Should Monetary Policy Lean Against Housing Market Booms?*

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Abstract

Should monetary policy lean against housing market booms? We approach this question using a small-scale, regime-switching New Keynesian model, where housing market crashes arrive with a logit probability that depends on the household debt gap. This crisis regime is characterized by an elevated risk premium on mortgage lending rates and a binding zero lower bound on the policy rate, imposing large costs on the economy. Using our set-up, we examine the optimal level of monetary leaning, introduced as a Taylor rule response coefficient on the household debt gap. We find that the costs of leaning in normal times outweigh the benefits from a lower crisis probability. Although the decline in the crisis probability reduces the volatility in the economy, this is achieved by lowering the average level of debt, which severely hurts borrowers and leads to a decline in overall welfare.

Keywords: monetary policy, leaning against the wind, regime-switching DSGE model, financial crisis, household debt, housing.

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1 Introduction

Household debt increased rapidly in the U.S. during the early 2000s. In particular, the household debt-to-disposable income ratio increased from close to 117 percent in 2000 to a peak level of 166 percent in 2007Q4 (see Figure 1). This expansion was accompanied by a sharp rise in house prices, since mortgages and home equity loans were the main drivers of new household borrowing. In hindsight, this rapid increase posed a significant financial stability risk to the U.S. economy, exposing the financial system to a sudden reversal in housing markets. The resulting financial crisis had severe macroeconomic implications, leading to a painful and prolonged contraction, now referred to as the *Great Recession*, with households engaging in a long deleveraging process and conventional monetary policy being constrained by the zero lower bound (ZLB).

Credit booms may significantly increase the probability and the impact of economic tail events (i.e., crises). Housing booms in many advanced and emerging economies were followed by busts, imposing significant costs on the economy (Jorda et al., 2015). Demirgüç-Kunt and Detragiache (1997) document that banking crises in developed and developing countries were typically preceded by a sharp increase in private sector borrowing from banks. Büyükkarabacak and Valev (2010) show that the rise in bank lending to households, rather than to corporations, was the primary culprit in most banking crisis episodes. More recently, Schularick and Taylor (2012) utilize a logit probability model with a panel of advanced economies, and find that a rapid increase in bank loans to households and businesses significantly increases the probability of a financial crisis within the next five years. Bauer (2014) uses a similar methodology to find that countries with a sizable overvaluation in the housing markets face a significantly higher probability of a sharp correction following a house price boom.[1]

Crises are costly events, which countries would rather avoid. In many bust episodes observed around the world, asset prices fell sharply, credit availability became more limited, and the economy went into protracted recessions as households, businesses, and the financial institutions that lent to them, went into deleveraging mode. There is ample evidence in the literature showing that recessions following financial crises, especially those that are accompanied by high leverage, are far costlier than the average recession and last longer as agents try to repair their balance sheets following a crisis, which dampens the recovery (Koo, 2008).

For central banks, the question remains as to whether monetary policy should *lean* against financial imbalances as they emerge, especially those related to the household sector and housing.[2] On the one hand, leaning could reduce the frequency and severity of financial crises, allowing the economy to largely avoid deep and persistent recessions that impose substantial welfare losses on

[1] The literature linking credit developments to subsequent financial crises is vast. See Reinhart and Rogoff (2010), Jorda et al. (2015), and Emanuelsson et al. (2015) for a more comprehensive list of relevant papers.

[2] In a *flexible* inflation-targeting framework, monetary policy leaning can be implemented through altering the horizon with which inflation is expected to return to target. For example, when inflation is below target but household debt developments pose financial stability risks, the path of the policy rate can remain accommodative, and yet follow a slightly steeper trajectory than otherwise. As a result, inflation would be expected to come back to its target level slightly later than the usual 6- to 8-quarter horizon.

agents. Also, leaning can reduce the amplification (i.e., *financial accelerator*) effects of high leverage on output and inflation volatility (Kiyotaki and Moore, 1997; Bernanke et al., 1999).[3] On the other hand, leaning limits the amount of debt during expansions, hurting borrowers who partly rely on leverage to finance their consumption and housing expenditures. Furthermore, leaning may in fact lead to greater volatility of macroeconomic variables during normal times, especially when the financial cycle is off-phase vis-à-vis the business cycle, prompting the central bank to alter rates at inopportune times for inflation and output (Borio, 2012). Thus, from the perspective of a policymaker, who is minimizing a standard loss function that depends on inflation and output volatility, leaning can end up leading to higher losses, if these short-run inflation and output deviations are large relative to the longer-term benefits from the reduced frequency and severity of crises.[4]

In this paper, we assess the relative benefits and costs of leaning against housing market booms within the context of a small-scale, regime-switching New Keynesian dynamic stochastic general equilibrium (DSGE) model. The core of the model is a simplified version of Iacoviello (2005), where borrowing and lending occur between two types of households, with borrowing subject to a constraint. In this set-up, there exists the possibility of the economy switching to a crisis regime, which is associated with a significant increase in the risk premium on mortgage lending, and therefore, a large credit contraction as well as a steep decline in economic activity and inflation. Crises can be especially costly because the ZLB constraint on the policy rate becomes binding, rendering monetary policy ineffective. The probability of switching from the normal to the crisis regime is time-varying, and is endogenously determined based on the aggregate household debt *gap*, which is calculated as the percent deviation of real household debt from its steady state, similar to Woodford (2012) and Ajello et al. (2016).[5] In normal times, housing market booms, along with a sharp increase in household debt, can occasionally arise in the model economy due to favorable credit supply shocks.

We calibrate the model parameters to match key features of the U.S. economy in the long-run. We also conduct an empirical analysis along the lines of Schularick and Taylor (2012), and run panel logit regressions to pin down the regime-switch parameters that link household debt to crisis probabilities. Unlike Schularick and Taylor (2012), we focus on household debt in the post-war period and use quarterly data from the Bank of International Settlements (BIS), which allows us to consider a larger set of countries, albeit for a shorter time period. We compute the solution of

[3] There may also be a case for leaning if monetary policy itself is the main source of financial imbalances through the risk-taking channel of the monetary policy transmission mechanism, whereby persistently low rates (i.e., *low-for-long*) may lead to increased risk-taking on financial intermediaries' balance sheets. We abstract from this issue in our paper.

[4] Leaning could also reduce the credibility of central banks, since agents may start to view large and persistent deviations of inflation from its target as a weakening of the central bank's commitment to the target. We leave this for future research.

[5] Our model is stationary, and therefore does not capture the upward trend in the U.S. household debt-to-income ratio in the earlier periods. As such, we are attributing this trend increase to fundamental factors (such as financial innovation), and assessing financial risk based on the household debt gap, which is the percent deviation of household debt from this trend. Of course, the long-run trend in the debt-to-income ratio may itself be indicative of financial imbalances. We abstract from this possibility in our paper, although this feature would likely not alter our main conclusions. Since monetary policy generates only temporary effects on the level of household debt, it would likely not be the policy of choice when dealing with long-lasting imbalances captured in the trend.

our dynamic general equilibrium model using projection methods to better capture the inherent non-linearities in our regime-switching model, including the ZLB constraint on the policy rate and the *asymmetric leaning* of monetary policy (i.e., policy responding only to *positive* debt gaps).[6] Our solution technique is *global* and non-linear, and is based on the envelope condition method (ECM) of Maliar and Maliar (2013), which iterates on the value function derivatives to find the policy functions.[7]

In our benchmark experiment, we find that, while leaning successfully reduces the tail risks inherent in the debt cycle dynamics, it leads to a reduction in overall welfare. In particular, leaning is able to reduce the aggregate volatility in the system both through the decline in crisis probabilities and the reduction in the strength of the financial accelerator mechanism. However, this comes at the expense of reducing the average level of household debt, which significantly hurts borrowers that rely on leverage to finance their consumption and housing expenditures. Taken together, the benefits in terms of reduced second moments are surpassed by the first-order costs imposed on borrowers. Our benchmark results suggest that the insurance cost of reducing the likelihood of a tail event is simply too high, implying that, in general, central banks should not lean.[8]

In a follow-up experiment, we consider *symmetric* leaning (i.e., leaning against negative debt gaps as well as positive debt gaps) and show that this type of leaning is unable to effectively reduce the average crisis probability but can nevertheless be welfare improving, since it provides insurance to borrowers during downturns. In further experiments, we show that our baseline results regarding leaning stay qualitatively the same, if there was no ZLB constraint on the policy rate, or if there was asymmetry in the borrowing constraint, so that deleveraging episodes during crises lasted longer than the leveraging episodes during normal times, or if the logit crisis probability function was somewhat steeper for positive household debt gaps.

1.1 Related literature

Monetary policy leaning against household imbalances has received considerable attention in the literature that uses extensions of the Iacoviello (2005) set-up.[9] These papers do not incorporate

[6] We also allow for the borrowing constraint on impatient households to be occasionally binding in our computational procedure, but this constraint turns out to be always binding in our simulations.

[7] There is also a growing literature which computes solutions to Markov-switching DSGE models using perturbation techniques. For more on these techniques, see Farmer et al. (2011), Foerster et al. (2014), and Maih (2015).

[8] The case for monetary leaning is further weakened when we take into account that there are more targeted tools (such as macroprudential policies) available to address financial imbalances (Alpanda et al., 2014). There is also room to be skeptical regarding the effectiveness of monetary leaning in reducing household debt in the first place, especially when one differentiates between the stock and the flow of household debt and considers fixed-rate mortgages (Svensson, 2013; Alpanda and Zubairy, forthcoming; Gelain et al., 2015). In particular, while monetary tightening would reduce new household loans (i.e., the flow of debt), the real value of the existing stock of debt may actually increase as a result of disinflation, akin to the debt deflation spiral envisaged in Fisher (1933). In our set-up here, leaning is quite effective in reducing real household debt, largely consistent with the findings in the cross-country study of Bauer and Granziera (2016), yet not enough to tip the scale in favor of leaning.

[9] A very partial list includes Basant Roi and Mendes (2007), Christensen and Meh (2011), Rubio (2011), Gelain et al. (2013), Lambertini et al. (2013), Alpanda and Zubairy (forthcoming), Gelain et al. (2015), and papers cited therein. Monacelli (2008) investigates the Ramsey-type optimal policy, as well as optimal policy with simple rules, in the context of a similar New Keynesian model with durable goods and collateralized household debt. Also see

the possibility of a crisis regime, capturing the need for monetary leaning mainly through the financial accelerator effects of household debt. The justification for an active policy against financial imbalances, and the reason why policy in the form of leaning could potentially raise welfare, is either due to the presence of *exuberance* shocks, which drive a wedge between the observed price of housing and its underlying fundamental, or due to the pecuniary externality arising from the borrowing constraint and the financial accelerator mechanism (Lorenzoni, 2008; Bianchi and Mendoza, 2010; Korinek, 2011). In particular, a change in asset prices affects the borrowing constraints of all borrowers, but this side effect is not internalized by a single agent who is deciding whether to purchase more housing through additional borrowing. In contrast, our model features an additional, and potentially more important, type of externality that arises due to the effect of aggregate household debt on the probability of a crisis. In particular, each agent's debt level is small relative to the aggregate; therefore, although agents are aware of the link between aggregate debt and crisis probabilities, they do not internalize their own debt's contribution to the overall crisis probability.

Our paper is closest to Ajello et al. (2016), who also consider optimal monetary leaning within the context of a simple New Keynesian model with an endogenous probability of crises tied to the level of credit. We differ from, and to some degree complement, their paper in important ways. First, we use a standard infinitely-lived agent set-up in our model, while Ajello et al. (2016) consider only a two-period economy. A two-period set-up may potentially bias the results against leaning. As they also acknowledge in a footnote, leaning today would have benefits in terms of reducing the crisis probability for an extended period of time, since household debt levels are very persistent. Second, Ajello et al. (2016) do not include any shocks in their model except for the crisis shock itself. This could also potentially bias the results against leaning, because shocks (such as credit supply shocks, as we have in our model) introduce an asymmetry into the model due to the convex functional form of the crisis probability in the relevant region of debt. In particular, favorable shocks that raise the household debt level also increase the probability of a crisis, but more so than the decline in crisis probability one would observe with adverse shocks. If these non-crisis shocks are normally distributed, optimal policy would feature more leaning in absolute value with respect to positive shocks than with negative shocks. Thus, the optimal level of leaning is likely to be stronger than the 3 basis points (bps) found in the benchmark case of Ajello et al. (2016), if there were other shocks present in their economy apart from the crisis shock itself.[10] Third, Ajello et al. (2016) link the macro variables in the model to the level of credit in reduced form, similar to Woodford (2012), while we use the standard borrowing constraint framework in Iacoviello (2005) to capture these links. Thus, in our set-up, leaning has the additional benefit of reducing the financial accelerator effects of leverage, apart from the decline in crisis probability.[11] Finally, Ajello et al. (2016) assume

Bernanke and Gertler (1999), who study monetary leaning against equity price movements in a model featuring an external finance premium and the financial accelerator.

[10] Note, however, that the ZLB constraint may also introduce an additional asymmetry into the model in the presence of non-crisis shocks, which could move optimal leaning in the other direction. In particular, adverse demand shocks (which also reduce debt) would get the economy closer to the ZLB, which the policy-maker may want to avoid as much as possible, leading to a stronger policy response.

[11] In their Appendix, Ajello et al. (2016) also consider a feedback effect from debt to output in a reduced form

that agents do not have rational expectations in terms of understanding how changes in aggregate debt affect the probability of switching to the crisis regime and assume that agents view the crisis probability as a constant, while agents in our set-up are fully rational. Thus, although agents in our set-up cannot by themselves change the probability of a crisis and treat the crisis probability as an externality, they know that once a positive credit supply shock hits, the crisis probability would increase in the medium term.[12]

Our paper is also related to the literature on sovereign debt crises and "sudden stops". Mendoza (2010) considers a small open economy business cycle model where agents face a borrowing constraint with respect to their foreign debt. This constraint is slack in normal times but can occasionally become binding, especially, when the leverage ratio is sufficiently high. When the constraint binds, the rate at which agents borrow from abroad includes an endogenous premium over the world interest rate. This increase in the external finance premium generates sudden stop dynamics, characterized by a sharp decline in output and its components. Unlike Mendoza (2010), in our model, the borrowing constraint is binding in equilibrium at all times, including in normal times.[13] Nevertheless, high levels of household debt can at times trigger an increase in the risk-premium between the borrowing rate and the policy rate, which then generates crisis (or sudden stop) dynamics in the system.

The next section introduces the model. Section 3 describes the calibration of model parameters and the computation procedure. Section 4 presents the results, and Section 5 concludes.

2 Model

The model is a closed-economy, regime-switching DSGE model with housing and household debt. Similar to Iacoviello (2005), there are two types of households in the economy, patient and impatient households (i.e., savers and borrowers), and the borrowing of impatient households is constrained by the collateral value of their housing. The household credit gap affects the probability of switching from the normal to the crisis regime, similar to Woodford (2012) and Ajello et al. (2016).

The rest of the model is standard. On the production side, goods producers use labor services to produce an output good that can be used for consumption. Goods prices are sticky due to the presence of price adjustment costs similar to Rotemberg (1982). Monetary policy is conducted via a Taylor rule, with the policy rate being subject to the ZLB constraint. In what follows, we present each type of agent's optimization problems in more detail.

fashion and show that the extent of optimal leaning in this case would be far larger than in their baseline.

[12] Also see Svensson (2015), who formalizes a simple multi-period cost-benefit approach using empirically motivated impulse responses and the Schularick and Taylor (2012) probability function. Similar to our analysis, Svensson's work suggests that leaning is not beneficial; however, his analysis does not allow for first-order effects, which we find to be important when considering the implications from leaning. Also see Gerdrup et al. (2016) and Benigno et al. (2016) who consider a small open economy extension of the Ajello (2016) setup.

[13] Note that we do allow borrowing constraints to be occasionally binding in our computational procedure, but the constraint is never slack in equilibrium.

2.1 Households

2.1.1 Patient households (savers)

The economy is populated by a unit measure of infinitely-lived savers, whose intertemporal preferences over consumption, $c_{P,t}$, housing, $h_{P,t}$, and labor supply, $n_{P,t}$, are described by the following expected utility function:[14]

$$E_t \sum_{\tau=t}^{\infty} \beta_P^{\tau-t} \left(\log c_{P,t} + \xi \log h_{P,t} - \frac{n_{P,t}^{1+\vartheta}}{1+\vartheta} \right), \tag{1}$$

where t indexes time, $\beta_P < 1$ is the time-discount parameter, ξ determines the relative importance of housing in the utility function, and ϑ is the inverse of the Frisch-elasticity of labor supply.

The patient households' period budget constraint is given by

$$c_{P,t} + q_t \left(h_{P,t} - h_{P,t-1} \right) + \frac{B_t}{\left(1+\chi_t\right) P_t} + \frac{D_t}{P_t} \leq w_{P,t} n_{P,t} + \frac{R_{t-1} B_{t-1}}{P_t} + \frac{R_{t-1}^m D_{t-1}}{P_t} + \frac{T_t}{P_t}, \tag{2}$$

where P_t is the price level, q_t denotes the relative price of housing, $w_{P,t}$ is real wage rate for patient households, and T_t denotes the lump-sum transfers received by households (such as the profits of goods producers). Patient households lend to impatient households and the government in nominal amounts of D_t and B_t, respectively, and receive predetermined gross nominal interest rates of R_t^m and R_t in return next period.

The χ_t term in the budget constraint above is a portfolio preference term, similar to Smets and Wouters (2007) and Alpanda (2013). In equilibrium, this term drives a wedge between the expected returns from mortgage loans and government bonds as

$$R_t^m = \left(1+\chi_t\right) R_t. \tag{3}$$

In this set-up, an increase in χ_t incentivizes patient households to increase their holdings of government debt at the expense of other asset holdings, such as mortgage loans (i.e., *flight-to-safety*). Thus, shocks to this portfolio term act as credit supply shocks in our set-up, altering the cost of borrowing faced by impatient households.[15]

We assume that the portfolio preference term, χ_t, is composed of a regime component, $\chi_{r,t}$, and a transient component, $\chi_{T,t}$:

$$\chi_t = \chi_{r,t} + \chi_{T,t}. \tag{4}$$

The regime component takes on only two values: χ_0 in the normal regime (i.e., $r_t = 0$), and $\chi_1 > \chi_0$ in the crisis regime (i.e., $r_t = 1$). When the economy switches from the normal to the crisis regime,

[14] Following Iacoviello (2005), we normalize the size of each type of household (patient and impatient) to a unit measure and capture the economic importance of each type through their respective shares in labor income.

[15] Also, see Justiniano et al. (2015a), who consider an alternative way of introducing credit supply shocks in a similar set-up with savers and borrowers through constraints on lending (along with the more standard constraints on borrowing).

the sharp increase in the regime component of χ_t would lead patient households to try to increase their holdings of government debt, reminiscent of a *flight-to-safety* episode, while they limit their supply of credit (i.e., mortgage loans) to impatient households. The transition between the normal and crisis regimes is governed by a Markov chain with transition probabilities given by

$$\begin{array}{|l|c|c|}\hline & \text{Normal } (r_t = 0) & \text{Crisis } (r_t = 1) \\ \hline \text{Normal } (r_{t-1} = 0) & 1 - \gamma_t & \gamma_t \\ \hline \text{Crisis } (r_{t-1} = 1) & \delta & 1 - \delta \\ \hline \end{array}, \tag{5}$$

where the probability of switching from the crisis to the normal regime, δ, is assumed to be constant, as in Woodford (2012). γ_t is the time-varying probability of having a crisis in period t conditional on being in the normal regime in $t-1$. This transition probability is determined based on the *aggregate* household debt gap with a logit specification:

$$\gamma_t = \frac{\exp\left(\omega_1 + \omega_2 \frac{d_{t-1} - \bar{d}}{\bar{d}}\right)}{1 + \exp\left(\omega_1 + \omega_2 \frac{d_{t-1} - \bar{d}}{\bar{d}}\right)}, \tag{6}$$

where ω_1 and ω_2 are parameters of the logit function, $d_{t-1} = D_{t-1}/P_{t-1}$ denotes real debt brought from the previous period, and $\bar{d}$ is the steady-state value of debt in the normal regime.[16]

The transient component of the portfolio preference term, $\chi_{T,t}$, follows an AR(1) process as

$$\chi_{T,t} = \rho_\chi (r_t)\, \chi_{T,t-1} + \varepsilon_t, \text{ with } \varepsilon_t \tilde{\ } N(0, \sigma_\chi). \tag{7}$$

Note that the persistence term, $\rho_\chi (r_t)$, switches based on the economic regime, $r_t \in \{0, 1\}$. We assume that the temporary component's persistence reverts to 0 in the crisis regime (i.e., $0 = \rho_\chi (1) < \rho_\chi (0) = \rho_\chi$), ensuring that a persistent increase in credit supply during the normal regime prior to the crisis gets reversed during the crisis regime making the downturn more costly.[17]

The patient households' objective is to maximize utility subject to the budget constraint and appropriate No-Ponzi conditions. The first-order conditions with respect to consumption and labor are standard. The optimality condition for housing equates the marginal cost of acquiring a unit of housing to the marginal utility gain from its housing services plus its discounted expected resale value next period as

$$q_t = \xi \frac{c_{P,t}}{h_{P,t}} + E_t \left[\left(\beta_P \frac{\lambda_{P,t+1}}{\lambda_{P,t}} \right) q_{t+1} \right], \tag{8}$$

[16] We could instead make the crisis probability depend on the house price gap (Bauer, 2014) or credit growth during the preceding five years (Schularick and Taylor, 2012), rather than the credit gap. These alternatives would increase the number of states in the model and raise the computational burden. We thus use the credit gap in the logit specification, which broadly conforms with the specification in Ajello et al. (2016). Note that the credit gap and credit growth in the preceding five years are likely to be highly correlated in our set-up.

[17] This assumption is not crucial for any of the results, but lowers the incidence of consecutive crises in our simulations. In particular, with high persistence, the debt overhang triggered by the first crisis significantly outlasts the duration of the crisis regime, keeping the risk of a second crisis elevated even after the economy switches back to the normal regime. With lower persistence, imbalances are significantly reduced over the crisis duration.

where $\lambda_{P,t}$ is the Lagrange multiplier on the budget constraint.

Similarly, the optimality condition for government bonds (or mortgage loans) generates the Euler condition, which equates the marginal utility cost of forgone consumption from saving to the expected discounted utility gain from the resulting interest income:

$$1 = E_t \left[\left(\beta_P \frac{\lambda_{P,t+1}}{\lambda_{P,t}} \right) \frac{R_t \left(1 + \chi_t\right)}{\pi_{t+1}} \right]. \tag{9}$$

Note that an increase in the spread term, χ_t, would lead patient households to reduce their consumption expenditures, and increase their savings in the form of government bonds. Since the latter is assumed to be in zero supply in equilibrium, patient households will instead increase their housing demand while reducing their consumption expenditures. As noted before, arbitrage between acquiring government bonds and lending to impatient households implies that the equilibrium mortgage and policy rates are linked as $R_t^m = (1 + \chi_t) R_t$. Thus, patient households would also be happy to increase their savings in the form of mortgage loans, since their returns from these loans also increase with χ_t, but the demand of impatient households for mortgage loans declines substantially in equilibrium, driving equilibrium lending levels down. The accompanying decline in house prices is what facilitates the purchase of housing by patient households from impatient households in equilibrium.[18]

Similarly, housing booms in the model will be associated with a persistent decline in the transient component of χ_t. In particular, the resulting increase in credit supply would lead to an increase in borrowing by impatient households, which in turn would result in an increase in aggregate consumption, output, and inflation. Intuitively, the decline in χ_t captures the increase in the willingness of investors and financial intermediaries to lend in mortgage markets, along with their willingness to hold mortgage-backed and related securities. Thus, in our model, the financial vulnerability associated with a housing debt boom (i.e., an increase in the probability of a crisis) is due to an increase in credit supply, similar to Justiniano et al. (2015a).[19] Similarly, the crisis regime is characterized by a sudden increase in χ_t, leading to a sharp decline in mortgage credit supply. Intuitively, this is meant to capture the interruption in financial intermediation during the recent financial crisis, which was triggered by the unwillingness of investors and financial intermediaries to supply credit to mortgage-related markets or to institutions which directly or indirectly were exposed to these markets.

[18] In a model with an elastic supply of government bonds, low elasticity of substitution between consumption and housing, and variable housing supply, an increase in χ_t would induce an increase in government bond holdings, as well as a decline in consumption, residential investment, household debt and house prices. Our model here generates similar aggregate results, except that the housing of patient households increases along with the decline in house prices.

[19] Alternatively, one can generate a household debt boom through favorable housing preference shocks or an increase in "irrational exuberance" regarding expectations of future capital gains from housing. The former would counterfactually predict housing rents (captured by the marginal utility of housing) to be more volatile than house prices, and that the house price-to-rent ratio should have decreased during the housing boom (Piazzesi and Schneider, 2016).

2.1.2 Impatient households

The economy is also populated by a unit measure of infinitely-lived impatient households. Their utility function is identical to that of patient households, except that their time-discount factor is assumed to be lower in order to facilitate borrowing and lending across the two types of consumers; i.e., $\beta_I < \beta_P$. The impatient households' period budget constraint is given by

$$c_{I,t} + q_t \left(h_{I,t} - h_{I,t-1} \right) + \frac{R^m_{t-1} D_{t-1}}{P_t} \leq w_{I,t} n_{I,t} + \frac{D_t}{P_t}, \tag{10}$$

where $w_{I,t}$ denotes the real wage rate of impatient households.

Impatient households face a borrowing constraint in the form of

$$D_t \leq \rho_d D_{t-1} + (1-\rho_d)\, \phi P_t q_t h_{I,t}, \tag{11}$$

where ρ_d determines the persistence of debt as in Iacoviello (2015), and ϕ is the fraction of assets that can be collateralized for borrowing, i.e., the loan-to-value (LTV) ratio.[20] The former parameter is important to break the synchronicity between the credit cycle and output, with credit becoming more persistent than the standard business cycle as ρ_d increases. Also note that the borrowing constraint formulation above is stated in nominal terms and therefore allows for debt-deflation type effects of inflation on the *real* stock of existing debt.

The first-order conditions of the impatient households with respect to consumption and labor are similar to those of patient households. For housing, the optimality condition equates the marginal cost of acquiring housing with the marginal utility and expected capital gains, but now the marginal cost is dampened by the shadow gain due to the relaxation of the borrowing constraint with the increase in the level of housing. This condition can be written as

$$\left[1 - \mu_t (1-\rho_d)\, \phi\right] q_t = \xi \frac{c_{I,t}}{h_{I,t}} + E_t \left[\beta_I \frac{\lambda_{I,t+1}}{\lambda_{I,t}} q_{t+1} \right], \tag{12}$$

where $\mu_t \geq 0$ is the Lagrange multiplier on the borrowing constraint, which is strictly positive when the borrowing constraint is binding and equal to 0 otherwise. Similarly, the optimality condition for borrowing is given by

$$1 - \mu_t = E_t \left[\beta_I \frac{\lambda_{I,t+1}}{\lambda_{I,t}} \left(\frac{R^m_t - \rho_d \mu_{t+1}}{\pi_{t+1}} \right) \right], \tag{13}$$

which equates the marginal gain from borrowing (minus the shadow price of tightening the borrowing constraint) with the expected interest costs. Note that borrowing today relaxes the borrowing constraint in the future as well due to the persistence term; hence, this benefit is subtracted from the expected marginal cost term on the right-hand side.

[20] The collateral constraint captures the notion that, in the case of default, the lender is able to collect only a fraction of the collateral pledged and is thus not willing to lend further (Kiyotaki and Moore, 1997). We do not derive the collateral constraint from an optimal credit contract but impose it directly, following other papers in this literature.

2.2 Goods production

There is a unit measure of monopolistically competitive goods producers indexed by j. Their technology is described by the following production function:

$$y_t(j) = zn_{P,t}(j)^{\psi}\, n_{I,t}(j)^{1-\psi}\,, \tag{14}$$

where $y_t(j)$ denotes output of firm j, ψ is the share of patient households in the labor input, and z is the level of aggregate total factor productivity.

Goods are heterogeneous across firms, and are aggregated into a homogeneous good by perfectly-competitive final-goods producers using a standard Dixit-Stiglitz aggregator. The demand curve facing each firm is given by

$$y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\eta} y_t, \tag{15}$$

where y_t is aggregate output, and η is the elasticity of substitution between the differentiated goods. Thus, the gross markup of firms at the normal regime steady-state is given by $\theta = \eta/(\eta-1)$.

Firm j's profit in period t is given by

$$\frac{\Pi_t(j)}{P_t} = \frac{P_t(j)}{P_t} y_t(j) - w_{P,t} n_{P,t}(j) - w_{I,t} n_{I,t}(j) - \frac{\kappa}{2}\left(\frac{P_t(j)}{\pi^* P_{t-1}(j)} - 1\right)^2 y_t, \tag{16}$$

where price stickiness is introduced through quadratic adjustment costs with κ as the level parameter, and π^* is the inflation target.[21]

A firm's objective is to choose the quantity of inputs, output and its own output price each period to maximize the present value of profits (using the patient households' stochastic discount factor), subject to the demand function they are facing for their own output from the goods aggregators. The first-order condition for prices yields the following New Keynesian Phillips curve:

$$\left(\frac{\pi_t}{\pi^*} - 1\right)\frac{\pi_t}{\pi^*} = E_t\left[\beta_P \frac{\lambda_{P,t+1}}{\lambda_{P,t}}\left(\frac{\pi_{t+1}}{\pi^*} - 1\right)\frac{\pi_{t+1}}{\pi^*}\frac{y_{t+1}}{y_t}\right] - \frac{\eta-1}{\kappa}\left(1 - \frac{w_{P,t}}{\theta\psi y_t / n_{P,t}}\right). \tag{17}$$

Note that, at the optimum, the marginal product of each input is equated to its respective marginal cost; hence, the relative demand for the two types of households' labor are related to the two wage rates as follows:

$$\frac{n_{P,t}}{n_{I,t}} = \frac{\psi}{1-\psi}\frac{w_{I,t}}{w_{P,t}}. \tag{18}$$

[21] As explained later, price adjustment costs partly reduce real resources available for consumption, and are therefore wasteful in this economy. We have defined the price adjustment cost relative to a reference price change implied by the inflation target. Thus, a positive inflation target does not result in this type of a first-order resource cost in the model economy.

2.3 Monetary policy

Monetary policy is conducted using a Taylor rule on the nominal interest rate, which is subject to the ZLB. Hence,

$$R_t = \max\left\{1,\ R_{t-1}^{\rho}\left[\overline{R}\left(\frac{\pi_t}{\pi^*}\right)^{a_\pi}\left(\frac{y_t}{\overline{y}}\right)^{a_y}\left(\max\left\{\frac{d_t}{\overline{d}},1\right\}\right)^{a_d(r_t)}\right]^{1-\rho}\right\}, \tag{19}$$

where ρ is the smoothing term in the Taylor rule, and a_π, a_y, and a_d are the long-run response coefficients for inflation, the output gap, and the household debt gap, respectively. $\overline{R}$, $\overline{y}$, and $\overline{d}$ denote the steady-state values of the nominal interest rate, output, and household debt in the normal regime.

Note that the second *max* operator on the right hand side ensures that leaning is implemented in an asymmetric fashion, i.e., it is active only when the household debt gap is positive but not otherwise. Thus, the policy rate follows the standard Taylor rule when the debt gap is negative but is slightly higher than what the standard Taylor rule would prescribe when the debt gap is positive.[22]

Note also that the leaning parameter is regime-specific, whereby we set $a_d = 0$ during crisis periods but let it to be positive during normal times. As a result, we allow leaning against household debt only during normal times, but not during crises. While the consequences of leaning during crises are small, it nevertheless introduces an additional negative welfare impact on impatient households by further limiting their borrowing when they are already suffering from a contracting economy. Thus, introducing this additional asymmetry in leaning improves the chances for leaning to be beneficial.

2.4 Market clearing conditions and timing of events

The goods market clearing condition is given by

$$c_{P,t} + c_{I,t} = y_t - \frac{I_\pi \kappa}{2}\left(\frac{\pi_t}{\pi^*} - 1\right)^2 y_t, \tag{20}$$

where $I_\pi \in [0,1]$ determines the extent to which the price adjustment costs of firms reduce real resources in the economy, while the rest are treated as lump-sum transfers to patient households.[23]

We assume that government bonds are in zero supply; hence, $B_t = 0$ for all t. The stock of housing is assumed to be in fixed supply as in Iacoviello (2005); hence,

$$h_{P,t} + h_{I,t} = \overline{h}. \tag{21}$$

[22] In Section 4, we also consider the implications of symmetric leaning, whereby monetary policy responds to negative, as well as positive, household debt gaps.

[23] The choice of I_π does not qualitatively affect the main results regarding the optimality of leaning, but it does have a quantitative effect on the volatility of the economy.

The timing of events is as follows. The economy enters period t with an aggregate state vector of $d_{t-1}, h_{I,t-1}, R_{t-1}, \chi_{t-1}$, and r_{t-1}. Note that the past mortgage rate, R^m_{t-1}, is known as well, since $R^m_{t-1} = (1 + \chi_{t-1}) R_{t-1}$. Furthermore, the crisis probability in period t, γ_t, is also known, since this depends on the lagged value of the aggregate household debt, d_{t-1}. At the beginning of period t, the innovation for the AR(1) credit supply shock, ε_t, as well as the crisis regime, r_t, are realized. Next, agents choose consumption, housing, labor supply, etc., and markets clear. The state vector passed over to period $t+1$ is then given by $d_t, h_{I,t}, R_t, \chi_t$, and r_t. The model's equilibrium is defined as prices and allocations, such that households maximize the expected discounted present value of utility, firms maximize expected profits subject to their constraints, and all markets clear.

3 Calibration and Computation

3.1 Calibration

We calibrate most of the parameters using the steady-state relationships of the model, as well as picking values typically used in the related literature. For the crisis probability parameters in (6), we use our estimates from panel logit regressions that link various debt gap measures to crisis probabilities. Table 1 summarizes the list of parameter values.

The trend inflation factor, π^*, is set to 1.005, corresponding to a 2% annual inflation target. The time-discount factor of patient households, β_P, is set to 0.990 to match an annualized 4% real risk-free interest rate in normal times. The discount factor of impatient households, β_I, is set to 0.97 following Iacoviello and Neri (2010). The parameter ϑ is calibrated to 2 to ensure that the Frisch elasticity of labor supply is 0.5, while the level parameter for housing in the utility function, ξ, is set to 0.12 following Iacoviello and Neri (2010).

The price markup parameter, θ, is set to 1.1, reflecting a 10% net markup in prices. The price adjustment cost parameter, κ, is set to 100, which generates a slope for the New Keynesian Phillips curve that is largely consistent with estimates in the related DSGE literature. We set I_π equal to 0.1, implying that only 10 percent of the price adjustment costs pose a direct burden on real resources, while the rest is transferred back to patient households in a lump-sum fashion. The wage share of patient households, ψ, is set to 0.748, broadly in line with Iacoviello (2005) after one considers the patient households' income share in that paper including capital income.

We calibrate ϕ to 0.75, close to the average LTV ratio on outstanding mortgages in the U.S. data.[24] The persistence parameter in the borrowing constraint, ρ_d, is set to 0.66, to generate a fairly slow deleveraging process akin to the period following the crisis. The transient component of the portfolio preference term, $\chi_{T,t}$, follows an AR(1) process with a regime-switching persistence parameter, $\rho_\chi(r_t)$. In the normal regime, this persistence parameter is set to 0.985, while in the crisis regime it is reduced to 0. The standard deviation of the shock innovations, σ_χ is set to 0.0003.

[24] Note that the average LTV ratio on all outstanding mortgages we use here is slightly lower than the *marginal* LTV ratio on new mortgages extended in the data, which is closer to 0.84 or 0.91 depending on whether one considers the mean or the median among the new mortgage loans (Alpanda and Zubairy, forthcoming; Duca et al., 2016).

Together, these parameters generate household debt gaps of a similar magnitude and persistence as those observed in recent U.S. data (see Figure 1).

For the Taylor rule coefficients, we use the mean values of the prior distributions used in Smets and Wouters (2007). In particular, the response coefficients for inflation and the output gap, a_π and a_y, are set to 1.5 and 0.125, respectively, and the smoothing parameter, ρ, to 0.75. We set the leaning parameter, a_d, to 0 in the crisis regime, and vary its value between 0 and 0.024 in the normal regime when conducting our experiments.

Probability of crises The probability of entering a crisis is governed by a logit function, which in turn is characterized by two parameters, ω_1 and ω_2. We set these parameters to -4.95 and 5.02, respectively, based on our estimates from panel logit regressions linking various debt gap measures to financial crisis probabilities. Our baseline logit specification implies that crisis probabilities are in the order of 3% (in annualized terms) at the steady-state level of household debt, but increases to about 4% as the debt gap increases to 15%. In what follows, we briefly describe the empirical analysis we conducted, leaving details to Appendix A.

To obtain our estimates, we run panel logit regressions of the form

$$\text{logit}\left(Crisis_{i,t}\right) = \alpha_i + \beta DGap_{i,t-1} + \varepsilon_{i,t}, \tag{22}$$

where i indexes countries, and t denotes time in quarters. $Crisis_{i,t}$ is a financial crisis dummy variable, which takes on a value of 1 at the start date of a crisis and 0 otherwise, α_i captures country-specific fixed effects, and $DGap_{i,t-1}$ is a debt gap measure.[25]

Our main source for the crisis dummy variable is Laeven and Valencia (2012), who report the monthly dates of systemic banking crises for a large set of countries. For robustness, we also construct two other crisis dummy variables by adding some additional systemic and non-systemic financial crisis dates from other sources, as further explained in Appendix A. Table A1 in this appendix provides a list of the baseline crisis dates, $Crisis_{i,t}$, the additional systemic crisis dates used in the first alternative, $Crisis1_{i,t}$, and the additional non-systemic crisis dates used in the second alternative, $Crisis2_{i,t}$. Our baseline case includes 42 crises in 33 countries, while $Crisis2_{i,t}$ includes 22 more crises with 4 additional countries in the sample.

Constructing a gap measure for household debt requires taking a stand on the trend level of debt. We construct our baseline debt gap measure, $DGAP^{HH}_{i,t}$, by considering the 12-quarter difference in the household debt-to-GDP, similar to Büyükkarabacak and Valev (2010) and Jorda et al. (2015).

[25] We use the lag of the debt gap measure in our regressions to make the specification more consistent with our structural model, but this also helps reduce issues related to simultaneity. As the debt gap measure is highly persistent, we do not include more lags of this variable in our specification. We also do not include any other control variables in our regression in order to capture the overall effect of the household debt gap on the crisis probability. This likely introduces an upward (omitted variable) bias in our estimates of β, since other variables that are positively correlated with the debt gap might also explain part of the variation in the crisis probability. However, this does not pose a major problem in our context, since a higher β would indicate that the logit crisis probability function we use is steeper than the actual, which would bias our results in favor of leaning. Note that our baseline results are against leaning despite this potential bias.

For robustness, we also construct five other debt gap measures by detrending the household debt-to-GDP measures by (i) country-specific linear time trends, (ii) country-specific quadratic time trends, (iii) common linear time trend, (iv) common quadratic time trend, and (v) country-specific HP-trend. These alternative measures are labeled $DGAP1_{i,t}^{HH}$ through $DGAP5_{i,t}^{HH}$. We also construct an analogous set of six debt gap measures using the total borrowing of the non-financial private sector rather than household debt, since the former series more closely resemble the data series used in related papers in the literature, and also provide longer time series for certain countries in the sample. These alternative six measures are labeled analogously, but with a NFP superscript instead of an HH. The source of data for the debt-to-GDP variable is the *Long series on total credit and domestic bank credit to the private non-financial sector* dataset of the BIS, which provides panel data on household borrowing in the post-war period.

Tables 2a and 2b provide a summary of the estimates for the U.S.-specific fixed effect, $\widehat{\alpha}_{US}$, and the slope coefficient for debt gap, $\widehat{\beta}$, obtained from the above logit regression, using the various measures (with the baseline results reported in the last rows). When compared with the estimates in Schularik and Taylor (2012) and Ajello et al. (2016), our baseline estimates point to a slightly steeper logit probability function in the relevant range of household debt, and some of our alternative estimates indicate a much steeper logit probability function. Our robustness checks using the whole non-financial private sector instead of the household debt series in our baseline case suggest that the difference in the estimates is partly due to this choice of series. Note that a flat crisis probability function implies that the marginal benefit of reducing household debt through monetary leaning is expected to be small, since the probability of a crisis does not move much with respect to debt. This is exactly the results found by Ajello et al. (2016) and Svensson (2015). By considering a slightly steeper logit function, we allow leaning to potentially be more successful in reducing crisis probabilities.

Severity of crises In the model, the severity of a crisis can be measured by the cumulative loss in output during the crisis, which in turn is determined by the average output fall per period and the duration of the crisis regime.[26] Both of these aspects are difficult to measure in the data, since the size of the output loss depends on the underlying trend assumed for real output. If, for example, the crisis has a permanent negative impact on the level or the growth rate of trend output, the cumulative output loss might be very large, potentially infinite. On the other hand, if we focus narrowly on the acute crisis periods and define recovery as the return of output to its pre-crisis peak level, then the cumulative output loss would be relatively small. Our model abstracts from the possibility that crises may have permanent effects on the level or the growth rate of output.

Our target range for the cumulative output loss from a crisis is between 7.9 and 27.7 percent. The lower bound of this is based on Schularick and Taylor (2012), who find that the cumulative real output loss over the five years following a financial crisis in the post-war period is 7.9 percent.

[26] In our set-up, a longer average crisis duration also leads to a larger drop in the output gap per period, everything else equal, because labor supply falls more when households anticipate a longer crisis, leading to a larger output loss.

The upper bound is based on the recent U.S. experience. In particular, the cumulative difference between the pre-crisis linear trend of output and actual output is around 27.7 percent for the period 2008Q2 - 2015Q2.[27]

We set δ to 0.1, implying an average crisis duration of 10 quarters. In the normal regime, we let the average risk premium on mortgages be equal to 2 percent, by setting $\chi_R(0)$ equal to 0.005. In the crisis regime, this regime component of the risk premium, $\chi_R(1)$, is set to 0.018, which implies that the spread between mortgages and the policy rate increases by 5.3 percentage points (pp) on an annualized basis for the duration of a crisis. This is slightly higher than what was observed in the data. In particular, the spread between adjustable-rate mortgages and 1-year government bonds increased by about 4 pp following the crisis. Note however that our model abstracts from other financial shocks that the economy encountered during the crisis. In order to match a cumulative output loss of 14.9 percent during a typical crisis in our baseline model, a figure near the middle of our target range discussed above, we require a slightly higher risk premium shock than what is observed in the data. Our target for the cumulative output loss represents a reasonable compromise, since the target boundaries discussed above relate to GDP and therefore include investment, which is absent from our model.[28] If we consider the cumulative real aggregate consumption loss following the Great Depression for the U.S. (using the narrow definition of consumption declining and returning to its previous peak level), we find a consumption downturn that lasts 11 quarters, with a peak decline of 2.7 percent and a cumulative decline of 14.9 percent. Moreover, a comprehensive cross-country study by the International Monetary Fund (IMF 2009) confirms that private consumption losses are, on average, much smaller than output losses following a financial crisis (see their Figure 8).

3.2 Computation

We compute the solution of the model using projection methods to better capture the non-linearities inherent in our model: namely, the ZLB constraint on the policy rate and the asymmetric leaning of monetary policy with respect to the household debt gap.[29] Our solution technique is global and non-linear. In particular, we utilize the envelope condition method (ECM) of Maliar and Maliar (2013), which iterates on the value function derivatives to find the policy functions. Details regarding the computational strategy are provided in Appendix B.

4 Results

In this section, we first analyze the dynamics of the model economy using impulse responses following an unexpected switch from the normal to the crisis regime or a housing demand shock during normal

[27] This may also be an underestimate, since it excludes any further output losses from the crisis post-2015Q2.

[28] In the data, investment appears to be the biggest contributor to the decline in real GDP during crises; in particular Schularick and Taylor (2012) report a cumulative real investment loss over the five years following a crisis of 25.7 percent.

[29] As noted, even though we allow the borrowing constraint to be occasionally binding, it always binds in our simulations.

times. We then investigate the optimal degree of leaning in the Taylor rule, by maximizing welfare based on a weighted average of households' expected lifetime utility. We conclude this section by conducting robustness checks on our welfare results; in particular, we investigate how the benchmark results would change if (i) the ZLB does not constrain monetary policy, (ii) leaning is conducted symmetrically with respect to both positive and negative debt gaps, or (iii) the persistence parameter in the borrowing constraint is regime-specific. We also consider alternative parameterizations for the logit function determining crisis probabilities.

4.1 Model dynamics

In Figure 2, we present the impulse responses of model variables following a switch to the crisis regime, which is accompanied by a sharp rise in the risk-premium on mortgage debt for 10 periods. Note that even though the crisis lasts for 10 periods in our example, agents in the model place a $\delta = 0.1$ probability on returning to the normal regime in each period. Hence, this is *not* a perfect foresight exercise, whereby agents know exactly that the crisis is going to last 10 periods. The increase in the risk-premium during a crisis leads to a persistent decline in the borrowing of impatient households, who, as a result, reduce their demand for housing and consumption goods. Patient households reduce their consumption as well, while they use up savings to purchase the housing offered by impatient households. Nevertheless, this is not enough to reverse the fall in the overall demand for housing, leading to a fall in house prices. The decline in overall demand for consumption goods leads to a significant fall in (non-housing) output and inflation as well, which forces the central bank to cut the policy rate to the ZLB and keep it there for several periods.[30] After the impact period, the fall in the policy rate is accompanied by a fall in the mortgage rate, R^m, but the latter still hovers around its normal-regime steady-state value due to the risk premium in the crisis regime.

Figure 3 presents the impulse responses of model variables to a negative 25 basis points (quarterly) innovation in the transitory component of the risk premium shock, with and without leaning, conditional on staying in the normal regime throughout the impulse horizon.[31] The results are qualitatively similar to those obtained from the crisis shock above, except that we are now considering a favorable shock to the risk premium on mortgages, and the persistence of the shock now encompasses the transitory rather than the regime component of the risk premium shock. We first consider the case when monetary policy does not lean against household debt (i.e., $a_d = 0$ in the normal regime as well). The decline in the risk premium as a result of the increase in credit supply from patient households, allows impatient households to increase their borrowing persistently and purchase more housing and consumption goods. The increase in the demand for consumption goods leads to a pickup in inflation, while the increase in housing demand leads to a rise in house prices.[32] The

[30] Note that the nominal policy rate is 4% at the steady state of our model given the calibrated parameter values; hence the ZLB is reached once the policy rate is cut by 1 pp in quarterly terms relative to the steady state.

[31] Again, agents expect that the economy could switch to the crisis regime with γ_t probability, but this is never realized over the impulse horizon.

[32] Note that the relative response of house price would be stronger if housing was agent-specific and could not be

patient households increase their consumption expenditures slightly, due to the declining relative price of consumption goods, while they sell part of their housing stock to the borrowers at higher prices. Both inflation and output pick up as a result of the favorable shock, leading the central bank to raise the policy rate through the Taylor rule.

The main cost of monetary policy leaning arises from the successful reduction of household debt during normal times, as shown in Figure 3, where the dashed line depicts the case when the leaning parameter, a_d, is set equal to 0.024.[33] This is due to the fact that, as debt builds up, the policy rate increases and stays above its benchmark case for an extended period. This reduction in household debt due to leaning leads to first-order adverse effects on the consumption of impatient households, and therefore reduces their welfare as we discuss in the next section. Note that the peak response of debt is significantly later than the peak responses of inflation and output due to the persistence term in the borrowing constraint of impatient households. Hence, the business cycle is out of phase with the credit cycle in our setup. Despite this lack of synchronicity, however, keeping interest rates slightly higher than the baseline case here has stabilizing effects on output and inflation, where the resulting gaps in inflation and output are smaller throughout the shock, leading to second order benefits from leaning in terms of reducing the volatility of the system.

These two impulse responses in combination give us a sense of what drives the main results of the paper. First, the size of the two main forces in the model are clearly disproportionate, since crisis events are huge in comparison to regular business cycle movements. Thus, a policy that successfully reduces the risk of a crisis could potentially reduce the overall volatility of inflation and output. Second, leaning can clearly influence household debt volatility; however, this hurts borrowers during housing market booms. These lead us to two quantitative questions, which we will explore in the next subsection: (i) Is leaning successful in reducing the probability of a crisis enough to significantly decrease the overall volatility in the system? (ii) Do the benefits from leaning of lowering economic volatility outweigh the welfare costs to borrowers? Our answers to these questions are a reserved yes to (i) and no to (ii).

4.2 Optimal degree of leaning

In this subsection, we analyze the optimal degree of leaning within the context of the Taylor rule in (19). In order to do this, we randomly generate credit supply shocks and run 125 simulations of our model, each for a length of 4,000 periods.[34] We start each simulation from the normal-regime specific steady state, and burn the initial 300 periods.

To find the optimal degree of leaning, we search for the Taylor rule parameter, $a_d \geq 0$, active only

traded across the two types of agents, or if housing could only be traded across agents subject to large adjustment costs. Conversely, if the housing supply was not a constant in the aggregate and the model featured housing production, then the response of house price would be relatively more muted, since a favorable credit supply shock would also lead to an increase in the quantity of housing.

[33] As we explain later, we consider a_d over the interval $[0, 0.024]$ in our simulations. Our upper bound for a_d implies a close to 200 basis points increase in the policy rate in annualized terms given a positive 20 percent debt gap.

[34] To generate the switching between regimes, we compare γ_t in the normal regime and δ in the crisis regime to random numbers picked from a uniform [0,1] distribution.

in the normal regime, that maximizes social welfare, W. Social welfare is defined as the weighted average of the utility-based welfare measures for the patient and impatient households as:

$$W = (1 - \beta_P) V_P + (1 - \beta_I) V_I. \tag{23}$$

Note that the weights are picked so that the same constant consumption stream would result in equal welfare across the two types of agents, following Lambertini et al. (2013). The welfare of each household type is given by

$$V_i = \frac{1}{1-\beta_i} \frac{1}{N \times T} \sum_{j=1}^{N} \sum_{t=0}^{T} u\left(c_{i,t}^j, h_{i,t}^j, n_{i,t}^j\right) \text{ for } i \in \{P, I\}, \tag{24}$$

where N denotes the number of simulations and T is the number of periods in each simulation. To make it easier to comprehend these measures, we convert them into *lifetime consumption equivalents* (LTCE) relative to the no-leaning benchmark case. So, the reported welfare numbers provide the relative gain (or loss) in consumption needed to compensate the households for changing from a policy regime without leaning to one with leaning. Across experiments, we keep as our utility reference point the case of no leaning under the baseline calibration.

To contemplate volatility benefits of leaning, we also consider a standard loss function that depends on the variance of inflation and the output gap with equal weights:

$$L = var(\pi) + var(y). \tag{25}$$

In order to discuss the success of leaning, we also determine the probability of entering into a crisis regime conditional on being in normal times under each policy. To obtain a good approximation of this probability, we integrate the logit function using the estimated kernel density of household debt conditional on being in normal times (Epanechnikov, 1969).

In all the experiments below, we consider variations in a_d over the interval $[0, 0.024]$. Our range for a_d might appear small, but that is misleading. To see this, consider the case of a positive 20% debt gap. If a_d is set equal to 0.024, it would imply that the policy rate would be around 200 bps higher on an annualized basis relative to the standard Taylor rule, all else constant. We think that this is a reasonable upper bound for the degree of leaning a central bank might implement.[35]

4.2.1 Benchmark case

Figure 4 plots the mean and variance of inflation, output and household debt in the baseline model, along with the associated welfare and loss function estimates, as the leaning parameter a_d is varied. From a welfare perspective, leaning is found to be undesirable; specifically, as we increase the leaning parameter, a_d, welfare goes down monotonically by up to 0.13 pp in terms of LTCE. Using the ad hoc loss function perspective, we find that leaning is indeed successful in reducing the overall volatility

[35] Note also that the model becomes unstable as we increase a_d above this threshold, similar to Gelain et al. (2015).

in the economy. Specifically, the unconditional standard deviations of output, inflation and debt, as well as the probability of a crisis, decrease significantly with leaning.

The key driver behind this is the success of leaning in dealing with household debt. In particular, leaning dampens the fluctuations of household debt by discouraging impatient households from borrowing. This effect is successful enough to shift the right-tail of the distribution to the left, as shown in Figure 5, leading to reductions in the mean and variance of debt. In turn, the quarterly probability of a crisis is reduced from 0.68 to 0.62 percent. On the other hand, the lower average debt level hurts borrowers by reducing their consumption and housing expenditures. This affects expectations and creates disincentives to work, while also reducing inflation pressures, all of which contribute to a slightly lower mean level of inflation along with a negligible impact on mean output. The first-order losses on borrowers from reduced debt clearly dominates the second-order benefits from reducing the economy's volatility. In effect, what makes leaning a success by the loss function criterion (i.e., lower debt level, which reduces crisis probabilities and volatility) also makes it a failure in the welfare realm, since it inflicts first-order pain on the borrowers.

4.2.2 Other experiments

To highlight the importance of various aspects of the model, such as the ZLB constraint and asymmetric leaning, we now conduct additional experiments, and present results in comparison to the benchmark case.

No ZLB on the policy rate

Recently, several central banks have lowered their deposit rates into negative territory, suggesting that the effective lower bound on the policy rate is below zero.[36] Furthermore, central banks possess a variety of unconventional policy tools (such as quantitative easing), which could potentially serve a similar purpose as lowering the policy rate. Thus, the ZLB may not be as important a constraint on policy as assumed in our benchmark case.

The first column of Figure 6 compares the results from the baseline model with ZLB (solid line) to an alternative model without the ZLB constraint (dashed line). Not surprisingly, welfare is higher in the absence of the ZLB constraint, regardless of the amount of leaning. In particular, relative to the baseline case, the welfare benefits of not having the ZLB constraint are in the order of about 70 bps in LTCE.[37] However, with regards to the welfare implications of leaning, our baseline result stays intact qualitatively with leaning leading to a reduction in overall welfare, although the effects of leaning are now smaller relative to the baseline case.

Note that, without the ZLB, the mean level of debt and the probability of a crisis are higher relative to the benchmark case, regardless of the level of leaning. This is related to the fact that,

[36] Theoretically, the ZLB on the policy rate exists because, at negative rates, banks and depositors would switch their reserves and deposits into currency. In practice, this may entail significant storage and transaction costs, so agents may be willing to accept some negative interest on their liquid holdings.

[37] In the welfare plot, we show both the benchmark and the alternative welfare measures relative to the stochastic steady-state welfare in the normal regime.

without the ZLB constraint, monetary policy is better able to support borrowers during a crisis, as shown by the lower volatility of debt relative to the benchmark economy. As a result, crises are not as costly as in the benchmark case, and need not necessarily be avoided as much. Hence, with no ZLB, more debt is accumulated than otherwise, and the average crisis risk goes up regardless of the degree of leaning.[38]

In summary, the costs of leaning are slightly lower in the absence of the ZLB constraint, but leaning is still found to be non-optimal. A contributing factor to this result is that "cleaning" through expansionary monetary policy after a crisis is now easier, since the ZLB constraint is no longer a concern. These results suggest that taking negative interest rates and unconventional monetary policy options into account is unlikely to change our benchmark assessment regarding leaning.

Symmetric leaning

We next consider the case of symmetric leaning (see second column of Figure 6). In our experiments so far, we allowed leaning for only positive debt gaps, whereas we now allow monetary policy to systematically respond to both positive and negative debt gaps. Symmetric leaning has two counteracting consquences for the probability of a crisis, it increases the mean level of debt in the economy and reduces the variance. This is also visible from the resulting debt distribution under symmetric leaning, compared to the baseline case, see Figure 7. The overall effect of these two counteracting forces is in fact a slight increase in the crisis probability with leaning. Hence, our model suggests that, in order to reduce the probability of crises, monetary policy needs to lean *asymmetrically*, responding only to positive debt gaps, as in our baseline case.

The results from this experiment are also insightful in understanding the benefits and costs of leaning asymmetrically. On the one hand, leaning raises the average debt level and lowers the standard deviation of debt, thus helping borrowers. Symmetric leaning hugely decreases the probability of the household debt gap exceeding 15 percent, but it also significantly reduces the amount of time when debt becomes very low, providing insurance to borrowers. On the other hand, symmetric leaning leads to a sizable increase in inflation and output volatility, since household debt is significantly more persistent relative to inflation and output and follows a lower-frequency cycle.[39] For low levels of leaning, the welfare gains from the former effect are actually higher than the losses associated with the latter. In particular, for $a_d = 0.017$, leaning results in an overall 27 basis points increase in LTCE relative to no leaning. Thus, the costs of asymmetric leaning stem from the fact that they are born by the borrowers and are first order, while the benefits are second order and mostly go to

[38] In the benchmark model, the ZLB is hit 4.23 percent of the time on average with no leaning (i.e., $a_d = 0$). Leaning reduces the frequency of hitting the ZLB by 18 basis points as a_d is increased to 0.024. Note that the presence of the ZLB decreases the likelihood of hitting the ZLB. Specifically for the case of no leaning, the mere presence of the ZLB with all its negative consequences lead to a reduction in the frequency of ZLB episodes by 228 basis points.

[39] In a model similar to ours, but without regime switching, Gelain et al. (2015) also find that symmetric leaning leads to higher volatility of output and inflation. Based on that insight, they suggest to replace debt *gap* with debt *growth* in the Taylor rule, in order to reduce this volatility increase associated with leaning. They also show that leaning against the household debt gap when debt is persistent can introduce indeterminacy into the system even for small values of the leaning parameter, likely due to the lack of synchronization between the business and credit cycles.

the lenders.[40]

Asymmetry in the borrowing constraint

In our model, impatient households go through a deleveraging process, and substantially reduce their debt levels, when the economy goes into a crisis regime (see Figure 2). Arguably, the deleveraging process implied here might be too fast given most household debt is in the form of long-term mortgages. Furthermore, there may be an asymmetry with respect to how fast agents accumulate debt in normal times versus how fast they can deleverage and shed debt from their balance sheets during crisis periods (Justiniano et al., 2015b; Alpanda and Zubairy, 2016).[41]

To investigate the implications of this kind of borrowing asymmetry for monetary leaning, we let the borrowing constraint persistence parameter, ρ_d, in (11) be regime-specific with $\rho_d\,(0) = 0.66$ in the normal regime as in the baseline case, but with $\rho_d\,(1) = 0.96$ in the crisis regime (see the third column of Figure 6). The increase in the persistence parameter during crisis periods slows down the deleveraging that can take place and cushions the fall in in the impatient households' borrowing and their expenditures on housing and consumption. Thus, the overall welfare is higher in this alternative model relative to the baseline. Nevertheless, the implications of leaning on welfare are qualitatively and quantitatively similar to our baseline case. In particular, the costs of (asymmetric) leaning are still found to be larger than their benefits.

Steeper logit function

The case for leaning may potentially be stronger, if the logit function determining the probability of a crisis was steeper than in our baseline case, since now leaning could reduce the crisis probability by a larger amount. Figure 8 plots the baseline logit function, we used previously, along with two possible alternatives. As noted before, the baseline logit function used in our simulations, although somewhat steeper relative to other estimates in the literature, remains rather flat in the relevant region of debt, which renders the effects of leaning on the crisis probabilities rather mute. We thus consider even steeper alternatives.

We first consider an alternative among our estimates in Table 2a. In particular, we consider the estimates from the estimation that uses the same set of crisis dates as our baseline, but uses the first alternative debt gap measure, $DGAP1_{i,t}^{HH}$, which was constructed using country-specific linear trends in the household debt-to-GDP ratio, as opposed to 3-year differencing. In particular, ω_1 and ω_2 are now set to -5.33 and 14.64, respectively. As Figure 8 indicates, this alternative logit function is significantly steeper than our baseline when the debt gap exceeds 5 percent, while it also implies

[40] Symmetric leaning would work best, if the slope of the crisis probability function is very flat for negative debt gaps and is very steep for positive debt gaps. This way, leaning during downturns would not increase the crisis probability by much and provide insurance to borrowers, while during upturns, leaning would be more effective in reducing crisis probabilities.

[41] Justiniano et al. (2015b) consider an asymmetry in the borrowing constraint vis-a-vis changes in house prices. In particular, the persistence parameter is equal to 0 when house prices are increasing, but is close to 1 when house prices are falling. This ensures that fast leveraging can occur on the upside, while the deleveraging process following adverse shocks takes a long time. Alpanda and Zubairy (2016) show how such an asymmetry in the borrowing constraint can arise endogenously when loan contracts are long-term and agents are allowed to extract home equity from their houses only when their equity surpasses a threshold value.

a lower crisis probability, when household debt is around the steady-state or below it. In particular, the probability of a crisis is only 2 percent in annualized terms, when the debt gap is 0 (compared to around 2.9 percent in the baseline case), while the crisis probability is about 19 percent as the debt gap increases to 15%.

The welfare implications from having this steeper logit function are summarized in the first column of Figure 9. With no leaning (i.e., $a_d = 0$), the steeper logit function results in a lower overall crisis probability, as agents have a higher incentive to avoid taking on more debt, when the economy approaches high debt areas. As such, the standard deviation of debt is lower along with crisis probabilities, and welfare is higher, relative to the baseline case. With leaning, the crisis probability decreases more than the baseline case due to the steeper logit curve. Welfare is not impacted as much however since the mean level of debt is not reduced with leaning as much as before. These results indicate that lowering the crisis probability through monetary leaning requires strong asymmetry, either in the policy response, as in our baseline model (which is nevertheless welfare-reducing), or in the logit function itself (with far less adverse implications on welfare).[42]

In the second column of Figure 9, we investigate the effects of a hypothetical crisis probability function that assigns near 0 probability to a crisis until the debt gap is 10 percent, while the crisis probability increases rather steeply thereafter. This crisis probability function is referred to as the "danger zone" specification in Figure 8. In this case, leaning is extremely successful in reducing the crisis probability. In particular, when a_d is set to 0.024, then the crisis probability is reduced from close to 0.80 percent in the no leaning case to almost 0 percent. Welfare is nevertheless maximized at an in-between value for a_d of 0.01, which allows for a positive probability for crises of 1.1 percent annualized. This example illustrates that asymmetric leaning can significantly reduce the probability of a crisis and increase welfare, when the crisis probability function is very steep and the risk is associated with high debt levels.

No crises

The third column of Figure 9 goes to the other extreme, and eliminates crises altogether from the model. In particular, we set ω_1 and ω_2 to 0 to render the probability of switching to the crisis regime, γ_t, equal 0 for all t. The world without crises results in much lower volatility in the system, highlighting the importance of the "extensive margin" of switching between crisis and non-crisis period in generating volatility in the baseline model. In the absence of crises, agents also take on higher levels of debt, resulting in higher welfare levels relative to the baseline model with occasional crises. Leaning, similar to the baseline case, leads to a reduction in the average level of debt in the economy, which imposes first-order welfare losses on agents, surpassing the second-order gains from reduced volatility.

Interestingly, note that welfare under leaning (with $a_d = 0.024$) in the absence of crises (dotted line) is still higher than the welfare under no leaning (i.e., $a_d = 0$) in the presence of crises (solid line). Thus, if leaning was able to eliminate crises, not through its direct effect on the level of

[42] Considering *symmetric* leaning, along with this steeper logit function, yields an increase in welfare with leaning, but a smaller reduction in crisis probabilities, relative to the baseline case.

household debt but through other means (so we could jump from the left end of the solid line to the right-hand side of the dotted line in the welfare plot), then it would be significantly welfare improving, in the order of 0.7 LTCE. Of course, this is an overstatement as leaning would likely not be able to eliminate crises altogether, but it could potentially shift the logit curve down and thus lead to a significant decline in crisis probabilities, and thereby lead to an increase in welfare. In the next subsection, we explore this possibility further.

Leaning and shifting the logit curve

In our analysis so far, we have captured the link between household debt and the probability of switching to the crisis regime using a logit specification, which is in line with the empirical literature that investigates this link (e.g., Schularick and Taylor, 2012).[43] We have thus implicitly assumed that the parameters of the logit function that relates the household debt gap to the crisis probability is not affected by the presence of monetary leaning. In other words, although leaning reduces the probability of a crisis through a movement along the logit curve, it does not lead to a shift in the logit curve itself. Note that, if leaning could also shift the logit curve down, it could lead to a much larger decline in crisis probability, thereby potentially raising welfare. In the extreme case, monetary leaning could eliminate the probability of a crisis altogether, which clearly raises welfare as we discussed in the previous subsection. As the strength of leaning increases, welfare is reduced in the no crisis economy too. Nevertheless, the welfare associated with a no-crisis economy with leaning is higher than the welfare associated with a crisis economy without leaning. Thus, if leaning was able to shift down the logit crisis probability function significantly, it could potentially increase welfare, overturning our baseline results.

To alleviate this concern, we investigate in which direction, if at all, would the logit curve shift, if monetary policy deviated from the standard Taylor rule. In particular, we let the level parameter in the logit specification in (6), ω_1, depend on whether monetary policy is leaning or not (i.e., whether $a_d = 0$ or $a_d > 0$). If ω_1 is lower in the presence of leaning, i.e., if $\omega_1(a_d > 0) < \omega_1(a_d = 0)$, leaning would reduce the crisis probability directly through a shift down in the logit function, as well as through the decline in household debt considered before (with an elasticity determined by ω_2).

To quantify the change in ω_1 under leaning versus no leaning, we first run country-by-country Taylor rule regressions for each country i as:

$$R_{i,t} = \beta_{i,0} + \beta_{i,1} R_{i,t-1} + \beta_{i,2}\pi_{i,t-1} + \beta_{i,3}\Delta y_{i,t-1} + \varepsilon_{i,t}, \tag{26}$$

where $\Delta y_{i,t}$ denotes the growth rate of output.[44] Using the residuals of the above regression, we

[43] Ideally, the logit relationship should come about endogenously in the model from first principles, rather than being superimposed onto the set-up. One possibility, for example, would be to consider slack borrowing constraints in normal times, which occasionally become binding, similar to the small open economy setup of Mendoza (2010). This is more difficult to do, however, in our closed economy set up. In particular, it is possible to entertain borrowing constraints which are usually binding, but can occasionally become slack as house prices go up, as in Iacoviello and Guerrieri (2016). The reverse, however, cannot be sustained as an equilibrium, since borrowing becomes infinite in normal times given the difference in the discount factors of the patient and impatient households.

[44] The data used in the regression are obtained from Haver Analytics. For details on the data, see Appendix A. We

construct a dummy variable, $I_{i,t}$, which takes a value of 1 when the residual is positive, and 0 otherwise. This dummy variable thus captures the periods when the monetary policymaker has set the interest rate higher than what is implied by their Taylor rule. Note that monetary leaning against household debt was rarely exercised by policymakers prior to the crisis. Thus, the dummy variable constructed here provides us with exogenous variation in the interest rate gap (i.e., deviations of the interest rate from what is implied by the Taylor rule) that are unrelated to household debt, and therefore unrelated to the crisis probability.

We now use this constructed dummy variable, $I_{i,t}$, as an additional variable in the logit crisis probability regression, we used before in our calibration section, to get estimates for ω_1 and ω_2. In particular, we now run

$$\text{logit}\left(Crisis_{i,t}\right) = \alpha_i + \xi I_{i,t-1} + \beta DGap_{i,t-1} + \varepsilon_{i,t}, \tag{27}$$

where ξ captures the effect of a positive interest rate gap on the crisis probability. As noted before, although our dummy variable captures the deviations of the interest rate from the Taylor rule that are unrelated to household debt, and therefore unrelated to the crisis probability, it can still provide us with an estimate as to how a deviation from the Taylor rule that is related to leaning would impact the crisis probability. To that effect, when the dummy variable takes on a value of 1, the resulting intercept parameter effectively becomes $\alpha_i + \xi$, which we can use as our ω_1 parameter under leaning (i.e., $\omega_1(a_d > 0) = \alpha_i + \xi$), while the estimate for α_i would still provide the ω_1 parameter under no leaning (i.e., $\omega_1(a_d = 0) = \alpha_i$). As before, we use the estimate for the β to set the value for ω_2.

Table 3 summarizes the results from the above regression using six different interest rate gap dummies, $I_{i,t}$, we have constructed from equation (26) using various different measures for the short-term interest rate and the inflation rate (see Appendix A for details). The crisis dummy and the debt gap measures refer to the baseline measures we had used in our calibration section. Note that our estimates for α_{US} and β remain very close to our baseline estimates in Table 2. More importantly, all the estimates for ξ are positive (albeit mostly insignificant), indicating that leaning would cause, if anything, an *upward* shift in the logit function rather than a downward shift. Hence leaning could in fact lead to an increase in the crisis probability, rather than a decline, which would further deteriorate its implications on welfare. Our finding here that positive interest gaps could increase, rather than decrease, crisis probabilities is also consistent with the findings in Bauer (2014), who also reports a positive coefficient on the probability of a house price correction from positive interest rate gaps. One possibility for this is the prevalence of adjustable rate mortgages on the riskier side of the mortgage spectrum. In particular, leaning would raise the interest rate burden of borrowers with adjustable rate mortgages, making them more vulnerable to defaults in the presence of adverse shocks.

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use output growth instead of the output gap in the Taylor rule regressions as the latter would require us to take a stand on the level of potential output in each country.

5 Conclusion

In this paper, we assess the relative benefits and costs of leaning against household imbalances within the context of a small-scale, regime-switching New Keynesian model. We find that leaning is generally welfare reducing. In particular, leaning is able to reduce the volatility of the main economic variables through the reduction of crisis probabilities, but this comes at the expense of lower average debt levels, hurting borrower households through the reduction in their consumption and housing expenditures. These first-moment effects on welfare turn out to be stronger, than the benefits in terms of the reduction in second moments.

In future work, we would like to endogenize the relationship between household debt and crisis probability, which we currently capture using a logit function based on the related empirical literature. Similarly, the relationship between household debt and crisis probability may be related to the risk composition of loans rather than solely to their aggregate quantity. Thus, the model could be extended to feature different risk characteristics in household loans (e.g., prime versus subprime), with only the riskier types contributing substantially to the crisis probability. This may increase the costs of leaning, unless leaning is conducted only with respect to the riskier type of loans. Finally, we also would like to extend the model to incorporate features that have been shown in the literature to significantly improve the fit of DSGE models in capturing business cycle dynamics, such as habit formation in consumption, indexation in inflation, and other real and nominal frictions (Smets and Wouters, 2007). This, however, would likely require the use of perturbation methods instead of computationally costly projection methods.[45]

[45] For example, the Matlab-based RISE (Rationality In Switching Environments) toolbox utilizes perturbation methods to compute solutions for regime-switching models with an endogenous probability of switching and can be applied to large-scale DSGE models (Maih, 2015).

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A Data Sources for the Empirical Analysis on Crisis Probability

Crisis dummy: We use the dates of systemic financial and banking crises to construct our crisis dummy variable, $Crisis_{i,t}$, which takes on a value of 1 at the start date of a crisis and 0 otherwise. Our main source for this variable is Laeven and Valencia (2012; LV-IMF hereafter), which reports banking crisis start dates by year and month for a large set of countries. We convert their month information to quarters in the usual way. In the few cases where the crisis month information is missing, we try to find the corresponding quarter of these crises from other sources; and if we cannot, we assume that the crisis occurred in the 2nd quarter of the corresponding year.[46]

For robustness, we construct two other crisis dummy variables by adding some additional systemic and non-systemic financial crisis dates to our baseline list from other sources. These other sources are Schularick and Taylor (2012; ST hereafter), Jorda, Schularick and Taylor (2015; JST hereafter), Buyukkarabacak and Valev (2013; BV hereafter), Bordo et al. (2001; BEKM hereafter), Haldane et al. (2005; HHSS hereafter), Caprio et al. (2003; CKLN-WB hereafter), and Basel Committee on Banking Supervision (2004; BCBS04 hereafter), which include some systemic financial and banking crises that do not appear in the LV-IMF database.[47] BEKM also contains some banking crises that are classified as non-systemic. In the few cases where the same crisis is dated differently in the LV-IMF database versus these other sources, we stick with the date designation in LV-IMF. Table A1 provides a list of the baseline crisis dates, $Crisis_{i,t}$, the additional systemic crisis dates used in the first alternative dummy variable, $Crisis1_{i,t}$, and the additional non-systemic crisis dates used in the second alternative, $Crisis2_{i,t}$.

Debt gap measure: We consider several different measures of the debt gap, which requires taking a stand on the trend level of debt. We construct our baseline debt gap measure, $DGAP^{HH}_{i,t}$, by considering the 12-quarter difference in the household debt-to-GDP. This measure is similar to the ones used in BV, who consider only a 1-year difference in the debt-to-GDP ratio, and also to ST and JST, who consider 5-year differences in the real debt level rather than the debt-to-GDP ratio. Our measure considers 3-year differences instead of 1 to be able to capture rapid increases in debt that may occur slightly more than a year before a crisis occurs. ST, for example, find that the second lag of debt growth is the most significant in predicting financial crises in a yearly logit, and the first lag may often enter with the opposite sign, indicating a slowdown in debt growth right before a crisis occurs. Our choice of taking 3-year differences rather than 5 is motivated by the fact that ST typically do not find the 4th and 5th lags of real growth to be significant; but this choice also allows us to retain more observations in the regressions.[48] Unlike ST and JST however, we

[46] Note that the debt gap measure is highly persistent; thus, assuming that the crisis occurred in a particular quarter does not alter the results by much when we do sensitivity analysis for this choice.

[47] BEKM and the World Bank's database CKLN-WB contain annual crisis dates for a large set of countries, similar to LV-IMF. ST reports annual crisis dates and bank credit data for a small set of developed economies dating back to the 1870s. JST updates this data to differentiate between mortgage versus non-mortgage credit. BV also considers a small set of countries including some emerging markets, and differentiates between household and business credit in their regressions. HHSS lists the start and end years for 33 systemic financial crises in developed and emerging market economies between 1977 and 2002. BCBS04 lists recent banking crises in advanced economies.

[48] As noted, ST uses the growth rate of bank loans in the last 5 years as the test variable in their logit regressions.

choose to consider the difference in the debt-to-GDP ratio rather than the growth in real debt to ensure that we do not attribute a positive debt gap to a country whose income level is keeping pace with its debt.

For robustness, we also construct five other debt gap measures by detrending the household debt-to-GDP measures by (i) country-specific linear time trends, (ii) country-specific quadratic time trends, (iii) a common linear time trend, (iv) a common quadratic time trend, and (v) country-specific HP-trends. These alternative measures are labeled $DGAP1_{i,t}^{HH}$ through $DGAP5_{i,t}^{HH}$. Note that all of our measures allow household debt to grow faster than GDP in the long run as financial innovation potentially outpaces growth in productivity in the real economy.

We also construct an analogous set of six debt gap measures using the total borrowing of the non-financial private sector rather than household debt, since this data series more closely resembles the data series used in related papers in the literature, and also provides a longer time series for some countries. These six measures are labeled analogously, but with a NFP superscript instead of HH, i.e., $DGAP_{i,t}^{NFP}$, and $DGAP1_{i,t}^{NFP} - DGAP5_{i,t}^{NFP}$.

Our source of data for the debt-to-GDP variable is the *Long series on total credit and domestic bank credit to the private non-financial sector* dataset of the BIS, which provides panel data on non-financial sector's borrowing in general and household sector's borrowing in particular, as a share of GDP. We also constrain our coverage in terms of countries and dates to the availability of this BIS series.

Taylor rule regressions: The data on short-term nominal interest rate, inflation rate, and real GDP growth rate used in the Taylor rule regressions are obtained from Haver Analytics. Real GDP growth rates are constructed using the real GDP index (in local currency) from the *International Financial Statistics* of the IMF. For the short-term interest rate, we use three different measures corresponding to the policy rate, the money market rate and the 90-day government bond yield. For the inflation rate, we use two different measures corresponding to the percent change in the consumer price index (CPI) and the percent change in the GDP deflator. Using these different series, we can construct 6 separate measures for the interest rate gap dummy, $I_{i,t}$. $I1_{i,t}$ is constructed using the policy rate for the interest rate and GDP deflator for inflation, while $I2_{i,t}$ is constructed using the policy rate and the CPI. Similarly, $I3_{i,t}$ uses the market market rate and GDP deflator, $I4_{i,t}$ uses the market market rate and CPI, $I5_{i,t}$ uses the government bond yield and GDP deflator, and $I6_{i,t}$ uses the government bond rate and CPI.

In one of their robustness checks, ST uses the loans-to-GDP ratio as a control variable in order to capture financial development, and find positive and significant coefficients for this variable. As argued in the main text, this variable could also be capturing the debt gap's effect on the crisis probability above and beyond ST's main test variable.

Table A1. List of financial crisis dates[a]			
Country	Systemic banking crises in LV-IMF	Other systemic crises	Non-systemic crises
Argentina	1989Q4, 1995Q1, 2001Q4		
Australia		1991Q1[b]	
Austria	2008Q3		
Belgium	2008Q3		
Brazil	1994Q4		
China	1998Q4		
Czech Republic	1996Q2		
Denmark	2008Q3	1987Q2*	
Finland	1991Q3		
France	2008Q3		1994Q2*
Germany	2008Q3		1974Q2[c]
Greece	2008Q3		1991Q2*
Hong Kong			1982Q2*, 1998Q1
Hungary	1991Q2*, 2008Q3		
India	1993Q2*		
Indonesia	1997Q4		1992Q2*
Ireland	2008Q3		
Italy	2008Q3	1990Q2*	
Japan	1997Q4	1992Q2*	
Korea	1997Q3		
Luxembourg	2008Q3		
Malaysia	1997Q3		1985Q2*
Mexico	1981Q2, 1994Q4		
Netherlands	2008Q3		
Norway	1991Q4		
Poland	1992Q2*		
Portugal	2008Q3		
Russia	1998Q3, 2008Q3	1995Q3	
Singapore			1982Q2*
South Africa			1977Q2*, 1989Q2*
Spain	1977Q4, 2008Q3		
Sweden	1991Q3, 2008Q3		
Switzerland	2008Q3		1991Q4
Thailand	1983Q2*, 1997Q3		
Turkey	2000Q4		1991Q1, 1994Q2
United Kingdom	2007Q3	1974Q1[d], 1984Q2*, 1991Q3	
United States	1988Q1[e], 2007Q4	1984Q2[f]	

Notes: (a) The sample of countries and time periods are determined by the availability of credit data from the BIS and the occurrence of at least one financial crisis during the available years. Only Canada and Saudi Arabia are excluded from the sample due to the latter criterion. Benchmark crisis dates are from LV-IMF, while additional dates are obtained primarily from ST, JST, BV, BEKM, HHSS, and CKLN-WB. See the main text for more on these sources. When there was not enough information regarding the exact quarter of a crisis, we used Q2 as the default. These crises are designated by an asterisk (*) after the date.

(b) JST lists this Australian crisis date as 1989, but the major bank failures started in February 1991.

(c) Herstatt crisis in Germany (BCBS04).

(d) The *secondary banking crisis* in the U.K. actually broke out in December 1973, although the crisis date is listed as 1974 in JST. We thus use 1974Q1 as the crisis date.

(e) The peak of the Savings and Loan crisis in the U.S. was 1988, but there were some failures before 1988. As such, we decided to date the quarter of the crisis as Q1, and keep the 1998 as the year of the crisis, consistent with LV-IMF.

(f) The Continental Illinois National bank, then the 6th largest financial bank in the U.S. and a preeminent wholesale lender, faced a run on its deposits in May 1984.

B Computational Appendix

In this section, we outline an envelope condition method (ECM) approach to solving our model. The ECM approach was originally proposed in Maliar and Maliar (2013), and is based on iterating on the *derivatives* of value functions, as opposed to the standard value function iteration approach or the collocation approach on the Euler equations. Its main advantage is the replacement of complex root-finding problems with simple algebra; thus, it is faster than value function approximation and more robust in terms of convergence relative to using the collocation method on Euler conditions. We adapt the method to our needs by, first, writing the optimization problems of the patient and impatient households as Bellman equations, and then, deriving the corresponding first-order and envelope conditions that characterize equilibrium (see Stokey et al., 1989). We also write the Phillips curve and the labor demand expressions of the firm, along with the Taylor rule of the central bank and the feasibility conditions, consistent with the recursive notation used in the rest of the model.

As outlined below, the core of the algorithm works through initializing the value function derivatives (i.e., initializing the approximating polynomials' parameters), and updating them until sufficient convergence is achieved. We use a linear-spline to approximate the value function derivatives, with an evenly-spaced grid of 7 points for each of the 4 endogenous state variables. We use a 5-point quadrature for the innovations in the temporary component of the credit supply shock when evaluating expectations.[49] The general outline of the algorithm is as follows:

[49] The resulting mean absolute error for the Euler equations was 0.001 percent in consumption equivalents. Increasing the grid size of each endogenous state to 8, or increasing the quadrature on the housing shock innovations to 6 nodes, did not materially change the precision of the solution.

1. We find the deterministic steady state (conditional on the normal regime) for all the variables and the value function derivatives.

2. We use the steady-state values in step 1 as initial guesses for the value function derivatives, and construct a grid over a compact subset of the state space, $S = (d, h_I, R, \chi, r)$. Note that the regime state, r, takes on a value of 0 or 1. We also create a quadrature over the innovations of the temporary component of the credit supply shock with nodes ε_j and weights ω_j for $j = 1, ..., J$.

3. We use the value function derivatives given in step 2 to solve for all the current decisions of households, including the state variables affecting the next period. The ECM approach simplifies this step, and allows us to obtain the optimal choices fairly easily.

4. Using the solution from step 3 and the previous value function derivatives, we update the value function derivatives using the equilibrium conditions below:

$$V_d^P(S) = \frac{R(1+\chi)}{\pi}\beta_P E V_d^P(S'), \tag{28}$$

$$V_h^P(S) = u_h(c_P, h_P', n_P) + \beta_P E V_h^P(S'), \tag{29}$$

$$V_d^I(S) = \left(\frac{\rho_d - R^m}{\pi}\right)\mu + \frac{R^m}{\pi}\beta_I E V_d^I(S'), \tag{30}$$

$$V_h^I(S) = -u_h(c_I, h_P', n_I) - (1-\rho_d)\phi q \mu + \beta_I E V_h^I(S'), \tag{31}$$

$$\Gamma(S) = -\frac{\eta - 1}{\kappa}(1 - \Omega\theta) y \lambda_P + \beta_P E\left[\Gamma(S')\right], \tag{32}$$

where $\Gamma(S)$ is defined as

$$\Gamma(S) = E\left[\lambda_P\left(\frac{\pi}{\pi^*} - 1\right)\frac{\pi}{\pi^*} y\right], \tag{33}$$

and

$$\chi = \chi_r + \chi_T. \tag{34}$$

The first four updating rules for the value function derivatives are obtained by combining the first-order and envelope conditions of the Bellman equations of patient and impatient households, while the last expression is the Phillips curve equation. To evaluate the expectations on the right-hand side of these expressions, we use the quadrature over the stochastic shock and the Markov chain probabilities. For example,

$$\begin{aligned} V_d^P(d, h_I, R, \chi, r) &= \frac{R(1+\chi)}{\pi}\beta_P E V_d^P(S') \\ &\approx \frac{R(1+\chi)}{\pi}\beta_P \left\{ \begin{array}{c} \sum_{r'=0}^{1} \gamma(d, r') \sum_{j=1}^{J} \omega_j V_d^P(d', h_I', R', \rho_\chi(r)\chi + \varepsilon_j, r') \\ \sum_{r'=0}^{1} \delta(r') \sum_{j=1}^{J} \omega_j V_d^P(d', h_I', R', \rho_\chi(r)\chi + \varepsilon_j, r') \end{array} \text{ for } \begin{array}{c} r = 0 \\ r = 1 \end{array} \right\} \end{aligned}$$

where

$$\gamma(d, r') = \left\{ \begin{array}{c} 1 - \gamma(d) \\ \gamma(d) \end{array} \text{ for } r' = \begin{array}{c} 0 \\ 1 \end{array} \right\} \text{ and } \delta(r') = \left\{ \begin{array}{c} \delta \\ 1 - \delta \end{array} \text{ for } r' = \begin{array}{c} 0 \\ 1 \end{array} \right\}.$$

5. We iterate on step 4 above until we reach convergence on the value function derivatives. At each step, we also check the convergence of the policy functions that we need to update the states, in particular for d' and h_I'.

Table 1. Benchmark calibration

	Symbol	Value
Inflation target (gross, qtr.)	π^*	1.005
Discount factor	$(\beta_P,\ \beta_I)$	$(0.99,\ 0.97)$
Inverse labor supply elasticity	ϑ	2
Level parameter for housing in utility	ξ	0.12
Gross markup in price	θ	1.1
Price adjustment cost	κ	100
Share of patient household in labor income	ψ	0.748
Fraction of price adj. costs affecting resources	I_π	0.1
LTV ratio on mortgage debt	ϕ	0.75
Persistence in the borrowing constraint	ρ_d	0.66
Switch prob. from crisis to normal regime	δ	0.10
Logit parameters for γ_t (switch prob. from crisis to normal)	$\omega_1,\ \omega_2$	-4.948, 5.017
Regime component of risk premium	$\chi_R(0),\ \chi_R(1)$	$0.005,\ 0.018$
Persistence of transient component of risk premium	$\rho_\chi(0),\ \rho_\chi(1)$	0.985, 0
St.-dev. of transient component of risk premium	σ_χ	0.0003
Taylor rule - persistence	ρ	0.75
- inflation	a_π	1.5
- output gap	a_y	0.125
- debt gap (baseline model, with leaning)	$a_d(0),\ a_d(1)$	$[0 - 0.024]$,0

Table 2a. Logit regression of crisis on the household debt gap

	$CRISIS$		$CRISIS1$		$CRISIS2$	
	$\widehat{\alpha}_{US}$	β	$\widehat{\alpha}_{US}$	β	$\widehat{\alpha}_{US}$	β
$DGAP^{HH}$	-4.9478***	5.0172	-4.5699***	5.8178*	-4.5813***	6.0927*
	(0.6918)	(3.6498)	(0.5864)	(3.3127)	(0.5870)	(3.2239)
$DGAP1^{HH}$	-5.3284***	14.6392***	-4.6656***	10.4606***	-4.6398***	9.9159***
	(0.7650)	(3.4936)	(0.6293)	(3.1094)	(0.6195)	(2.9027)
$DGAP2^{HH}$	-5.3885***	18.5945***	-4.7902***	15.2857***	-4.8033***	15.5500***
	(0.7439)	(3.8947)	(0.6370)	(3.4673)	(0.6368)	(3.3468)
$DGAP3^{HH}$	-6.9276***	7.5173***	-5.7314***	4.8394**	-5.8700***	5.3225***
	(1.0609)	(2.4331)	(0.8689)	(1.9998)	(0.8764)	(2.0011)
$DGAP4^{HH}$	-6.9922***	9.0958***	-5.9994***	6.7357***	-6.1249***	7.2496***
	(0.9357)	(2.8523)	(0.8052)	(2.3625)	(0.7958)	(2.2821)
$DGAP5^{HH}$	-4.8354***	-8.9261	-4.4229***	0.2808	-4.4232***	3.0654
	(0.71383)	(23.1189)	(0.5809)	(19.6042)	(0.5807)	(18.0884)

Table 2b. Logit regression of crisis on the nonfinancial private debt gap

	$CRISIS$		$CRISIS1$		$CRISIS2$	
	$\widehat{\alpha}_{US}$	β	$\widehat{\alpha}_{US}$	β	$\widehat{\alpha}_{US}$	β
$DGAP^{NFP}$	-5.0735***	5.1695***	-4.6821***	5.4494***	-4.6335***	4.7139***
	(0.7013)	(1.4155)	(0.5779)	(1.2712)	(0.5772)	(1.0111)
$DGAP1^{NFP}$	-4.8415***	2.0604	-4.4318***	2.0476	-4.4323***	2.1042
	(0.7081)	(2.0560)	(0.5800)	(1.8292)	(0.5799)	(1.6249)
$DGAP2^{NFP}$	-4.8422***	2.1780	-4.4392***	2.8007	-4.4408***	2.9332
	(0.7078)	(3.5106)	(0.5806)	(4.0228)	(0.5802)	(3.2386)
$DGAP3^{NFP}$	-5.2179***	1.6389	-4.7821***	1.5323	-4.7880***	1.5566*
	(0.7659)	(1.1796)	(0.6275)	(0.94712)	(0.6186)	(.8445)
$DGAP4^{NFP}$	-5.2023***	1.8320	-4.7973***	1.8539	-4.8192***	1.9577*
	(0.7679)	(1.4760)	(0.6422)	(1.3553)	(0.6285)	(1.1882)
$DGAP5^{NFP}$	-4.8378***	6.5782***	-4.4297***	7.3625***	-4.4279***	6.2848***
	(0.7086)	(2.3671)	(0.5802)	(2.3756)	(0.5803)	(2.1446)

Notes: The estimates for the fixed effect parameters other than for the U.S. are omitted. Robust standard errors in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 3. Logit regression with interest rate gap dummy			
	$\widehat{\alpha}_{US}$	ξ	β
using $I1_{i,t}$	-5.5876***	1.0797	4.4513
using $I2_{i,t}$	-5.2788***	0.5936	4.8247
using $I3_{i,t}$	-5.5890***	0.9819*	5.0242
using $I4_{i,t}$	-5.3078***	0.6114	5.0483
using $I5_{i,t}$	-5.6025***	1.02436*	4.8237
using $I6_{i,t}$	-5.1201***	0.3009	4.9759

Notes: The estimates for the fixed effect parameters other than for the U.S. are omitted. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively, calculated using robust standard errors.

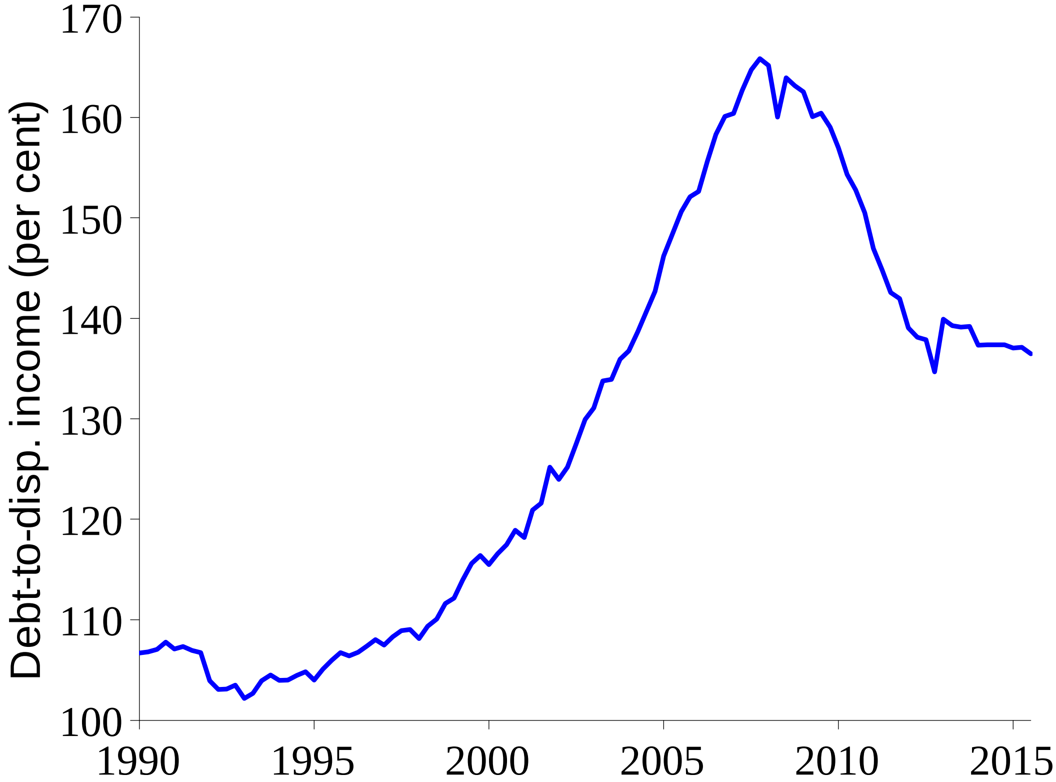

Figure 1: U.S. household debt-to-disposable income ratio. *Source*: Federal Reserve Board.

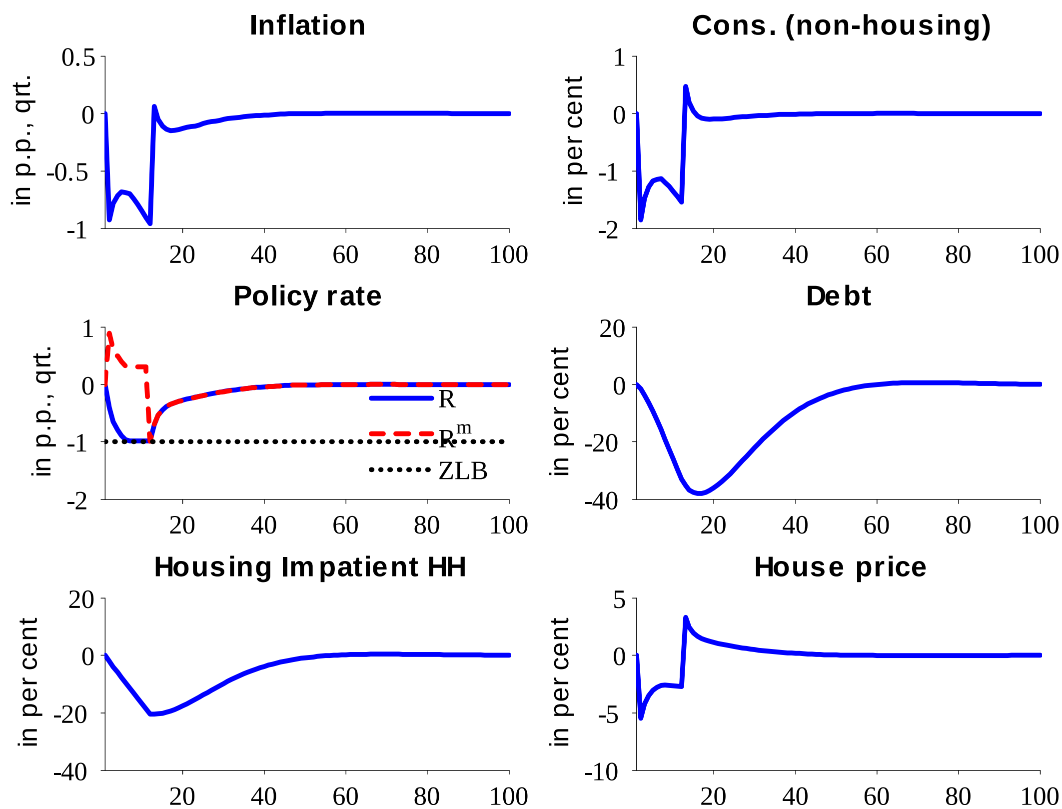

Figure 2: Impulse responses of key model variables following a crisis shock induced by a sharp rise in the risk premium on mortgage debt for 10 periods

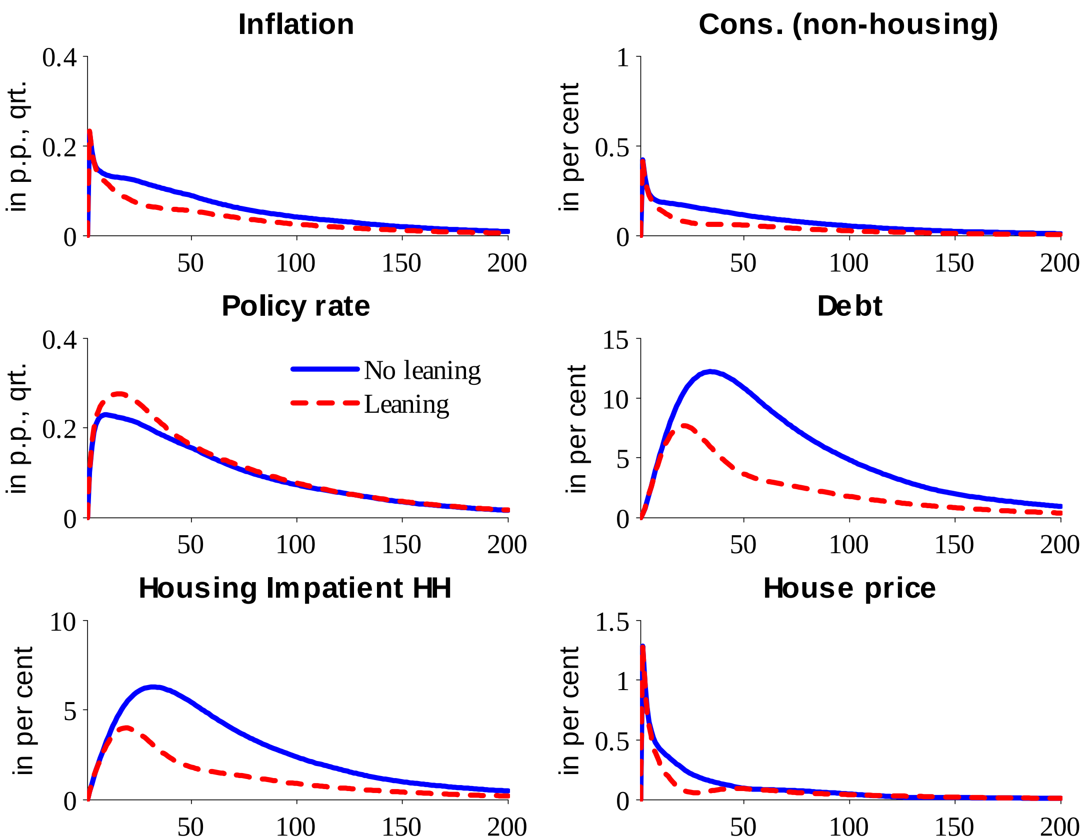

Figure 3: Impulse responses of key model variables following a stimulative credit supply shock in the normal regime. Solid lines denote the case with no leaning (i.e., $a_d = 0$) and dashed lines denote the case with monetary policy leaning (with $a_d = 0.024$)

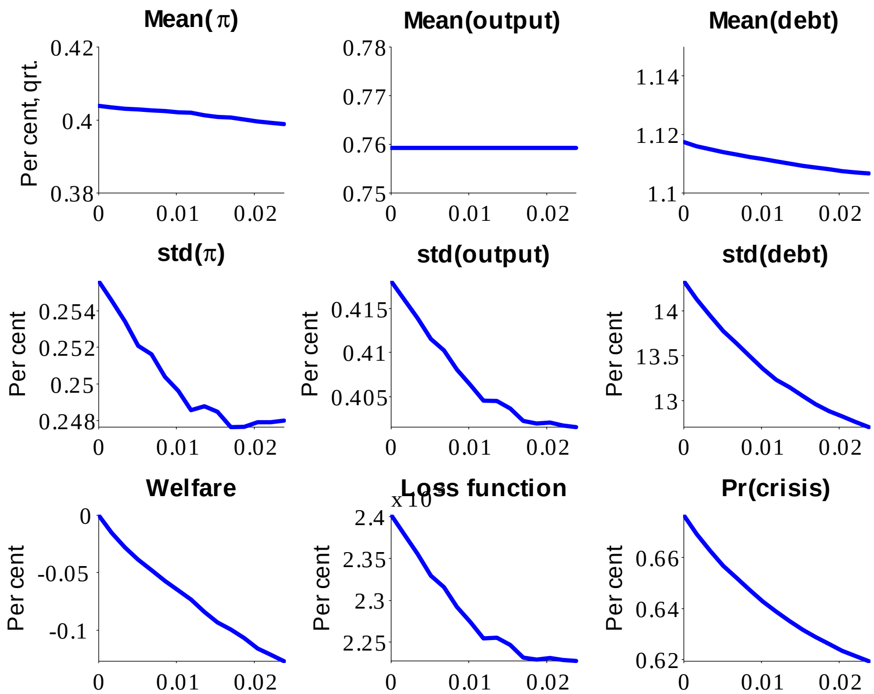

Figure 4: First and second moments as well as social welfare, loss function and crisis probability depending on the degree of leaning, a_d

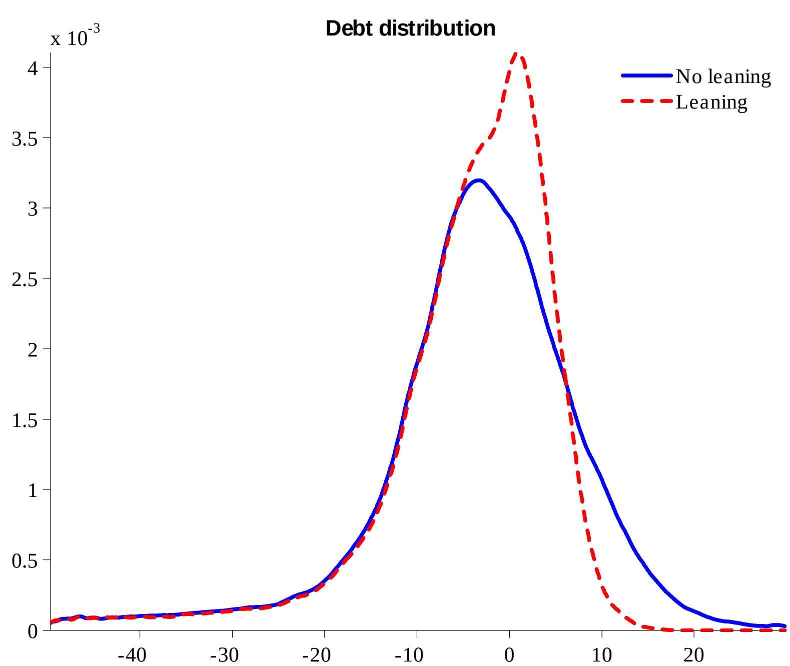

Figure 5: Debt distribution for the benchmark calibration and the case of no leaning (blue line, $a_d = 0$) and leaning (red dashed line, $a_d = 0.024$)

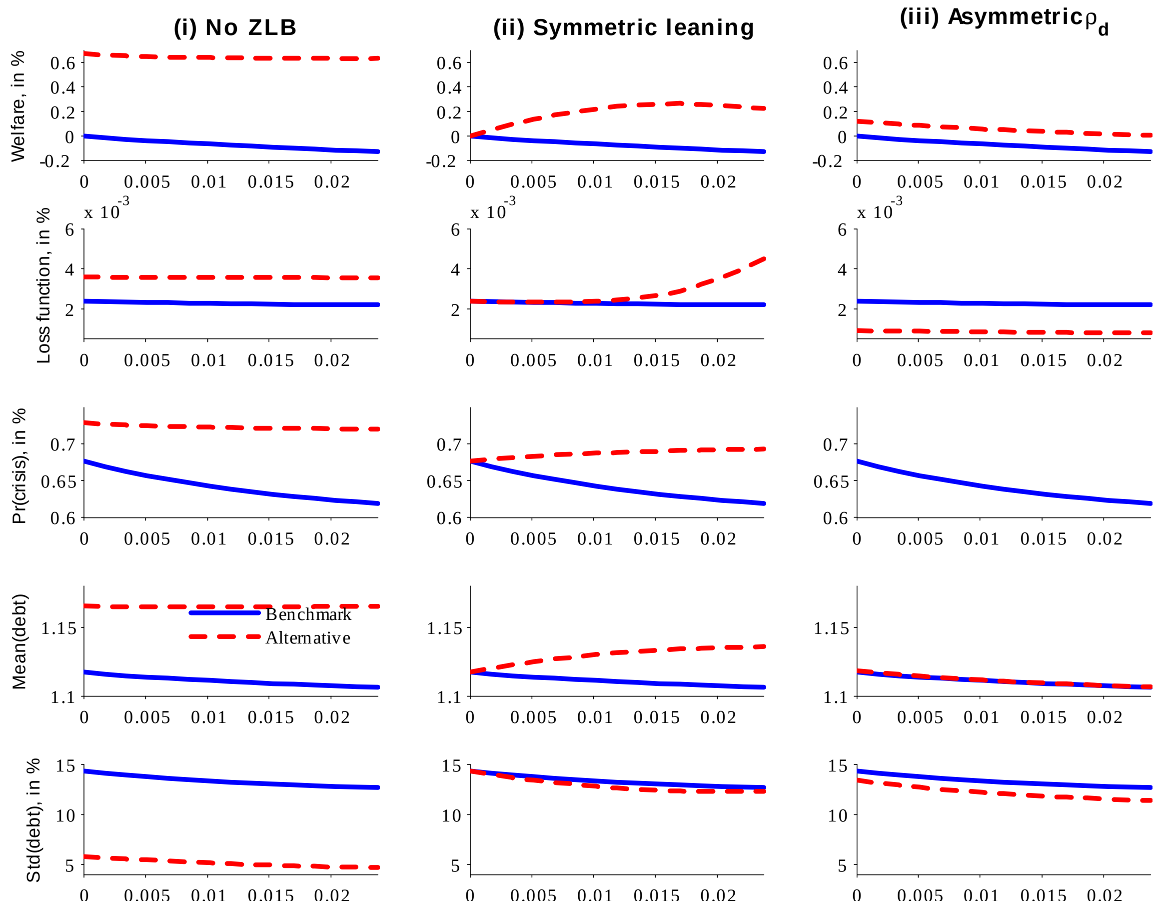

Figure 6: The effects of leaning under the baseline model (solid line) versus alternative models in each column (dashed line). The columns denote model with (i) no ZLB constraint on the policy rate, (ii) symmetric leaning, and (iii) asymmetry in the borrowing constraint, respectively.

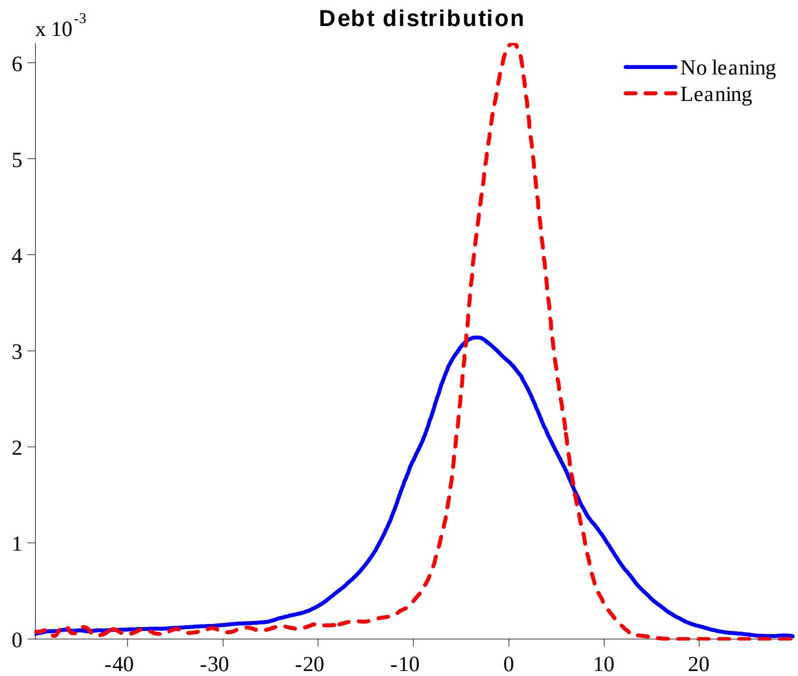

Figure 7: Debt distribution for the benchmark calibration and the case of no leaning (blue line, $a_d = 0$) and symmetric leaning (red dashed line, $a_d = 0.024$)

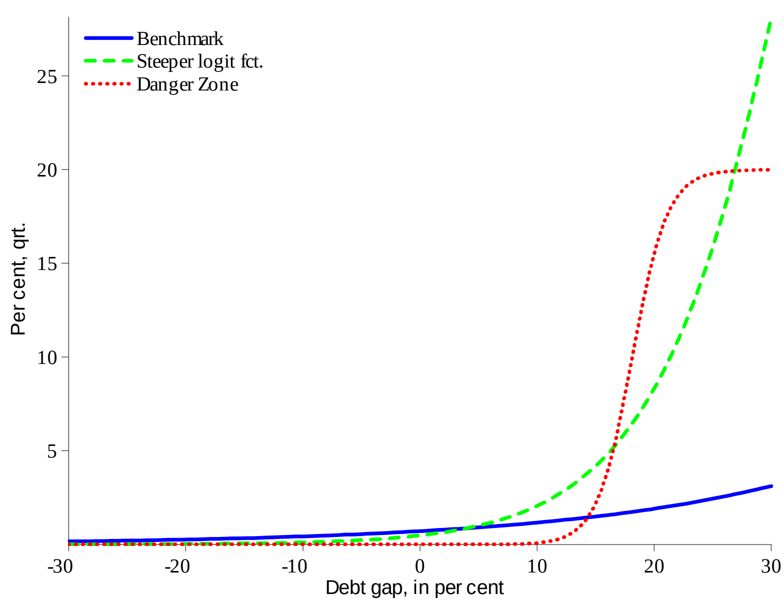

Figure 8: The estimated logit functions for housing crisis probability as a function of household debt gap in the baseline case (i.e., logit regression with household debt gap constricted from 3-year differences in household debt-to-GDP ratios), an alternative where household debt gaps were constructed using country-specific linear trends (Steeper logit function) and a hypothetical logit function that is fairly flat till debt levels exceed the trend by more than 10 per cent (Danger zone).

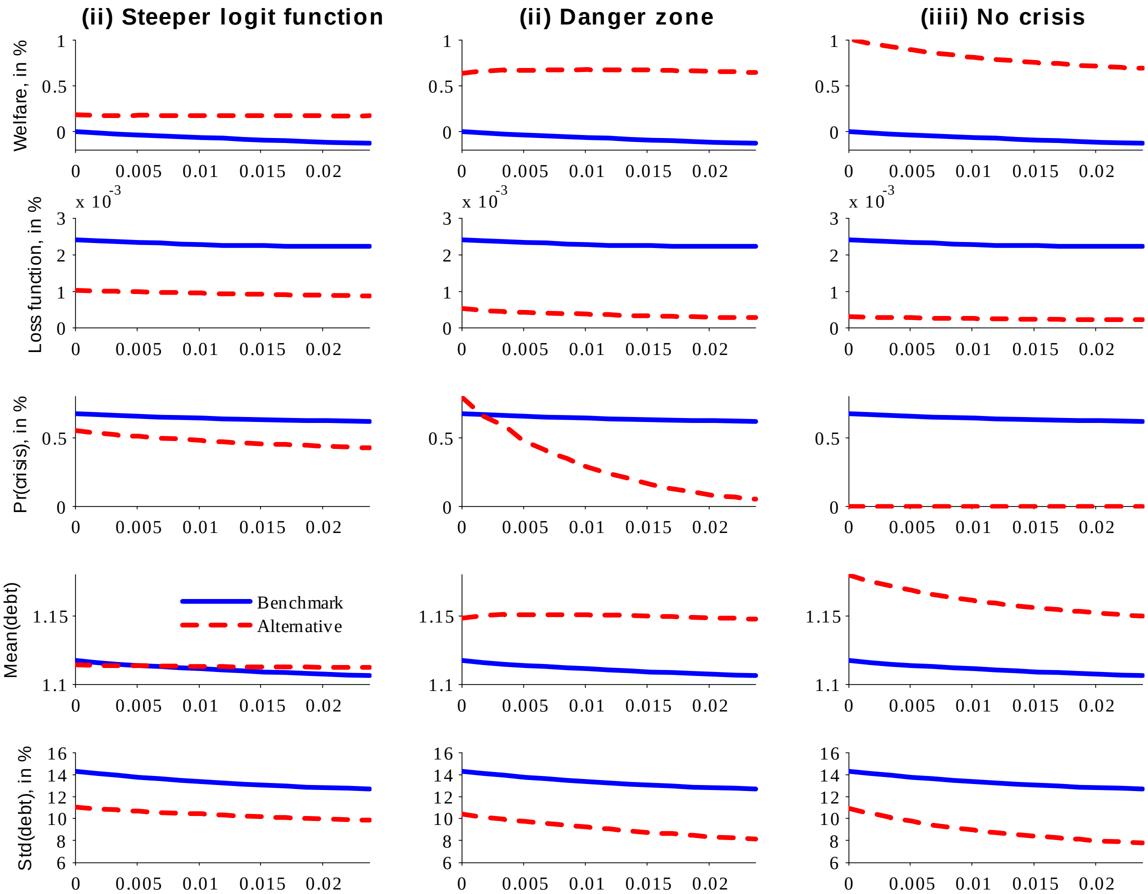

Figure 9: The effects of leaning under the benchmark logit crisis probability function (solid line) versus alternative crisis probabilities (dashed line). The columns denote model with (i) steeper logit function, (ii) "danger zone" scenario, and (iii) no crises, respectively.