

# HOUSEHOLD LEVERAGING AND DELEVERAGING

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ABSTRACT. U.S. households' debt skyrocketed between 2000 and 2007, and has been falling since. This leveraging (and deleveraging) cycle cannot be accounted for by the relaxation, and subsequent tightening, of collateral requirements in mortgage markets observed during the same period. We base this conclusion on a quantitative dynamic general equilibrium model calibrated using macroeconomic aggregates and microeconomic data from the Survey of Consumer Finances. From the perspective of the model, the credit cycle is more likely due to factors that impacted house prices more directly, thus affecting the availability of credit through a change in collateral values. In either case, the macroeconomic consequences of leveraging and deleveraging are relatively minor, because the responses of borrowers and lenders roughly wash out in the aggregate. These results suggest that household debt overhang alone cannot account for the slow recovery from the Great Recession.

## 1. INTRODUCTION

The evolution of U.S. households' debt since the turn of the XXI century has been remarkable. As shown in figure 1.1, the ratio of mortgage debt to GDP rose by about 30 percentage points between 2000 and the beginning of the financial crisis, three times more than in the previous episode of credit expansion in the 1980s. Since then, this ratio has fallen by about 10 percentage points, orders of magnitudes more than at any time since the Great Depression. Here, and in the rest of the paper, we focus on mortgage debt because it represents about 70 percent of total household liabilities in the United States, but the picture would look very similar if we used a more comprehensive measure of household debt.

This unprecedented leveraging cycle has attracted a great deal of attention, contributing to bring the connection between household debt and the macroeconomy front and center

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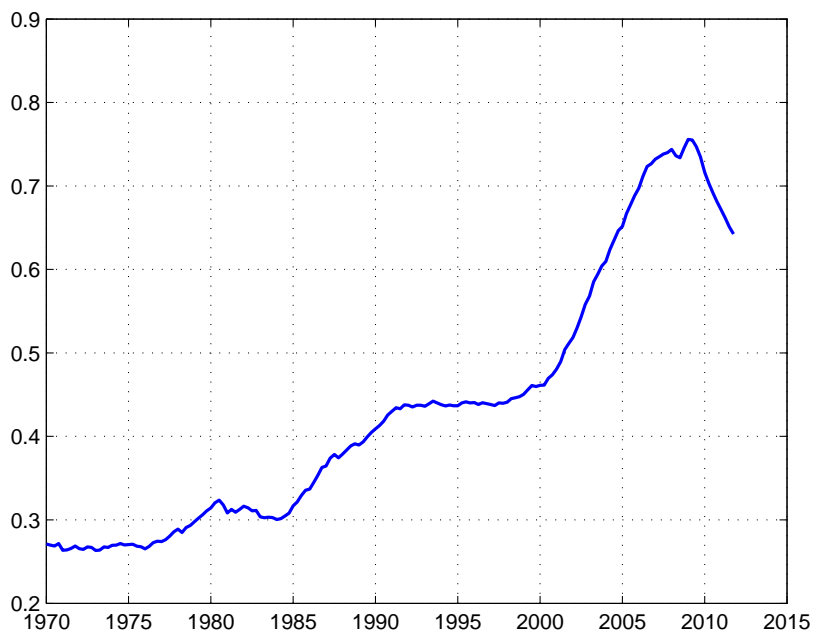


FIGURE 1.1. Mortgages-to-GDP ratio. Mortgages are defined as home mortgages from the balance sheet of U.S. households and nonprofit organizations (Flow of Funds, Table B.100, line 33, unique identifier Z1/Z1/FL153165105.Q). They include loans made under home equity lines of credit and home equity loans secured by junior liens.

in the public and academic debates (e.g. Eggertsson and Krugman, 2012, Guerrieri and Lorenzoni, 2012, Midrigan and Philippon, 2011, Mian and Sufi, 2009 and 2011, Mian, Rao and Sufi, 2012, IMF, 2012, and McKinsey Global Institute, 2012). In particular, Eggertsson and Krugman (2012, EK hereafter) and Guerrieri and Lorenzoni (2012, GL hereafter) have modeled the idea that a negative shock to consumers' ability to borrow pushed the U.S. economy against the zero lower bound, exacerbating the Great Recession and delaying the recovery from it.

This paper adds to this debate a quantitative perspective on the causes and consequences of the exceptional leveraging cycle documented in figure 1.1. It does so in the context of a general equilibrium model consistent with many empirical features of the U.S. economy. Its main finding is that household deleveraging *in isolation* is not a strong enough force to account for the slow recovery from the Great Recession.

The model has three key ingredients. First, heterogeneity in households' desire to save generates borrowing and lending, and hence a role for debt. Since household debt in the U.S. is held primarily in the form of mortgages, the second key feature of the model is a collateral constraint that limits debt to a fraction of home values. As a consequence, house prices play a crucial role in the dynamics of household debt, a connection that is evident in the data, but which is missing from the more stylized models of EK and GL. To highlight the link between these two variables, figure 1.2 displays the historical evolution of house prices and of the ratio between mortgages and the value of real estate. The massive boom in home values that started in the late 1990s was matched by an increase in debt of similar magnitude, so that the mortgage-to-real estate ratio (or debt-to-collateral ratio) remained roughly stable until 2006. When house prices collapsed, this ratio spiked, since lenders cannot force the repayment of outstanding mortgages, even if the value of the real estate collateralizing them falls. This downward "stickiness" of mortgage debt is necessary to match the observed jump in the mortgage-to-real estate ratio, and it is the third key ingredient of the model.

Both micro and macro data inform the model's calibration. The Survey of Consumer Finances (SCF) disciplines the degree of heterogeneity among households, while the Flow of Funds provides information on debt and real estate values. For this calibration exercise, we match the model's steady state to the period of relative stability of the 1990s, because the subsequent swings in debt and house prices are most naturally interpreted as large deviations from such a steady state. The alternative strategy of calibrating to a pre-bust steady state around 2006, which is common in the literature, seems hard to justify in light of the pictures above. An advantage of our calibration approach is that it calls for a comprehensive view of the recent credit cycle, encompassing both its leveraging and deleveraging phases.

Our standard macroeconomic model, extended to incorporate borrowing and lending, is a laboratory to study the quantitative importance of the mechanisms connecting household debt and aggregate outcomes highlighted by the theoretical literature on deleveraging, and in particular by EK. Within this broad objective, this paper focuses on the implications of two main potential drivers of the leveraging cycle: a change in credit limits, for given house values, and a change in house values, for a given credit limit. This distinction appears in the model because houses collateralize borrowing, as they do in the data.

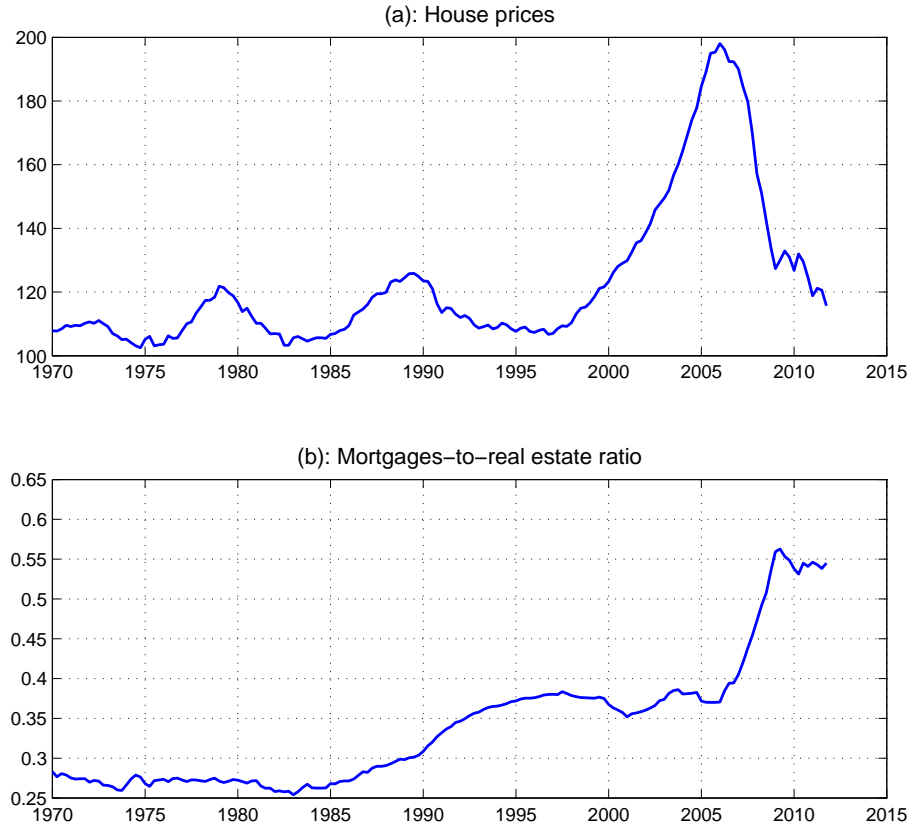


FIGURE 1.2. House prices are measured by the Real Home Price Index calculated by Robert Shiller and available here: <http://www.econ.yale.edu/~shiller/data/Fig2-1.xls>. Real estate is defined as the market value of real estate from the balance sheet of U.S. households and nonprofit organizations (Flow of Funds, Table B.100, line 3, unique identifier Z1/Z1/FL155035005.Q). Mortgages are defined as in Figure 1.1.

This distinction is also relevant because it captures the two main narratives of the credit boom and bust of the 2000s. These two stories have potentially very different implications for our understanding of the root causes of the Great Recession and for the policies that might avoid a repeat of a similar experience. According to the first narrative, the exogenous force behind the explosion of debt and its subsequent fall was a “credit liberalization” cycle—an overall loosening of credit standards that allowed more borrowing against unchanged collateral values, followed by an abrupt retrenchment during the financial crisis (e.g. Mian and Sufi, 2009; Favara and Imbs, 2011). The second story sees the boom and

bust in house prices, driven by factors largely unrelated to credit availability, as the main independent cause of the credit cycle (e.g. Shiller, 2007; Mian and Sufi, 2011; Dynan, 2012). According to this “valuation” view, the appreciation of collateral due to the steep rise in house prices facilitated more borrowing, even for given credit standards. And when house prices collapsed, the credit cycle went in reverse.

We model the “liberalization” cycle as an exogenous increase in the loan-to-value (LTV) ratio on mortgage borrowing, followed by an abrupt return to its original level. This modeling device captures the quantitative loosening and subsequent tightening of borrowing constraints at the intensive margin during the U.S. credit cycle, as in most other macro work on the topic. To capture the “valuation” story, instead, we engineer a run-up (and subsequent drop) in home prices driven by a shock to households’ taste for housing services. This modeling approach captures the idea that collateral values were the main independent cause of the changes in household debt, and allows us to illustrate its implications, although it punts on the ultimate source of the observed swing in house prices.

The experiments outlined above lead us to three main conclusions. First, the credit liberalization cycle produces a counterfactual evolution of the debt variables. In particular, debt increases far less than during the boom, while the debt-to-real estate ratio falls when credit tightens, rather than spiking as documented earlier. The main reason for these two counterfactual predictions is that house prices barely move in response to a relaxation of the collateral requirements in mortgage markets, and their subsequent tightening. Therefore, the value of the collateral does not rise during the credit expansion, failing to amplify the impulse of the initial liberalization. And on the way down, house values do not fall enough to cause the spike in the debt-to-collateral ratio observed in the data. This result is robust to a wide range of calibrations and is consistent with the findings of Iacoviello and Neri (2010) and Kiyotaki et al. (2010), who show that shocks to LTV ratios have negligible effects on house price dynamics.<sup>1</sup>

Our second conclusion is that the valuation story provides a much closer account of the data on debt. The large increase in house prices that we engineer slackens the borrowing

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<sup>1</sup>Related to this point, the quantitative literature on collateral constraints that followed Kiyotaki and Moore (1987) (e.g. Cordoba and Ripoll, 2004) showed that collateral values are a weak amplification mechanism of technology shocks. More recently, however, Liu, Wang and Zha (2011) reach opposite conclusions in the context of a DSGE framework with a richer set of shocks.

constraint, driving debt higher. When house prices fall, collateral values plunge, but outstanding debt does not fall by much, resulting in the spike in the debt-to-collateral ratio observed in the data. The key source of this pattern is the asymmetry in the borrowing constraint. This feature differentiates our model from most other models of collateralized borrowing in the literature, in which the tightening of the constraint forces an abrupt contraction of the entire outstanding stock of debt (e.g. Boz and Mendoza, 2011; GL; Favilukis et al., 2012, Garriga et al. 2012).

Finally, we find that the aggregate macroeconomic consequences of the leveraging cycle are relatively minor, regardless of its source. This is because borrowers and lenders react in opposite ways to the shocks that cause the credit cycle. When borrowers delever, cut their consumption and work harder, lenders do exactly the opposite. Qualitatively, this behavior is not surprising in this class of models. Our contribution is to document that these responses roughly cancel out quantitatively in a plausibly calibrated model.

Moreover, in our experiments, the nominal interest rate is always far from the zero lower bound, which is the crucial amplification mechanism of deleveraging shocks in EK and GL. This is another dimension in which the asymmetry of the borrowing constraint plays an important role. Without it, debt would fall more, and so would the interest rate, to induce patient households to consume the resources no longer absorbed by the borrowers. The presence of capital accumulation is another important factor preventing a more dramatic fall in interest rates, since the interest sensitivity of investment demand cushions the impact of any given shock to desired saving on the interest rate, as discussed by Christiano (2004). The role of these realistic modeling ingredients in our results highlights the importance of an empirically driven quantitative approach to modeling the leverage cycle and its consequences, and makes us doubt the common view that household deleveraging was in and of itself a major driver of the Great Recession and the fundamental headwind slowing the recovery.

An important qualification to this conclusion is that our experiments focus exclusively on the household sector's leveraging and deleveraging cycle. In the model, lending comes directly from households, with no role for frictions in financial intermediation that might amplify the impact of the household credit cycle, spread it to other sectors of the economy, and give rise to an independent macroeconomic shock, as in Curdia and Woodford (2009) or Gertler and Kiyotaki (2010). Moreover, the borrowers in our model hold no productive

capital, and all investment is undertaken by the unconstrained savers. This assumption seems natural, since our borrowers want to consume, rather than save, and it is the most direct extension of the standard “pre-crisis” DSGE framework (e.g. Christiano, Eichenbaum, and Evans, 2005). Of course, in reality capital is accumulated by firms, and some of them are constrained in their ability to borrow and were forced to delever during the crisis (Liu, Wang, and Zha, 2011). We choose to ignore these alternative channels through which the credit cycle most likely affects macroeconomic dynamics to isolate the role of household debt, because this is the channel that is both less studied in macroeconomics, and most often cited as central to the unfolding of the Great Recession.<sup>2</sup>

From a modeling standpoint, our paper follows the large literature on collateral constraints spawned by Kiyotaki and Moore (1987). More specifically, we follow Iacoviello (2005) in assuming a dichotomy between borrowers and lenders based on their impatience, as well as in the modeling of housing and mortgage debt. The particular form of the borrowing constraint we adopt is inspired by Campbell and Hercowitz (2009), although we take more explicitly into account the asymmetry of mortgage contracts. Kiyotaki et al. (2010), Mendoza (2010), Boz and Mendoza (2011), and Garriga et al. (2012) explore the consequences of credit market liberalization in models with credit constrained households, but do so in a small open economy setting with exogenous interest rates. Therefore, these papers cannot address the role of the zero lower bound in propagating deleveraging shocks. Favilukis et al. (2012) also consider a credit liberalization experiment in a rich general equilibrium framework with incomplete markets and idiosyncratic risk, but their focus is on risk premia in the housing market. They find that risk premia provide a powerful propagation mechanism for changes in the availability of credit, a nexus from which our model abstracts. Our focus on the role of household debt in the macroeconomy is closest to EK and GL. Relative to these papers, our model features endogenous collateral values that affect households’ ability to borrow, a key feature of the data. In addition, we work with a DSGE specification closer to those normally used for estimation (e.g. Christiano, Eichenbaum and Evans, 2005 and Smets and Wouters, 2007), which also differentiates our

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<sup>2</sup>Another potentially relevant ingredient missing in the model are “subprime” borrowers. Mian and Sufi (2009) show that the newly acquired ability of these households to access credit markets in the 2000s was an important driver of the credit boom, and the main source of defaults during the bust. Some preliminary experiments we conducted in our model suggest that the inclusion of this extensive margin of the liberalization cycle does not have a major impact on its quantitative implications. Further research along these lines would be needed, however, to establish the robustness of this conclusion.

approach from Midrigan and Philippon (2011). Like us, they study both the leveraging and deleveraging phase of the credit cycle. However, they focus on the effects of liquidity shocks, while we emphasize the importance of shocks to collateral values.

The rest of the paper proceeds as follows. In sections 2 and 3 we present the model and its calibration. In section 4 we discuss the results of the two main experiments described above, whose robustness is analyzed in section 5. Section 6 concludes.

## 2. MODEL

This section presents the quantitative model used to analyze the macroeconomic causes and consequences of the boom and bust cycle of U.S. households' debt in the 2000s. The model builds on Iacoviello (2005) and Campbell and Hercowitz (2009). The key assumption is that households exhibit heterogeneous desires to save, which generate borrowing and lending among them. Moreover, they own houses, which serve as collateral. This last feature is motivated by the fact that mortgages represent by far the most important component of U.S. households' liabilities.

The economy is populated by four classes of agents: households, house producers, goods producers, and a government. Their optimization problems and the market clearing conditions are as follows.

**2.1. Households.** The economy is populated by a continuum of two types of households, which differ only by the rate at which they discount the future. Patient households are denoted by  $l$ , since in equilibrium they are the ones saving and lending. They represent a share  $1 - \psi$  of the population. Their discount factor is  $\beta_l > \beta_b$ , where  $\beta_b$  is the discount factor of the impatient borrowers. At time 0, representative household  $j = b, l$  maximizes the utility function

$$E_0 \sum_{t=0}^{\infty} \beta_j^t \left[ \log C_{j,t} + \phi \log H_{j,t} - \varphi \frac{L_{j,t}^{1+\eta}}{1+\eta} \right],$$

where  $C_{j,t}$  denotes consumption of non-durable goods,  $L_{j,t}$  is hours worked, and  $H_{j,t}$  is the stock of houses. This specification of the utility function assumes that the service flow of houses is proportional to (or a power function of) the stock. All variables are in per-capita terms.

The utility maximization problem is subject to the nominal flow budget constraint

$$P_t C_{j,t} + P_t^h \Xi_{j,t} + P_t I_{j,t} + R_{t-1} D_{j,t-1} \leq W_{j,t} L_{j,t} + R_t^k K_{j,t} + \Pi_{j,t} - P_t T_{j,t} + D_{j,t}.$$



In this expression,  $P_t$  and  $P_t^h$  are the prices of the consumption good and of houses, while  $R_t^k$  and  $W_{j,t}$  are the nominal rental rates of capital and labor. The wage is indexed by  $j$  because the labor input of the borrowers is not a perfect substitute for that of the savers.  $D_{j,t}$  is the amount of one period *nominal* debt accumulated by the end of period  $t$ , and carried into period  $t + 1$ , with gross *nominal* interest rate  $R_t$ .  $\Pi_{j,t}$  is the share of profits of the intermediate firms accruing to each household of type  $j$  and  $T_{j,t}$  are lump-sum taxes and transfers from the government.

The stocks of houses and capital evolve according to the accumulation equations

$$\begin{aligned} H_{j,t+1} &= (1 - \delta_h) H_{j,t} + \Xi_{j,t} \\ K_{j,t+1} &= (1 - \delta_k) K_{j,t} + \left(1 - S_k \left(\frac{I_{j,t}}{I_{j,t-1}}\right)\right) I_{j,t}, \end{aligned}$$

where  $\Xi_{j,t}$  is residential investment (i.e. new houses),  $I_{j,t}$  is investment in production capital, and  $\delta_h$  and  $\delta_k$  are the rates of depreciation of the two stocks. The function  $S_k$  captures the presence of adjustment costs in investment, as in Christiano, Eichenbaum, and Evans (2005), and is parametrized as follows

$$(2.1) \quad S_k(x) = \zeta_k \frac{1}{2} (x - e^\gamma)^2,$$

so that, in steady state,  $S_k = S'_k = 0$  and  $S''_k = \zeta_k > 0$ , where  $e^\gamma$  is the economy's growth rate along the balanced growth path, further described below.

**2.1.1. The borrowing limit.** Households' ability to borrow is limited by a collateral constraint, similar to Kiyotaki and Moore (1997). We model this constraint to mimic the asymmetry of mortgage contracts. When home prices increase, households can refinance their loans and therefore borrow more against the higher value of the entire housing stock. When prices fall, however, the lower collateral value leads to less lending against new houses, but lenders cannot require faster repayment of the debt already outstanding. A similar asymmetry applies when minimum loan-to-value ratios at origination increase or decrease.

More formally, we write the collateral constraint as

$$D_{j,t} \leq \bar{D}_{j,t} = \begin{cases} \theta_t P_t^h H_{j,t+1} & \text{if } \theta_t P_t^h \geq \theta_{t-1} P_{t-1}^h \\ (1 - \delta_h) \bar{D}_{j,t-1} + \theta_t P_t^h \Xi_{j,t} & \text{if } \theta_t P_t^h < \theta_{t-1} P_{t-1}^h. \end{cases}$$

If credit conditions ease and/or collateral values increase (i.e.  $\theta_t P_t^h$  rises), households can borrow up to a fraction  $\theta_t$  of the current value of their entire housing stock. This is the standard formulation of the collateral constraint, which implicitly assumes that all outstanding mortgages will be refinanced to take advantage of the new, more favorable conditions.

On the contrary, if  $\theta_t P_t^h$  falls, households need not repay the outstanding balance on their mortgage, over and above the repayment associated with the depreciation of the housing stock ( $\delta_h$ ).<sup>3</sup> Therefore, the new less favorable credit conditions only apply to the flow of new mortgages, collateralized by the most recent house purchases. Besides being realistic, the asymmetry built in this formulation of the collateral constraint is an important ingredient in the results, because it allows the model to reproduce a sudden increase in the debt-to-collateral ratio when house prices plunge, like in 2006/07.

Given their low desire to save, impatient households borrow from the patient in equilibrium. In fact, near the steady state, they borrow as much as the collateral constraint allows them to, and hence they choose to hold no capital. Absent the constraint, they would borrow even more, so it is clearly not optimal for them to hold any asset. For simplicity, we impose that the borrowers do not accumulate capital also when the collateral constraint does not bind away from the steady state, even if it might be optimal for them to do so. This assumption is the most straightforward generalization of the standard framework, in which investment is undertaken by the unconstrained representative household. As a result, however, investment demand is not constrained by the borrowing limit. In fact, investment rises during the crisis, as the interest rate falls to equilibrate the goods market. This counterfactual behavior of investment could be addressed by adding further

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<sup>3</sup>This formulation assumes that the amortization rate of the mortgage coincides with the depreciation rate of the housing stock. In section 5, we will allow for a higher amortization rate, so that households build equity in their house over time, as in Campbell and Hercowitz (2009).

frictions in the market for capital goods, but this addition would detract from our focus on household debt and the attending frictions.<sup>4</sup>

**2.2. Goods producers.** There is a continuum of intermediate firms indexed by  $i \in [0, 1]$ , each producing a good  $Y_t(i)$ , and a competitive final good sector producing output  $Y_t$  according to

$$Y_t = \left[ \int_0^1 Y_t(i)^{\frac{1}{1+\lambda}} di \right]^{1+\lambda}.$$

Intermediate firms, which are owned by the lenders, operate the constant-return-to scale production function

$$Y_t(i) = A_t^{1-\alpha} K_t^\alpha(i) \left[ (\psi L_{b,t}(i))^\nu ((1-\psi) L_{l,t}(i))^{1-\nu} \right]^{1-\alpha} - A_t F.$$

They rent labor (of the two types) and capital on competitive markets paying  $W_{b,t}$ ,  $W_{l,t}$  and  $R_t^k$ .  $F$  represents a fixed cost of production, and is chosen to ensure that steady state profits are zero. The labor augmenting technology factor  $A_t$  grows at rate  $\gamma$ . The intermediate firms operate in monopolistically competitive markets and set their price  $P_t(i)$  subject to a nominal friction as in Calvo (1983). A random set of firms of measure  $1 - \xi_p$  optimally reset their price every period, subject to the demand for their product, while the remaining  $\xi_p$  fraction of prices do not change.

An important reason for introducing nominal rigidities in this context is to have a meaningful zero lower bound (ZLB) for nominal interest rates. The ZLB has been an important constraint for monetary policy in the last few years and it has been shown to be a potentially crucial amplification mechanism for the macroeconomic effects of deleveraging (e.g. EK and GL).

**2.3. House producers.** The production of new houses is undertaken by perfectly competitive firms. They purchase an amount  $I_t^h$  of final goods and use the technology

$$\Xi_t = \left( 1 - S_h \left( \frac{I_t^h}{I_{t-1}^h} \right) \right) I_t^h$$

to transform them into houses, which are then sold to households. We adopt this decentralization of the production of houses, rather than building the adjustment cost in the

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<sup>4</sup>For instance, EK's appendix includes an extension of their baseline endowment economy, in which capital accumulation is undertaken by the borrowers, the agents who are forced to repay their debt. Under this specification, investment falls along with non-durable consumption, although the deleveraging agents in this environment are probably best thought of as constrained firms, rather than households.

accumulation equation, so as to have an explicit house price variable in the model.<sup>5</sup> The function  $S_h$  is parametrized as in equation (2.1), with elasticity parameter  $S_h'' = \zeta_h > 0$ . This formulation of the production of houses is appealing for its simplicity, while still allowing to parametrize the rigidity of housing supply.<sup>6</sup> If  $\zeta_h = 0$ , the supply of houses is perfectly elastic, and their relative price is equal to one. As  $\zeta_h$  increases, the supply of houses becomes more and more rigid. The case of fixed supply along the balanced growth path corresponds to infinite adjustment costs.

House producers maximize the expected discounted value of future profits

$$E_0 \sum_{t=0}^{\infty} \beta_l^t \Lambda_{l,t} \left[ P_t^h \Xi_t - P_t I_t^h \right],$$

where  $\Lambda_{l,t}$  is the marginal utility of income of the lenders, who are assumed to own these firms. Since lenders are unconstrained in equilibrium, and thus always satisfy their Euler equation, their discount factor is the one that pins down the steady state real interest rate. Therefore, this ownership assumption would return the standard representative agent setup in the limit with no impatient households.

**2.4. Government and monetary policy.** The government collects taxes, pays transfers, consumes a fraction of final output, and sets the nominal interest rate.

We assume that government spending is a constant fraction  $g$  of final output, and that the government balances its budget, i.e.

$$G_t = gY_t = \psi T_{b,t} + (1 - \psi) T_{l,t},$$

so that patient households can only lend to impatient households, and the net supply of borrowing is 0. In addition, we assume that total taxes levied on borrowers represent a constant share  $\chi$  of government spending

$$\psi T_{b,t} = \chi G_t.$$

<sup>5</sup>See Justiniano, Primiceri and Tambalotti, 2011 for a similar argument with regards to the price of investment goods.

<sup>6</sup>Davis and Heathcote (2005) calibrate a multi-sector neoclassical model in which the production of houses requires land and structures. They conclude that the presence of land (a quasi-fixed factor in their model) effectively plays the role of an adjustment cost.

If  $\chi = 0$ , the entire tax burden is on the savers, while if  $\chi = \psi$  borrowers and savers pay the same amount per-capita. Therefore, we can interpret the parameter  $\chi$  as capturing the extent of government redistribution.

Monetary policy sets the short-term nominal interest rate based on the feedback rule

$$\frac{R_t}{R} = \max \left\{ \frac{1}{R}; \left( \frac{R_{t-1}}{R} \right)^{\rho_R} \left[ \left( \frac{(\pi_t \cdot \pi_{t-1} \cdot \pi_{t-2} \cdot \pi_{t-3})^{1/4}}{\pi} \right)^{\tau_\pi} \left( \frac{Y_t}{e^{y_t^*}} \right)^{\tau_y} \right]^{1-\rho_R} \right\},$$

where  $\pi_t$  is the gross rate of inflation,  $\pi$  is the Central Bank's inflation target, and  $y_t^*$  is a measure of trend output, which is computed as the DSGE approximation of the exponential filter of log-output, as in Curdia, Ferrero, Ng, and Tambalotti (2011). The parameters  $\rho_R$ ,  $\tau_\pi$  and  $\tau_y$  capture the degree of inertia, and the strength of the interest rate reaction to the deviations of annual inflation from the target and of output from trend.

**2.5. Resource Constraint.** The economy's resource constraint is

$$Y_t = \psi C_{b,t} + (1 - \psi) C_{l,t} + I_t^h + \psi I_{l,t} + G_t,$$

where  $I_{l,t}$  is the amount of per-capita investment undertaken by the lenders, who are the only households accumulating capital. This constraint is obtained by aggregating the budget constraints of borrowers and lenders with that of the Government, using the zero profit conditions of the competitive firms, the definition of profits for the intermediate firms, and the debt market clearing condition

$$0 = \psi D_{b,t} + (1 - \psi) D_{l,t}.$$

### 3. CALIBRATION

We parametrize the model so that its steady state matches some key statistics for the period of relative stability of the 1990s. As mentioned in the introduction, choosing a later period would be problematic, because the large swings in debt and house prices observed in the 2000s are likely to represent large deviations from such a steady state. The calibration is summarized in table 1 and is based on U.S. aggregate and micro data.

Time is in quarters. We set the Central Bank's inflation target ( $\pi$ ) equal to the average gross rate of inflation (1.005, or 2% per year), and the growth rate of productivity in steady state ( $\gamma$ ) to match average GDP growth (0.5%) during the 1990s. In steady state,

Households	$\beta_l$ 0.998	$\beta_s$ 0.99	$\varphi$ 1	$\eta$ 1	$\psi$ 0.61	$\phi_b$ 0.1	$\phi_s$ 0.1	$\theta$ 0.85	
Production	$\gamma$ 0.005	$\nu$ 0.5	$\alpha$ 0.3	$\lambda$ 0.2	$\xi$ 0.75	$\delta_h$ 0.003	$\delta_k$ 0.025	$\zeta_k$ 2	$\zeta_h$ $\infty$ or 600
Policy	$\pi$ 1.005	$\rho_R$ 0.8	$\tau_\pi$ 2	$\tau_y$ 0.125	$\chi$ 0.55	$g$ 0.175			

TABLE 1. Parameter values.

$R = \frac{e^{\gamma\pi}}{\beta_l}$ . Therefore, we choose a value of 0.998 for the lenders' discount factor ( $\beta_l$ ), to obtain an annualized steady state nominal interest rate of 4.9%, close to the average Federal Funds Rate. For the borrowers' discount factor ( $\beta_b$ ) we pick a value of 0.99, so that the relative impatience of the two groups is similar to that in Campbell and Hercowitz (2009) and Krusell and Smith (1998). Since the size of the house price response to a credit liberalization is somewhat sensitive to the value of  $\beta_b$ , we conduct some robustness checks on this parameter in section 5. The labor disutility parameter ( $\varphi$ ) only affects the scale of the economy, so we normalize it to 1. We also pick a Frisch elasticity of labor supply ( $1/\eta$ ) equal to 1. This value is a compromise between linear utility, which is typical in the Real Business Cycle literature (Hansen, 1985), and the low elasticities of labor supply usually estimated by labor economists and more common in the empirical DSGE literature.

We parametrize the degree of heterogeneity between borrowers and lenders using the Survey of Consumer Finances (SCF), which is a triennial cross-sectional survey of the assets and liabilities of U.S. households. We identify the borrowers as the households that appear to be liquidity constrained, namely those with liquid assets whose value is less than two months of their total income. We compute the value of liquid assets following Kaplan and Violante (2012) as the sum of money market, checking, savings and call accounts, directly held mutual funds, stocks, bonds, and T-Bills, net of credit card debt. We apply this procedure to the 1992, 1995 and 1998 SCF, and obtain an average share of borrowers equal to 61%, which directly pins down the parameter  $\psi$ . Given this split between borrowers and savers, we set the production parameter  $\nu$  equal to 0.5 to match their relative labor income (0.64) in the SCF. In addition, we choose the parameter controlling the progressivity of the tax/transfer system to match the ratio of hours worked by borrowers and lenders (1.08). This requires setting  $\chi = 0.55$ , which implies a moderate level of overall redistribution. The

resulting ratio between the total income of the borrowers and savers is 0.52, which is close to that in the SCF (0.46).

The housing preference parameters  $\phi$ , the depreciation of houses  $\delta_h$  and the initial loan-to-value ratio ( $\theta$ ) are chosen jointly to match three targets. The first target is the real estate-to-GDP ratio, which we estimate from Flow of Funds (FF) and NIPA data as the average ratio between the market value of real estate of households and nonprofit organizations and GDP (1.2). The second target is the debt-to-real estate ratio, for which we use FF data on the average ratio between home mortgages and the market value of real estate of households and nonprofit organizations (0.36). The third target is the ratio of residential investment to GDP (4%). Hitting these targets requires  $\delta_h = 0.003$ , which is consistent with the low end of the interval for the depreciation of houses in the Fixed Asset Tables, and  $\theta = 0.85$ , which is in line with the cumulative loan-to-value ratio of first time home buyers estimated by Duca et al. (2011) for the 1990s.

On the production side, we follow standard practice and set the elasticity of the production function  $\alpha = 0.3$ , and the depreciation of productive capital ( $\delta_k$ ) to 0.025. The average net markup of intermediate firms ( $\lambda$ ) is 20%, which is in the middle of the range of values used in the literature. We choose a value of 0.75 for the Calvo parameter ( $\xi$ ), which is consistent with the evidence in Nakamura and Steinsson (2008). For the second derivative of the investment adjustment cost function ( $\zeta_k$ ) we pick a value of 2, in line with the estimates of Eberly, Rebelo and Vincent (2012). As for the adjustment cost parameter in home production ( $\zeta_h$ ), we initially set it to infinity, thus imposing a fixed supply of housing along the balanced growth path. The purpose of this extreme parametrization is to generate an upper bound on the variation in house prices produced in the credit “liberalization” experiment. In the simulation of the “valuation” story, instead, we choose a lower value of  $\zeta_h$ , to match the increase in the residential investment-to-GDP ratio observed in the data over the period 2000-2006.

We interpret  $G$  as the difference between GDP and the sum of consumption and investment, and set the  $G$ -to- $Y$  steady state ratio equal to 0.175, as in the data. Finally, we need to parametrize the monetary policy reaction function. In line with available empirical estimates of the Taylor rule in the post-1984 period, we choose a considerable amount of interest rate inertia ( $\rho_R = 0.8$ ), a moderate reaction to the output gap ( $\tau_y = 0.125$ ), and a relatively strong reaction to inflation ( $\tau_\pi = 2$ ).

The main results illustrated in the next section are robust to changes in most of these parameter values. However, in section 5, we present alternative, more extreme parameterizations of the model, and conduct an extensive sensitivity analysis.

#### 4. RESULTS

The calibrated model presented above is our laboratory to study the macroeconomic consequences of changes in households' ability to borrow. We focus on two experiments, trying to shed light on the relative role of two potential sources of the leveraging cycle. First, we exogenously perturb the tightness of the collateral constraint by changing the required LTV ratio  $\theta$ . The purpose of this exercise is to simulate the effects of a credit "liberalization" and its reversal. Second, we shock the consumers' taste for housing services to generate a swing in house prices similar to that observed in the data. This price swing affects households' ability to borrow by changing collateral values. Although this experiment uses a shortcut to generate the observed movements in house prices, it is useful to size the potential of the valuation channel to generate realistic movements in household debt.

To preview the results, we find that the "valuation" experiment generates the right quantitative dynamics of debt over the credit cycle, while exogenous changes in the required LTV do not. However, under both scenarios, the impact of household leveraging and deleveraging on the macroeconomy is small, because borrowers and lenders respond in opposite ways to the change in leverage. These responses roughly cancel out quantitatively. Moreover, in the deleveraging phase, the ZLB is never binding. These results are robust to a wide range of calibrations. Therefore, we conclude that the workhorse general equilibrium framework with household borrowing and lending is quantitatively inconsistent with the conventional wisdom that sees household deleveraging as the crucial force behind the Great Recession and the slow recovery from it.

**4.1. Mortgage market liberalization and its reversal.** Our first set of results is based on a baseline experiment in which the collateral requirements are first loosened over several periods, and then abruptly tightened. We generate these changes in the tightness of the collateral constraint by varying  $\theta$ —the initial LTV ratio of borrowers. Since  $\theta$  is a parameter in the model, we refer to this variation as an "exogenous" shock to households' ability to borrow. As illustrated in figure 4.1a, we assume that the initial LTV on mortgages goes from 0.85 in the initial steady state at the end of 1999, to 0.95 at its peak in 2006, and then



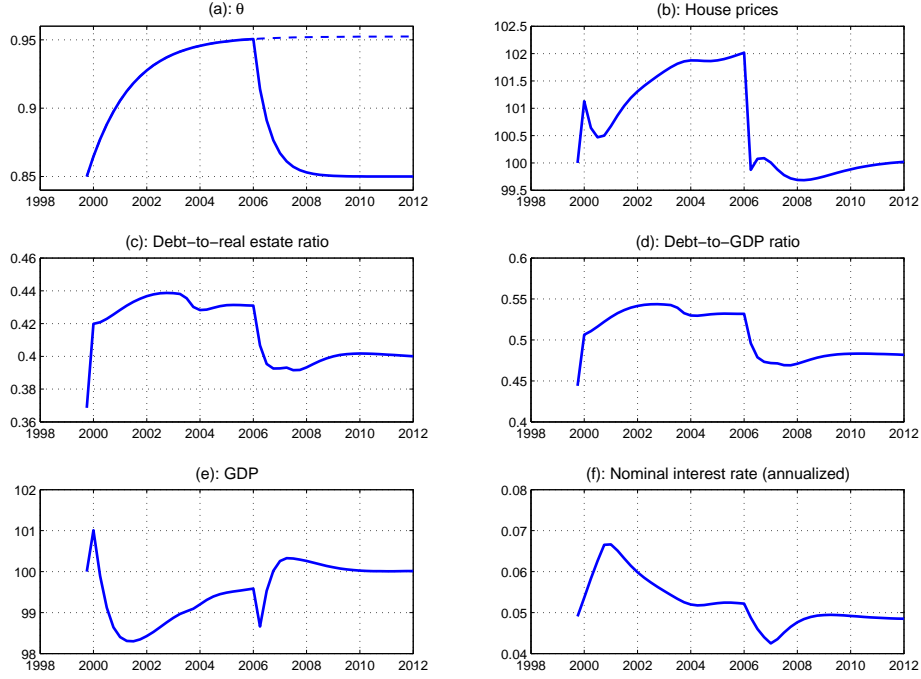


FIGURE 4.1. Credit liberalization experiment: debt and macro variables.

back to 0.85 by 2008. The evolution of  $\theta$  between 2000 and 2006 is perfectly foreseen by agents after the initial surprise in 2000, but following this first shock they assume that the required LTV will settle at 0.95 after 2006, as shown by the dashed line. Therefore, agents are surprised again in 2006, when  $\theta$  collapses back to 0.85 over the course of a little more than one year. After the second shock in 2006, the rest of the path for  $\theta$  is again perfectly anticipated and the model settles back down to its initial steady state.

We compute the response of the model's endogenous variables to these changes in  $\theta$  by solving the system of non-linear difference equations given by the first order conditions of the agents' optimization problems and the market clearing conditions. The algorithm used to solve this nonlinear forward-looking model adapts Julliard, Laxton, McAdam and Pioro (1998) to account for the asymmetry of the borrowing constraint, and for the fact that this constraint binds always in steady state, but only occasionally during the transitions.

The movements in  $\theta$  fed into the model are calibrated to roughly match the evidence on cumulative LTVs for first time home buyers presented in Duca et al. (2011), which is reproduced in figure 4.2. Their calculations suggest that cumulative LTVs were fairly stable

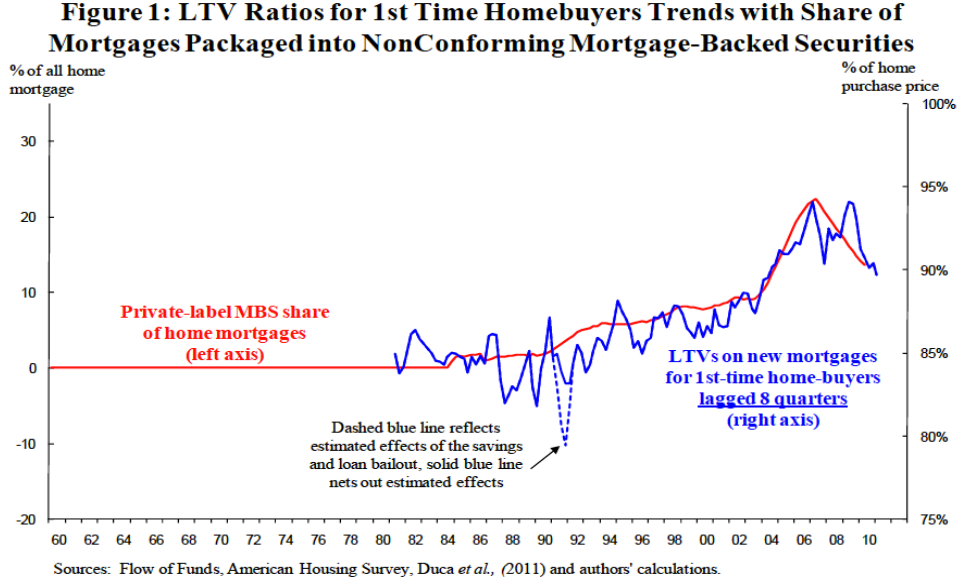


FIGURE 4.2. Cumulative LTVs.

around 85% during the 1980s and early 1990s, and started rising gradually in the second half of the 1990s. LTVs then took off right around the turn of the century, reaching a peak of almost 95% at the height of the housing boom, after which they fell back down to 90%. Computing cumulative LTVs for new borrowing is a complicated exercise, given the available data on mortgages. Therefore, we do not regard these calculations as definitive evidence on cumulative LTVs during this period. However, the work of Duca *et al.* (2010 and 2011) provides the most comprehensive evidence to this effect. The movements in  $\theta$  that it documents seem plausible, if perhaps a bit conservative. As a robustness check, therefore, we consider an experiment with larger swings in  $\theta$  in section 5.

The macroeconomic implications of the changes in  $\theta$  described above are depicted in figure 4.1. House prices (panel b) barely move. In the baseline calibration, they rise by about 2% in the “boom”, and then fall sharply back to their initial level once credit tightens. The limited impact of changes in  $\theta$  on house prices is consistent with the findings of Kiyotaki *et al.* (2010), Iacoviello and Neri (2010), and Midrigan and Philippon (2011). An intuitive reason for the muted response of house prices to a credit liberalization in our model is the behavior of lenders. When the collateral constraint loosens, houses become more valuable to the borrowers, who wish to buy more of them. However, this increase in demand for houses is met by the lenders, who do not use their homes as collateral

and thus value them less than the borrowers. Of course, in equilibrium, the valuation by the two groups must be the same, since houses are homogenous, and this equalization of marginal values is achieved precisely by some reallocation of houses from the lenders to the borrowers. This reallocation increases the marginal utility of the housing stock in the hand of the lenders, and decreases it for the borrowers, thus compensating for the higher collateral value enjoyed by the latter. This margin of adjustment is independent from the overall flexibility of housing production, and remains operative even if the overall supply of housing is fixed, as in our baseline calibration.

What is the quantitative bite of this source of flexibility in the housing supply faced by the borrowers? This is an important check on the baseline results, since it is not clear that the reallocation of the housing stock from the lenders to the borrowers featured in the model actually took place in the data. To answer this question, we consider a small open economy version of the model, in which borrowers are the only domestic agents. Therefore, they face a rigid supply of houses, as in a wide swath of the literature on borrowing constraints (i.e. Mendoza, 2010, Kiyotaki et al. 2010, Garriga et al. 2012). As we show in section 5.2, the rise in house prices following the credit liberalization is 50 percent larger in the SOE specification than in the baseline. This larger increase, however, is still one order of magnitude smaller than in the data, suggesting that our results are not particularly sensitive to the elasticity of housing supply coming from the lenders.

We now turn to the behavior of household debt in the liberalization experiment. In the data, the ratio of mortgages to real estate is roughly stable in the first half of the 2000s, but it spikes when house prices collapse. This spike reflects the asymmetric nature of mortgage contracts: lenders cannot unilaterally reduce the value of outstanding debt, even when the value of the collateral falls. This is how households end up “under water” on their mortgages, owing more money than their house is worth. In the model, the evolution of debt-to-real estate values is at odds with this evidence (panel c). The debt-to-collateral ratio rises by about five percentage points during the expansionary phase and falls by somewhat less when collateral requirements tighten in 2006. This behavior is a mechanical implication of the hump-shaped path of  $\theta$ , which makes people borrow more initially, and then less, against the value of their house. The fact that the increase in leverage at the time of the financial liberalization is higher than the subsequent fall at the time of the tightening reflects the asymmetry built into the borrowing constraint. However, this asymmetry is insufficient to

generate the spike in the debt-to-collateral ratio seen in the data, because the fall in house prices is too small in the model.

The debt-to-GDP ratio (panel d) rises until 2006 and then falls, roughly following the evolution of the debt-to-collateral ratio. Qualitatively, this behavior is broadly consistent with the data, but it is off quantitatively. In the data, the mortgages-to-GDP ratio rises by 30 percentage points over the boom period—from about 45% in 2000, to 75% at the peak—but only 10 percentage points in the model. In summary, the model does imply an increase in debt in the early 2000s, as one would expect. However, the change in  $\theta$  alone does not generate a large enough boom in credit. The crucial missing link is the unprecedented rise in house prices experienced by the U.S. economy, which the model cannot replicate.

Moving on now to more standard macroeconomic indicators, we see in figure 4.1e that GDP increases for only one period after the liberalization, but then falls, while the opposite happens when the constraint tightens. In panel f, the short-term nominal interest rate rises at first, to encourage savers to lend more, and then falls when the  $\theta$  returns to its original level. However, the nominal interest rate never reaches the ZLB in the baseline calibration, making the recession that follows the retrenchment in  $\theta$  short and shallow.

*4.1.1. Asymmetric collateral constraints, investment, and the ZLB.* The ZLB is an important channel for the amplification of deleveraging shocks, as emphasized by EK and GL, but it does not bind in our model, in large part because of the asymmetry of the borrowing constraint. If we ignore this asymmetry, as in most of the literature, and tighten the borrowing constraint also on the outstanding stock of debt, the nominal interest rate falls much more than in the baseline: as low as 0.7%, as shown in figure 4.3. This figure also illustrates that the outstanding level of debt declines sharply in this case, generating a counterfactual collapse in both the debt-to-GDP and the debt-to-collateral ratios. The recession is much more severe in this case, with GDP contracting by roughly 6%.

Another factor that prevents a more pronounced fall of the interest rates is the presence of capital accumulation. When capital is endogenous, the shift in desired saving triggered by changes in agents' ability to borrow happens along an elastic demand for investment, rather than against a fixed supply of assets as in models with no capital (Christiano, 2004). To evaluate the importance of this channel of transmission of deleveraging shocks, figure 4.4 plots the results of a simulation with a much higher investment adjustment cost parameter (ten times higher, i.e.  $\zeta_k = 20$ ), which results in a more sluggish investment response. In this

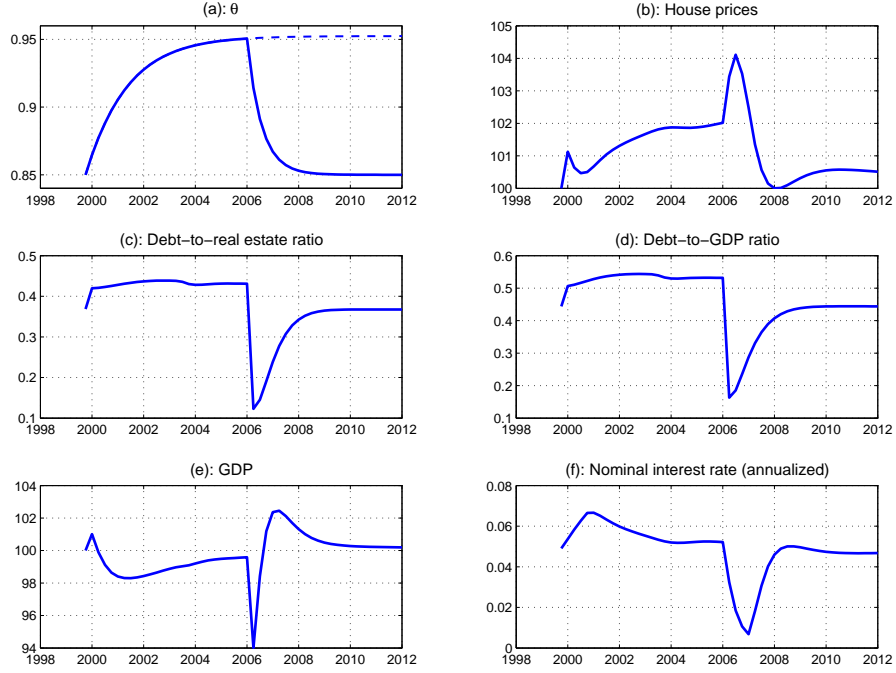


FIGURE 4.3. Credit liberalization experiment without the asymmetry of the collateral constraint : debt and macro variables.

case, interest rates would reach a level of about 3.75% during the credit contraction, falling only slightly more than in the baseline experiment. Very little would change if we eliminated investment dynamics completely, using nearly infinite adjustment costs ( $\zeta_k = 20000$ ), as also shown in Figure 4.4.<sup>7</sup>

4.1.2. *The interaction of borrowers and lenders.* In this section, we explore further how the interaction between borrowers and savers shapes the behavior of the macroeconomy following an exogenous change in households' ability to borrow. To this end, figure 4.5 reports the evolution of consumption, the housing stock and hours worked for borrowers and lenders separately. Borrowers increase their consumption of non-durables, houses and leisure following the increase in  $\theta$ , and curtail them when  $\theta$  falls. Intuitively, a looser borrowing constraint allows them to get closer to satisfying the desire for early consumption dictated by their relative impatience. In fact, the borrowing constraint does not bind for

<sup>7</sup>Another factor that might contribute to pushing the risk-free rate closer to the ZLB is the value that investors attribute to liquidity and safety (Krishnamurthy and Vissing-Jorgensen, 2012). This consideration is not captured in our framework, since we abstract from risk altogether.

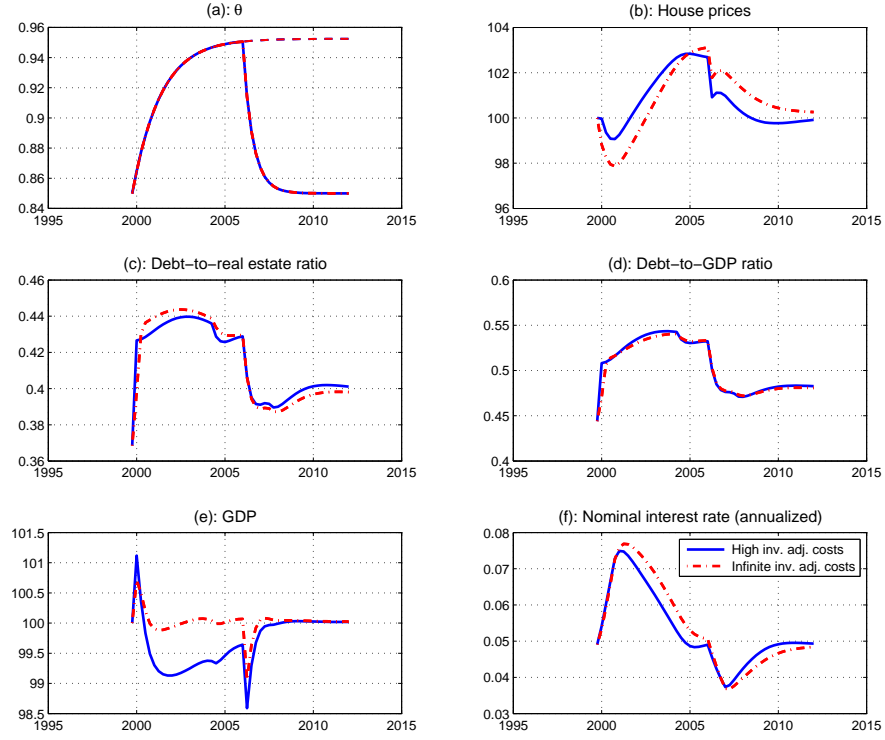


FIGURE 4.4. Credit liberalization experiment with high and infinite investment adjustment costs: debt and macro variables.

several periods after the initial shock, although the fact that the constraint will bind again in the future continues to affect their current behavior, as emphasized for instance by Guerrieri and Iacoviello (2012). On the other side of the ledger, lenders need to mobilize the extra resources consumed by the borrowers. They do so in response to a higher interest rate, which induces them to consume less, sell part of their housing stock, reduce their accumulation of capital, and work harder. Quantitatively, the effects are large for each class of agents, but roughly offset each other in the aggregate. As a result, the effects of the credit liberalization cycle on the macroeconomy are fairly muted.

Together with the counterfactual evolution of house prices and of the debt-to-GDP ratio, which move way too little, and of the debt-to-real estate ratio, which goes in the wrong direction, these results are the basis for the conclusion that exogenous shifts in collateral requirements for existing borrowers are probably not the main driver of the macroeconomic

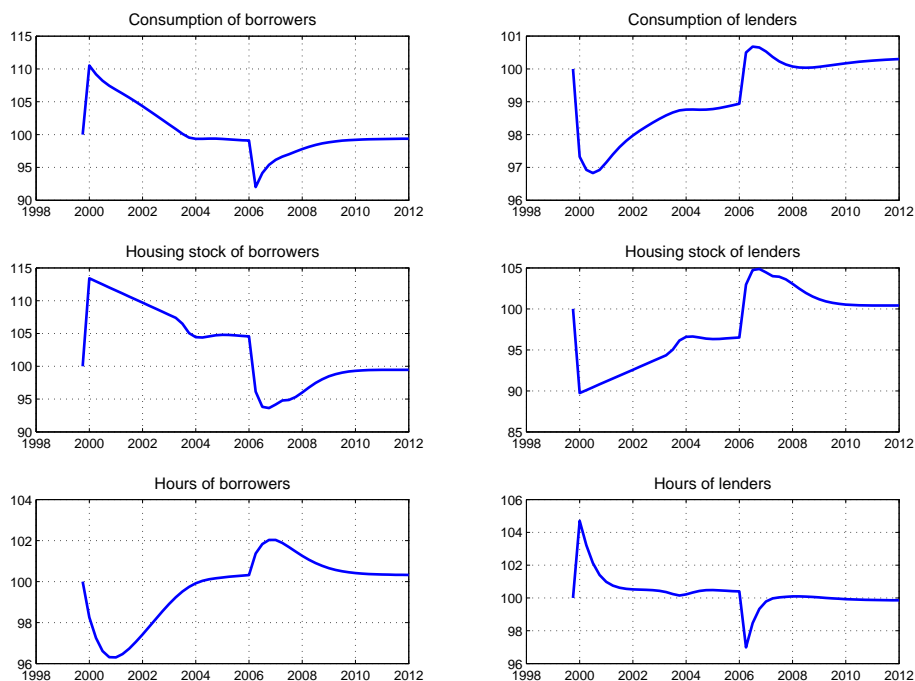


FIGURE 4.5. Credit liberalization experiment: borrowers and lenders.

outcomes observed during the credit boom and bust of the 2000s. This conclusion is also consistent with the observation that house prices started falling in the second quarter of 2006, well before the turmoil in financial markets that presumably drove the credit tightening. This simple observation represents an additional challenge to the hypothesis that an exogenous reversal of an ongoing wave of credit liberalization was the main trigger of households' deleveraging, motivating the exploration of the "valuation" view of the credit cycle undertaken in the next section.

**4.2. A shock to home prices.** The results presented above cast some doubts on a strong connection between the process of credit liberalization as captured by exogenous changes in LTVs and the large movements in house prices observed during the 2000s. And without these movements, it is hard to reproduce the observed evolution of debt and leverage. As an alternative, this subsection explores a scenario in which the fluctuations in house prices are driven by independent factors, unrelated to changes in credit conditions. This scenario captures the hypothesis that the evolution of collateral values was the primary

engine behind the credit boom and bust, without taking a strong stance on the underlying drivers of those values. Its objective is to investigate the transmission of “valuation” shocks and their potential to generate a credit cycle with the right empirical features.

To implement this idea, we engineer a large cycle in house prices, which mimics the one observed in the data, through changes in households’ preference for housing services. Although we do not regard taste shocks as the primitive driver of price dynamics in the data, they are an essential device to generate empirically plausible movements in collateral values in most DSGE models with housing.<sup>8</sup>

Figure 4.6 presents the results of this experiment. By construction, prices rise by more than 50% between 2000 and 2006, and drop abruptly after that, as shown in the first panel of the figure. The consequences of this large swing in house prices are depicted in the remaining panels. Overall, these simulations are much more consistent with the data than those obtained by perturbing the initial LTV,  $\theta$ . First, the debt-to-GDP ratio rises steadily, from 0.45 in 2000 to 0.7 at the peak, and subsequently falls by 5 to 10 percentage points, just as in the data. Similarly, the debt-to-real estate ratio is fairly stable during the boom, spikes when house prices plunge and subsequently declines somewhat. An important contributor to this behavior of the debt-to-collateral ratio, which *rose* significantly during the great deleveraging, is the asymmetry of the collateral constraint, which accounts for the empirical fact that mortgage principals are fixed in nominal terms, but the value of the underlying collateral can change abruptly.

Compared to the effects on the debt variables, those on GDP are much smaller in this experiment, and overall quite similar to those under the credit liberalization scenario. As in that case, the reason for the muted aggregate impact of the credit boom and bust is that the two sets of households behave in opposite ways. During the boom, borrowers consume more, accumulate more houses and work less, while lenders cut their consumption, sell some of their houses, reduce their accumulation of capital, and work harder. The opposite happens during the bust. As a result, GDP falls in the first two years of the simulation, after rising slightly on impact, but then recovers through 2008, and falls somewhat once house prices collapse. The initial behavior is qualitatively consistent with the evolution of GDP in the data, although we would not go as far as claiming that the recession of 2001

<sup>8</sup>See in particular Iacoviello and Neri (2010), who also present some evidence on the extent to which taste shocks might in fact be considered “structural.” Liu et al. (2012) reach similar conclusions in a model in which firms use land as collateral.



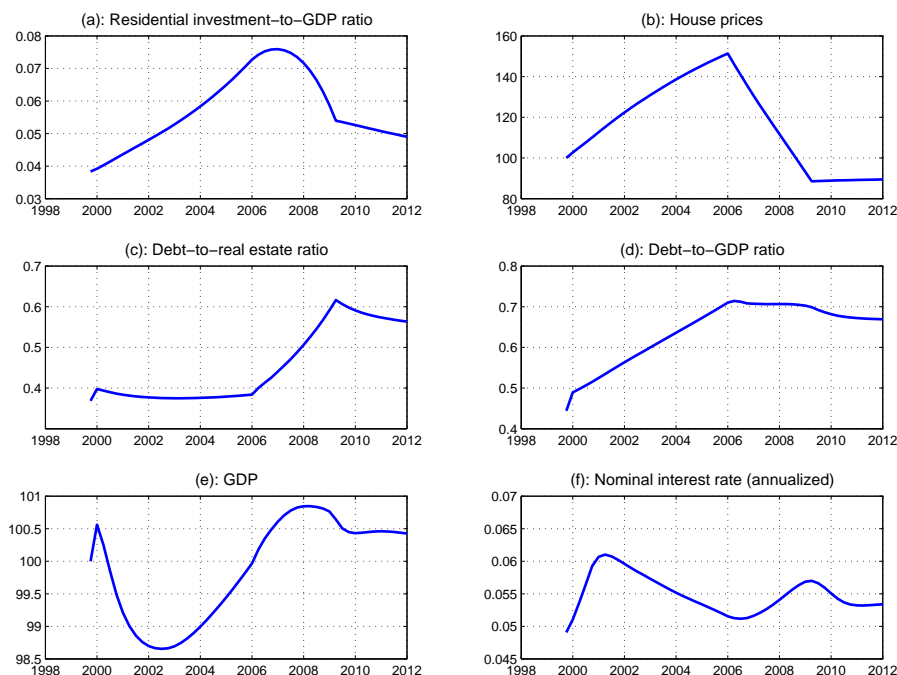


FIGURE 4.6. Valuation experiment: debt and macro variables

and the sluggish recovery that followed were caused by the housing boom to come. What is clearly counterfactual, also in this experiment, is the behavior of the nominal interest rate, which hovers between 5 and 6 percent, while it was considerably lower in the data. Studying more closely the reasons for this discrepancy between the interest rate predicted by the model and that observed in practice is an interesting topic for future research.

The main qualification to apply to these results is that the demand shock driving the price of houses represents a change in fundamentals with many side effects on the equilibrium behavior of economic agents, rather than an independent impulse to collateral values alone. For this reason, we see these results as merely suggestive of the potential for the collateral channel to produce a credit cycle consistent with the one observed in the data.

## 5. SENSITIVITY AND EXTENSIONS

In this section, we show that the results on the effects of a credit liberalization cycle illustrated in section 4.1 are robust both to alternative calibrations of the key parameters

of the model, as well as to a modification of the framework in which domestic agents can borrow from the rest of the world.

**5.1. Alternative calibrations.** We start by considering an alternative calibration in which borrowers are more impatient, and thus might respond more aggressively to a loosening of the credit constraint. We then analyze the effects of credit liberalization cycles of larger magnitude. More specifically, we perform the following experiments:

- (1) **Greater borrower impatience** (Lower  $\beta_b$ ). We set the discount factor of the borrowers ( $\beta_b$ ) to 0.98, and analyze the effect of an increase in the LTV from 0.85 to 0.95, like in the baseline.
- (2) **Larger change in LTV** (Lower initial  $\theta$ ). We set the initial  $\theta$  equal to 0.75 and let it rise to 0.95, before letting it fall back to its pre-liberalization value. This experiment doubles the variation of the LTV relative to the baseline.
- (3) **Combined liberalization** (Change in  $\theta$  and  $\varrho$ ). To capture the emergence of mortgages with lower amortization rates, such as interest-only mortgages, during the housing boom, we assume that the credit liberalization also entails a slower repayment of existing loans, in addition to a higher initial LTV. To incorporate this consideration, we modify the borrowing constraint of section 2 to allow for the loan repayment rate to differ from the depreciation rate of the collateral, as in Campbell and Hercowitz (2009). The borrowing constraint therefore becomes

$$D_{j,t} \leq \bar{D}_{j,t} = \begin{cases} \theta_t P_t^h \sum_{i=0}^{\infty} (1 - \varrho)^i \Xi_{j,t-i} & \text{if } \theta_t P_t^h \geq \theta_{t-1} P_{t-1}^h \\ (1 - \varrho) \bar{D}_{j,t-1} + \theta_t P_t^h \Xi_{j,t} & \text{if } \theta_t P_t^h < \theta_{t-1} P_{t-1}^h, \end{cases}$$

where  $\varrho$  denotes the amortization rate of the loan. We set the initial amortization rate to 0.006 (two times the baseline value), and simulate the effects of a combined transition of  $\theta$  from 0.85 to 0.95, and of  $\varrho$  from 0.006 to 0.003. After 6 years, as  $\theta$  reverts to its original level, the amortization rate also returns to 0.006.

- (4) **Simultaneous Changes** (All). We combine the previous three experiments. With  $\beta_b$  equal to 0.98, we analyze the effects of a simultaneous change of  $\theta$  from 0.75 to 0.95 and of  $\varrho$  from 0.006 to 0.003, together with its reversal.

Parameter	Description	Baseline	Lower $\beta_b$	Lower initial $\theta$	Change in $\theta$ and $\varrho$	All
$\beta_b$	Discount factor, borrower	.99	.98	U	U	.98
$\theta$	Initial LTV	.85	U	.75	U	.75
$\varrho$	Amortization rate	.003	U	U	.006	.006
$\phi_b$	Housing preference, borrower	.1	.114	.12	.15	.23
$\phi_l$	Housing preference, lender	.1	.1	.09	.07	.06

TABLE 2. Baseline and alternative model parameterizations. “U” means unchanged relative to the baseline.

The parameter values in these alternative experiments are summarized in table 2. Compared to the baseline, we allow for different housing preference parameters for borrowers and lenders ( $\phi_b$  and  $\phi_l$ ) and let them vary across experiments. This modification is necessary to match the steady state targets discussed in section 3, i.e. the ratios of debt to real estate, real estate to GDP and residential investment to GDP.

Figure 5.1 presents the effects of a credit liberalization cycle in the baseline calibration and in the four alternatives described above. To facilitate comparisons, house prices and GDP have been normalized to 100 in the initial steady state. Consider the first three experiments, which differ from the baseline for the value of a single parameter. Panels b, c and d show that they all boost the response of debt and house prices relative to the baseline. However, the movements of these variables remain an order of magnitude smaller than in the data, or plainly at odds with them, as for the debt-to-collateral ratio.

Not surprisingly, the results are closest to the data in the last experiment, which combines all the parameter changes. The cycle in house prices is more pronounced than in the baseline, with a maximum appreciation of about 20 percent. As a consequence, the debt-to-GDP ratio rises considerably, although the peak is somewhat higher, and the decline more abrupt than in the data. Still, the model cannot replicate the relatively stable debt-to-real state ratio during the house price boom, and the 20 percent jump in this ratio recorded around 2007. The paths for GDP and the nominal interest rates implied by the model are also at odds with the data. Initially, there is a sharp rise in GDP, accompanied by a surge in inflation (not shown). The increase in GDP is driven by a boom in the consumption of borrowers, as the collateral constraint is relaxed. At the same time, the nominal interest rate climbs to ten percent, well outside the range of values observed in the last decade. Following the initial boom, GDP contracts *before* the tightening of financial conditions, as

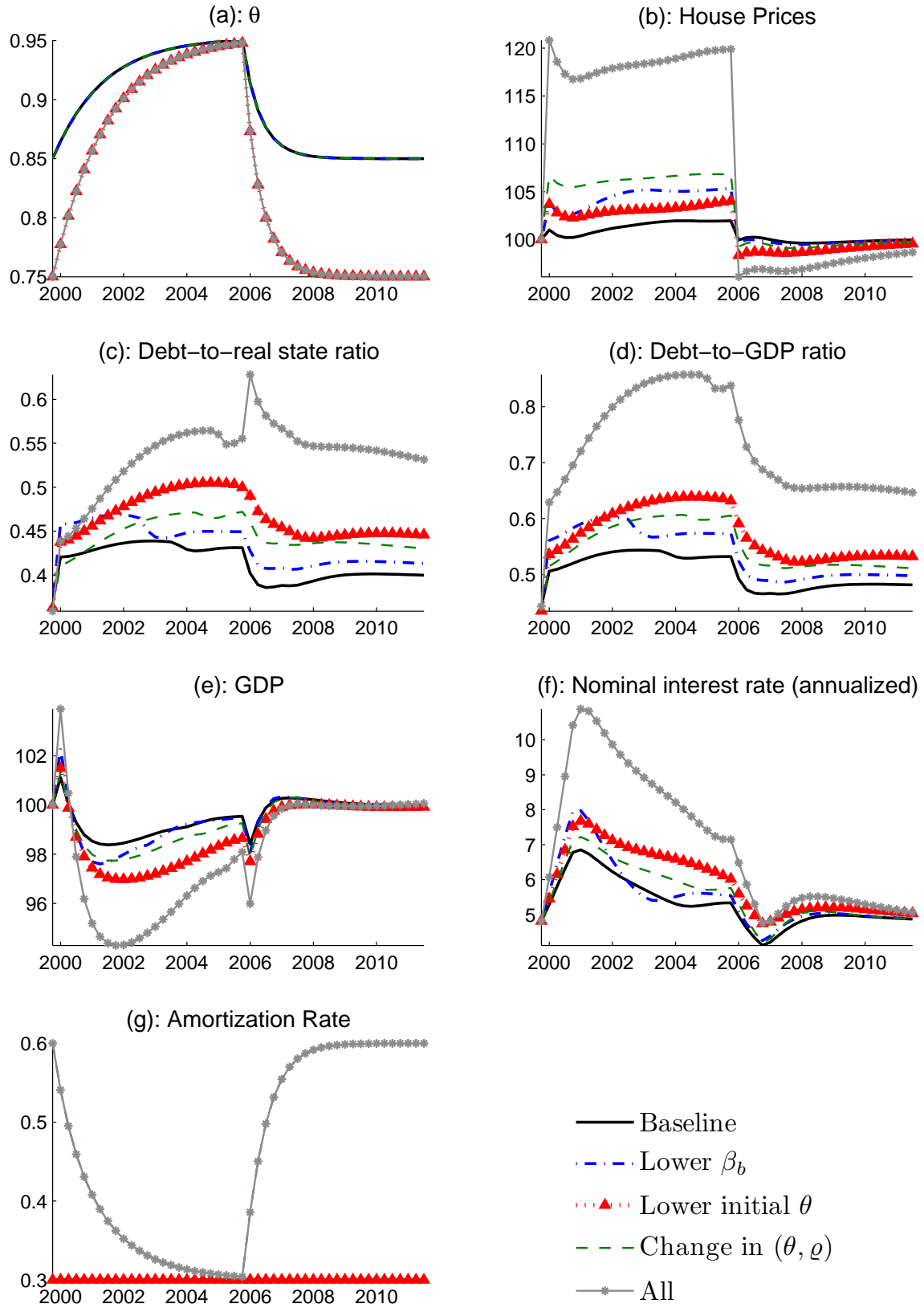


FIGURE 5.1. Transitions paths for alternative experiments

lenders curtail their consumption of non-durables and services, and investment in physical capital declines. Finally, the nominal interest rate trends down as the credit cycle unwinds, but it remains well above the ZLB due to the asymmetric borrowing constraint.

A further problem with this calibration is that it requires assigning a considerably higher utility of housing to borrowers than to lenders, as shown in table 2. As a consequence, borrowers hold more real estate than lenders in steady state, which is counterfactual.

Overall, these results confirm that the credit liberalization story as told by our model is very hard to reconcile with the empirical evidence, even under fairly extreme calibrations chosen to favor that hypothesis.

**5.2. A small open economy version of the model.** In our baseline model, lenders and borrowers behave in opposite ways, and the effects of changes in  $\theta$  on house prices and the macroeconomy are fairly muted. Of course, the extent to which the behavior of lenders counterbalances that of the borrowers depends on the assumption that these are the only agents engaged in the credit market of our closed economy. To assess the robustness of the results to this assumption, this subsection considers the opposite extreme case of a small open economy (SOE) without lenders.

This SOE version of the model deviates from the baseline specification along the following dimensions: (i) The economy is populated by only one type of agents with a discount factor equal to  $\beta_b$ ; (ii) these agents borrow from abroad at a constant real world interest rate calibrated to 2.9% (the steady state real interest rate in the baseline); (iii) the goods market is competitive and prices are flexible. The purpose of the second and third assumptions is to simplify the model by allowing us to ignore demand from the rest of the world and the constraints on domestic monetary policy imposed by the open-economy environment. This simple framework therefore extends the models of Mendoza (2010) and Boz and Mendoza (2010), and resembles that in Garriga et al. (2012).

We parameterize this version of the model to match the same targets as in the baseline, which leaves most of the parameters unchanged.<sup>9</sup>The main exception is the value of the initial LTV  $\theta$ , which needs to be considerably lower (0.36) to match the debt-to-GDP ratio

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<sup>9</sup>We could also calibrate the model to match the net debt of the U.S. household sector, as in Boz and Mendoza (2010). We do not pursue this strategy because this exercise is meant as a check on the robustness of our results, rather than as an stand-alone open-economy analysis.

in an economy populated only by borrowers.<sup>10</sup> Given this parameterization, we subject the model to a financial liberalization and its reversal. In the baseline experiment of section 4.1, the increase in the LTV from 0.85 to 0.95 generates an increase in debt equal to 5.2% of GDP at unchanged house prices. In the SOE, we choose the size of the change in  $\theta$  to match this number, so as to make the initial impulse to credit comparable in the closed and open economies.<sup>11</sup> This increase in  $\theta$  drives house prices 3.1% higher, a larger rise than in the baseline, implying a “multiplier” of debt on house prices 50% larger in the open than in the closed economy. However, this reaction of house prices remains an order of magnitude smaller than in the data.

These results suggest that the muted response of house prices to a financial liberalization is not due to the closed economy nature of the model. In terms of real effects, consumption and investment expand by roughly 2 and 10 percent during the boom, but GDP declines by 1 percentage point, due to the effect on the current account deficit of interest payments on a higher stock of debt.

## 6. CONCLUSIONS

We calibrated a standard general equilibrium model with borrowers and lenders, to be consistent with micro and macro evidence from the SCF and the Flow of Funds. When we subject the model to a “credit liberalization” cycle, whose magnitude is calibrated to match the evolution of initial loan to value ratios on home mortgages in the U.S. over the 2000s, house prices barely move. As a result, the behavior of household debt is counterfactual. On the contrary, when we engineer a boom and bust cycle in home prices driven by changes in demand, the debt variables move as in the data, including the spike in the debt-to-collateral ratio observed in 2007-08, when prices collapsed. In both experiments, however, the aggregate macroeconomic reaction to the changes in debt tends to be small, in part because the nominal interest rate remains far from the zero lower bound.

These experiments suggest that stories pointing to house values and their evolution as the primary source of the credit cycle are more promising than those based on exogenous

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<sup>10</sup>There are two additional changes with respect to the baseline. First, the housing preference parameter,  $\phi_b$  is set to 0.134 as opposed to 0.1, to match the real estate-to-GDP ratio. Second, the value of the investment adjustment cost parameter is 0.1, since we were not able to solve the model with the original value of 2.

<sup>11</sup>Based on this criterion,  $\theta$  increases from 0.36 to 0.4, a 12 percent rise, the same percentage variation as in the baseline.

shifts in collateral requirements. Moreover, the limited macroeconomic impact of household leveraging and deleveraging under both scenarios suggests that, in isolation, debt overhang in the household sector is unlikely to be the crucial headwind holding back the recovery from the Great Recession. Additional frictions are needed to account for the disappointing performance of the US economy since the financial crisis, either as independent sources of shocks, or as mechanisms to further amplify the drivers of the credit cycle already considered in this paper.

For example, rehypothecation—a common practice in the period preceding the Great Recession—might lead to an expansion of credit beyond the value of the assets collateralizing it. Similarly, it would be interesting to consider the interaction between household collateral constraints and funding frictions for financial intermediaries, in a model where banks are needed to channel savings to borrowers and investing firms. In this setup, disruptions in financial intermediation (due, for instance, to falling asset prices or non-performing loans) would affect not only consumption by households, but also firms and investment, resulting in a more severe and protracted contraction in economic activity. In a similar vein, the real effects of a credit cycle could be larger if movements in house prices affected the health of the balance sheet of financially constrained entrepreneurs.

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