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 liberalization, and subsequent tightening, of credit standards 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 collateral channel.

1. INTRODUCTION

The evolution of U.S. households' debt since the turn of the XXI century has been remarkable. Figure 1.1 shows the ratio of household mortgages to GDP, which we take as our measure of household leverage. This ratio was roughly constant around 0.3 between 1970 and 1985. In the second half of the 1980s it increased above 0.4, a level at which it was stable again for more than a decade. The mortgages-to-GDP ratio rose by about 30 percentage points between 2000 and the peak of 75 percent in 2007, at the beginning of the financial crisis. This increase was three times larger than in the previous episode of credit expansion in the 1980s. Since then, debt to GDP has fallen by about 10 percentage points, orders of magnitude more than at any time since the Great Depression. Therefore, by historical standards the debt cycle since the turn of the century appears truly exceptional. We focus on mortgage debt because it represents about 70 percent of all household debt in the United States, but a very similar picture would hold if we used a more comprehensive measure of household liabilities, or if we had used disposable income as a denominator instead.

This unprecedented credit cycle has attracted a great deal of attention. In particular, the idea that household deleveraging, that is the reduction in household debt documented above, is the main headwind holding back the recovery has gained common currency in the public debate.[1] Assessing the empirical validity of this channel requires answering several questions. What are the macroeconomic effects of household deleveraging? Is it

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PRELIMINARY AND INCOMPLETE.The views expressed in this paper are those of the authors and are not necessarily reflective of views at the Federal Reserve Banks of Chicago, New York or the Federal Reserve System.

[1]The first hit in a Google search for "household deleveraging" is a blog post from The Big Picture (http://www.ritholtz.com/blog/2012/02/household-deleveraging-slows-recovery/), which opens with the

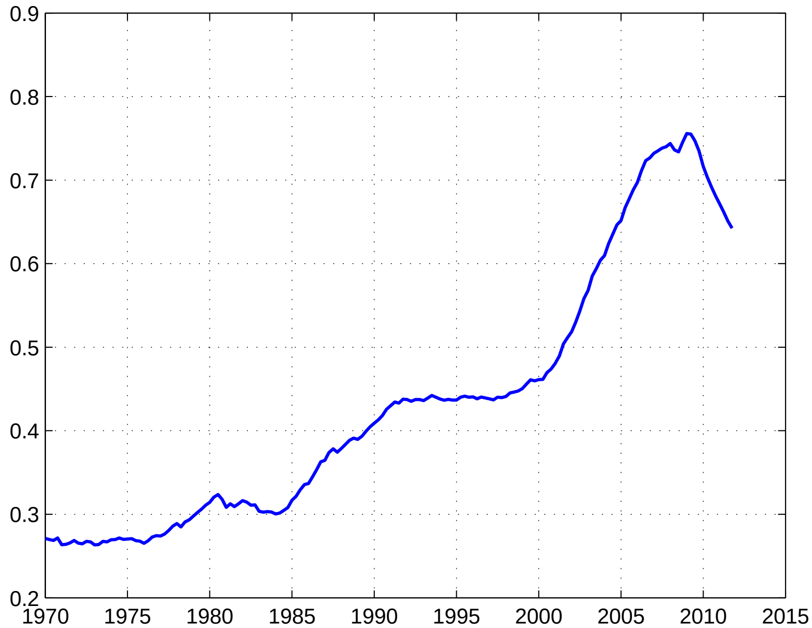

FIGURE 1.1. Ratio between home mortgages of U.S. households and non-profit organizations and GDP Source: BEA and Flow of Funds

large enough to represent a material drag on the recovery? More generally, what are the main causes and consequences of the unprecedented run up and subsequent decline in debt documented in figure 1.1? In this paper, we provide quantitative answers to these questions from the perspective of a general equilibrium model.

This model has three key ingredients. First, heterogeneity in households' desire to save generates borrowing and lending, and hence a role for debt. Since U.S. households' debt is held primarily in the form of mortgages, the second key feature of the model is a collateral constraint that limits households' debt to a fraction of the value of their houses. As a consequence, house prices play a crucial role in the dynamics of debt. To highlight the connection between debt and house values, 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 house prices that started in the late 1990s was matched by an equal run-up of debt, so that the mortgage-to-real estate ratio (or debt-to-collateral ratio) remained approximately constant until 2006. The sudden increase of this ratio in 2006 is due to the fact that lenders cannot recall outstanding mortgages, but the value of the real estate collateralizing them can collapse. This downward "stickiness" of mortgage debt is crucial to match this observation, and it is the third key ingredient of the model.

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following statement: "Why has the recovery been so weak? The short answer is Household Deleveraging." (Search performed on July 19, 2012) See also IMF (2012, Chapter 3) and the references therein.

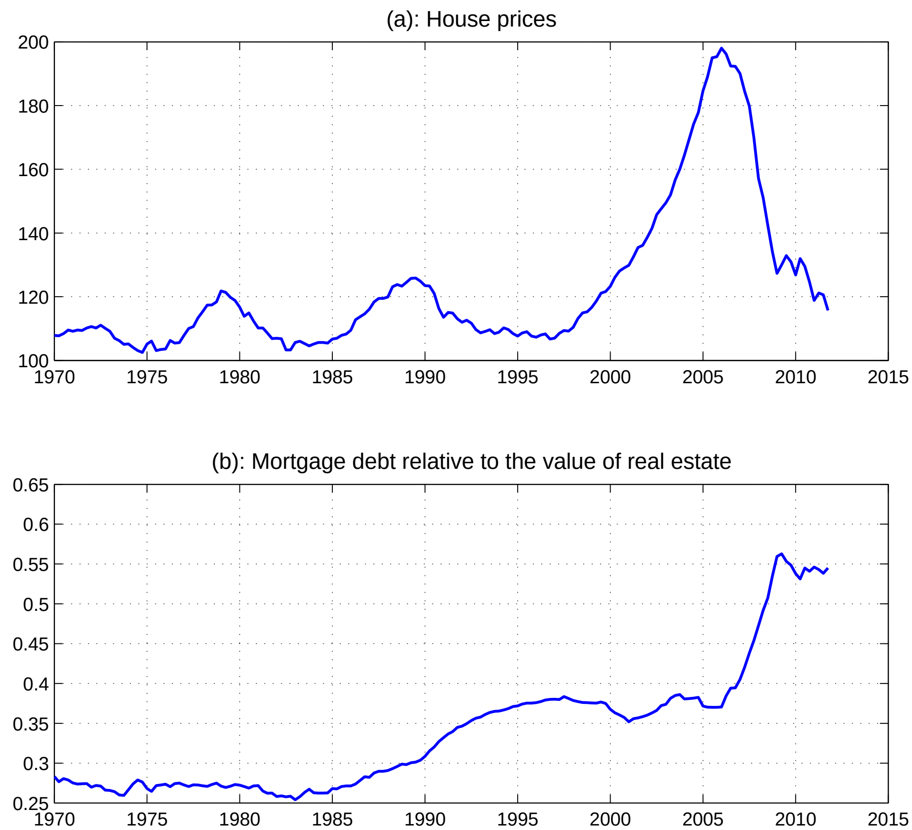

FIGURE 1.2. House Prices and the ratio of mortgage debt to the value of real estate

Both micro and macro data inform the calibration of the model. The Survey of Consumer Finances (SCF) disciplines the degree of heterogeneity among households, while the Flow of Funds provides information on aggregate 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. Choosing a later period would be unreasonable, because the subsequent swings in debt and house prices cannot plausibly be interpreted as a steady state. An advantage of this calibration strategy is that it calls for a more comprehensive view of the recent credit cycle, encompassing both its leveraging and deleveraging phases.

We subject the model to two experiments that capture two popular narratives of the credit boom and bust of the 2000s. These two stories correspond to the two essential reasons why households' ability to borrow can change in the model, and which also play a crucial role in reality. According to the first narrative, the exogenous force behind the explosion, and subsequent fall, of debt was a "credit liberalization cycle", i.e. an overall loosening of lending standards followed by an abrupt retrenchment during the financial crisis (e.g. Mian and Sufi, 2009; Favara and Imbs, 2011). The second narrative sees the boom and bust in house prices, driven by factors unrelated to credit availability, as the main independent cause of the credit boom and bust (e.g. Shiller, 2007; Mian and Sufi, 2011; Dynan, 2012). According to this "valuation" view, the steep rise in house prices facilitated more borrowing due to the appreciation of the underlying collateral, even for given credit standards. And when house prices collapsed, the credit cycle went in reverse.

We model the "credit 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 one important dimension of the credit liberalization actually observed in the U.S. economy, the quantitative loosening of borrowing constraints at the intensive margin, and subsequent tightening of credit standards. This is in keeping with most other macro work on the topic (e.g. Eggertsson and Krugman, 2012; Guerrieri and Lorenzoni, 2012;), although exploring some of the other dimensions of liberalization is on our research agenda. To capture the "valuation" view of the credit boom, we engineer a run-up (and subsequent drop) in house prices driven by a shock to households' taste for shelter. This modeling approach captures the idea that house prices were the main independent cause of the changes in debt, although it punts on the ultimate source of their unprecedented movements. Our reliance on taste shocks is simply to illustrate the workings of the valuation channel, rather than intended as a theory of the forces ultimately responsible for the large swings in house prices observed.

The experiments outlined above lead us to two main conclusions. First, the "credit liberalization cycle" story is a non-starter, since the evolution of the debt variables implied by the model is at odds with the data. In particular, debt increases far less than observed during the boom, while the debt-to-collateral (real estate) ratio falls when credit tightens, rather than spiking as documented earlier. The main reason for these two counterfactual predictions from the model is that house prices barely move in response to a mortgage market liberalization, and its subsequent withdrawal. Therefore, house prices do not inflate the value of the collateral during the credit expansion, providing very little amplification of the initial credit liberalization. On the way down, they do not depress house values, which in the data is what causes the debt-to-collateral ratio to spike. This result is robust to a wide range of calibrations and is consistent with the findings of Iacoviello and Neri (2010) and Kyotaki et al. (2010), who show that shocks to LTV ratios have negligible effects on house price dynamics.

Second, the "valuation" story fits the data better. Changes in house prices, which do not originate from shocks to credit availability, generate dynamics that resemble much more closely those in the data. The large increase in house prices that we engineer slackens the borrowing constraint, thus driving debt higher. When house prices fall in 2006, debt does not fall much, but collateral values plunge, causing the spike in debt-to-collateral observed in the data. An important ingredient in this conclusion is the asymmetry in the borrowing constraint. This feature differentiates our model from most other models of collateralized borrowing in the literature (e.g. Boz and Mendoza, 2011; Eggertsson and Krugman, 2012; Guerrieri and Lorenzoni, 2011; Favilukis et al., 2011), in which the tightening of the constraint generated by a fall in collateral values forces an abrupt contraction of the outstanding stock of debt.

From a modeling standpoint, our paper follows the large literature on collateral constraints spawned by Kyotaki and Moore (1987). More specifically, we follow Iacoviello (2005) and Iacoviello and Neri (2010) 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. In terms of the ideas, as we explore on the role of debt and deleveraging in the macroeconomy, we are close to Eggertsson and Krugman (2012), Guerrieri and Lorenzoni (2011) and Midrigan and Philippon (2011). Favilukis, Ludvigson and Van Nieuwerburgh (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 this channel provides a powerful propagation mechanism for changes in the availability of credit. Boz and Mendoza (2011) reach similar conclusions regarding the importance of credit liberalization in a small open economy model with learning (see also Garriga et al., 2012).

The rest of the paper proceeds as follows. In sections 3 and 4 we present the model and its calibration. In section 5 we discuss the results of the two main experiments described above, whose robustness is analyzed in section 6. Section 7 concludes.

2. Literature review

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3. Model

In this section, we present the quantitative model used to analyze the macroeconomic effects 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 have heterogeneous desires to save, which generates 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. We now present their optimization problems and the market clearing conditions.

3.1. **Households.** The domestic 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 β_b is the discount factor of the impatient borrowers. At time 0, representative household $j = b, l$ maximizes the utility function

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

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. $\Pi_{j,t}$ are 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

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

where $\Xi_{j,t}$ is residential investment (i.e. new houses), $I_{j,t}$ is investment in production capital, and δ_h and δ_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

$$S_k(x) = \zeta_k \frac{1}{2} (x - e^{\gamma})^2, \tag{3.1}$$

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

3.1.1. *The borrowing limit.* Households' ability to borrow is limited by a collateral constraint, somewhat similar to that in Kiyotaki and Moore. We model this constraint to mimic the asymmetry of mortgage contracts in the US. When house prices increase, households can refinance their loans and therefore borrow more against the higher value of their 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 outstanding balances. A similar asymmetry applies when minimum loan-to-value ratios at origination increase or decrease.

More formally, the collateral constraint is

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

where ϱ is the amortization rate of the mortgage and θ the loan-to-value ratio of borrowers, which in the model summarizes credit conditions. In our baseline calibration we assume that the amortization rate coincides with the depreciation rate for houses (δ_h) which results in the simpler expression:

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

If credit conditions ease and/or collateral values increase (i.e. $\theta_t P_t^h$ rises), households can borrow up to a fraction θ_t of the current value of their entire housing stock. This is the standard formulation of the collateral constraint. It implicitly assumes that households will refinance all their outstanding mortgages 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 amortization rate, equal to the depreciation of the housing stock ,δ_h.[2] Therefore, the new less favorable credit conditions that engender a decline in collateral values only affect the flow of new mortgages, collateralized by the most recent house purchase. Besides being realistic, the asymmetry built in this formulation of the collateral constraint is an important ingredient in our results, because it allows the model to reproduce a sudden increase in household leverage when house prices plunge, like in 2006.

Given their low desire to save, impatient households borrow from the patient in equilibrium. In fact, local to the steady state, they borrow as much as the collateral constraint allows them to, and therefore, they choose not to hold any capital. Without the constraint, they would borrow even more, so it is clearly not optimal for them to hold any asset. For simplicity, we impose that borrowers do not accumulate capital also when the collateral constraint does not bind, even if it might be optimal for them to do so.

[2] In section 6 we allow for a higher amortization, so that households build equity in their house over time, as in Campbell and Hercowitz (2009) .

3.2. **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 γ. 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 ξ_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 clearly been a relevant 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. Eggertsson and Krugman, 2012; Guerrieri and Lorenzoni, 2011).

3.3. **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 accumulation equation, so as to have an explicit house price variable in the model.[3] The function S_h is parametrized as in equation (3.1), 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.[4] If $\zeta_h = 0$, the supply of houses is perfectly elastic, and their relative price is equal to one. As ζ_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.

[3]See Justiniano, Primiceri and Tambalotti, 2011 for a similar argument with regards to the price of investment goods.

[4]Davis and Heatchote (2005) calibrate a multi-sector neo-classical 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.

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.

3.4. **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 it's 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 χ of government spending

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

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 χ as capturing the extent of government redistribution.

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

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

where π_t is the gross rate of inflation, π is the Central Bank's inflation target, and $\frac{Y_t}{A_t}$ corresponds to the deviation of GDP from the economy's stochastic trend. [5] The parameters ρ_R, τ_π and τ_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.

3.5. **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

[5] An alternative would be estimate a measure of trend output computed as the DSGE approximation of the exponential filter of log-output as in Curdia, Ferrero, Ng and Tambalotti (2011).

Households	β_l 0.998	β_s 0.99	φ 1	η 1	ψ 0.61	ϕ_b 0.1	ϕ_s 0.1	θ 0.85
Production	γ 0.005	ν 0.5	α 0.3	λ 0.2	ξ 0.75	δ_h 0.003	δ_k 0.025	ζ_k 2
Policy	π 1.005	ρ_R 0.8	τ_π 2	τ_y 0.125	χ 0.55	g 0.175		

Table 1. Parameter values

conditions of the competitive firms, the definition of profits for the intermediate firms, and the debt market clearing condition

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

4. 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 unreasonable, because the subsequent swings in debt and house prices cannot plausibly be interpreted as 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 (π) equal to the average gross rate of inflation (1.005, or 2% per year), and the growth rate of productivity in steady state (γ) to match average GDP growth (0.5%) during the 1990s. In steady state, $R = \frac{e^{\gamma}\pi}{\beta_l}$. Therefore, we choose a value of 0.998 for the lenders' discount factor (β_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 (β_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 β_b, we conduct some robustness checks on this parameter in section 6. The labor disutility parameter (φ) 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 85), 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. Following Kaplan and Violante (2012), we compute the value of liquid assets 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 ψ. We also set the production parameter ν equal to 0.5 to match the relative labor income of borrowers and savers (0.64). 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 $\{\phi_b,\phi_l\}$, the depreciation of houses δ_h and the initial loan-to-value ratio (θ) are chosen jointly to match three key 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 (120%). 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 (36%). The third target is the ratio of residential investment to GDP (4%). We set ϕ_b equal to ϕ_l , which leaves us with three targets and parameters. 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. Regarding the weight for housing in preferences, these are set to $\phi_s = \phi_l = 0.1$ and are key in hitting the ratio of residential investment to GDP. Finally, recall that in this baseline calibration the amortization rate, ϱ is equal to the depreciation rate of houses.

On the production side, we follow standard practice and set the elasticity α in the production function equal to 0.3, and the depreciation of productive capital (δ_k) to 0.025. The average net markup of intermediate firms (λ) 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 (ξ), which is consistent with the evidence in Nakamura and Steinsson (2008).[6] For the second derivative of the investment adjustment cost function (ζ_k) we pick a value of 2, in line with the estimates of Eberly, Rebelo and Vincent (2012). As for the supply of houses, we set the adjustment cost parameter (ζ_h) to infinity, imposing therefore fixed supply of housing along a balanced growth path. The purpose of this extreme parametrization is to generate an upper bound on the variation in house prices that can result from the two experiments considered below.

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

[6]Note that we do not allow for indexation to either steady state or last period inflation.

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 6, we present alternative, more extreme parametrizations of the model in some parameters, and conduct an extensive sensitivity analysis.

5. Results

The calibrated model presented above is our laboratory to study the macroeconomic consequences of changes in households' ability to borrow. To this end, we run two experiments, which are meant to shed light on the relative role of two broad sources of variation in household debt. First, we exogenously perturb the collateral constraint by changing the required LTV ratio of borrowers. The purpose of this exercise is to simulate the effects of a credit liberalization and its reversal. Second, we shock households' desire for houses to generate large swings in their price, which affect their ability to borrow by changing the value of the collateral. As mentioned in the introduction, this second experiment is not intended as an empirical explanation for the large swings in house prices, but instead used simply to illustrate the workings of the valuation channel. To preview the results, we find that the second experiment is much more successful in reproducing the US experience of the last decade.

5.1. **Mortgage market liberalization and its reversal.** Our first set of results comes from a baseline experiment in which the borrowing constraint is first loosened over several periods, and subsequently tightened more abruptly. We generate these changes in the tightness of the collateral constraint by varying θ—the initial LTV ratio of borrowers. Since θ is a parameter in the model, we refer to this as an "exogenous" shock to households' ability to borrow. As illustrated in figure 5.1a, 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 the peak in 2006, and then back to 0.85 by 2008. The evolution of θ between 2000 and 2006 is perfectly foreseen by agents ,after the initial surprise in 2000, who expect that the required LTV will settle at 0.95 after 2006, as shown by the dashed line. Therefore, the collapse in θ collapses back to 0.85 over the course of a little more than one year is unanticipated. After the second surprise in 2006, the rest of the path for θ is again perfectly anticipated and the model settles back down to its initial steady state.

The movements in θ 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 5.2. These authors' calculations suggest that cumulative LTVs were fairly stable around 85% during the 1980s and early 1990s, and started rising gradually in the second half of the 1990s. They took off right around the turn of the century, reaching a peak of almost 95% at the height of the boom, after which they fell back down to 90%. Computing cumulative LTVs for new borrowing is a complicated exercise, given the available

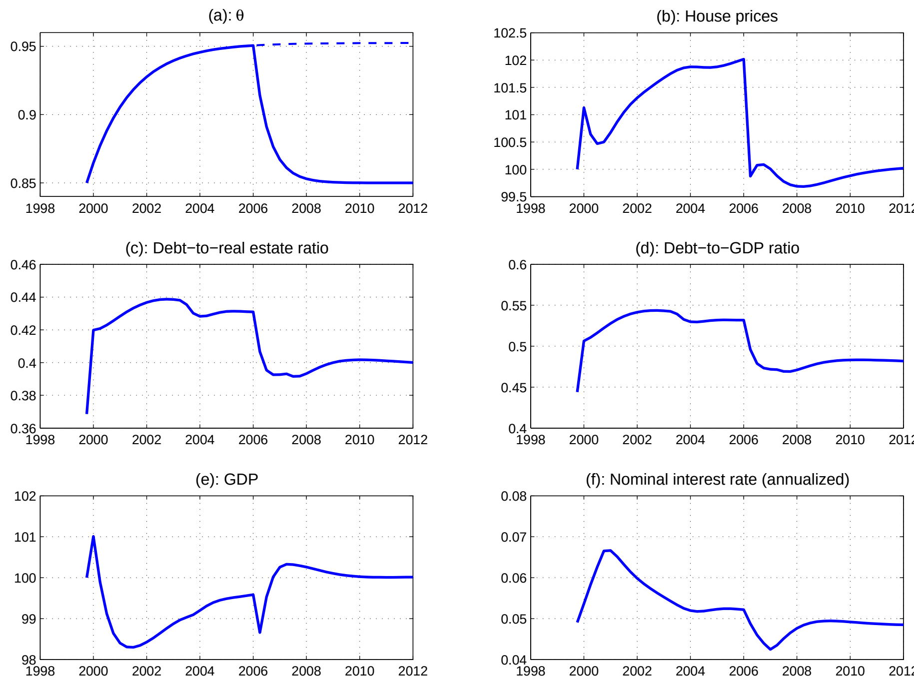

FIGURE 5.1. Credit liberalization experiment: debt and macro variables

sources of data on mortgages, as also discussed by Duca at al. (2011). Therefore, we do not regard these calculations as definitive evidence on cumulative LTVs during this period, an issue which has been amply debated in the literature. However, the work of Duca et al. 2010, 2011) is the most comprehensive source of data of this kind that we are aware of, and it documents movements in θ that seem plausible, if perhaps a bit conservative. As a robustness check, we also consider an experiment with larger swings in θ in section 6.

The macroeconomic implications of the changes in θ described above are depicted in figure 5.1. House prices (panel b) barely move. In the baseline calibration, house prices 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 θ on house prices is consistent with the findings of Kyotaki et al. (2010), Iacoviello and Neri (2010), and Midrigan and Philippon (2012). In our model, part of the reason for the muted response of house prices to a credit liberalization is the behavior of lenders. When the collateral constraint loosens, houses become more valuable to the borrowers, who wish to buy more of them. If this were an open economy with only impatient households borrowing from abroad, this increase in demand would amplify the effects on house prices (though would still broadly result in modest effects). In our model, however, the increase in demand for houses by the borrowers is met by the lenders, who do not use their homes as collateral and thus value them less than the borrowers. Of

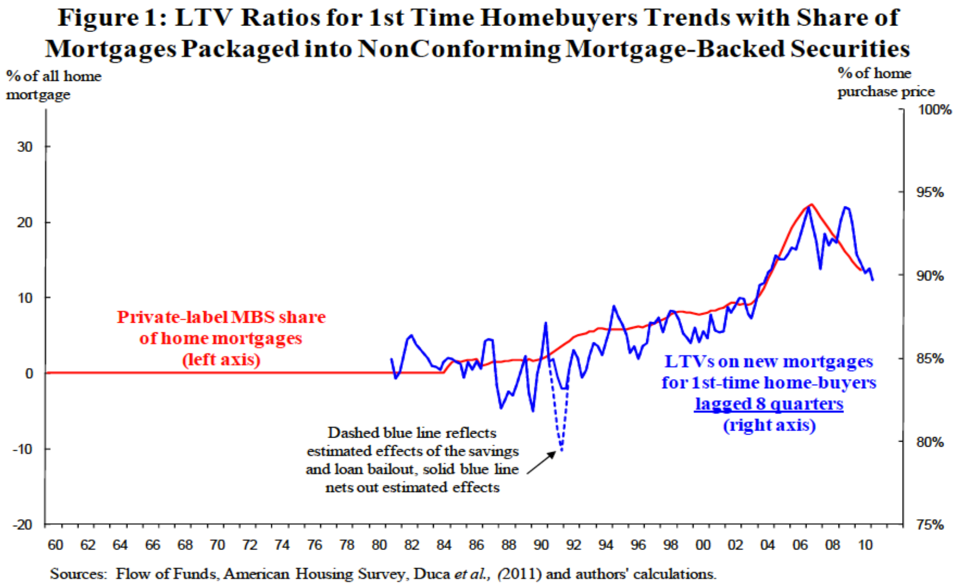

Figure 5.2. Cumulative LTVs

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. Note that this margin of flexibility in the supply of houses to the borrowers 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.

We now turn to the behavior of households' debt. Recall that, in the data, the ratio of mortgages to real estate is roughly stable in the first half of the 2000s, but then spikes when house prices collapse. This spike reflects the asymmetric nature of mortgage contracts: the value of outstanding debt cannot be reduced, even when the value of the collateral falls. This is how households end up "under water" on their mortgages, owning more money than their house is worth. In the model, the evolution of debt-to-real estate values is the opposite of what we see in the data (panel c). This debt-to-collateral ratio rises during the expansionary phase, by about five percentage points, and falls by somewhat less when lending standards tighten in 2006. This behavior is a mechanical implication of the hump-shaped path of θ, which makes people borrow initially more and then less against the value of their house. Moreover, the fact that the increase in this ratio 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 already alluded to. Nonetheless, 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 relative to what was observed.

The debt-to-GDP ratio (panel d) rises until 2006 and then falls, roughly following the evolution of the debt-to-collateral ratio. The qualitative evolution of this variable is broadly consistent with the data, but it is off in terms of magnitudes. In the data, the mortgages to GDP ratio rises by 30 percentage points over the boom period, from about 0.45 in 2000, to 0.75 at the peak, and the rise is gradual over these years. In the model, the increase is only 10 percentage points, and half of this happens at the time of the liberalization. These observations confirm that the model does predict an increase in debt in the early 2000s, as one would expect. However, the change in θ alone is insufficient to generate a large enough boom in credit. Once again, the crucial missing link appears to be the unprecedented rise in house prices experienced by the U.S. economy, which the model is unable to replicate.

Moving on now to more standard macroeconomic indicators, we see in figure 5.1e that GDP increases for only one period after the liberalization, but then falls, while the opposite happens when the constraint tightens unexpectedly. Panel f shows that the short-term nominal interest rate rises first, to encourage savers to extend more loans to the borrowers, following the loosening of the collateral constraint. The opposite happens in 2006 as the LTV returns to its original level. However, the nominal interest rate never reaches the zero lower bound (ZLB) in the baseline calibration, which is another reason why the recession that follows the retrenchment in θ is short and shallow.

The ZLB is an important channel for the amplification of deleveraging shocks, as emphasized by Eggertsson and Krugman (2012) and Guerrieri and Lorenzoni (2011). The asymmetry in the borrowing constraint discussed above is an important reason why the bound is not binding in our model. In simulations in which this asymmetry is ignored, as in most of the literature, such that the tightening of the borrowing constraint also affects the outstanding stock of collateral, the economy can easily fall in a liquidity trap, which in turn deepens and prolongs the deleveraging recession.

To better understand the behavior of the macroeconomy following an exogenous change in households' ability to borrow, figure 5.3 reports the evolution of consumption, the housing stock and hours worked for borrowers and lenders separately. The overall message of this picture is that borrowers and lenders behave in opposite ways, as intuition would suggest, so that the overall effect of changes in θ on the macroeconomy is fairly muted. Quantitatively, the exact balance between the behavior of the borrowers and the lenders depends of course on the assumption that domestic lenders are the only counterpart to borrowers in our closed economy model. However, an open economy calibration roughly based on U.S. data during the crisis suggests that the closed economy assumption might not be too extreme in this regard, as shown in the robustness section.

More in detail, borrowers increase their consumption of non-durables, houses and leisure following the increase in θ, and curtail them when θ 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 several

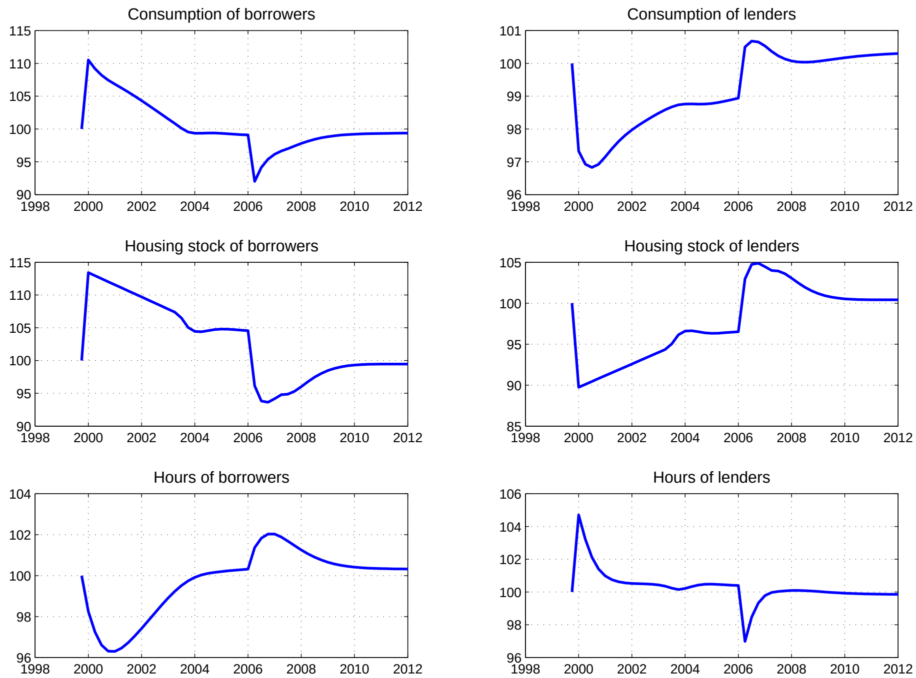

Figure 5.3. Credit liberalization experiment: borrowers and lenders

periods after the initial shock, although the fact that the constraint will bind again in the future continues to have an effect on their current behavior, as emphasized for instance by Guerrieri and Iacoviello (2012). On the other side of the ledger, the lenders need to mobilize the extra resources now consumed by the borrowers. The increase in the interest rate described above is what induces them to consume less, sell a part of their housing stock, and work harder.

Quantitatively, the effects are large for both classes of agents, but they are of roughly similar magnitudes. Therefore, they approximately wash out in the aggregate. If this economy only featured the borrowers, as in a small open economy (e.g. Boz and Mendoza, 2010) and in most informal discussions of the effects of deleveraging, we would conclude that exogenous changes in credit availability would only modestly alter the response of house prices, but would have large macroeconomic consequences, albeit of the opposite direction that here. [7] In general equilibrium, when we take into account that for every borrower there must be a lender, and that the responses of the two classes of agents to the shock have opposite sign, these effects turn out to be much smaller. Together with the counterfactual evolution of house prices and debt-to-GDP, which move way too little,

[7]Intuitively, a loosening of the borrowing constraint would allow an expansion in consumption but necessitate a larger amount of resources devoted to financing foreign borrowing. The latter effect can dominate for reasonable calibrations, resulting in GDP declines.

and of debt-to-real estate, which moves in the wrong direction, these results lead us to the conclusion that exogenous shifts in credit availability are unlikely to be an important driver of the macroeconomic outcomes observed during the credit boom and bust of the 2000s.

5.2. **A shock to housing demand.** The results presented above rule out a strong connection between the process of credit liberalization and large movements in house prices. This result should not be interpreted as diminishing the role of collateral as an amplification mechanism. Instead, our findings speak to the missing link between exogenous changes in the collateral and substantial swings in the prices of houses. In this subsection, we explore the alternative scenario in which the fluctuations in house prices are driven by independent factors, unrelated to changes in credit conditions. This scenario is consistent with the hypothesis that the evolution of house prices and collateral values might have been the primary engine behind the credit boom and bust. Of course, an un appealing feature of this story is that it does not shed light on the underlying factors that lead to the unprecedented increase in house prices.

We engineer a large cycle in house prices, which mimics the one observed in the data, by shocking the households' preference for housing services. Figure 5.4 presents the results of this experiment. Prices rise by more than 50% between 2000 and 2006, and drop abruptly after that, as shown in the first panel of the figure. We do not regard taste shocks as the primitive driver of price dynamics in the data. However, most DSGE research with an explicit role for housing finds that preference shocks are an essential ingredient to replicate the observed behavior of house prices, which confirms their usefulness as a shortcut to generate an "exogenous" cycle in collateral values.[8]

The macroeconomic consequences of the sustained rise and abrupt drop in house prices are depicted in the remaining panels of figure 5.4. Overall, these simulations paint a picture that is much more consistent with the data than the one obtained by perturbing the initial LTV θ. First, the debt-to-GDP ratio rises steadily, from 0.45 in 2000 to 0.7 at the peak. It 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 the behavior of the debt-to-collateral ratio *, which rose* significantly during the great deleveraging, is the asymmetry of our collateral constraint, which accounts for the empirical fact that mortgage principals are fixed in nominal terms in the short-run, 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 not too dissimilar from those under the credit liberalization scenario. As in that case, the reason for the muted aggregate impact of the credit boom and

[8]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 at al. (2012) reach similar conclusions in a model in which firms use land as collateral.

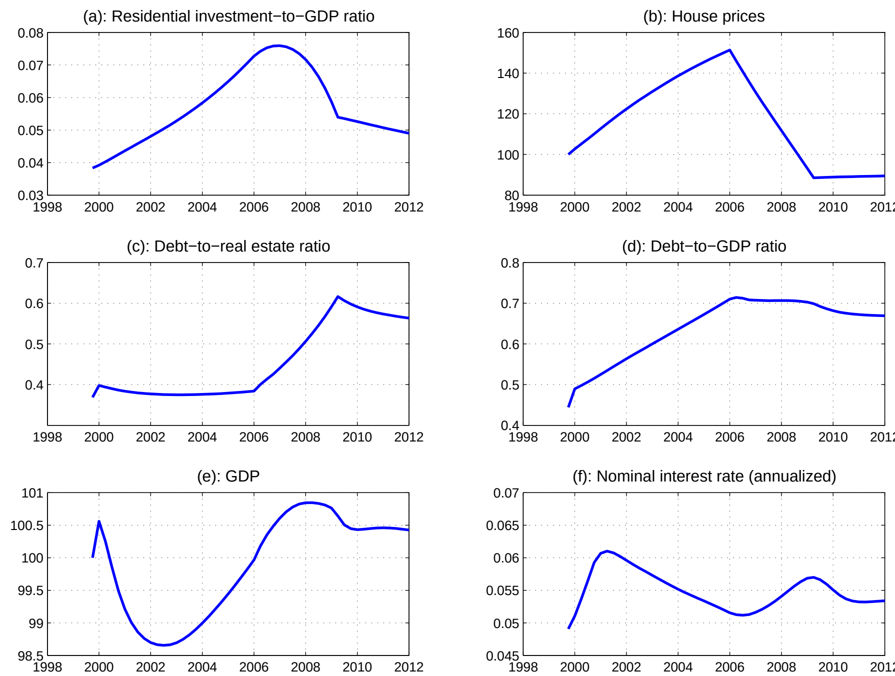

FIGURE 5.4. Valuation experiment

bust is that the two sets of households behave in opposite ways.. During the credit boom, borrowers consume more, accumulate more houses and work less, while lenders cut their consumption, sell some of their houses and work harder. The opposite happens during the bust. As a result, GDP falls in the first two years of the experiment, after rising slightly on impact, but then recovers through 2008, and falls slightly 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 subsequent housing boom was the cause of the recession of 2001 and of the sluggish recovery that followed. What is clearly counterfactual, also in this experiment, is the behavior of the nominal interest rate, which hovers between 5 and 6 percent in the simulation, while it was mostly below the steady state (average level of the 1990s) 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.

More in general, the results of this experiment are subject to the caveat that the demand shock driving the price of houses represents a change in fundamentals with many effects on the equilibrium behavior of economic agents, rather than a clean, exogenous impulse to collateral values alone. For this reason, we see these results as merely suggestive of

Parameter	Description	Baseline	Lower β_b	Lower initial θ	Change in θ, ϱ	All
ϱ	Amortization rate	.003	U	U	.006	.006
β_b	Discount factor, borrower	.99	.98	U	U	.98
θ	Initial LTV	.85	U	.75	U	.75
ϕ_b	Housing preference, borrower	.1	.114	.12	.15	.23
ϕ_l	Housing preference, lender	.1	.1	.09	.07	.06

Panel A: Baseline and Alternative Calibrations. U denotes unchanged from to baseline.

Steady State	Description	Baseline	Lower β_b	Lower initial θ	Change in θ, ϱ	All
$\frac{d^b}{p^h h}$	Debt to real estate	0.36	0.36	0.36	0.36	0.36
$\frac{d^b}{4y}$	Debt to GDP	0.44	0.44	0.44	0.44	0.44
$\frac{p^h h}{4y}$	Real estate to GDP	1.20	1.20	1.20	1.19	1.23
$\frac{p^h q}{y}$	Residential Inv to GDP	.04	.04	.04	.04	.04
$\frac{h_b}{h_l}$	Housing borrower to lender	.49	.49	.60	.92	1.23

Panel B. Initial Steady State

Table 2. Parameter values and steady states across calibrations

the potential for the collateral channel to produce a credit cycle consistent with the one observed in the data.

6. Sensitivity and Extensions

6.1. **Robustness.** We assess the robustness of our results to different calibrations of crucial parameters for the transmission of a credit liberalization cycle. In particular, we consider alternative values for the discount factor of the borrower, β_b, the amortization rate, ϱ, and the initial loan-to-value ratio, θ, both individually and all jointly. Values for these parameters in the baseline and these alternative calibrations are reported in the top panel of Table 2. We also allow for different housing preference coefficients for borrowers, ϕ_b and lenders, ϕ_l, and further let them vary across calibrations (same panel). This is required to match the steady state targets discussed in section 4, i.e. the ratios of debt to real estate, real estate to GDP and residential investment to GDP. These steady state values as well as the ratio of real state holdings by borrowers and lenders are shown in the second panel of Table 2.

6.1.1. *Four Alternative Calibrations and Experiments.* The four calibrations that we consider differ in the magnitude, and/or more broadly the definition, of a credit liberalization. In particular, some calibrations augment the change in LTV with variations in the amortization rate which could further boost the quantitative effects of relaxing the collateral constraint.

(1) **Greater borrower impatience (label, lowerβ_b).** This first parametrization features more impatient borrowers', with their discount factor set at 0.98 (second column). As in the baseline, a credit liberalization corresponds to an increase in the LTV from 0.85 to 0.95 for 6 years, followed by a brisk return to its initial value.

(2) **Larger LTV change** (lower initial θ). In this case, β_b is back at 0.99, but the initial θ is fixed instead to 0.75 (third column). Allowing the LTV to rise to 0.95 before falling back to its pre-liberalization value doubles the absolute variation in θ, compared to the baseline. Hence, this exercise is intended to capture the relatively larger decrease in down-payments reported in other papers as part of a credit liberalization.

(3) **Combined liberalization** (change in θ and ϱ). The calibration in the fourth column departs from the baseline only through a higher initial amortization rate of 0.006. In this case the liberalization synchronizes the transition of θ from 0.85 to 0.95 percent, with a fall in ϱ to its minimum admissible value, the depreciation rate of houses δ_h (fixed at 0.003). After 6 years, as the LTV reverts to its original level, the amortization rate also returns to 0.006. This second aspect of the liberalization is intended to capture the emergence during the housing boom of mortgages with lower amortization rates, such as interest only mortgages.

(4) **Simultaneous Changes** (all). The last parametrization combines all previous changes. That is, $\{\beta_b, \theta, \varrho\}$are fixed at 0.98, 0.75 and 0.006 initially. The variation in the amortization rate is as in the third calibration, while θ rises and falls to 0.95 as in the second one.

6.1.2. *Results.* Transition paths following a credit liberalization cycle in the four different calibrations and the baseline are shown in Figure 6.1. Panels (a) and (g) display the trajectories of the LTV and amortization rate, which as explained differ across experiments. To facilitate comparisons, house prices and GDP have been normalized to 100 in the initial steady state.

Consider the first three calibrations only, where each departs from the baseline in a single parameter. Panel (b) shows that they all boost the response of house prices relative to the baseline (solid). However, these variations are still an order of magnitude below those observed in the data, topping 7 percent for the case of a combined liberalization in θ and ϱ (dashed). For the remaining variables the effects are qualitatively similar to the baseline, inheriting all criticisms made in section 5. Quantitatively instead, the effects are modestly larger and in general most amplified for debt variables in the case of a larger LTV change through a lower initial θ (dashed, triangles). Overall, neither of these calibrations alone is capable of resolving the problems evidenced with the baseline.

Results seem considerably more promising for the case of all simultaneous changes (solid with dots). Now the rise and fall in house prices reaches roughly 20 percent. The combined effect exceeds the sum of the individual alternative calibrations, evincing the non-linear

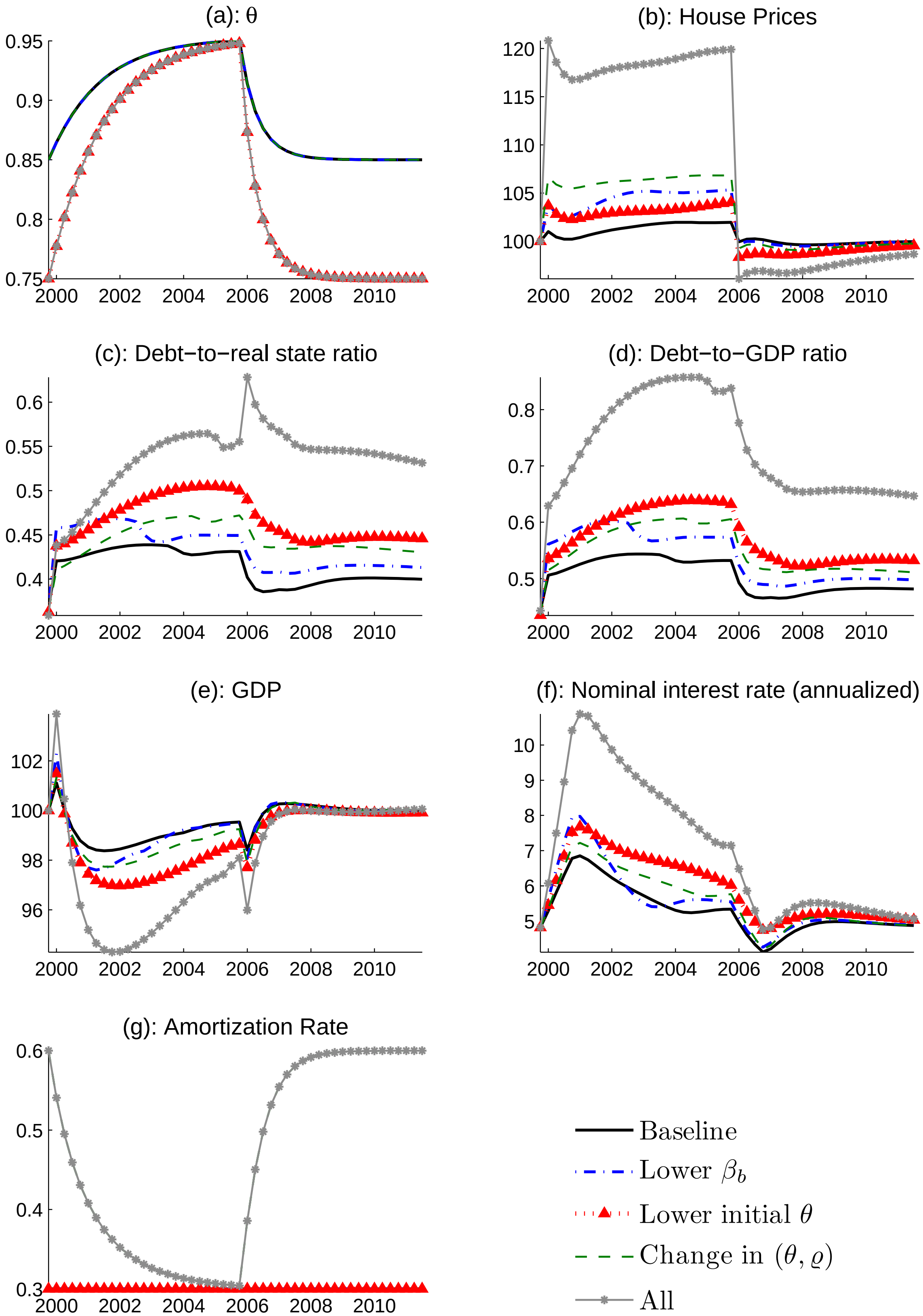

FIGURE 6.1. Transitions paths for alternative parametrization and experiments

nature of the model. Of course, the increase and decline in house prices following changes in the LTV and amortization rate are immediate, rather than gradual due to the perfect foresight nature of the experiment. Further encouragement with these results comes for the path of debt to GDP, which broadly resembles the data, particularly in failing to return to the original steady state (i.e. average values of the 1990s), after 2006. Still, the peak in the model at 85 percent is somewhat higher, while the decline more abrupt that what is observed in figure 1.1.

Unfortunately, a number of problems remain unresolved with this calibration and broader definition of a credit liberalization cycle. First, the model cannot replicate the relatively stable ratio of debt-to-real state during the run-up in house prices (figure 1.2). Second, even if this ratio does rise somewhat as prices fall, the effect is considerably smaller than the 20 percent jump recorded around 2007. As explained earlier, the discrepancy in the evolution of leverage and debt-to-collateral values in the data reflects the large swings in house prices, which this calibration cannot match. Third, the paths for GDP and nominal interest rates implied by the model are also at odds with the data. Initially there is a sharp rise in GDP and surge in inflation (not shown) driven by a boom in the consumption of borrowers as the collateral constraint is relaxed. In response, and in order to induce additional lending required by borrowers, the nominal interest rate climbs to ten percent (with a reasonable calibration of the policy rule), which is well outside the range of historical values observed for the federal funds rate in the last decade. Fourth, following the initial boom, the credit liberalization results in a sharp contraction in GDP *before* financial conditions tighten, as lenders consume less non-durables and services, and investment in physical capital declines. Indeed, according to the model the collapse in GDP during the early 2000s exceeds the relatively mild recession engendered once house prices fall. Finally, as the credit cycle unwinds the nominal interest rate trends down, (as does inflation) but remains well above the zero lower bound.

An additional unappealing feature of the calibration and experiment under all simultaneous changes is that it entails assigning borrowers a considerably higher weight for housing in utility than lenders. More specifically, matching the steady state targets requires a housing preference parameter for borrowers roughly four times that of lenders (0.23 vs. 0.06) as shown in table 2, first panel. This implies a ratio of real state holdings by borrowers to lenders, $\frac{h_b}{h_l}$, of 1.23, about four times larger than in the data.

To summarize, neither of the first three calibrations makes considerable progress in getting the model closer to the data. Changing all parameters simultaneously and therefore considering a broader definition of a credit liberalization can indeed explain up to 1/5 of the variation in house prices. However, in this case model's implications for the ratio of debt to real state, GDP and nominal interest rate is problematic, and it requires imposing seemingly implausible differentials in housing preferences between borrowers and lenders.

6.2. **Injection of foreign funds (TO BE WRITTEN).**

6.3. **Non-separable utility (TO BE WRITTEN).**

6.4. **Wage rigidities (TO BE WRITTEN).**

7. Conclusions

We calibrate a 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" and subsequent retrenchment, 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 house prices driven by changes in the demand for houses, the debt variables move as in the data, including the spike in debt to collateral values observed in 2007-08, when house prices collapsed. This evidence suggests that stories that point to house values and their evolution as the primary source of the credit cycle are more promising than ones based on exogenous shifts in credit availability. Investigating the possible microfoundations of such stories is on our agenda for future research.

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