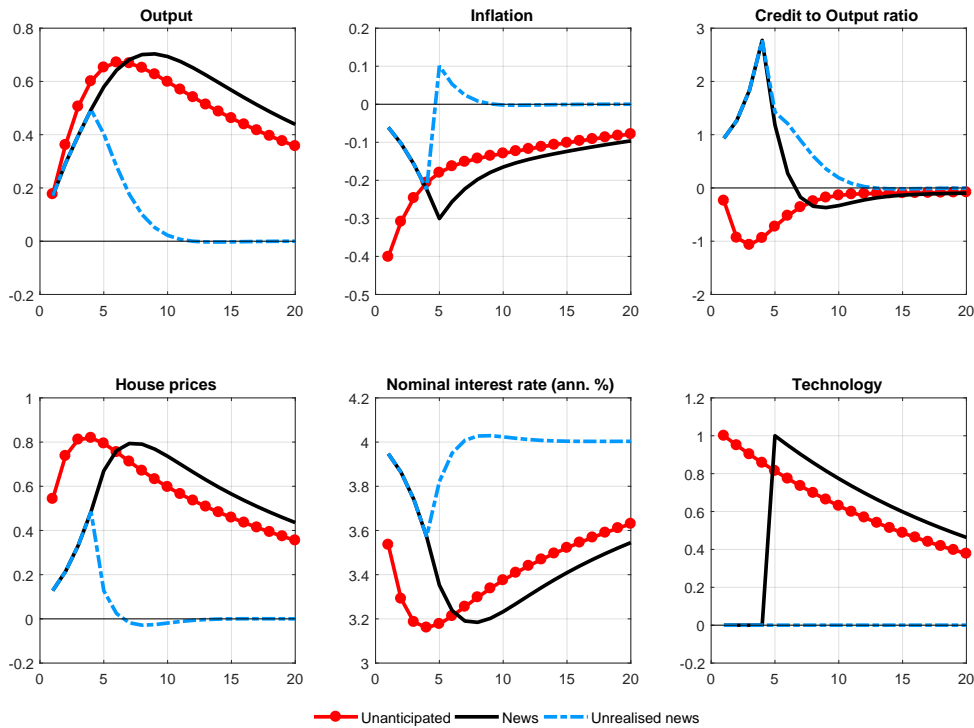


Figure 14: Impulse responses to technology shocks

Notes: Values on x-axis are quarters; y-axis are % deviations from steady state, except for interest rates

The response of some variables to a technology news shock is the opposite of those discussed above. In the case of an anticipated improvement to technology a year into the future, impatient households increase their borrowing and consumption immediately, the latter by several orders of magnitude greater than savers. Furthermore there is now a steady *increase* in credit which is driven by a corresponding increase in house prices. The dynamics of the real interest rate play an important role in explaining these differences. Inflation starts falling despite increases in marginal costs, on account of an expected reduction in future marginal costs from the improvement in productivity, and bottoms out upon the realisation of the higher productivity. Meanwhile the response of the nominal interest is more muted, since inflation falls only gradually, and the nominal rate is subject to some inertia. As a result the rise in the real interest rate is contained, which explains the increase in credit. As in the case of a housing demand shock, anticipation effects again lead to a slightly stronger boom than in the benchmark case. This is because house prices peak towards the end of the second year following the shock, which keep borrowers' consumption buoyant over a longer period.<sup>56</sup>

In the event that the anticipated productivity shock does not occur, the boom in the economy stops abruptly and output falls back to its pre-shock level. Inflation shoots up since the rise in marginal costs in the anticipation stage is not reversed by an actual improvement in productivity,

<sup>55</sup> [Liu et al. \(2013\)](#) show that permanent or temporary shocks to Total Factor Productivity do not lead to amplification in the case when it is firms which face the borrowing constraint, as neither shock in their model leads to sizeable changes in land prices. While in this paper technology shocks do raise house prices, amplification is muted by the strong rise in the real interest rate.

<sup>56</sup> The cumulated increase in output is about 16.9% higher than the steady state for the benchmark case, compared to about 19.2% in the case of a news shock.

and this reduces the real interest rate temporarily. As a result borrowers reduce their consumption and leverage at a slower rate, even though house prices fall back to their original level very quickly. Although the boom in output and house prices is short-lived, optimistic expectations about productivity fail to generate a boom-bust cycle.

### C.1.2 Shocks to monetary policy

An unanticipated negative shock to nominal interest rates, defined as a nominal interest rate below what the Taylor rule prescribes, is expansionary. This is a basic feature of the short-run non-neutrality of monetary policy due to nominal rigidities, present even in ‘first-generation’ New Keynesian models that are void of any financial frictions (Binder et al., 2017). The drop in the nominal rate boosts demand by lowering the real interest rate thereby reducing the opportunity cost of saving. In this model most of the increase in output is not driven by consumption smoothing from patient households, but by consumption from impatient households, whose borrowing limit rises as the real interest rate falls. The increase in demand for the final good pushes up marginal costs and hence inflation, driving the real interest rate further down. Borrowers find it optimal to use part of the increase in credit to invest in more housing, while savers respond primarily by increasing their labour supply. Since the shock is not intrinsically persistent, the boom lasts only for about 2 years, at which time credit, house prices and output are at their steady state values.

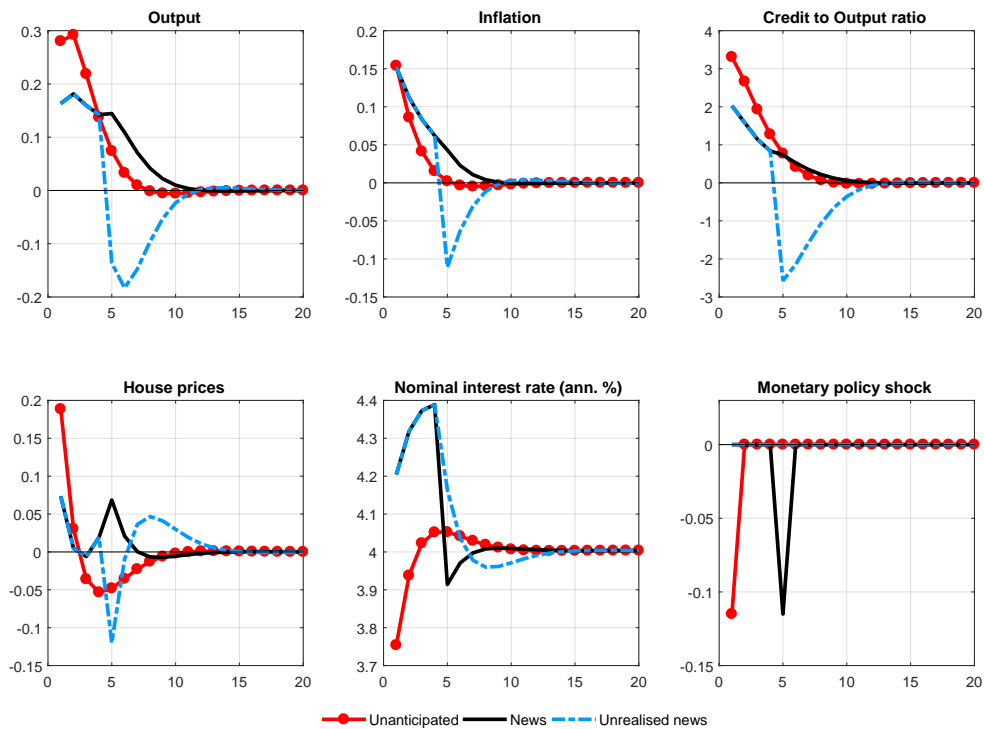


Figure 15: Impulse responses to monetary policy shocks

Notes: Values on x-axis are time in quarters, on y-axis are % deviations from steady state, except for the interest rate.

Anticipation of an interest rate cut one year in the future is also expansionary, however the model predicts a smaller initial impact on output. This is because while anticipation of a lower nominal rate stimulates demand before the rate has moved, borrowing is at a relatively higher real interest rate than in the benchmark shock. Moreover, the increase in demand and inflation

stimulates an immediate *increase* in the nominal rate, as the monetary authority responds to a perceived demand shock. As a result impatient households' credit, consumption and housing investment rise by less. As monetary policy actually cuts the nominal rate in quarter 5, the real cost of borrowing falls, which supports higher credit relative to the benchmark case. This however has a small effect on house prices. As a result output and inflation remain higher for a few additional quarters. In sum, both unanticipated and anticipated monetary policy shocks are both expansionary and generate a boom in output and credit.

If the expected monetary loosening does not take place in quarter 5, the model predicts a sharp correction in output, inflation and credit, arising from a revision to expectations. Since the nominal rate does not fall, current levels of consumption, borrowing and labour are out of line with optimal decisions and hence are all revised. Impatient households deleverage, cutting back on their consumption and run down their debt. The drop in demand lowers inflationary pressures, causing the real interest rate to rise, which further depresses consumption and borrowing. The economy experiences a short recession as a result of the excessive optimism on borrowing conditions.

While an unrealized monetary policy shocks can give rise to a boom-bust cycle, the effect comes mainly from the dynamics of the real interest rate, with little amplification and feedback between house prices and credit, and consequently house prices do not deviate too much from fundamental value. The only shock that can generate amplification and feedback between credit and house prices is a housing demand shock. Because of this, only excessively optimistic expectations about future asset prices can generate a sizeable boom-bust episode reminiscent of the development and bursting of a bubble. For this reason I restrict my attention to housing demand shocks.

## C.2 Negative shocks

Figures 16 – 18 below illustrate the reaction of the economy under the three types of housing demand shocks, when these shocks are negative. In each case, the response of the economy is assessed in the case of a fixed LTV ratio, and under symmetric and asymmetric macroprudential rules that govern the movement in the LTV ratio. Under the first two policy scenarios the responses of the economy are simply mirror images of those under a positive shock. By definition, the responses under the asymmetric rule are not mirror images, but reflect the fact that the policy response is weaker, such that the LTV ratio is moved by less in absolute terms.

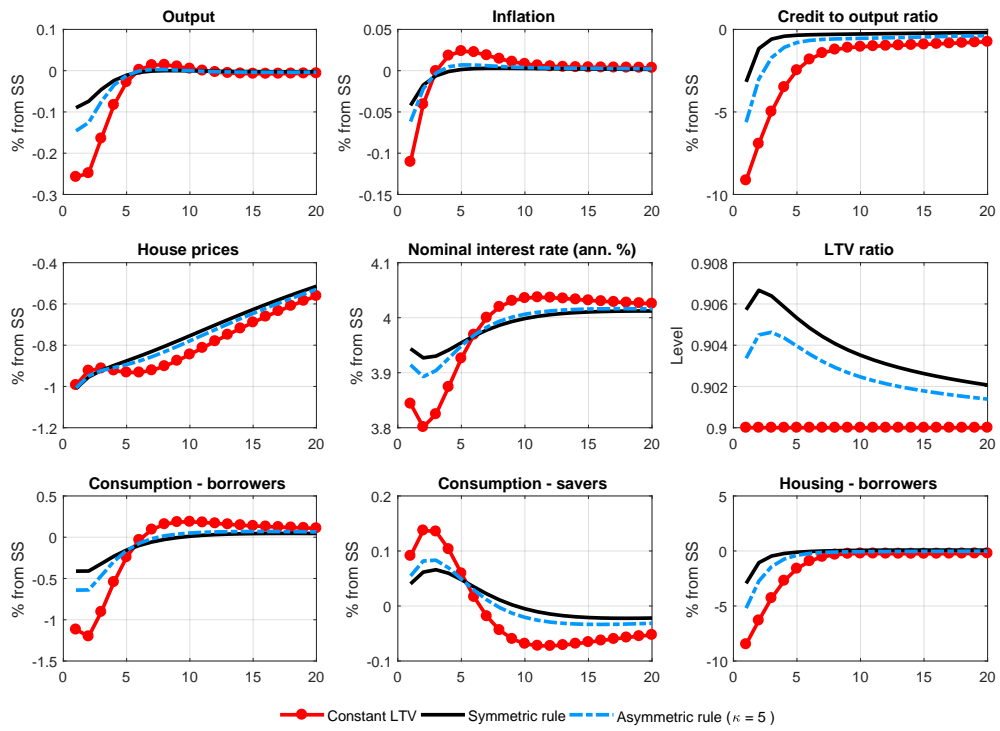


Figure 16: Impulse responses to a negative unanticipated housing demand shock  
 Note: Values on x-axis are time in quarters, on y-axis are percentage deviations from steady state, except for the interest rate.

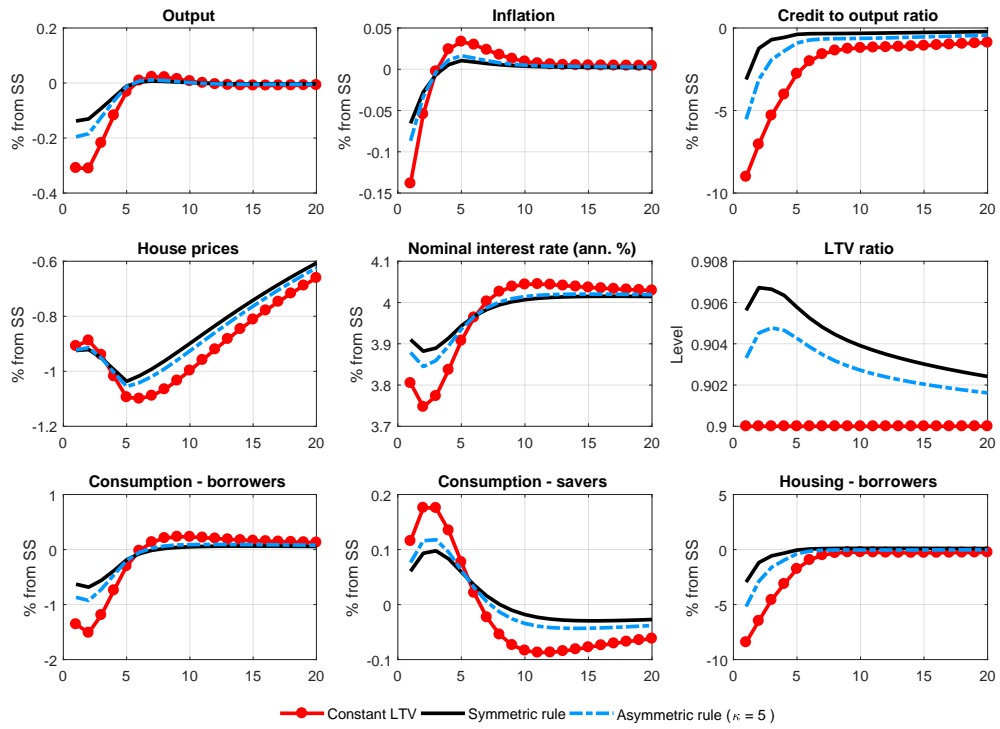


Figure 17: Impulse responses to a negative housing demand news shock  
 Note: Values on x-axis are time in quarters, on y-axis are percentage deviations from steady state, except for the interest rate.

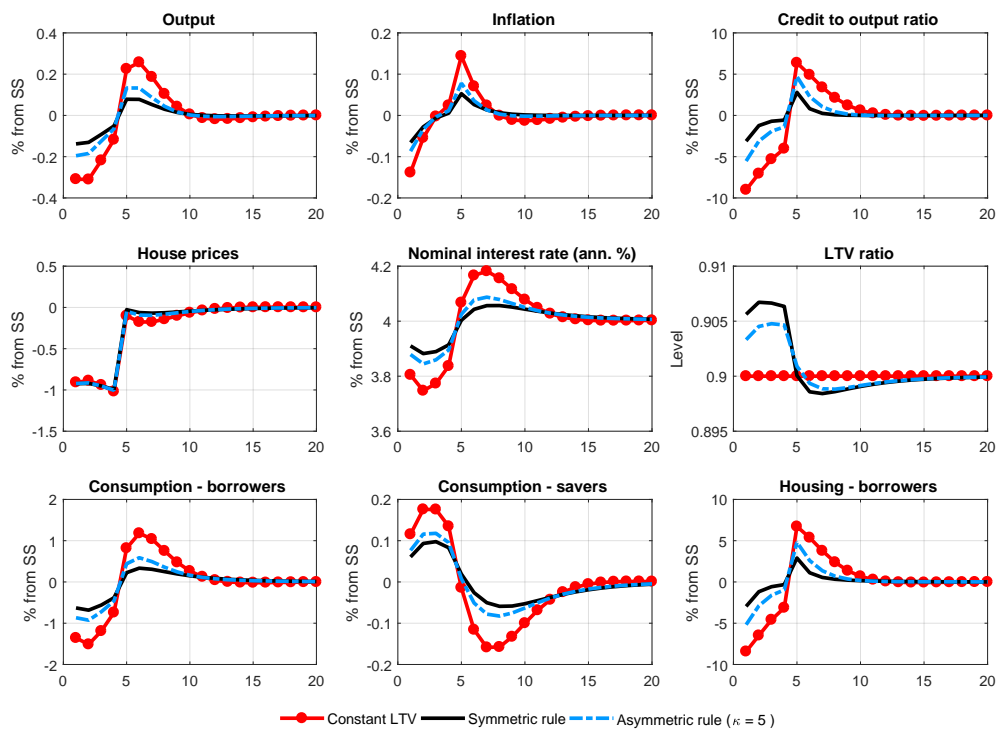


Figure 18: Impulse responses to a negative unrealized housing demand news shock  
 Note: Values on x-axis are time in quarters, on y-axis are percentage deviations from steady state, except for the interest rate.