Credit Supply versus Housing Demand in the U.S. Boom-Bust Cycle*

Yavuz Arslan Bulent Guler Burhan Kuruscu

Abstract

We present two sets of evidence that credit supply played a quantitatively significant role in the US housing market circa 2008. First, we develop a general equilibrium model featuring heterogeneous households who make housing tenure decisions and take out long-term mortgages, firms that acquire working capital through short-term bank loans, and banks whose ability to intermediate funds depends on their capital. Second, we provide bank- and county-level empirical evidence consistent with the credit supply mechanism. Our quantitative findings show that changes in credit supply, stemming from exogenous shocks to bank leverage and/or endogenous shifts in bank balance sheets, played a significant role in the housing market boom-bust and the overall economy. While a housing demand shock substantially contributed to the movements in the price-rent ratio, it had a smaller impact on wages and consumption and generated a contraction in output during the boom phase. Furthermore, our analysis shows that a credit supply expansion causes a decline in the bank lending rate and an increase in both mortgage debt and firm loans, generating positive comovement between them. Conversely, an increase in housing demand raises mortgage debt, but reduces firm borrowing, rather than generating broad-based credit expansion. Our empirical evidence is consistent with the credit supply mechanism.

JEL Codes: E21, E32, E44, G21, G51.
Keywords: Credit Supply; House Prices; Financial Crises; Household, Firm, and Bank Balance Sheets; Leverage; Foreclosures; Mortgages; Consumption; and Output.

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1 Introduction

Understanding the drivers of the housing boom and the subsequent 2008 financial crisis remains crucial for both economic policy and theory. Early research emphasized the role of credit supply in driving both the boom and the severe economic bust (Mian and Sufi (2009), Shin (2012), Jermann and Quadrini (2012), Chodorow-Reich (2014), Favara and Imbs (2015), Landvoigt et al. (2015), Jensen and Johannesen (2017), Justiniano et al. (2019), and Favilukis et al. (2017)). More recent work, however, argues that shifts in housing demand, which in turn affect credit demand rather than credit supply, were the primary driver of the boom-bust cycle (Adelino et al. (2016) and Kaplan et al. (2020), henceforth KMV).[1]

In this paper, we demonstrate that credit supply played a quantitatively significant role across the entire cycle. Our contribution builds on two pillars: a quantitative general equilibrium model and corresponding empirical evidence. Our theoretical framework builds on Kaplan et al. (2020) who argue that shifts in credit supply do not generate significant changes in house prices in the presence of a rental market for housing and long-term mortgages. In particular, we also model the household sector as overlapping generations facing idiosyncratic income risk under incomplete markets, making housing tenure decisions (renting versus owning) and borrowing through long-term defaultable mortgages. However, we extend their framework in two crucial ways that prove essential for understanding the role of credit supply. First, we explicitly model bank balance sheet constraints: banks issue short-term loans to firms and long-term mortgages to households, but their ability to intermediate funds depends on their capital. The balance sheet constraint makes credit supply dependent on bank equity and hence bank leverage. Second, we incorporate firms' financial dependence by modeling their need for working capital loans from banks.

The tight link between bank leverage and credit supply allows us to study the effect of credit supply changes resulting from changes in bank leverage observed in the data. To study the boom-bust episode, we first calibrate the model to match several US data moments regarding household and bank balance sheets before 1998. We then introduce an unexpected credit supply expansion via an increase in bank leverage, calibrated to match its observed rise in the data.

On its own, this shock accounts for over 20 percent of the increase in the price-rent ratio

[1] See Gertler and Gilchrist (2018) for a review of the crisis and the literature.

from 1998 to 2006. To account for the remainder, we introduce an anticipated housing demand shock, following Kaplan et al. (2020), concurrently with the leverage shock and jointly calibrate both shocks to match the observed increase in bank leverage as well as the price-rent ratio. We incorporate the housing demand shock for three reasons. First, we aim to assess the relative contributions of these shocks not only to changes in the price-rent ratio but also to the broader economy. Second, even if our primary focus were on the effects of the leverage shock, potential interactions between the two shocks could amplify or dampen each other's impacts.[2] Finally and most importantly, we show that these shocks generate different comovements across aggregates that we can compare with the data.

In 2008, both shocks are reversed to their initial steady-state values, triggering the crisis. Despite not being a calibrated target, bank leverage declines during the bust, as in the data. Overall, the benchmark economy features a boom-bust cycle similar to the one observed in the US: house price-rent ratio, GDP, consumption, bank loans, mortgage debt, firm loans, and bank leverage rise significantly during the boom and contract sharply during the bust, and the credit spread spikes at the time of the bust, consistent with the data.

Equipped with a framework that generates a sizable boom-bust cycle in the financial, housing, and real sectors, we begin by comparing the implications of credit supply versus housing demand shocks. First, exogenous shocks to bank leverage shift bank credit supply, thereby altering the equilibrium bank lending rate. Movements in this rate affect model dynamics both *directly* via household borrowing costs and *indirectly* through their effect on labor income (since firms partly depend on bank borrowing). As bank leverage increases, the equilibrium lending rate declines, reducing the cost of borrowing for both households and firms.

Our results show that the credit supply shock alone accounts for the entire decline in the bank lending rate and generates increases in firm loans and output that exceed those observed in the benchmark economy during the boom. It also accounts for more than a fifth of the increase in the price-rent ratio, more than half of the increase in household mortgage debt, and most of the increase in consumption. Thus, in a credit supply–driven boom, declining bank lending rates stimulate both mortgage and commercial borrowing through lower borrowing costs, generating a positive comovement between mortgages and firm loans that contrasts sharply with the housing demand–driven boom discussed next.

[2] Indeed, as we show in Section 5.1, the two shocks together generate a housing boom larger than the sum of the booms generated by each shock individually.

By contrast, a positive housing demand shock raises mortgage demand and house prices, relaxing household collateral constraints and increasing net worth. Although households expand consumption and mortgage borrowing during the boom, aggregate capital falls. Quantitatively, the housing demand shock generates a larger increase in the price-rent ratio, but yields significantly smaller gains in consumption and mortgage debt. In addition, at odds with the data, it generates a contraction in firm loans and aggregate output. Overall, this analysis demonstrates that credit supply expansions naturally generate positive comovement between mortgage debt and firm borrowing, whereas the housing demand shock fails to produce this synchronized expansion—a discriminating model implication that we evaluate in the empirical section.

During the bust, both shocks cause a deterioration in bank balance sheets due to lower mortgage valuations and increased foreclosures. Consequently, banks are forced to reduce credit supply in response to declines in their equity, leading to a spike in the bank lending rate and substantially amplifying the downturn.

Through a series of experiments, we illustrate how credit supply shifts generate a significant boom-bust cycle in our framework. First, we analyze the impact of movements in the equilibrium bank lending rate, the primary channel through which credit supply shifts transmit to the aggregate economy. The decline in the bank lending rate during the boom accounts for more than a fifth of the increase in the price-rent ratio and most of the increase in consumption, closely mirroring the effects of the leverage shock.

During the bust, because of the deterioration of bank balance sheets described earlier, the bank lending rate plays a larger role, accounting for more than half of the decline in the price-rent ratio and about 60 percent of the drop in consumption. Furthermore, while the lending rate during the boom was driven entirely by the bank leverage shock, the rate spike during the bust is primarily driven by the leverage shock, alongside a modest contribution from the housing demand shock.

Next, we decompose how changes in the lending rate affect price-rent ratio and consumption *directly* through household borrowing costs and *indirectly* through firm borrowing costs and wages. Our analysis reveals that, across both the boom and the bust, the direct interest rate channel accounts for a large portion of the movements in price-rent ratios, with the indirect wage channel also serving as an important contributor. For consumption, by contrast, the vast majority of the response across both episodes is driven by the indirect wage channel, while the direct channel plays a modest, secondary role.

We then quantify the amplification arising from bank balance sheet deterioration during the bust. We find that this mechanism accounts for about three-quarters of the benchmark economy's decline in labor income, 40 percent of the drop in the price-rent ratio, and about one-third of the contraction in consumption. When we decompose the effect of the spike into its direct and indirect effects, we find that the direct effect accounts for the entirety of the decline in the price-rent ratio but a smaller portion of the decline in consumption.

Finally, we use the model to evaluate the cross-sectional implications of the credit supply channel, focusing on empirical patterns that have previously been interpreted as evidence against it. Recent micro-level studies document that credit expanded uniformly across income quantiles during the boom (e.g., Adelino et al. (2016), Foote et al. (2021), and Albanesi et al. (2022)). Because earlier literature suggested credit supply expansions should primarily benefit lower-income households, this uniform growth was widely taken as evidence against the credit supply view. In contrast, our model demonstrates that credit supply alone can generate such uniform expansion.

In the empirical analysis, we explore whether the comovements in aggregates generated by each shock are consistent with the credit supply mechanism we highlight or the housing demand mechanism. First, using bank- and county-level data, we document a strong positive correlation between mortgage and firm loan growth. This parallel movement is consistent with the credit supply channel and is difficult to reconcile with a housing demand shock alone. Second, we examine an implication of the model's key transmission mechanism: that a credit-supply-induced reduction in interest rates stimulates economic activity through both mortgage and firm lending channels. Consistent with this prediction, we find that counties with larger declines in mortgage interest rates also exhibited simultaneous increases in housing market activity, firm lending, household incomes, and employment during the boom. Third, examining bank-level data during both the boom (1998-2006) and bust (2006-2011) periods, we find that changes in bank leverage coincided with changes in mortgage lending, commercial lending, and interest rates in ways that align with the credit supply channel in our model.

Related literature

Our paper contributes to the literature that studies the dynamics of the housing market and the macroeconomy around the 2008 financial crisis. Using a model with a representative borrower and a representative saver, Justiniano et al. (2019) demonstrate that credit supply, driven by looser lending constraints in the mortgage market, accounts for the unprecedented rise in home prices, the surge in household debt, the stability of debt relative to home values, and the fall in mortgage rates.[3] However, Kaplan et al. (2020) argue that the absence of the rental market and/or long-term defaultable mortgages is critical for obtaining large effects of credit conditions on house prices since, with rental markets, households can rent a house of their desired size if they are constrained in purchasing one. With these extensions, Kaplan et al. (2020) argue that shifts in household demand due to shocks to house price expectations, rather than changes in credit conditions, were the main driving force behind the boom-bust cycle in the housing market. They also find that temporary shocks to the interest rate, essentially a credit supply shock, do not move house prices. Subsequent work qualifies this near-neutrality result: Greenwald and Guren (2025) show that once the segmentation between owner-occupied and rental housing is disciplined by the data, credit conditions have sizable effects on house prices, and Krivenko (2023) shows that moving shocks concentrate marginal homebuyers among younger and more credit-sensitive households, strengthening the credit supply channel.

Despite modeling a detailed household structure, similar to Kaplan et al. (2020), we find a more significant role for credit supply due to two key differences.[4] First, we consider permanent changes in bank leverage, calibrated to match the observed changes in the data, which generate permanent changes in the bank lending rate, rather than the LTV, PTI, or temporary interest rate shocks. Second, the credit supply shock in our framework is not an isolated shock to households since firms also need to borrow from banks to produce

[3] In a similar vein, Kiyotaki et al. (2011) and Adam et al. (2012) find that the decline in interest rates contributed substantially to the house price boom in the U.S. On the other hand, Greenwald (2016), using a representative borrower and a representative saver, and Huo and Ríos-Rull (2013), Sommer et al. (2013), and Favilukis et al. (2017), using heterogeneous agent frameworks, show that changes in maximum LTV or payment-to-income (PTI) ratios can generate significant changes in house prices and consumption. At the macroeconomic level, focusing on the business cycles including the 2008 crisis, Jermann and Quadrini (2012) find that shocks to firms' financing conditions significantly influence the dynamics of real and financial variables.

[4] Nevertheless, we confirm their findings that LTV, PTI, or temporary interest rate shocks barely move house prices.

output. Thus, changes in bank leverage generate changes in the bank lending rate, which then affect households both directly through their borrowing cost and indirectly through firm borrowing costs. This, in turn, creates a boom-bust cycle in the housing market and the rest of the macroeconomy. We further provide empirical evidence for the correlated responses of household and firm borrowing in response to changes in bank lending rate. Moreover, our analysis highlights the importance of endogenous contractions in credit supply due to deteriorating bank balance sheets in amplifying the crisis.

Landvoigt (2016), Diamond and Landvoigt (2022), and Nord et al. (2024) also combine banking and household sectors, as in our model.[5] Our paper has many points of contact with Diamond and Landvoigt (2022), who also show the importance of credit supply for the boom-bust in house prices and mortgage debt. Unlike Landvoigt (2016) and Diamond and Landvoigt (2022), we model the feedback from banks' credit supply to firm borrowing, which significantly contributes to the boom-bust. Furthermore, the richer heterogeneity in our household sector allows us to compare our model's implications with cross-sectional facts, which were argued to be against the credit supply channel. Nord et al. (2024) study distributional effects of banking sector losses.

Mechanisms in our model are supported by empirical findings as well. First, with detailed data from periods after 1996, Fraisse et al. (2020), Gropp et al. (2019), Aiyar et al. (2014), De Marco et al. (2021), Jiménez et al. (2017), and Gete and Reher (2018), causally link regulatory tightenings to declines in credit, and contractions in economic activity. Second, Gilchrist and Zakrajšek (2012) and Gertler and Gilchrist (2018) show that credit spreads spike during downturns, predicting declines in subsequent economic activity. The credit spread dynamics in our model are similar to the excess bond premium dynamics reported in these papers. Third, Glaeser et al. (2013) and Justiniano et al. (2019) find that interest rates on firm loans and mortgages declined during the boom. Jayaratne and Strahan (1997) and Favara and Imbs (2015) find significant declines in lending interest rates after the branching deregulation in the US. For the crisis period, Ivashina and Scharfstein (2010) document a more than 50 percent decline in capital expenditure and working capital loans to corporations. Similarly, Adrian et al. (2013) find that capital expenditure and working capital loans to firms have declined substantially, while interest rates on loans more than quadrupled during

[5] Elenev (2017), Elenev et al. (2016), and Elenev et al. (2021) also use an approach similar to these papers to address different questions from ours.

the crisis. We provide additional support for the credit supply mechanism.

Finally, our framework combines key elements from two strands of literature. On the one hand, an active literature studies the pricing of default risk in the context of household debt, while abstracting from bank balance sheet effects.[6] On the other hand, the literature on bank balance sheets has studied how depletion of banks' capital reduces their ability to intermediate funds.[7] However, in this literature, banks' asset structure typically takes a simple form, such as one-period bonds, or lacks the rich heterogeneity observed in banks' portfolios. By combining these two strands of the literature, our model allows us to study the rich interactions among households, firms, and banks.

2 Quantitative Model

The model is deliberately based on Kaplan et al. (2020). The economy is composed of four sectors: (i) households, (ii) financial intermediaries (banks), (iii) non-financial firms, and (iv) the government. There is perfect competition in all markets.

There is no aggregate uncertainty. Boom-bust transitions are generated by two unexpected shocks, both perceived as permanent. Other than the shock periods, there is perfect foresight. Since households are ex post heterogeneous, all the endogenous prices, value functions, and policy functions depend on the aggregate state of the economy and the distribution of households. For notational convenience, we suppress these dependencies.

2.1 Households

We assume that households supply labor inelastically until the mandatory retirement age J_r and live until age J (with $J > J_r$). A household's income process $y(j, z_j)$ is given by $y(j, z_j) = (1-\tau)\, w \exp(f(j) + z_j)$ for $j \leqslant J_r$ and $y(j, z_j) = w y_R(z_{J_r})$ for $j > J_r$, where $f(j)$ captures the deterministic life-cycle component of income and z_j captures the stochastic component of income modeled as an AR(1) process: $z_j = \rho_\varepsilon z_{j-1} + \varepsilon_j$ with $\varepsilon_j \sim \text{i.i.d. } N(0, \sigma_\varepsilon^2)$.

[6] Among others see Chatterjee et al. (2007), Livshits et al. (2010, 2007), Jeske et al. (2013), Corbae and Quintin (2015), Chatterjee and Eyigungor (2015), Arslan et al. (2015), Guler (2015), Hatchondo et al. (2015), Mitman (2016), Gete and Zecchetto (2024), Kaplan et al. (2020), and Garriga and Hedlund (2020).

[7] See Mendoza and Quadrini (2010), Gertler and Kiyotaki (2010, 2015), Gertler and Karadi (2011), Bianchi and Bigio (2022), and Corbae and D'Erasmo (2013, 2021). See also Bernanke and Gertler (1989), Bernanke et al. (1999), Kiyotaki and Moore (1997), and Buera and Moll (2015) which have studied the financial accelerator mechanism in the context of non-financial firms.

The variable w is the wage per efficiency unit of labor, and τ is the labor income tax rate. Function $y_R(z_{J_r})$ approximates the US retirement system.

Households receive utility from consumption and housing services and can choose between renting and owning a house of their desired size. Household preferences take the following formulation:

$$V_i = \mathrm{E} \sum_{j=1}^{J} \beta^{j-1} u_j \left(c_j^i, s_j^i\right),$$

where E is the expectations operator, β is the discount factor, c_j^i is consumption, and s_j^i is housing services at age j for individual i (which equals the housing stock for homeowners).

Housing Choices: Households enter the economy as *active* renters and can stay as renters by renting a house of the desired size at the price p_r per unit. They can also purchase a house and become homeowners at any time. There is no unsecured borrowing in the model. However, households have access to the mortgage market to finance their housing purchases subject to a minimum down payment and maximum payment-to-income (PTI) requirement. The terms of mortgage contracts, down payment, and mortgage pricing are endogenous and depend on household characteristics. Homeowners can choose to stay as homeowners or become renters again, by either selling their houses or defaulting on mortgages. Homeowners can pay the existing mortgage or obtain a new one through refinancing. Households also can upgrade or downgrade their houses by selling the current house and buying a new one.[8]

Several transaction costs are associated with housing market transactions. A seller has to pay a fraction φ_s of the selling price. Obtaining a mortgage from banks involves a fixed cost (φ_f) and a variable cost (φ_m) as a fraction of the mortgage debt at the origination. Homeowners pay τ_h fraction of their house value as property tax to the government. Moreover, homeowners need to pay δ_h fraction of their house value as maintenance cost to the construction companies to offset the depreciation of the house.

Defaulting on a mortgage is possible but costly. After default, households lose the equity in their house and become *inactive* renters; that is, they temporarily lose access to the mortgage market. Inactive renters also incur a utility cost as long as they remain inactive renters. They become active renters with probability π. Therefore, agents have three statuses regarding

[8]The household sector builds on the ones in Arslan et al. (2015) and Guler (2015) but is extended in important ways, such as refinancing, flexible housing and rental sizes.

their housing decision: homeowner, active renter, or inactive renter.

Mortgage Payments: For tractability, we assume that mortgages mature by the end of life. We restrict contracts to fixed-rate mortgages, which are fully characterized by their maturity and periodic payment m. We assume that the mortgage payments follow the standard amortization formula computed at the bank lending rate r_ℓ.[9]

Optimization Problem of Households: We present the optimization problem of a purchaser here (the rest of the optimization problems are in Appendix B.1). If an active renter chooses to purchase a house, she chooses the mortgage debt level d that determines $q^m(d; a', h, z, j)$, the price of the mortgage at the origination, which is a function of the current state of the household (income realization z and age j), house size h, and asset choice a'. Then, the optimization problem of an active renter who chooses to buy a house is given by

$$V_j^{rh}(a, z) = \max_{c,d,h,a' \geqslant 0} \left\{ \left(u_j(c, h) + \beta E \left[V_{j+1}^h(a', h, d', z') \right] \right) \right\} \tag{1}$$

subject to

$$\begin{aligned} c + (1+\tau_h) p_h h + \varphi_f I_d (d > 0) + a' + m_j(d) &= y(j, z) + a(1+r_k) + d\left(q^m(d; a', h, z, j) - \varphi_m\right), \\ d &\leqslant (1-\iota_d) p_h h, m_j(d) \leqslant \iota_m y(j, z) \\ d' &= (d - m_j(d))(1+r_\ell) \end{aligned}$$

where V^h is the continuation value for a homeowner, p_h is the house price, r_k is the rate of return on financial assets, τ_h is the property tax rate, $m_j(d)$ is the mortgage payment at age j as a function of loan amount d, ι_d is the minimum down payment requirement, ι_m is the maximum PTI limit, and I_d is an indicator function.

2.2 Non-financial Firms

There are three types of non-financial firms: (i) Goods-producing Firms, (ii) Construction Firms, and (iii) Real Estate Firms.

[9]See Appendix B.1 for the equation characterizing mortgage payments. The mortgage interest rate differs across households since ex post households are heterogeneous. Ideally, the amortization schedule should be computed at the individual mortgage interest rate instead of risk-free lending rate r_ℓ. However, to avoid using an additional state variable, we assume that mortgage amortization is computed at r_ℓ, as in Hatchondo et al. (2015) and Kaplan et al. (2020). Then, individual default risk will show up in the pricing of the mortgages at the origination rather than in the mortgage interest rate. Thus, essentially all households pay a premium (buy points) at the origination to reduce the mortgage interest rate to risk-free lending rate r_ℓ.

2.2.1 Goods-producing Firms

A continuum of perfectly competitive goods-producing firms produce output by combining capital K and labor N_g. These firms also choose hours per worker (or labor utilization rate), u. The wage per efficiency unit of labor $w(\overline{w}, u)$ (same as w in $y(j, z_j)$) is assumed to depend on the hours worked, that is, $w(\overline{w}, u) = \bar{w} + \vartheta \frac{u^{1+\psi}}{1+\psi}$, where ϑ and ψ are constants. In this formulation, hours are chosen by the firms, and workers supply hours inelastically, but u, $\overline{w}$, and hence $w(\overline{w}, u)$ are determined in equilibrium. This formulation generates a positive relation between aggregate hours and wages that mimics an aggregate labor supply response to aggregate wages.[10]

Following Cooley and Quadrini (1999, 2004), Mendoza (2010), and Jermann and Quadrini (2012), we assume that goods-producing firms finance a fraction μ of the wage payment in advance from banks and pay interest on that portion. Then, the representative firm's problem is given by

$$\max_{K, N_g, u} \mathbb{Z}K^{\alpha}(N_g u)^{1-\alpha} - (r_k + \delta_k)K - (1 + \mu r_\ell)\, w(\overline{w}, u)\, N_g, \tag{2}$$

where $\mathbb{Z}$ is TFP, and δ_k is the depreciation rate of capital. Since a worker's labor income depends on hours worked, labor income and output decline when the firm reduces work hours in response to an increase in bank lending rate r_ℓ.[11]

2.2.2 Construction Firms

Construction firms produce new houses, I_h, using labor and land according to the following technology: $I_h = L_p^{\theta_h} N_h^{1-\theta_h}$, where L_p is the land demand and N_h is the labor demand by the construction firms. Labor is perfectly mobile across all sectors. Land permits are sold by the government in a competitive market at price q_L. The problem of construction firms is:

$$\max_{N_h, L}\{p_h I_h - w N_h - q_L L_p\} \tag{3}$$

where w is the same wage workers receive from goods-producing firms. We assume the supply of land permits is fixed at $\bar{L}_p$. Aggregate housing stock follows the law of motion:

[10] In the Internet Appendix, we show that this formulation is equivalent to assuming no labor utilization on firms but flexible labor supply for households together with GHH preferences for labor (Greenwood et al., 1988).

[11] We could have achieved the same effect with endogenous labor supply. In that case, the firm would reduce labor demand, which would reduce wages. Households would reduce labor supply and output would decline. We choose this formulation because it is easier to handle computationally.

$H' = (1 - \delta_h) H + I_h$.

2.2.3 Real Estate Firms

A real estate firm enters the period with $(1 - \delta_h) H_r$ units of rental housing stock where δ_h is the depreciation rate of housing and pays property tax proportional to H_r. Then, it chooses H'_r. In that period, the company receives net rent $(p_r - \kappa) H'_r$ and pays dividend $x_r = p_h (1 - \delta_h - \tau_h) H_r - p_h H'_r + (p_r - \kappa) H'_r - \frac{\eta}{2} p_h (H'_r - H_r)^2$ to shareholders where p_r is the rental price per unit of housing, κ is the maintenance cost, and $\eta \geqslant 0$ is a parameter governing the adjustment cost of rental units for the real estate firm. The objective of the real estate companies is to maximize their total market value:

$$(1 + r_k) V^{rc} (H_r) = \max_{H'_r} p_h (1 - \delta_h - \tau_h) H_r - p_h H'_r + (p_r - \kappa) H'_r - \frac{\eta}{2} p_h (H'_r - H_r)^2 + V^{rc} (H'_r), \tag{4}$$

Since both capital and rental company shares are riskless in the steady state and along the transition path, both assets pay the same return except for the two unanticipated shock periods.[12] Given this, the first-order condition of the real estate company gives the rental price as a function of house price and rental housing stock:

$$p_r = \kappa + p_h + \eta p_h \left(H_r - H_r^{-1}\right) - \frac{(1 - \delta_h - \tau_h) p'_h + \eta p'_h (H'_r - H_r)}{1 + r'_k}. \tag{5}$$

where H_r^{-1} denotes the rental housing stock of the real estate firm in the previous period. This equation characterizes the supply of rental housing. The demand for rental housing comes from households' housing choices.

2.3 Banks

We assume a competitive banking industry with a continuum of identical banks that are risk-averse and maximize the present discounted value of utility from consumption: $u\left(c^B\right)$, where c^B is the banker's consumption. There is no entry or exit from the banking sector. Banks fund their operations from their net worth ω and by borrowing B' in the international market at a risk-free interest rate r'. They lend L'_k to the firm at r'_ℓ, and issue mortgages and purchase existing mortgages.

[12] At the time of an unexpected shock, capital and the rental housing return could be different. Then, the realized return will be different from the contracted return, and these profits/losses are borne by the households proportional to their asset holdings.

Let $\theta = (d; a, h, z, j)$ define the type of a mortgage, ω be the bank's net worth, and $\ell'(\theta)$ be the amount of investment in mortgage type θ (which includes any newly issued as well as existing mortgages). Then, the bank's problem is given by

$$\Psi(L, B) = \max_{\{c^B, L'_k, \ell, B'\}} \left\{\log\left(c^B\right) + \beta_L \Psi(L', B')\right\} \tag{6}$$

$$c^B + L'_k + \int_\theta p_\ell(\theta)\, \ell'(\theta) = \omega + B',$$

where β_L is the banker's discount factor, $p_\ell(\theta)$ is the price of a type-θ mortgage. The bank's net worth evolves according to

$$\omega' = \int_\theta \int_{\theta'} \nu^l(\theta')\, \Pi(\theta'|\theta)\, \ell'(\theta) + L'_k\left(1 + r'_\ell\right) - B'\left(1 + r'\right),$$

where $\nu^l(\theta) = m_\ell(\theta) + p_\ell(\theta)$, $\Pi(\theta'|\theta)$ is the endogenous transition probability governed by exogenous household characteristics and choices, and $m_\ell(\theta)$ is the mortgage payment banks receive from a household with current state vector θ. These payments depend on the actions of the homeowners. If the homeowner sells the house or refinances the mortgage, it is equal to the remaining mortgage principal, d. If the homeowner defaults on the mortgage, it is equal to the resale value of the house, $p_h h(1 - \varphi_e)$. Lastly, if the homeowner chooses to stay in the current house, it is equal to the periodic mortgage payment ($\frac{r_\ell(1+r_\ell)^{J-j}}{(1+r_\ell)^{J-j+1}-1} d$), which depends on the maturity tied to the age of the individual, mortgage interest rate, r_ℓ, and mortgage principal, d:

$$m_\ell(\theta) = \begin{cases} d & \text{if sell/refinance} \\ p_h h(1 - \varphi_e) & \text{if default} \\ \frac{r_\ell(1+r_\ell)^{J-j}}{(1+r_\ell)^{J-j+1}-1} d & \text{if stay} \end{cases} \tag{7}$$

Banks can default at the beginning of a period by diverting a fraction ξ of their assets and reneging on their creditors. Upon defaulting, a bank is permanently excluded from intermediation but can save at the risk-free rate r. We interpret ξ as capturing the enforcement, collateral, and regulatory environment that governs creditors' willingness to fund banks; Section 3 discusses its empirical counterparts. We denote the bank's default value by

$\tilde{\Psi}^D\left(\xi\tilde{L}'\right)$, where $\tilde{L}' = \left(\int_\theta \int_{\theta'} \nu^l(\theta')\,\Pi(\theta'|\theta)\,\ell'(\theta) + L'_k\,(1+r'_\ell)\right)$ represents the gross asset value realized at the end of the period, while $L' = L'_k + \int_\theta p_\ell(\theta)\,\ell'(\theta)$ is the initial investment. Creditors lend to the bank only up to the point where default is avoided in equilibrium, yielding the enforcement constraint:

$$\Psi(L', B') \geqslant \tilde{\Psi}^D\left(\xi\tilde{L'}\right). \tag{8}$$

The bank faces no uncertainty in its net worth, even though each mortgage is risky. A continuum of borrowers within each type θ ensures a deterministic return. A key implication of this continuum assumption is that all assets must yield the same return r'_ℓ. Therefore, the price of type-θ mortgages satisfies $p_\ell(\theta) = \frac{1}{1+r'_\ell}\int_{\theta'} \nu^l(\theta')\,\Pi(\theta'|\theta)$ for all θ; that is, the price of each mortgage is the expected present discounted value of its mortgage payments.

Since the bank is indifferent between investing in any asset, we do not have to keep track of its asset distribution. Then, using $p_\ell(\theta) = \frac{1}{1+r'_\ell}\int_{\theta'} \nu^l(\theta')\,\Pi(\theta'|\theta)$, we can show that $\tilde{L'} = (1+r'_\ell)\,L'$ and that the bank's enforcement constraint in (8) simplifies to

$$(1-\phi)(1+r'_\ell)\,L' \geqslant (1+r')\,B', \tag{9}$$

where the *haircut* ϕ is defined recursively as: $\phi = \xi^{1-\beta_L}\left(\phi' + {}^{(1+r')}/_{(1+r'_\ell)} - 1\right)^{\beta_L}$.[13] This condition establishes an endogenous upper bound on bank leverage, dictating that the bank can borrow up to a fraction $1-\phi$ of its collateralized assets. This constraint is also equivalent to the lending constraint $L' \leqslant \beta_L\widehat{\lambda}\omega$ with $\widehat{\lambda} = \frac{(1+r')}{1+r'-(1-\phi)(1+r'_\ell)}$, similar to the one in Justiniano et al. (2019).[14]

A couple of remarks are in order. First, a decline in ξ lowers ϕ, which relaxes the constraint.[15] Second, because total lending is directly proportional to bank net worth ($L' \leqslant \beta_L\hat{\lambda}\omega$), loan supply contracts endogenously when bank balance sheets deteriorate during the bust.

[13] The Internet Appendix I provides the characterization of the bank's problem in detail.

[14] Because banks cannot issue equity and accumulate net worth only through retained earnings, our setup corresponds to the limiting case of prohibitively costly equity issuance in Justiniano et al. (2019): holding net worth fixed, the leverage constraint behaves like a lending limit proportional to net worth, and shocks to $\widehat{\lambda}$ operate like their lending-constraint shocks. The difference is that bank net worth is an equilibrium object in our model, so credit supply also contracts endogenously when mortgage values fall during the bust.

[15] In the frictionless case where banks cannot divert assets ($\xi = 0$), the haircut vanishes ($\phi = 0$) and the *collateral premium*, equivalently, *the credit spread*, $r'_\ell - r'$ collapses to zero.

The solution to the bank's problem is given as $L' = \beta_L \widehat{\lambda}\omega$ and $B' = \beta_L(\widehat{\lambda} - 1)\omega$. Perfect competition among banks together with absence of aggregate risk and continuum of households implies that we can separate the individual mortgage pricing problem from the bank portfolio problem. The price of each mortgage is pinned down through the following equation, which implies that, at the time of the mortgage origination, the present value of mortgage payments discounted at the risk-free lending rate should be equal to the loan amount:

$$dq^m(d; a', h, z, j) = m_j(d) + \frac{1}{1 + r'_\ell} \int_{\theta'} \nu^l(\theta') \Pi(\theta'|\theta) \tag{10}$$

Given d and all other individual state variables, solving this equation gives us $q^m(d; a', h, z, j)$.

2.4 Symmetric Equilibrium

We focus on a symmetric equilibrium in which each bank holds the market portfolio of mortgages. Since each bank's optimal consumption and investment choices are linear in its net worth, we obtain aggregation and can focus on the representative bank. This linearity also implies that the bank size distribution is irrelevant for aggregates: the number of banks is indeterminate in the steady state. Note also that mortgages and firm working-capital loans are funded from a single balance sheet subject to one leverage constraint; with no aggregate risk and perfect competition, both asset classes must earn the same expected return r'_ℓ, so a relaxation of the constraint compresses the spread on household and firm credit simultaneously. This is the sense in which bank leverage connects mortgage and firm lending in our framework. In equilibrium, all economic agents maximize their objectives given bank funding cost r and endogenous prices $\{r_\ell, r_k, \bar{w}, p_h, p_r\}$. Appendix B.5 presents all the equilibrium conditions.

Finally, note that a bank is a leveraged investor. Banks borrow the amount $\widehat{\lambda} - 1$ per unit of their net worth and earn an excess return $r_\ell - r$ on this amount in addition to r_ℓ they earn from their own net worth. Thus, a banker's gross return on net worth is equal to $1 + r'_\ell + (\widehat{\lambda} - 1)(r'_\ell - r')$. In the steady state, we have $1 + r_\ell + (\widehat{\lambda} - 1)(r_\ell - r) = 1/\beta_L$, which we use with the excess return $r_\ell - r$ and the leverage rate $\widehat{\lambda} - 1$ from the data to pin down the banker's discount rate in the calibration section.

Table I – Parameters (externally set and internally calibrated)

Panel A. Externally Set			Panel B. Internally Calibrated		
Parameter	Explanation	Value	Parameter	Explanation	Value
$1/\sigma$	elasticity of intertemporal substitution	0.5	β	discount factor*	0.983
$1/\epsilon$	elasticity of substitution	1.25	χ_d	utility cost of default	1.47%
α	capital share	0.3	$\underline{h}$	minimum house size	0.771
ψ	curvature on hours	0.5	r	deposit rate*	2.54%
ρ_ε	persistence of income*	0.97	γ	weight of housing services in utility	0.133
σ_ε	std of innovation to AR(1)*	0.20	μ	share of wage bill financed from banks	0.357
φ_s	selling cost for a household	7%	η	rental adjustment cost	3.5
φ_e	selling cost for foreclosures	25%	β_L	bank discount factor*	0.86
φ_f	fixed cost of mortgage origination*	4%	ξ	divertible share of bank assets	0.256
δ_h	housing depreciation rate*	1.5%	κ	rental maintenance cost*	0.019
φ_m	variable cost of mortgage origination	0.75%	$\bar{L}_p$	land permit supply	0.043
τ_h	property tax rate	1%	δ_k	capital depreciation rate*	8.35%
π	prob. of being an active renter*	0.14			
θ_h	share of land in house production	0.4			
ι_d	down payment requirement	5%			
ι_m	PTI limit	25%			

All parameters are reported in annual terms. Variables marked with (*) are converted from biennial to annual frequency in the model.

3 Calibration

3.1 Calibration of Stationary Model

A model period is two years. Households start the economy at age 25, work until they retire at age 65, and live until age 85. We construct the data moments by averaging the relevant U.S. data series over the period 1990–1995. Table I presents externally set and internally calibrated parameters under the columns labeled "External" and "Internal" respectively.

Preferences: We assume that households receive utility from consumption and housing services captured by the following CES utility specification: $u_j(c,s) = \frac{\left(e_j\left((1-\gamma)c^{1-\epsilon}+\gamma s^{1-\epsilon}\right)\right)^{\frac{1-\sigma}{1-\epsilon}}}{1-\sigma}$, where e_j is the exogenous equivalence scale capturing deterministic changes in household size and composition over the life-cycle. We assume that inactive renters incur a proportional utility cost to the consumption of both goods: $u_j^d(c,s) = \frac{\left((1-\chi_d)e_j\left((1-\gamma)c^{1-\epsilon}+\gamma s^{1-\epsilon}\right)\right)^{\frac{1-\sigma}{1-\epsilon}}}{1-\sigma}$. We choose $\epsilon = 0.8$, which implies an elasticity of substitution between housing and consumption of 1.25, consistent with the estimates in Piazzesi et al. (2007). Following the literature, we set $\sigma = 2$, which implies an elasticity of intertemporal substitution of 0.5.[16] We set e_j following

[16]Through a series of robustness exercises, we have found that the choice of ϵ and σ does not affect results significantly (Internet Appendix G).

McClements (1977). We calibrate χ_d to match the foreclosure rate of 3.6% (annualized) during the bust replicating the evidence around 2008-2010. We calibrate γ to match the share of housing services in GDP as 12 percent. Denoting Y as the final good or output of goods-producing firms, we calibrate the discount factor β to target capital-to-annual-output ratio of $\frac{K}{Y} = 2.4$, which corresponds to a wealth-to-annual aggregate output (GDP) of 3.62 similar to the ratio in Kaplan et al. (2020).[17]

Income Process: For the income process before retirement, we set the persistence parameter $\rho_\varepsilon = 0.94$ and $\sigma_\varepsilon = 0.28$, which correspond to an annual persistence of 0.97 and a standard deviation of 0.20, and set the deterministic part of the income process $(f(j))$ following Kaplan et al. (2020). Retirement income approximates the US retirement system, as in Guvenen and Smith (2014).

Production Sector: We set the capital share in output to $\alpha = 0.3$. We normalize $\mathbb{Z} = 1$. We calibrate the capital depreciation rate δ_k to match the share of non-residential investment in output of goods-producing firms as $\frac{\delta_k K}{Y} = 0.2$ as in the data.

We calibrate the labor utilization function curvature ψ to match the response of hours in the model to the data. We choose $\psi = 0.5$ with which the model generates an employment decline of 1.8 percent in response to a 1 percentage point increase in the bank lending rate, which falls in the middle of the employment effect found in Gertler and Gilchrist (2018). We target $u = 1$ in the steady state. From the firm's problem, $\vartheta = \left(\frac{1-\alpha}{1+\mu r_\ell}\right)\left(\frac{\alpha}{r_k+\delta_k}\right)^{\frac{\alpha}{1-\alpha}}$ gives us the calibrated value of ϑ.

Housing Market: The probability of an inactive renter becoming an active renter is set to 0.14 annually to capture the fact that the bad credit flag remains for about seven years in the credit history of households. We set the selling cost (φ_s) to 7 percent for regular sales and to 25 percent for foreclosed properties, consistent with the estimates of Campbell et al. (2011). We set the fixed mortgage origination cost $\varphi_f = 4$ percent of annual per-capita GDP and the variable cost of mortgage origination $\varphi_m = 0.75$ percent of the mortgage loan (Board of Governors of the Federal Reserve System (2008)). We set the down payment requirement to $\iota_d = 5$ percent and maximum PTI limit to $\iota_m = 25\%$ following Kaplan et al. (2020).

[17] In our model, in the steady-state aggregate output is : $Y_A = Y + p_r H + \delta_h p_h H$. As we target $\frac{K}{Y} = 2.4$, $\frac{p_r H}{Y_A} = 0.12$ (share of housing services in GDP), and $\frac{p_h}{p_r} = 13$ (ratio of house prices to rent prices), we have $\frac{p_h H}{p_r H}\frac{p_r H}{Y_A} = \frac{p_h H}{Y_A} = 0.12 \times 13 = 1.56$ and $\frac{\delta_h p_h H}{Y_A} = 0.015 \times 1.56 = 0.0234$. Then, aggregate wealth to annual GDP ratio is $\frac{K + p_h H}{Y_A} = \frac{K}{Y}\frac{Y}{Y_A} + \frac{p_h H}{Y_A} = 2.4 \times (1 - 0.12 - 0.0234) + 1.56 = 3.62$.

The ratio of house prices to annual rental payments is calibrated to 13 (Sommer et al. (2013)). We set the annual depreciation rate for housing units to $\delta_h = 1.5$ percent and property taxes to $\tau_h = 1$ percent following Kaplan et al. (2020). The steady-state relation between the rental price and house price is given by $p_r = \kappa + \frac{r_k+\tau_h+\delta_h}{1+r_k} p_h$. This gives us an estimate of κ given our target $\frac{p_h}{p_r} = 13$. We restrict the minimum house size for owner-occupied units to be $\underline{h}$ to match a homeownership rate of 66 percent.

Following Kaplan et al. (2020), we set the share of land in the production of houses, θ_h, to 0.4 generating price elasticity of housing supply of 1.5, consistent with the evidence provided in Saiz (2010). We calibrate the supply of land permits, $\bar{L}$, to match the share of construction in employment.[18]

The adjustment cost parameter η in real estate companies' problem is calibrated to match the evidence in Greenwald and Guren (2025). This parameter is irrelevant for the steady-state of the model as real estate firms face no adjustment cost at the steady-state. However, during the transition, as the rental stock adjusts, this parameter plays a crucial role in the movements of rental prices. As we increase this parameter, adjustment cost increases, and rental companies' supply of rental stock becomes more inelastic, which reduces the adjustments in the rental prices. Greenwald and Guren (2025) provide evidence to discipline this parameter. As in their paper, we target the ratio of the percentage change in the price-rent ratio to the percentage change in the homeownership rate. Their estimates imply a large band for this ratio with a minimum of 3.8. We calibrate η to match the lower bound of this range in response to the credit supply shock we use in our model. This gives us $\eta = 3.5$.

Financial Sector: To construct the share of mortgages in bank balance sheets, we use the loan-level information from FED Z1. The share is calculated as the ratio of one-to-four family residential mortgages to the sum of these residential mortgages and nonfinancial business

[18]Ideally we can use θ_h and $\bar{L}$ to match the share of residential investment in GDP and the share of construction in aggregate employment, which are both around 4-5% in the data. However, presetting θ_h and δ_h, following Kaplan et al. (2020), together with free labor mobility in the model between the two production sectors, do not allow us to match all these moments. When we set $\delta_h = 1.5\%$, this implies the share of residential investment in GDP as $\frac{\delta_h p_h H}{Y_A} = \delta_h \frac{p_h H}{Y_A} = 0.015 \times 1.56 = 2.34\%$, which is slightly lower than its data counterpart. When we set $\theta_h = 0.4$, this together with free labor mobility implies that the share of construction in employment is 2.35% in the model, slightly below its data counterpart. If we chose to match the share of the residential investment in GDP as 4% and the share of construction in employment as 5%, then we would have $\delta_h = 2.6\%$ and $\theta_h = 0.23$. Using these estimates does not change the main results of the paper significantly. We chose the former to stay as close as possible to Kaplan et al. (2020).

loans.[19] The average of this ratio between 1990 and 1995 is 0.54. We calibrate the fraction of wage bill financed through banks, μ, to match this ratio in the model.

In the steady state, we have $r_\ell - r = \frac{1-\beta_L(1+r)}{\widehat{\lambda}\beta_L}$, where $\widehat{\lambda} = \frac{(1+r)}{1+r-(1-\phi)(1+r_\ell)}$ is the endogenous leverage ratio and $\phi = \xi^{1-\beta_L}\left({(1+r)}/{(1+r_\ell)} - (1-\phi)\right)^{\beta_L}$ is the haircut. We calibrate r to match a mortgage debt-annual GDP ratio of 53 percent, and we target $r_\ell - r = 1.5$ percent, representing the average annual gap between the 30-year mortgage interest rate and the 10-year Treasury rate in the data. We also target the bank leverage ratio $\widehat{\lambda}$ as 10 following Gertler and Kiyotaki (2015). These two targets give us the bank's discount factor β_L and the bank's seizure rate ξ.

Overall, we have 12 parameters that we calibrate internally: discount factor (β), minimum house size $(\underline{h})$, deposit rate (r), weight of housing services in utility (γ), share of wage bill financed by banks (μ), utility cost of default (χ_d), adjustment cost of real estate companies (η), bank's discount factor (β_L), bank's asset seizure rate (ξ), maintenance cost for rental units (κ), capital depreciation rate (δ_k), supply of land permits $\left(\bar{L}_p\right)$. The last five of these parameters are identified directly through analytical moments obtained through the model as discussed above. This leaves us with seven parameters that we calibrate using the model simulated data to jointly match the following seven data moments (Table II): 66 percent average homeownership rate, 53 percent mortgage-debt-to-GDP ratio, capital-output ratio of 2.4, share of mortgages in bank balance sheet as 54 percent, share of housing services in GDP as 12 percent, evidence provided in Greenwald and Guren (2025), and annualized foreclosure rate of 3.6% during the bust period.[20]

3.2 Calibration of Boom-Bust Shocks

To study the role of bank credit supply, we generate a boom-bust cycle through two separate sets of unexpected shocks. We assume that, before 1998, the economy is at the steady state. In 1998, we shock the economy with unexpected leverage and housing demand shocks to generate the boom episode. The leverage shock is given as a linearly increasing shock over time, and the housing demand shock is announced to be realized in the future. The full path

[19] These variables can be obtained from FRED using labels HHMSDODNS and BOGZ1FL144123005A, respectively.

[20] η does not affect steady-state results and χ_d has minimal effect on the calibration of the steady-state as there is almost zero foreclosure in the steady-state. So, we, first, calibrate the first five parameters to match the steady-state moments, and then calibrate η and χ_d to match the moments related to the transition.

Table II – Moments

Statistic	Data	Model
Capital-output ratio*	2.4	2.4
Homeownership rate	66%	66%
Mortgage debt-GDP ratio*	53%	53%
Share of housing services in GDP	12%	12%
Ratio of mortgage loans to total loans in bank assets	0.54	0.54
Foreclosure rate during the bust period*	3.6%	3.6%
Mortgage premium*	1.5%	1.5%
Bank leverage ratio	10	10
House price-rental price ratio*	13	13
Price elasticity of housing supply	1.5	1.5
Share of construction in employment	2.35%	2.35%
Non-residential investment-output ratio	20%	20%

All moments are reported in annual terms. Variables marked with (*) are converted from biennial to annual frequency in the model.

of all shocks is common knowledge after their realization by all agents in the economy. To generate the bust episode, in 2008, we revert both of these shocks to their initial steady-state levels abruptly and unexpectedly. Below, we discuss how we calibrate these two shocks.

Leverage Shock: The boom and bust periods coincided with important changes in financial markets that shifted credit supply.[21] The Glass-Steagall Act, the bill that separated banking activities from investment banking ones, after being loosened for about a decade, was repealed in 1999. As a result, deposit-taking banks had the opportunity to expand their balance sheets. On the securitization side, from 1995 to 2005, the volume of private-label mortgage-backed securities increased dramatically from negligible levels to $1.2 trillion but disappeared with the crisis. We view both the regulatory changes and changes in investor sentiment toward mortgage-backed securities as the driving force behind the expansion and then contraction of funding to the banking system. Nevertheless, the distinction between the two is not critical for our analysis since the model is calibrated to match the increase in bank leverage until 2008 without taking a stand on the underlying reason.

In the model, the bank leverage is determined by ξ: a lower (higher) value for ξ reflects

[21]See Chernenko et al. (2014) for developments in the securitization market and Sherman (2009) for important changes in financial market regulation in the US.

greater (less) creditor confidence in banks and allows banks to have a higher (lower) leverage. To calibrate the changes in this parameter, we refer to two sources. First, Federal Reserve Bank of New York (2024) documents that the leverage ratio of the consolidated US banking organizations has increased by 25 percent from the first quarter of 1996 to the last quarter of 2007. We use the leverage ratio of all institutions (see page 34 of the report). Second, the Financial Stability Report by Board of Governors of the Federal Reserve System (2019) documents that the leverage ratio of securities brokers and dealers has increased by 50 percent from the first quarter of 1995 to the first quarter of 2008 (see Figure 3-5 in the report).

Both studies report marked-to-book leverage. However, in our model bank assets, L_{t+1}, and net worth, ω_t, are in market values and the ratio $L_{t+1}/\left(\omega_t - c_t^B\right)$ gives the marked-to-market leverage, which is the same as the book leverage when the economy is in steady state. However, after unexpected shocks, market and book values will no longer be equal. To be able to compare the model to the data, we compute the book values of bank loans and net worth and calculate the corresponding book leverage in our model. We calibrate the changes in parameter ξ to have an increase in the financial system book leverage by 37.5 percent (from 1996 to 2006), which falls in the mid-range of 25 percent and 50 percent. We feed this shock as a linear increase for T periods. We chose T to match a 50-basis-point decline in mortgage premium by 2008, consistent with the data. The calibration results in $T = 13$ and a 45 percent decline in ξ. The top left panel in Figure 4 compares the book leverage from our model and these sources.[22]

Housing Demand Shock: The boom leverage shock generates part of the increase in the price-rent ratio. We generate the remainder with a housing demand shock in the spirit of Kaplan et al. (2020). In 1998, we shock households' beliefs such that they believe the weight on housing in preferences, γ, will increase starting from 2010, and will stay at that level forever.[23] We calibrate the increase in γ so that both shocks together generate about a 38 percent increase in the price-rent ratio during the boom. Then, γ unexpectedly reverts to its

[22]In our framework, the leverage constraint and haircuts on collateralized loans are tightly linked. Available data suggest that haircuts more than doubled for most mortgage-related securities after the crisis (Committee on the Global Financial System (2010)), consistent with the leverage dynamics in our model.

[23]The choice of 2010 is disciplined by two considerations. First, we want this shock to be unrealized. Since the bust shock is introduced in 2008, we want the shock to be expected to occur after 2008. Second, we want the shock to be as small as possible while remaining consistent with the calibration of Kaplan et al. (2020). Delaying the realization of the shock to later periods would require a much larger shock to match the same moment targeted in the model.

initial steady-state value in 2008. The calibration results in an increase of 54% in γ.[24]

Government interventions at the bust: Even though both shocks return to their initial steady state levels in 2008, the model economy experiences a large bust, in which bank net worth becomes negative in the absence of any government intervention. This result suggests that the government interventions were necessary to keep the banking sector afloat during the crisis. In order to incorporate interventions into our framework that are consistent with the actual experience, we assume that the government borrows from international investors at the rate r in 2008 to finance bailouts to banks and rolls over its debt until 2038, after which it increases the labor income tax to balance the government budget in the long run.[25] We assume that the government injects equity into banks so that the bank net worth ω_t declines by 67 percent in 2008, the decline in market equity of bank holding companies reported in Begenau et al. (2019, Figure 3, left panel). With this intervention, the bank collateral premium or equivalently the credit spread $(r_\ell - r)$, the measure of the distress in the banking system, increases by 5.2 percentage points (top row, right panel, Figure 4). For comparison, the excess bond premium from Gilchrist and Zakrajšek (2012) and Gertler and Gilchrist (2018) increases by about 4 percentage points during the 2008 financial crisis. Finally, the total bailout amount in the model is 3.5 percent of GDP.[26]

4 Quantitative Results

In this section, we compare our model's distributional and aggregate implications during the boom-bust cycle with the data.

4.1 Distributional Implications

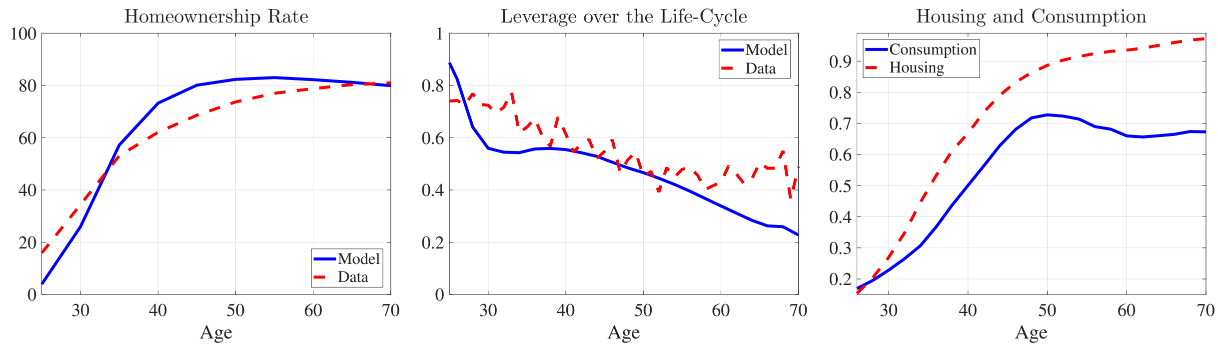
The life-cycle implications of the model closely match the data (Figure 1). The homeownership rate increases over the life cycle. Leverage declines with age, but more sharply than in the

[24]In our model, γ increases from 0.133 to 0.205 whereas in Kaplan et al. (2020) the same parameter increases from 0.12 to 0.2.

[25]The particular choice of the year after which the labor income tax is increased does not affect the boom-bust dynamics we report in the paper as long as it is in the distant future. We have also experimented with no tax increase as if the bailout amount is a windfall to check the sensitivity of our results. Again, we did not discern any noticeable effect on the boom-bust.

[26]The US Congress approved $700 billion as part of the Troubled Asset Relief Program (TARP) in October 2008. However, the authorization was later reduced to $475 billion by the Dodd-Frank Act of 2010, and about $443 billion was ultimately disbursed. Private sector GDP in 2009 was $11.8 trillion ($14.7 trillion total value added minus $2.9 trillion value added by the government). The amount of $700 ($475) billion is 6 (4) percent of GDP.

FIGURE 1 – Life-Cycle Properties: Model versus Data



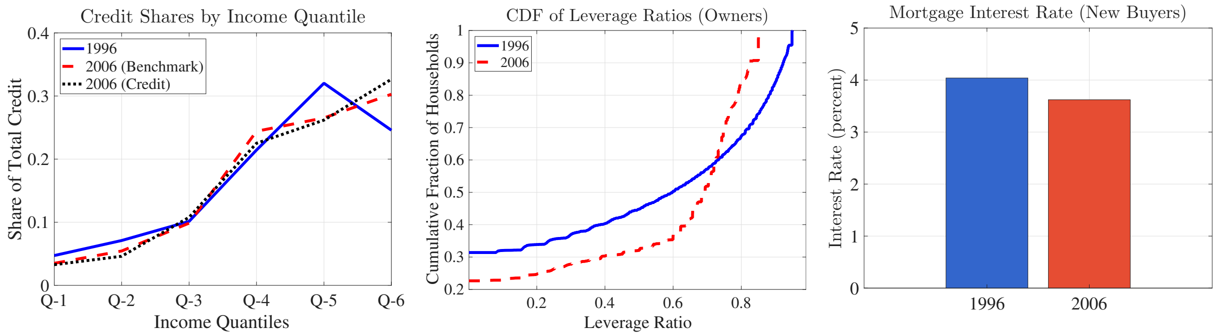
Notes: The graph shows the life-cycle properties of housing and mortgage debt. The left panel plots the homeownership rate. The middle panel plots mortgage debt relative to housing value. The data come from the 1995 Survey of Consumer Finances. The right panel plots consumption and housing expenditure over the life cycle from the model.

data after age 60. Average consumption and housing increase over the life cycle, consistent with the findings of Aguiar and Hurst (2013).

The left panel of Figure 2 shows that the credit shares of each income quantile remained stable from 1996 to 2006 in the benchmark model with two shocks, consistent with the evidence in Adelino et al. (2016), Albanesi et al. (2022), and Foote et al. (2021). This pattern has been interpreted as evidence against the credit supply channel, given that earlier literature considered credit supply expansions to be more relevant for lower-income households. However, as illustrated in the figure, we find that the leverage shock alone can generate this pattern. The reason for the similar credit growth across different income quantiles is that all types of households benefit from lower borrowing costs and higher labor income when the bank lending rate declines during the boom in response to the credit supply expansion.

The middle panel shows that household leverage is higher in 2006 than 1996 in the model, in part because the model generates endogenous increases in LTV ratios consistent with the data without appealing to exogenous changes in LTV limits. In fact, Keys et al. (2013) report that the average combined LTV of households increased by 15 percentage points during the boom. Our model generates a 14-percentage-point increase, almost matching the data. Finally, the right panel shows that interest rates on mortgages declined from 1996 to 2006, as in the data (Favilukis et al. (2017)).

FIGURE 2 – Cross-sectional Developments in Credit and Housing during the Boom



Notes: The graph plots several model-implied cross-sectional implications. The left panel plots the mortgage credit distribution across income quantiles in 1996 and 2006 for both the benchmark and the result from the model with only the credit supply shock. The middle panel plots the distribution of homeowner leverage ratios; the right panel reports mortgage interest rates for new buyers in 1996 and at the peak of the boom in 2006.

4.2 Boom-Bust Cycle in Aggregates

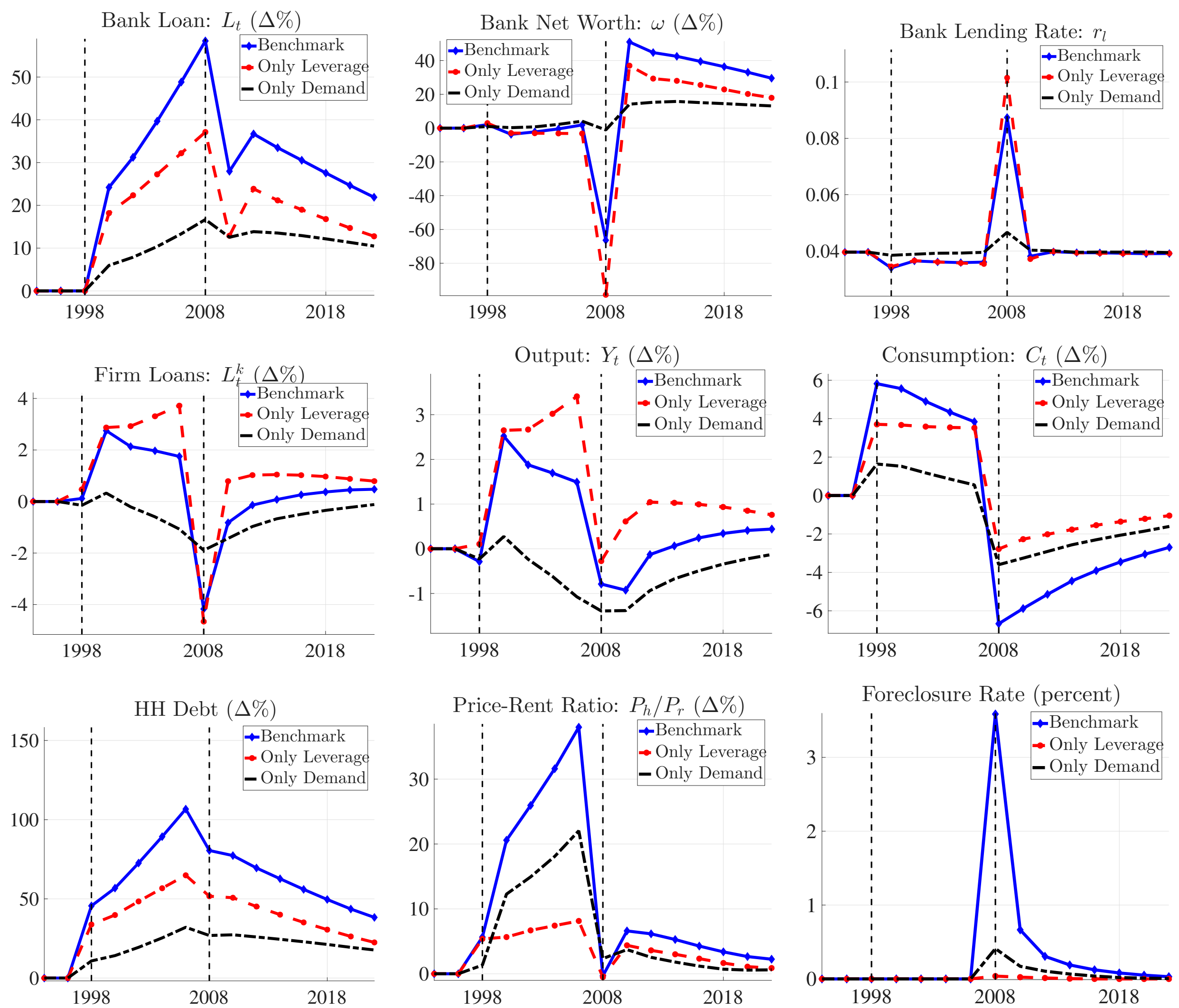
In Section 4.2.1, we examine the impulse responses to the leverage and housing demand shocks individually. We then turn to the benchmark economy with both shocks operating jointly, examining the banking sector (Section 4.2.2), the real sector (Section 4.2.3), and the housing market (Section 4.2.4).

4.2.1 Impulse Responses to Credit Supply versus Housing Demand Shocks

To illustrate the distinct transmission channels of the two boom-bust shocks, we first examine how the economy responds to the leverage and housing demand shocks individually. Figure 3 displays the separate macroeconomic trajectories generated by each shock in isolation.

Transmission of the leverage shock. In the leverage-only experiment, the boom begins with an expansion in bank lending capacity as bank leverage rises. For a given bank net worth, this increase shifts out the bank loan supply curve according to $L_{t+1} = \beta_L \hat{\lambda}_t \omega_t$, driving the loan expansion shown in the top-left panel of Figure 3. The resulting decline in the bank lending rate r_ℓ (top right panel) is the central mechanism transmitting the leverage shock to the economy. A lower r_ℓ reduces borrowing costs for both households and firms. Cheaper credit *directly* boosts household consumption and housing demand. In addition, because firms must finance a portion of their wage bill through bank loans, lower borrowing costs stimulate firm labor demand and bid up equilibrium wages, which provides an *indirect*, reinforcing boost to household consumption and housing demand.

Figure 3 – Impulse Responses to Credit Supply versus Housing Demand Shocks



Notes: The graph plots the dynamics of key variables during the boom-bust episode in the benchmark economy. The "demand" and "leverage" lines correspond to the model dynamics where only that shock is given to the model economy.

The bust is triggered as ξ returns to its initial value, causing $\hat{\lambda}_t$ to decline toward its baseline level.[27] While this decline in bank leverage directly reduces loan capacity and raises r_ℓ, the accompanying deterioration of bank balance sheets, driven by higher discounting of mortgage cash flows as well as higher foreclosures, substantially amplifies the spike in borrowing costs.

[27]The term $\widehat{\lambda}_t$ is an endogenous object defined in Section 2.3. The parameter that goes back to its steady-state level is ξ, which eventually decreases $\widehat{\lambda}_t$ to its initial steady-state level.

Although all variables affect each other simultaneously, we will proceed with an iterative approach in demonstrating the amplification mechanism during the bust. For this purpose, remember that the bank net worth in period t is given as

$$\omega_t = \int_\theta \int_{\theta'} \left(m_t\left(\theta'\right) + p_t\left(\theta'\right)\right) \Pi\left(\theta'|\theta\right) \Gamma_{t-1}\left(\theta\right) + L_t^k\left(1 + r_{\ell,t}\right) - B_t\left(1 + r_t\right).$$

The shock that generates the bust is a decrease in $\widehat{\lambda}_t$ back to its steady-state level that reduces loan supply through $L_{t+1} = \beta_L \hat{\lambda}_t \omega_t$. As a result, the equilibrium bank lending rate $r_{\ell,t+1}$ increases. However, a higher $r_{\ell,t+1}$ reduces the bank's net worth at time t by lowering mortgage valuations since $p_t\left(\theta\right) = \frac{1}{1+r_{\ell,t+1}} \int_{\theta'} \left(m_{t+1}\left(\theta'\right) + p_{t+1}\left(\theta'\right)\right) \Pi\left(\theta'|\theta\right)$ for all θ. In response, loan supply L_{t+1} declines further and $r_{\ell,t+1}$ increases more. With higher $r_{\ell,t+1}$, mortgage valuations and bank net worth decline further, which generates further increases in $r_{\ell,t+1}$ and future bank lending rates. This is the key mechanism through which the deterioration of bank balance sheets amplifies the transmission of a shock to bank leverage. Another contributing factor to the decline in bank net worth is the increase in foreclosures. However, we find that they have a relatively smaller effect on bank net worth.

The spike in r_ℓ and the sharp drop in bank net worth are short-lived because this amplification mechanism reverses in the recovery: falling lending rates restore mortgage valuations, which rebuilds bank net worth and expands credit supply.

Overall, Figure 3 shows that the credit supply shock is a primary driver of the boom in bank loans, firm loans, output, consumption and household debt, while also contributing significantly to the rise in the price-rent ratio. Symmetrically, the reversal of credit supply generates a sizable contraction across all these aggregates during the bust. Even though the leverage shock alone generates no foreclosures (bottom-right panel), the balance-sheet feedback loop triggers a severe collapse in bank net worth (top-middle panel), a sharp contraction in credit supply (top-left panel), and a dramatic spike in the lending rate (top-right panel).

Transmission of the housing demand shock. A positive housing demand shock shifts preferences toward housing services, bidding up house prices and the price-rent ratio (bottom-middle panel). This increase in housing valuations relaxes borrowing constraints as higher homeowner equity expands collateral capacity, enabling households to expand mortgage debt (bottom-left panel) and finance higher consumption (middle-right panel) through wealth and collateral effects.

However, because the shock originates on the household demand side rather than from an expansion in credit supply, the bank lending rate r_ℓ remains essentially flat throughout the boom (top-right panel). Consequently, borrowing costs for non-financial firms do not fall. At the same time, aggregate capital falls, leading to a contraction in aggregate output and firm loans (middle panel) that is at odds with the empirical data.

The bust is triggered when housing demand reverts to its baseline level, causing a sharp decline in house prices, pushing highly leveraged homeowners into negative equity, generating an increase in mortgage foreclosures (bottom-right panel). In contrast to the leverage shock—where bank balance-sheet distress originates from heavier discounting of future mortgage cash flows—the losses under the housing demand shock stem mainly from mortgage defaults. These write-downs reduce bank net worth ω_t (top-middle panel) and depress bank loan supply (top-left panel), which initiates a mechanism similar to the one above. Nevertheless, the bank balance sheet mechanism is much smaller, thus leading to a small increase in bank lending rate.

Comovement of Aggregates and Discriminating Model Implications. Comparing the two shock transmissions reveals sharp differences in their implied macroeconomic comovements during the boom. The credit supply shock generates synchronized positive comovement across household debt, firm borrowing, output, and consumption. In contrast, the housing demand shock primarily moves housing market valuations and mortgage defaults, but fails to generate a broad-based economic expansion while contracting aggregate output and firm loans. Thus, within the model's comparison of the two shocks, only the credit supply expansion reproduces the joint boom in corporate credit and real activity alongside mortgage debt. In Section 6, we evaluate whether county- and bank-level data exhibit the comovements implied by the credit supply mechanism or those implied by the housing demand channel.[28]

Having illustrated the transmission channels of each shock in isolation, we now turn to the quantitative performance of our benchmark economy, where both shocks operate jointly, examining its implications for the banking sector, the real economy, and the housing market.

[28]Although Martín et al. (2021) find that a housing demand shock initially crowds out non-housing credit before banks' net worth accumulation expands overall lending capacity, this channel is quantitatively not strong enough in our model to offset the decline in firm credit.

4.2.2 Banking Sector Dynamics

In the benchmark economy where the leverage and housing demand shocks operate simultaneously, the interaction of both forces generates a synchronized boom-bust across financial and real aggregates. The banking sector experiences a boom-bust cycle in the model, as in the data (Figure 4). The bank book leverage increases by 37.5 percent in the model, as it is calibrated to do. The decline in leverage during the bust, however, is not targeted, yet the model still matches it: leverage declines by 48.0 percent in the period following the bust shocks and recovers slowly. The leverage ratios of commercial banks and securities brokers and dealers in the data decline by 27 and 71 percent from 2008 to 2010, respectively.[29]

With higher leverage, the loan supply (both mortgages and firm loans) increases, and the bank lending rate r_ℓ declines. The bank net worth declines during the boom since the bank funding cost r has not changed and r_ℓ is lower. Thus, the banking sector supports more credit with lower bank net worth but with higher debt. The model generates a 58.9 percent rise in bank loans in the boom, exceeding the data. The share of mortgages in banks' portfolios also increases, as does the value of the mortgage pool.

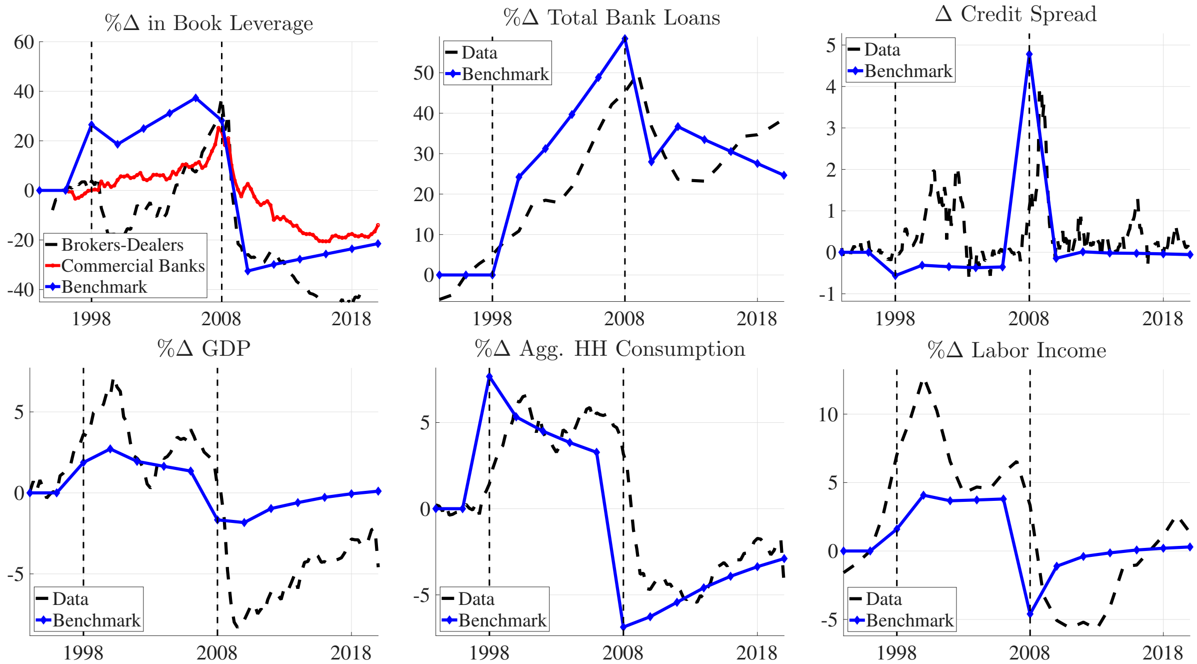
The crisis occurs as the leverage constraint and housing demand parameters revert to their initial steady-state levels. Consequently, the credit spread $r_\ell - r$ jumps by 5.2 percentage points, somewhat larger than the spike in the excess bond premium documented in Gilchrist and Zakrajšek (2012) and Gertler and Gilchrist (2018)[30], and mortgage valuations and bank net worth sink.[31] Since mortgages are long-term assets, banks cannot flexibly adjust their

[29]Consistent with what we report here, there is broad agreement that marked-to-book leverage is procyclical (Adrian and Shin (2010), Nuño and Thomas (2017), and Coimbra and Rey (2024)). The marked-to-market bank leverage $(L_{t+1}/(\omega_t - c_t^B))$ also increases during the boom but spikes at the time of the bust as bank net worth sinks, which is also consistent with the findings in Begenau et al. (2026).

[30]Our model has a single lending rate for mortgages and firm loans, so we compare the model spread with the excess bond premium, the natural proxy for firms' marginal borrowing cost. Posted spreads between mortgage rates and Treasury yields did not decline over the boom; they embed prepayment and duration premia and, during 2003 to 2006, a composition shift toward nonprime and adjustable-rate products. The household-side counterpart in our analysis is therefore the effective mortgage rate of new buyers, which declines in both the model and the data (Figure 2, right panel). Part of the observed decline in borrowing rates also reflects the global decline in safe rates (Caballero et al. (2008); Favilukis et al. (2017)); our deposit rate is fixed, so the model isolates the spread component.

[31]The dynamics of the bank lending rate are consistent with other empirical findings as well. During the boom, interest rates on firm loans and mortgages declined (Glaeser et al. (2013) and Justiniano et al. (2019)). Jayaratne and Strahan (1997) and Favara and Imbs (2015) find significant declines in lending interest rates after the branching deregulation in the US. For the crisis period, the lending interest rate on loans more than quadrupled (Adrian et al. (2013)).

FIGURE 4 – Boom-Bust Dynamics: The Banking and the Real Sectors



Notes: The graph plots the dynamics of key variables during the boom-bust episode. Data counterparts of bank loans, output, consumption and labor income are percentage deviations from their linear trends obtained from the 1985-2006 period. See Appendix A for data sources. In the text, we compute the bust changes relative to the peak of the boom. There is a recession in 2001 during the period we study, which the model does not attempt to capture. As a result, the model deviates from the data around that year.

balance sheets by issuing fewer mortgages. Therefore, they reduce their lending to firms.

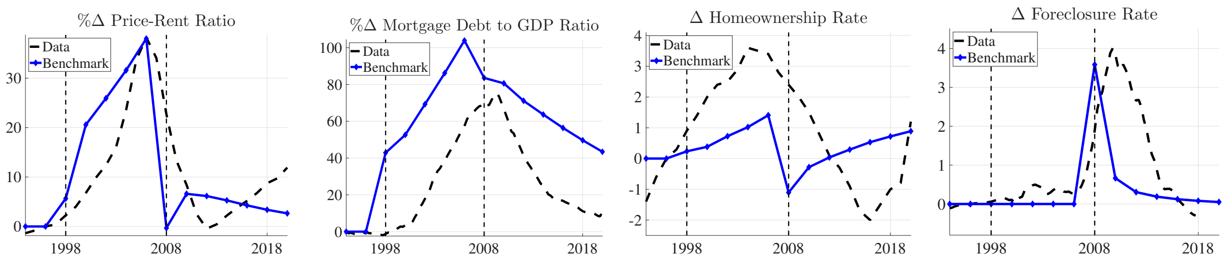
4.2.3 Real Sector Dynamics

At the peak of the boom, the US per capita GDP was almost 6 percent above its trend. GDP ($Y_A = Y + P_r H + P_h I_h$) in the model first jumps by about 2.5 percent, which gradually eases to 1.5 percent (bottom left panel in Figure 4) during the boom. With the crisis, GDP falls by about 2.3 percent from its peak. The aggregate labor income follows a boom-bust pattern similar to the output (bottom right panel), which is critical for the boom-bust dynamics in the housing market and consumption, as we analyze in Section 5.2.1. Overall, the model accounts for a portion of the boom-bust in GDP and labor income.

The response of aggregate consumption ($C_A = C + P_r H$) to the shocks is more abrupt (jumps, then gradually declines, and stays high) and slightly larger than the data (bottom row, middle panel, in Figure 4).[32] In the model, this is driven by the immediate response of wages and

[32]Since the bank borrowing rate r is exogenous, this model is essentially an open economy where output is

FIGURE 5 – Boom-Bust Dynamics: The Housing Sector



Notes: The graph plots the dynamics of key variables during the boom-bust episode. The data counterpart of house price is percentage deviation from its linear trend obtained from the 1985-2006 period. See Appendix for data sources.

house prices to new information from two unexpected shocks. Since wages and house prices are key determinants of consumption, their jump and fall with the boom and bust create a non-smooth consumption pattern.[33]

The response of the firms' labor demand to the changes in the bank lending rate is the key driver of the boom-bust in the production sector (Section 5.2.1). Our model generates changes in total per capita hours worked, labor income, and firm loans that are similar to the data. Moreover, there is substantial evidence that the labor decisions of firms are indeed influenced by financial conditions, which corroborates the predictions of our model.[34]

4.2.4 Housing Market Dynamics

The price-rent ratio increases by 38 percent during the boom (Figure 5). Recall that the housing demand shock is calibrated so that the two shocks jointly match this increase (Section 3). Despite not being a targeted moment, the model generates a significant bust in the price-rent ratio, closely tracking its empirical counterpart.

During the boom, the mortgage debt increases by 106.7 percent in the model before gradually declining after the bust. The foreclosure rate in the model remains near zero during the

given as $\mathsf{Y_A} = \mathsf{C} + \mathsf{I} + \mathsf{NX}$. In 1998, NX declines and stays negative. Thus, the model implies that there is a net capital inflow to the US during the boom period, which is broadly consistent with the data.

[33] The immediate response to unexpected shocks is a common issue in asset-pricing models.

[34] For example, Chodorow-Reich (2014) finds that firms that worked with weaker banks prior to the crisis reduced employment more. Benmelech et al. (2019) find similar evidence from the Depression era, and Popov and Rocholl (2018) bring evidence from Germany during the 2008 crisis. Finally, Ivashina and Scharfstein (2010) document a more than 50 percent decline in bank capital expenditure and working capital loans to corporations, and Adrian et al. (2013) find that capital expenditure and working capital loans to firms have declined substantially, while interest rates on loans more than quadrupled during the crisis. Jermann and Quadrini (2012) use a quantitative model and show that the worsening of firms' ability to borrow during the 2008 crisis played an important role on the deterioration in the labor market.

boom and jumps by 3.6 percentage points in the bust period (as in the data), as the sharp decline in house prices during the bust pushes many households into negative equity, which, combined with lower income, makes default optimal. The homeownership rate rises by 1.4 percentage points during the boom (smaller than the data), and declines sharply during the bust, though with a more muted trough than observed empirically, driven by the contraction in housing demand and the surge in mortgage defaults.

5 Quantitative Analyses of the Boom-Bust Cycle

Equipped with a model that can generate economic dynamics that are close to the data, we now study the drivers of the boom-bust cycle. Section 5.1 quantifies the contribution of each shock to the boom and the bust, and Section 5.2 disentangles the credit supply mechanism behind these results.

5.1 The Importance of Leverage and Housing Demand Shocks

In this section, we quantify the separate contributions of the bank leverage shock and the housing demand shock to the boom and bust phases (Table III). For the boom period, the contribution of each shock corresponds to the peak changes (1998–2006) from the single-shock economies analyzed in Section 4.2.1. These are reported under the "Boom/Only" columns of Table III, alongside the benchmark boom for comparison. As we discuss below, assessing the bust contributions requires a different approach: rather than tracing the unwinding of an isolated single-shock boom, we evaluate how each shock contributes to the downturn when hitting the economy at the peak of the full benchmark boom.

Because the underlying mechanisms interact, adding them sequentially to measure relative contributions would make findings sensitive to the ordering of the decomposition. We therefore evaluate the contribution of each shock in isolation by closing all other channels. In addition, to ensure our bust decomposition is not masked by policy interventions, we hold all other parameters and factors at their peak boom levels, and set the bailout amount to zero, and compute the downturn generated by that single shock. Because bailouts are absent both in the boom and in this counterfactual experiment, the change in a variable from the peak of the boom to the trough isolates the unmitigated contribution of that specific factor.

Focusing on the contribution of each shock to the boom, we find that the leverage shock accounts for virtually all of the decline in the bank lending rate (-0.4 percentage points) and the resulting rise in firm borrowing (3.7%) and wages (4.1%). It more than fully accounts

Table III – Contributions of the Leverage Shock (LS) and Housing-Demand Shock (HDS)

	Boom			Bust		
	Benchmark	Only		Benchmark	Only	
	$\Delta x_{(\text{LS + HDS})}$	Δx_{LS}	Δx_{HDS}	$\Delta x_{(\text{LS + HDS +Bailout})}$	Δx_{LS}	Δx_{HDS}
Bank lending rate (Δr_ℓ)	-0.4	-0.4	0.0	5.2	5.4	0.6
Firm loans ($\%\Delta L_k$)	1.8	3.7	-1.1	-5.6	-6.8	0.2
Output ($\%\Delta Y$)	1.5	3.4	-1.1	-2.0	-3.1	0.6
Wages ($\%\Delta w$)	3.8	4.1	0.1	-8.2	-7.4	-2.1
Consumption ($\%\Delta C$)	3.8	3.5	0.6	-9.7	-5.9	-4.9
Price/Rent ($\%\Delta$)	38.0	8.1	22.0	-31.8	-16.8	-24.5
Homeownership rate (Δ)	1.4	1.6	0.4	-2.8	-2.5	-0.4
Mortgage Debt ($\%\Delta$)	106.7	64.9	32.1	-19.2	-14.5	-11.6
House price ($\%\Delta p_h$)	31.9	9.4	17.1	-35.4	-13.2	-24.9
Foreclosure rate(Δ)	0.0	0.0	0.0	3.6	0.0	1.6

Note: The table reports the results where we decompose the role of leverage and housing demand shocks. "LS" refers to leverage shock, "HDS" refers to housing demand shock. "Only" columns report the results with only one of the shocks. In the boom, they report the changes at the peak (2006) in the single-shock economies shown in Figure 3. In the bust, they report the changes generated by a single bust shock that hits the economy at the peak of the benchmark boom, keeping all other parameters at their boom levels and without bailouts. The percent decline in the bust is calculated with respect to the value in that period had the bust not happened.

for the rise in aggregate output (3.4% under leverage alone versus 1.5% in the benchmark, where the housing demand shock pulls output down). It also generates a 3.5% increase in consumption (accounting for over 90% of the 3.8% benchmark gain), well over half of the expansion in mortgage debt (64.9%), and the bulk of the rise in the homeownership rate (1.6 percentage points). Furthermore, it raises the price-rent ratio by 8.1%, accounting for more than a fifth of the 38.0% benchmark increase.

In contrast, while the housing demand shock generates a larger increase in the price-rent ratio (22.0%), it reduces aggregate output (−1.1%), reduces firm borrowing (−1.1%), and contributes only modestly to the rise in consumption (0.6%). As shown in the impulse responses, the housing demand shock diverts savings into residential housing and depresses productive capital accumulation. This contraction in capital acts as a drag on production and labor demand, explaining why the joint expansion of output (1.5%) and wages (3.8%) in the benchmark boom is smaller than what the leverage shock generates on its own (3.4% and 4.1%, respectively). Thus, while both shocks lift housing valuations, within the model's comparison of these two shocks the housing demand experiment does not generate the broad-based expansion in firm credit and real activity produced by the leverage shock.

Turning to the bust, each shock alone generates a large downturn in the absence of bailouts (the Bust / Only columns in Table III). In fact, the sum of the busts generated by each individual shock exceeds the benchmark downturn for most variables. This occurs both because the two shocks interact non-linearly on bank balance sheets and because government bailouts significantly mitigated the actual crisis in the benchmark economy. Thus, our analysis suggests that the crisis would have been substantially more severe in the absence of these interventions.[35]

The two shocks play notably different roles in the bust. The leverage shock generates virtually all of the credit contraction: the bank lending rate rises by 5.4 percentage points under leverage alone, more than the 5.2 percentage point benchmark spike, while under the housing demand shock alone the bank lending rate rises only modestly (0.6 percentage points). Correspondingly, the leverage shock drives sharp drops in output (−3.1%), wages (−7.4%), and consumption (−5.9%). In contrast, the housing demand shock on its own causes a 2.1% decline in wages, leaves output slightly higher on impact (+0.6%), and generates a smaller consumption contraction (−4.9%).

The housing demand shock generates a larger decline in the price-rent ratio (−24.5% versus −16.8%) and plays a dominant role in foreclosure dynamics. Specifically, it generates a substantially larger spike in foreclosures than the leverage shock alone (1.6 versus 0.0 percentage points), reflecting that the loss of the ownership benefit makes foreclosure a more attractive option for a given price-rent decline.

Even though the bank balance sheet channel amplifies the bust generated by each shock, manifesting itself in a spike in the bank lending rate and concurrent declines in output and wages, the results indicate that this amplification operates almost entirely through the

[35]We do not report the amount of bust mitigated by the bailouts. In principle, we could compute the amount of bust generated by both shocks without bailouts, call it $\Delta x_{\text{LS+HDS}}$. Then the difference between the benchmark and the bust generated by this exercise would be the effect of bailouts: $\Delta x_{\text{bailout}} = \Delta x_{(\text{LS + HDS +Bailout})} - \Delta x_{(\text{LS+HDS})}$. However, as we noted earlier, the bank net worth becomes negative in the bust in the absence of bailouts. Figuring out how the economy evolves from that point generates further complications for our analysis. Thus, we cannot obtain $\Delta x_{\text{LS+HDS}}$. An alternative is to compute the effect of the bailouts as $\Delta x_{\text{bailout}} = \Delta x_{(\text{LS + HDS +Bailout})} - (\Delta x_{\text{LS}} + \Delta x_{\text{HDS}})$, which can be read as the residual from Table III. To the extent that $\Delta x_{\text{LS}} + \Delta x_{\text{HDS}} = \Delta x_{\text{LS+HDS}}$, these two exercises would give similar results. However, this equality does not necessarily hold since the ordering of decomposition matters.

leverage shock. The housing demand shock, on its own, does not generate high enough foreclosures or balance-sheet damage to trigger a large contraction in credit supply.

We conclude this section with three remarks. First, we find large effects of credit supply on the price-rent ratio, despite employing a housing and mortgage structure similar to that of Kaplan et al. (2020), henceforth KMV. Our analysis differs from theirs in three key aspects. Firstly, the credit supply shock in our framework is not an isolated shock to households, as firms' production also depends on bank credit. Consequently, credit supply operates not only *directly* through household borrowing costs, but also *indirectly* by influencing firms' borrowing costs and labor demand, and thus household income. We analyze the relative importance of these direct and indirect channels in Section 5.2.1. Secondly, we model permanent changes in bank leverage that translate into persistent changes in the bank lending rate, rather than the LTV, PTI, or transitory interest-rate shocks considered in Kaplan et al. (2020). In our model, permanent changes in the bank lending rate have large effects since labor income permanently increases. We quantify the importance of the permanent versus transitory shock in Appendix C.1 (Figure C.1). On the other hand, endogenous borrowing constraints render LTV and PTI limits almost irrelevant, similar to KMV.[36] Thirdly, credit supply is endogenous in our model: exogenous shocks generate changes in bank net worth, which translate into changes in credit supply. This mechanism is particularly important during the bust. We highlight the importance of this bank balance-sheet channel in Section 5.2.2.

Second, Adelino et al. (2016), Albanesi et al. (2022), and Foote et al. (2021) find that credit grew uniformly across income groups during the boom period, a result that has been interpreted as evidence against the credit supply channel since the previous literature considered the credit supply channel to be more relevant for lower-income households. We show that in fact the bank leverage shock alone can generate uniform credit growth across income groups (see left panel of Figure 2).

Third, housing demand and leverage shocks generate different comovement patterns: while credit supply expansions generate a positive comovement between firm and mortgage debt alongside falling lending rates, housing demand expansions do not. The empirical analysis in Section 6 shows that the data are consistent with the implications of the credit supply shock.

[36] See Figure C.2 in Appendix C.2.

5.2 Credit Supply Mechanism Disentangled

In this section, we conduct a series of counterfactual experiments to evaluate how changes in credit supply generate a significant boom-bust cycle in the economy. Because credit supply shocks operate through movements in the bank lending rate $\mathfrak{r}_\ell$, we focus on the effects of these changes and decompose their total impact into a direct channel (affecting household borrowing costs) and an indirect channel (affecting firm borrowing costs and, consequently, labor income). In the first experiment, we quantify the share of the boom-bust cycle accounted for by the path of the bank lending rate $\mathfrak{r}_\ell$ arising from the leverage shock alone, decomposing its impact into direct and indirect channels. The second experiment separates the permanent rate movements driven by regulatory leverage changes from the transitory spike caused by bank balance-sheet distress, isolating the extent to which this temporary credit contraction deepened the bust in our benchmark.

5.2.1 Direct and Indirect Effects of the Bank Lending Rate on the Boom-Bust

To analyze the role of the changes in the bank lending rate $\mathfrak{r}_\ell$ for the contribution of the leverage shock to the boom-bust cycle, we compute the boom-bust dynamics generated when all shocks are shut down and the benchmark $\mathfrak{r}_\ell$ sequence from the leverage shock generated in Section 5.1 is fed into the economy (as two unexpected shocks), while all other prices are solved endogenously. Results are shown under the "Leverage shock total $\mathfrak{r}_\ell$ effect" column in Table IV.

During the boom, the decline in $\mathfrak{r}_\ell$ (which is expected to be permanent) reflects the exogenous increase in bank leverage since the endogenous changes in bank balance sheets have a minimal effect. Thus, the total contribution of $\mathfrak{r}_\ell$ to the boom is very similar to the contribution of the leverage shock. Overall, the decline in $\mathfrak{r}_\ell$ generates increases of 4.1, 8.1, and 3.5 percent in wages, the price-rent ratio, and consumption, respectively.

Then we generate an $\mathfrak{r}_\ell$-induced bust by increasing $\mathfrak{r}_\ell$ unexpectedly (the leverage only shock bust sequence) while the economy is at the peak of the benchmark boom. The total effect of $\mathfrak{r}_\ell$ causes a 7.4 percent decline in wages, accounting for most of the 8.2 percent benchmark wage decline, which shows that the rise in $\mathfrak{r}_\ell$ is the primary cause of the decline in wages at the time of the bust. The total effects of $\mathfrak{r}_\ell$ on the price-rent ratio and consumption are

Table IV – Roles of Bank Lending Rate and Labor Income

	Benchmark	Leverage shock	Total r_ℓ effect decomposed	
	Boom	total r_ℓ effect	r_ℓ direct	wage effect
Bank lending rate (Δr_ℓ)	-0.4	-0.4	-0.4	–
Wages ($\%\Delta w$)	3.8	4.1	–	4.1
Price/Rent	38.0	8.1	3.4	2.2
Consumption ($\%\Delta C$)	3.8	3.5	0.2	3.5
	Bust			
Bank lending rate (Δr_ℓ)	5.2	5.4	5.4	–
Wages ($\%\Delta w$)	-8.2	-7.4	–	-7.4
Price/Rent	-31.8	-16.8	-14.8	-11.2
Consumption ($\%\Delta C$)	-9.7	-5.9	-0.6	-5.5

Notes: This table reports results on the role of bank lending rate $r_\ell$on house prices and consumption for the boom and bust separately. The "Total r_ℓ effect" column reports the results where the benchmark r_ℓ sequence in Figure 4 is fed into the economy (all prices are allowed to react but parameters are fixed). The "r_ℓ direct"column reports the results where all prices (except the house prices) and parameters are fixed. The "wage effect" column reports the results where the wage sequence from the "Total r_ℓ effect" exercise is fed into the economy while keeping the interest rate, the return on capital, and the parameters unchanged. The p_h and p_r are linked by the formula derived from the first-order condition of the rental company. Only focusing on changes in p_h keeping p_r constant does not significantly alter the results.

declines of 16.8 and 5.9 percent, respectively. [37]

Under the column "r_ℓ direct" we measure the direct effect of r_ℓ on the boom by feeding into the economy the r_ℓ boom sequence (a decline of 0.4 percentage points) keeping all parameters, the wage rate w and the return on capital r_k fixed at their steady-state levels. Under the column "wage effect" we measure the indirect effect of r_ℓ by feeding into the economy the boom wage sequence (obtained from the "Total r_ℓ effect" exercise), keeping parameters, r_ℓ and r_k at their steady-state levels. In both exercises, we solve house prices and rents endogenously. We follow the same methodology and terminology in Table V in Section 5.2.2.

These exercises show that the decline in r_ℓ during the boom generates a 3.4 percent increase in the price-rent ratio directly through household borrowing costs, and a 2.2 percent increase

[37]Notice that the effect of r_ℓ is broadly comparable to the effect of the leverage shock during the bust, but this does not have to be the case since the housing demand shock as well as bailouts play important roles in determining r_ℓ. The increase in r_ℓ from only the leverage shock is 5.4 percentage points, very close to the benchmark increase in r_ℓ, which is 5.2 percentage points.

indirectly through firm borrowing rates and labor income. The indirect channel is overwhelmingly more important for consumption: the labor income channel raises consumption by 3.5 percent, while the direct effect on household borrowing costs raises it by only 0.2 percent. This pattern reflects the fact that the changes in consumption are driven mainly by the changes in labor income and house prices, both of which respond to the wage channel.

In the bust period, the full path of r_ℓ directly lowers the price-rent ratio by 14.8 percent and consumption by 0.6 percent. The indirect wage channel generates an 11.2 percent decline in the price-rent ratio and a 5.5 percent decline in consumption, again accounting for the bulk of the consumption decline.

Comparing the boom and bust direct effects shows that, given the size of the r_ℓ change, a permanent decline in r_ℓ has a much larger direct effect on the house price than a (largely) temporary spike: a semi-elasticity of 8.5 (=3.4/0.4) in the boom versus 2.7 (=14.8/5.4) in the bust. The large gap between these semi-elasticities clarifies why the effect of interest rates on the price-rent ratio in the boom is higher than those found in the recent literature, such as KMV, Adelino et al. (2025) and Glaeser et al. (2013). Our results show that the effect of interest rates on the price-rent ratio depends critically on two things: (i) how persistent the interest rate shock is, and (ii) whether interest rates affect wages. Once the indirect wage channel is included, the boom semi-elasticity rises further, to 20.3 (=8.1/0.4). In contrast, the bust-period increase in r_ℓ has a much smaller direct effect on the price-rent ratio per percentage point, and the implied semi-elasticity is therefore closer to empirical estimates that identify the effects of temporary interest rate movements.

5.2.2 Role of Bank Balance Sheet Deterioration in the Bust

The 5.2 percentage point increase in the bank lending rate at the time of the bust reflects both the exogenous tightening of the bank leverage constraint and the temporary endogenous contraction of the credit supply due to the bank balance sheet deterioration during the bust period. Here, we focus on the latter and quantify the amplification generated solely by the bank balance sheet deterioration, which manifests itself as a 4.8 percentage point increase in the bank lending rate during the bust. To isolate the effect of this spike, we run an experiment where, at the peak of the boom, the economy is shocked with the same 4.8 percentage point increase in the bank lending rate. We solve all other prices endogenously.

Table V reports the results of this exercise and compares them with the benchmark. Quanti-

Table V – The Role of the Bank Balance Sheet Deterioration in the Bust

Variables	Benchmark Bust Δ%	Total effect of the spike in r_ℓ	Direct effect of the spike in r_ℓ
Bank lending rate (Δr_ℓ)	5.2	4.8	4.8
Wages ($\%\Delta w$)	-8.2	-6.3	–
Price/Rent	-31.8	-12.6	-12.6
Consumption ($\%\Delta C$)	-9.7	-3.1	-0.3

Notes: This table reports results on the role of the spike in the bank lending rate $r_\ell$during the bust on house prices and consumption. The "Total effect of the spike in r_ℓ" column reports the results where the 4.8 percentage point spike in r_ℓ is fed into the economy at the peak of the boom (all prices are allowed to react, but parameters are fixed). The "Direct effect" column reports the results where all prices except the house prices are fixed at the boom level.

tatively, the deterioration in bank balance sheets produces a 6.3 percent decline in wages, accounting for about three-quarters of the 8.2 percent decline in the benchmark. It also generates a 3.1 percent decline in consumption, explaining about one-third of the benchmark consumption decline of 9.7 percent.

The temporary spike in r_ℓ also accounts for a substantial part of the decline in the price-rent ratio, generating a 12.6 percent fall, compared with the 31.8 percent decline in the benchmark. This effect operates almost entirely through the direct channel, which alone produces a 12.6 percent fall, reflecting the sharp decline in house prices on impact when household borrowing costs spike. Consumption falls by 0.3 percent under the direct borrowing-cost channel alone, so most of the consumption effect operates through the wage and labor-income channel.

5.3 Robustness

We check the robustness of our results to alternative parameterizations of the rental market segmentation parameter, the elasticity of substitution between consumption and housing, the coefficient of risk aversion, the elasticity of intertemporal substitution, the bank leverage level, and the labor utilization function curvature, which are externally set in our benchmark. For each alternative parameterization, we recalibrate the remaining parameters following our benchmark strategy and simulate the boom–bust dynamics. Across all variations, the quantitative dynamics remain very close to the benchmark, confirming that our core substantive conclusions are robust (Figures G.1 and G.2 in the Internet Appendix G).

6 Empirical Evidence

Our model reveals testable differences between credit supply and housing demand expansions. A credit supply expansion lowers the equilibrium bank lending rate, which in turn increases both household mortgage borrowing and firm borrowing. Thus, mortgages and firm loans move in the same direction alongside falling lending rates. In contrast, under a housing demand shock, mortgage debt rises strongly while r_ℓ does not fall to stimulate firms.

Furthermore, our model links the credit supply expansion directly to the increase in bank leverage. Thus, an increase in bank leverage should be accompanied by a decline in the bank lending rate r_ℓ as well as simultaneous expansions in lending to both firms and households (in mortgages).

In this section, we provide three sets of results supporting the credit supply mechanism: (i) mortgages and firm loans comove at county and bank levels; (ii) lower lending rates are associated with higher mortgage debt, house prices, firm loans, employment, and labor income; and (iii) higher bank leverage is associated with lower lending rates and expanded credit.

We view these correlations as consistency checks rather than causal estimates, which are established in prior quasi-experimental work (Jayaratne and Strahan (1997), Favara and Imbs (2015), Chodorow-Reich (2014), Ivashina and Scharfstein (2010), Benmelech et al. (2019), and Popov and Rocholl (2018)). Rather, our goal is to evaluate, on the boom-bust episode itself, the joint predictions that distinguish the credit supply channel from the housing demand channel in our model. Two caveats apply. Common demand shocks or reverse causality from housing markets to bank balance sheets could contribute to the raw comovements, and county-level average mortgage rates partly reflect lender and product composition, which adds measurement error to the pass-through estimates below. Two features provide discriminating power. First, the two hypotheses disagree on prices: a housing-demand-driven credit expansion does not lower the bank lending rate, whereas a credit-supply-driven expansion lowers it, so the behavior of lending rates separates the two channels even when loan quantities co-move. Second, the reverse channel (housing demand raising bank profits, net worth, and hence lending capacity, documented by Martín et al. (2021) for the Spanish housing boom) is itself part of our model, but quantitatively not strong enough to generate the observed decline in lending rates (Section 5.1).

Our evidence is also complementary to the demand-side mechanism of Mian and Sufi (2014), in which credit-fueled household demand raises employment in non-tradable sectors. In our model, wages rise instead because a financial supply shock lowers firms' working-capital costs economy-wide; both mechanisms can operate simultaneously, and the boom-period cross-section alone cannot fully separate them. For the bust, Giroud and Mueller (2017) provide quasi-experimental evidence that employment losses were concentrated in financially constrained, high-leverage firms, which supports the firm-side transmission that our model emphasizes.

We analyze changes during two key periods: from the pre-boom (1998) to the peak of the boom (2006), and from its peak to the end of the crisis (2011). This timeline aligns well with our quantitative analysis. Our results are robust to alternative choices for the beginning and end dates of the boom and bust periods. We specifically avoid using 2007 because the first signs of the financial crisis emerged that year. We choose 2011 as the end of the crisis period because bank failures peaked in 2010.

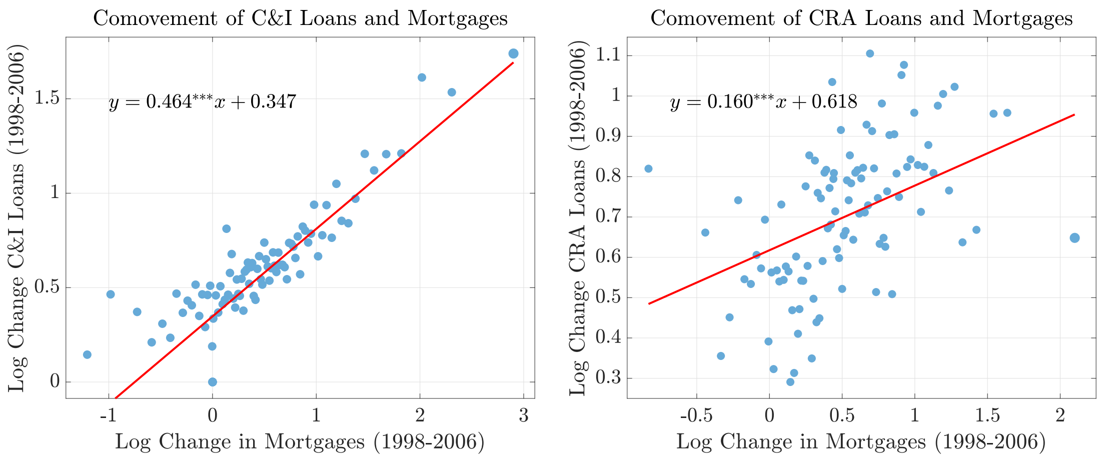
We use several datasets for our analysis. We use CoreLogic's Loan-Level Market Analytics (LLMA) to construct county-level averages of mortgage variables, including interest rates, FICO scores, house prices, loan origination amounts, mortgage type (FRM share), and loan-to-value ratios. We use Community Reinvestment Act (CRA) data for county-level small business lending and BLS county-level data on per-capita income and unemployment rates. We use Call Reports data for bank-level analysis, focusing on changes in bank capital ratios (the inverse of the bank leverage ratio), lending patterns, and various balance sheet measures. We provide information about the data as well as descriptive statistics in Appendix Section D.

6.1 The Comovement of Mortgages and Firm Loans

First, we analyze whether the changes in loans to firms and mortgages were positively correlated during the boom period. As we show in Table III, while the increase in bank leverage, and hence credit supply, increases both mortgage lending and firm lending, an increase in housing demand has a much weaker effect on lending to firms. We focus on the boom period, since during the bust, housing demand shocks can also generate a comovement between mortgages and firm loans because of their effects on credit supply.[38]

[38]The comovement is also strong in the bust in the data.

Figure 6 – The Comovement of Mortgages and Firm Loans During the Boom



Notes: The left panel of the figure plots the binscatter of log change in C&I loans and log change in closed-end first lien mortgages from 1998 to 2006. The data are from Call Reports. The right panel plots the binscatter of log changes in CRA loans and log changes in mortgage lending from 1998 to 2006 at the county level. The mortgage data are from CoreLogic. (*** Significant at 1%, ** Significant at 5%, * Significant at 10%).

We provide evidence of comovement from two data sets. First, we use bank-level Call Reports data and analyze how commercial and industrial (C&I) loans and mortgages in bank balance sheets changed from 1998 to 2006, the boom period. The left panel of Figure 6 plots our results, which suggest that bank mortgage lending and firm lending increased together during the boom period, supporting the credit supply mechanism of the paper.

Our second piece of evidence comes from county-level data. For mortgage lending, we use the CoreLogic originations data aggregated to the county level. For firm lending, we use the county-level CRA data, which cover bank lending to small firms by regulated banks. We report the results in Figure 6 (right panel), which shows that growth in firm loans and mortgages was strongly positively correlated at the regional level, as well.

These results are consistent with the credit supply mechanism. As credit supply increases, credit to households and firms increases together. If housing demand were the main driver of the boom, and credit supply played an insignificant role, we would not expect such comovement.[39]

[39]The positive comovement between firm loans and mortgages can also be generated by a productivity shock. However, as Figure F.1 in the Internet Appendix illustrates, while a positive productivity shock may lead to increases in both mortgages and firm loans, it also counterfactually results in an increase in bank lending rates.

6.2 County-level Evidence: Interest Rates and Economic Activity

Next, we use county-level variation in changes in mortgage interest rates to evaluate whether the data exhibit the comovements implied by the model's credit supply mechanism. In our quantitative model, an increase in credit supply lowers interest rates, which increases lending to firms and households. Since firms can finance at a lower rate, labor demand and wages increase. For each county, we calculate the changes in mortgage interest rates from 1998 to 2006 (boom), and from 2006 to 2011 (bust), and use these county-level changes in interest rates as proxies for the changes in credit supply during the boom and bust periods. Then, we examine how several county-level economic variables co-move with declines in county-level mortgage interest rates.

To evaluate this implication, we regress the changes in several variables from 1998 to 2006, and from 2006 to 2011 on changes in mortgage interest rates during the corresponding periods. We estimate the following model separately for the boom and bust periods:

$$\begin{aligned} \Delta \mathsf{Y}_{\mathtt{county},\{98-06,\,06-11\}} &= \beta + \alpha * \Delta \mathsf{r}_{\mathtt{county},\{98-06,\,06-11\}} + \\ &\quad \gamma \mathsf{CONTROLS}_{\mathtt{county}\,\{98,\,06\}} + \theta_{\mathtt{state}} + \epsilon_{\mathtt{county},\{98-06,\,06-11\}} \end{aligned} \tag{11}$$

where the dependent variables $\Delta \mathsf{Y}_{\mathtt{county},\ 98-06,\ 06-11}$ are the log changes in per-capita income, house prices, mortgage volume, firm lending, and changes in unemployment rate in a county during the boom (1998 to 2006) or the bust (2006-2011) period. The main explanatory variable is the county-level change in average mortgage interest rate during the respective period.

We also control for the initial county-level averages at the start of each period (1998 for the boom and 2006 for the bust), including average FICO scores, financial dependence, unemployment rates, housing appraised values (sale values give similar results), combined loan-to-value ratios, and the share of fixed-rate mortgages. We include state fixed effects $\theta_{\mathtt{state}}$ to account for state-level variation, such as differing policies. We cluster the standard errors at the state level.

Our quantitative model implies a negative correlation between the bank lending rate (i.e., a negative value for α) and per-capita income, house prices, mortgage volume, and firm lending, as well as a positive correlation (i.e., a positive α) with the unemployment rate.

Table VI – County-level Evidence

Panel A: Boom Period (1998-2006)

Explanatory Variables	(1) Unemployment Rate (change)	(2) Labor Income (log change)	(3) House Prices (log change)	(4) Mortgage Volume (log change)	(5) Firm Lending (log change)
Change in Mortgage Interest Rate	0.264***	-0.015**	-0.170***	-0.224***	-0.167**
	(0.094)	(0.006)	(0.058)	(0.076)	(0.069)
	0.007	0.024	0.005	0.005	0.019
Controls	Yes	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	2,566	2,572	2,572	2,573	2,570
R-squared	0.916	0.472	0.722	0.349	0.372

Panel B: Bust Period (2006-2011)

Explanatory Variables	(1) Unemployment Rate (change)	(2) Income (log change)	(3) House Prices (log change)	(4) Mortgage Volume (log change)	(5) Firm Lending (log change)
Change in Mortgage Interest Rate	1.107***	-0.076***	-0.449***	-0.156	-0.136**
	(0.394)	(0.014)	(0.087)	(0.133)	(0.051)
	0.007	0.000	0.000	0.247	0.011
Controls	Yes	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes	Yes
Observations	2,776	2,776	2,769	2,778	2,776
R-squared	0.825	0.459	0.735	0.582	0.273

Notes: The table reports estimates from weighted least squares regressions examining the relationship between changes in interest rates and county-level economic outcomes across different time periods (1998-2006 and 2006-2011), where the dependent variables are changes in unemployment rates, log changes in income, house prices, mortgage origination volumes, and lending to small firms in counties (CRA loans). The main independent variable is the change in average mortgage interest rates between periods in a county, and all regressions include county-level control variables measured at the start of each period: FICO scores, county financial dependence, unemployment rates, appraised values, combined loan-to-value ratios, and the share of fixed-rate mortgages. The dependent and explanatory variables are winsorized at the 1st and 99th percentiles to address potential outliers. The standard errors are clustered at the state level to account for within-group correlation. Results are reported with coefficient estimates, standard errors in parentheses, and corresponding significance levels (*** Significant at 1%, ** Significant at 5%, * Significant at 10%).

We use weighted least squares regressions (weighted by county labor force) to account for large heterogeneity in county sizes. The measurements from larger counties tend to be more precise, as they are based on larger samples, while small counties often show more variance in economic measures. Additionally, weighting helps address potential heteroskedasticity issues that arise from size-related variance in county-level data.

We report our results in Table VI. In panel A, we report the regression results from the boom period. In Panel B, we report the regression results from the bust period. For both periods, the coefficient signs are consistent with the model's credit supply mechanism. Conditional on the controls, counties with larger declines in mortgage interest rates had larger declines in unemployment and larger increases in labor income, house prices, mortgage volume, and firm lending. The estimated relationships are statistically significant for all reported outcomes except mortgage volume during the bust.

The estimated relationships are economically large. During the boom period, a one percentage point decrease in county-level mortgage interest rates is associated with a 0.264 percentage point reduction in unemployment rates. House prices increase by 0.170 log points, while mortgage volumes and firm lending increase by 0.224 and 0.167 log points, respectively. Income increases by 0.015 log points.[40]

The relationships are stronger during the bust. A one percentage point increase in county-level mortgage interest rates is associated with a 1.1 percentage point increase in unemployment rates. House prices decrease by 0.449 log points and income by 0.076 log points. Mortgage volumes and firm lending decline by 0.156 (not significant) and 0.136 log points respectively. The difference is most pronounced for real economic variables like unemployment and house prices.

We should note that the results are not directly comparable to the model findings since these results do not fully capture the general equilibrium forces. Moreover, as people can move across counties in response to relative changes in income, part of the response is absorbed by migration, so the cross-county estimates need not coincide with the aggregate responses in the model.

6.3 Bank-level Evidence

Our model implies that when bank leverage increases, bank lending increases and bank lending rates decline. Moreover, both bank lending in firm loans and mortgages increase. We evaluate these predictions using bank-level Call Reports data. We assess whether banks that lowered (or increased less) their capital ratios more during the boom (from 1998 to 2006) and bust (from 2006 to 2011) increased firm and mortgage lending more, and analyze their average bank lending rate movements. In particular, we estimate the following specification

[40] These numbers correspond to an 18.5 percent increase in house prices, a 25.1 percent increase in mortgage lending, an 18.2 percent increase in firm lending, and a 1.5 percent increase in income.

separately for the boom and the bust periods:

$$\Delta Y_{bank,\{98-06,06-11\}} = \beta + \alpha * \Delta CapitalRatio_{bank,\{98-06,06-11\}} + \gamma CONTROLS_{bank\{98,06\}} + \epsilon_{bank,\{98-06,06-11\}} \quad (12)$$

where the dependent variables $\Delta Y_{bank,\{98-06,06-11\}}$ are changes in bank total loans, C&I loans, household mortgages, and several measures of bank lending rate, during the boom and bust periods.[41] The main explanatory variable is the change in banks' capital ratio (equity/risk weighted assets) during the boom and the bust periods, which is the inverse of the leverage ratio in the model. We also control for major bank variables (log of total assets, liquidity ratio, cash-to-assets ratio, personal loans-to-assets ratio, commercial and industrial loans-to-assets ratio, securities-to-assets ratio, deposits-to-assets ratio, and residential loans-to-assets ratio) using values from the start of the boom and the bust periods. We cluster the standard errors at the bank holding company level.

The results are consistent with our model's predictions (Table VII). Both during the boom and the bust periods, banks that experienced larger declines in bank capital ratio (equivalently, larger increases in leverage) experienced larger increases in total loans, C&I loans and mortgages. They also experienced lower interest rates.

The comovement of bank capital ratios with lending and interest rates is economically significant. During the boom, a one standard deviation decline in bank capital ratio (0.061 in ratio units, or 6.1 percentage points) is associated with a 0.228 log point C&I loan growth (42.4 percent of mean growth), a 0.228 log point increase in total loan growth (38.4 percent of mean growth), and a 0.186 log point increase in mortgage loans (42.6 percent of mean growth). In parallel, lower capital ratios are associated with lower interest rate measures. The same one standard deviation decline in capital ratios is associated with a 0.12 standard deviation decline in interest income relative to loans and a 0.43 standard deviation decrease in net interest income relative to loans. Banks with larger declines in their capital ratios experienced stronger loan growth and larger declines in the reported lending-yield measures. These patterns are consistent with the model's leverage-expansion mechanism, but they do not identify a causal effect of lower capital.

[41] Following the banking literature, we use interest income relative to total loans, which is interest income divided by total loans.

TABLE VII – Bank-level Evidence

Panel A: Boom Period (1998-2006)

Explanatory Variables	(1) C&I Loans (log change)	(2) Total Loans (log change)	(3) Mortgages (log change)	(4) Average interest rate Interest Income on Loans (relative to loans, change)	(5) Average net interest rate Net Interest Income (relative to loans, change)
Change in Bank Capital Ratio (1/bank leverage)	-3.744***	-3.745***	-3.049***	0.004***	0.042***
	(0.211)	(0.147)	(0.203)	(0.001)	(0.002)
	0.000	0.000	0.000	0.000	0.000
Other Controls	Yes	Yes	Yes	Yes	Yes
Observations	5754	5,915	5854	5,904	5906
R-squared	0.122	0.223	0.133	0.032	0.259

Panel B: Bust Period (2006-2011)

Explanatory Variables	(1) C&I Loans (log change)	(2) Total Loans (log change)	(3) Mortgages (log change)	(4) Average interest rate Interest Income on Loans (relative to loans, change)	(5) Average net interest rate Net Interest Income (relative to loans, change)
Change in Bank Capital Ratio (1/bank leverage)	-3.318***	-3.212***	-3.300***	0.013***	0.127***
	(0.138)	(0.136)	(0.258)	(0.001)	(0.014)
	0.000	0.000	0.000	0.000	0.000
Other Controls	Yes	Yes	Yes	Yes	Yes
Observations	5643	5762	5663	5,753	5754
R-squared	0.194	0.342	0.240	0.377	0.448

Notes: The table reports estimates from least squares regressions examining changes in bank characteristics between 2006 and 2011 (Panel A) and between 1998 and 2006 (Panel B). The dependent variables include changes in commercial and industrial (C&I) loans, total loans, mortgage loans, and interest income measures. The main independent variable of interest is the change in equity ratio, measured as the changes from 1998 to 2006, and 2006 to 2011. All regressions include log of total assets, liquidity ratio, cash-to-assets ratio, personal loans-to-assets ratio, commercial and industrial loans-to-assets ratio, securities-to-assets ratio, deposits-to-assets ratio, and residential loans-to-assets ratio. The dependent and explanatory variables are winsorized at the 1st and 99th percentiles to address potential outliers. The standard errors are clustered at the bank holding company level to account for within-group correlation. Results are reported with coefficient estimates, standard errors in parentheses, and corresponding significance levels (*** Significant at 1%, ** Significant at 5%, * Significant at 10%).

7 Conclusion

In this paper, we developed a heterogeneous-agent model that features interactions between household, firm, and bank balance sheets and is consistent with important cross-sectional facts as well as the aggregate dynamics observed around 2008 in the United States. We used the model to evaluate the quantitative contributions of credit supply versus housing-demand shocks to the boom-bust.

We find that changes in bank leverage, calibrated to observed US data, account for a significant boom-bust in the price-rent ratio, household mortgage debt, firm borrowing, output, wages, and consumption around 2008. The credit supply expansion during the boom reduces the bank lending rate r_ℓ, which transmits through two distinct channels: a direct channel lowering household borrowing costs and an indirect channel lowering firm borrowing costs, boosting labor demand, and permanently raising equilibrium wages. This simultaneous reduction in borrowing costs generates a positive comovement between mortgage debt and firm credit alongside falling lending rates.

While shocks to housing demand can generate a larger boom-bust in the price-rent ratio, they have counterfactual implications for firm borrowing, output, and wages during the boom. Furthermore, they imply a much weaker firm-loan response during the boom. Specifically, while household mortgage debt increases strongly, the bank lending rate does not fall to stimulate firm credit. Consequently, the housing demand shock cannot generate the robust positive comovement between mortgage and firm debt driven by declining lending rates that characterizes the credit supply channel. We provide empirical evidence that the data are consistent with the credit-supply-driven comovement patterns.

On the other hand, the effects of both shocks are amplified in the bust due to endogenous declines in credit supply as banks are forced to cut back credit in response to declines in their equity. Thus, in the bust, both shocks generate declines in household mortgage debt and firm loans, resulting in a positive comovement driven by endogenous declines in credit supply.

Overall, we conclude that both exogenous shifts in credit supply associated with changes in bank leverage over the boom-bust cycle and endogenous contractions in credit supply caused by bank balance-sheet deterioration during the bust are important for understanding the boom-bust dynamics around 2008.

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APPENDIX

A Data Used in the Quantitative Analysis

Bank Book Leverage The data for banks are from Federal Reserve Bank of New York (2024); the data for securities brokers and dealers are from Board of Governors of the Federal Reserve System (2019).

GDP Real gross domestic product per capita, deflated using PCE chain-type price index (data series code: PCEPI), Quarterly, Seasonally Adjusted Annual Rate from FRED (data series code: GDP). We use quarterly data from 1985 to 2006 and linearly detrend it, and then take the percentage deviation of the data from 1985 to 2019 from this trend.

Aggregate Consumption Real personal consumption expenditures per capita, deflated using PCE chain-type price index (data series code: PCEPI), Quarterly, Seasonally Adjusted Annual Rate from FRED (data series code: PCE). We use quarterly data from 1985 to 2006 and linearly detrend it, and then take the percentage deviation of the data from 1985 to 2019 from this trend.

Labor Income Labor Income comes from FRED (data series code: BA06RC1A027NBEA) reported as total wages and salary by BLS. We deflate the data using the PCE chain-type price index (data series code: PCEPI). We linearly detrend it, and then take the percentage deviation of the data from 1985 to 2019 from this trend.

Total Bank Loans Total bank loans data come from FRED (data series code: QBPBSTASTLN). We annualize the data by taking the average of the quarterly observations, deflate them using the PCE chain-type price index (data series code: PCEPI). We linearly detrend it, and then take the percentage deviation of the data from 1985 to 2019 from this trend.

Homeownership Rate Homeownership rate data come from FRED (data series code: RHORUSQ156N). We annualize the data by taking the average of the quarterly observations in a year.

Price-Rent ratio The price-rent ratio is computed as the ratio of market value of owner-occupied real estate (data series code: BOGZ1FL155035013Q) and imputed rental of owner-occupied housing (data series code: A2013C1A027NBEA). Both data come from FRED.

House Prices House Price Index for the entire US (Source: Federal Housing Finance Agency) divided by the price index for nondurable consumption (line 6 of NIPA Table 2.3.4. Price Indexes for Personal Consumption Expenditures by Major Type of Product). We use quarterly data from 1985 to 2006 and linearly detrend it, and then take the percent deviation of the data from 1985 to 2018 from this trend. To obtain the changes relative to GDP, we divide the real house price index by the real GDP series.

Mortgage Debt Home Mortgage Liabilities. Source: Flow of Funds D3 Balance Sheet of Households and Nonprofit Organizations.

Foreclosure Rate Foreclosure data come from the Mortgage Bankers Association and are reported as the annual sum of foreclosures started in each quarter.

Credit Spread Credit spread data are the excess bond premium reported in Gilchrist and Zakrajšek (2012) and updated at `https://www.federalreserve.gov/econres/notes/feds-notes/ebp_csv.csv`

B Model Appendix

B.1 Value Functions for Households

B.1.1 Active Renters

An active renter has two choices: continue to rent or purchase a house, that is, $V^r = \max\left\{V^{rr}, V^{rh}\right\}$ where V^{rr} is the value function if she decides to continue renting and V^{rh} is the value function if she decides to purchase a house. If she decides to continue to rent, she chooses rental unit size s at price p_r per unit, makes her consumption and saving choices, and remains as an active renter in the next period. After purchasing a house, she begins the next period as a homeowner. The value function of an active renter who decides to remain as a renter is given by

$$V_j^{rr}(a,z) = \max_{c,s,a'\geqslant 0} \left\{\left(u_j(c,s) + \beta \mathrm{E}\left[V_{j+1}^r(a',z'\right]\right)\right\} \tag{B.1}$$

subject to

$$c + a' + p_r s = y(j,z) + a\,(1+r_k)\,,$$

where a is the beginning-of-period financial wealth, $p_r s$ is the rental payment, r_k is the return to savings, and w is the wage rate per efficiency unit of labor. The expectation operator is over the income shock z'.

B.1.2 Inactive Renters

Inactive renters are not allowed to purchase a house because of their default in previous periods. However, they can become active renters with probability π. Since they cannot buy a house, they only make rental size, consumption, and saving decisions. The value function of an inactive renter is given by

$$V_j^e(a,z) = \max_{c,s,a'\geqslant 0} \left\{u_j^d(c,s) + \beta\left[\pi \mathrm{E}\left[V_{j+1}^r(a',z')\right] + (1-\pi)\mathrm{E}\left[V_{j+1}^e(a',z')\right]\right]\right\} \tag{B.2}$$

subject to

$$c + a' + p_r s \;=\; y(j,z) + a\,(1+r_k)\,.$$

B.1.3 Homeowners

A homeowner's options are: 1) stay as a homeowner, 2) refinance, 3) sell the current house (become a renter or buy a new house), or 4) default. The value function of an owner is given as the maximum of these four options, that is, $V^h = \max\left\{V^{hh}, V^{hf}, V^{hr}, V^{he}\right\}$, where V^{hh} is the value of staying as a homeowner, V^{hf} is the value of refinancing, V^{hr} is the value of selling, and V^{he} is the value of defaulting (being excluded from the ownership option).

A stayer makes a consumption and saving decision given his income shock, housing, mortgage debt, and assets. Therefore, the problem of the stayer can be formulated as follows:

$$V_j^{hh}(a,h,d,z) = \max_{c,a'\geqslant 0} \left\{u_j(c,h) + \beta \mathrm{E}\left[V_{j+1}^h\left(a',h,d',z'\right)\right]\right\} \tag{B.3}$$

subject to

$$\begin{aligned} c + (\delta_h + \tau_h)\,p_h h + a' + m_j(d) &= y(j,z) + a\,(1+r_k) \\ d' &= \left(d - m_j(d)\right)(1+r_\ell)\,, \end{aligned}$$

where m is the mortgage payment following the standard amortization schedule computed at the bank lending rate r_ℓ.

The second choice for the homeowner is to refinance, which also includes prepayment. Refinancing requires paying the full balance of any existing debt and getting a new mortgage. We assume that refinancing is subject to the same transaction costs as new mortgage originations. So, we can formulate the problem of a refinancer as

$$V_j^{hf}(a,h,d,z) = \max_{c,d',a'\geqslant 0} \left\{u_j(c,h) + \beta E\left[V_{j+1}^h\left(a',h,d'',z'\right)\right]\right\} \tag{B.4}$$

subject to

$$\begin{aligned} c + d + (\delta_h + \tau_h)\, p_h h + \varphi_f I_d\,(d>0) + a' + m_j\left(d'\right) &= y(j,z) + a\,(1+r_k) + d'\left(q^m(d';a',h,z,j) - \varphi_m\right) \\ d' &\leqslant (1-\iota_d)\, p_h h,\ m_j\left(d'\right) \leqslant \iota_m y\,(j,z) \\ d'' &= \left(d' - m_j\left(d'\right)\right)(1+r_\ell) \end{aligned}$$

The third choice for the homeowner is to sell the current house and either stay as a renter or buy a new house. Selling a house is subject to a transaction cost equals a fraction φ_s of the selling price. Moreover, a seller has to pay the outstanding mortgage debt, d, in full to the lender, and the property taxes to the government. A seller, upon selling the house, can either rent a house or buy a new one. Her problem is identical to a renter's problem. So, we have

$$V_j^{hr}(a,h,d,z) = V_j^r\left(a + \frac{p_h h(1-\tau_h-\varphi_s)-d}{1+r_k}, z\right).$$

The fourth possible choice for a homeowner is to default on the mortgage, if she has one. A defaulter has no obligation to the bank. The bank seizes the house, sells it on the market, and returns any positive amount from the sale of the house, net of the outstanding mortgage debt and transaction costs, back to the defaulter. For the lender, the sale price of the house is assumed to be $(1-\varphi_e)\, p_h h$. Therefore, the defaulter receives $\max\{(1-\varphi_e)\, p_h h - d, 0\}$ from the lender. The defaulter starts the next period as an active renter with probability π. With probability $(1-\pi)$, she stays as an inactive renter. The problem of a defaulter becomes the following:

$$V_j^{he}(a,d,h,z) = \max_{c,s,a'\geqslant 0} \left\{u_j^d(c,s) + \beta E\left[\pi V_{j+1}^r\left(a',z'\right) + (1-\pi)\, V_{j+1}^e\left(a',z'\right)\right]\right\} \tag{B.5}$$

subject to

$$c + a' + p_r s = a\,(1+r_k) + y\,(j,z) + \max\{(1-\varphi_e)\, p_h h - d, 0\}.$$

The problem of a defaulter is different from the problem of a seller in three ways. First, the defaulter receives $\max\{(1-\varphi_e)\, p_h h - d, 0\}$ from the housing transaction, whereas a seller receives $(1-\tau_h-\varphi_s)\, p_h h - d$. We assume that the default cost is higher than the sale transaction cost, that is, $\varphi_e > \varphi_s + \tau_h$, and the defaulter receives less than the seller as long as $(1-\tau_h-\varphi_s)\, p_h h - d \geqslant 0$ (i.e., the home equity net of the transaction costs for the homeowner is positive). Second, a defaulter does not have access to the mortgage in the next period with some probability. Such an exclusion lowers the continuation utility for a defaulter. Third, a defaulter incurs a utility cost as long as s/he stays as an inactive renter. In sum, since defaulting is costly, a homeowner will choose to sell the house instead of defaulting as long as $(1-\tau_h-\varphi_s)\, p_h h - d \geqslant 0$ (i.e., net home equity is positive). Hence, negative equity net of selling costs and property taxes is a necessary condition for default in the model. Therefore, in equilibrium, a defaulter gets nothing from the lender.

B.1.4 Mortgage Contracts

The periodic payment m satisfies the standard amortization formula evaluated at the bank lending rate r_ℓ:

$$m_j(d) = d\,\frac{r_\ell(1+r_\ell)^{J-j}}{(1+r_\ell)^{J-j+1}-1},$$

where d is the outstanding principal. The formula follows the convention that the household pays before interest accrues within the period; outstanding debt next period is therefore $(d - m_j(d))(1+r_\ell)$.

B.2 Goods-Producing Firm's Problem

The goods-producing firm's first-order conditions are given as

$$\begin{aligned}
\alpha \mathbb{Z}\left(\frac{K}{N_g u}\right)^{\alpha-1} &= r_k + \delta_k \\
(1-\alpha)\mathbb{Z}u\left(\frac{K_t}{N_g u}\right)^{\alpha} &= \left(1+\mu r'_\ell\right)\left(\bar{w} + \vartheta\frac{u^{1+\psi}}{1+\psi}\right) \\
(1-\alpha)\mathbb{Z}\left(\frac{K_t}{N_g u}\right)^{\alpha} &= \left(1+\mu r'_\ell\right)\vartheta u^{\psi}.
\end{aligned}$$

B.3 Construction Companies' Problem

The first-order conditions for construction companies' problem are

$$\begin{aligned}
(1-\theta_h)\, p_h\left(\frac{L_p}{N_h}\right)^{\theta_h} &= w \\
\theta_h p_h\left(\frac{L_p}{N_h}\right)^{\theta_h-1} &= q_L
\end{aligned}$$

B.4 Government

The government runs a pay-as-you-go pension system. It collects social security taxes from working-age households and distributes to retirees. We assume the pension system runs a balanced budget:

$$\sum_{j=1}^{J_R}\sum_{z}\tau w \exp\left(f(j)+z\right)\pi_j(z) = \sum_{j=J_R+1}^{J}\sum_{z} y_R(j,z)\,\pi_j(z), \tag{B.6}$$

where $\pi_j(z)$ is the measure of individuals with income shock z at age j.

B.5 Definition of Equilibrium

We provide the definition of equilibrium for the steady state. The equilibrium definition for the transition is similar.

Definition 1. A Stationary Competitive Equilibrium is a collection of value functions for households, V^o $(o \in \{h, r, e\})$, for banks Ψ, for real estate companies, V^{rc}, policy functions for households' consumption (g_c), saving (g_a), housing services (g_s), housing stock (g_h), mortgage debt (g_d), tenure decisions (g_o), goods-producing firms' labor (N_g), capital (K), utilization (u), construction companies' labor demand, N_h, land permit demand, L_p, and new housing production, I_h, real estate companies' housing stock (H_r), banks' consumption (c_B), loans $\left(\ell, L^k, L\right)$, borrowing (B), prices for labor (w), capital (r_k), houses (p_h), land permits (q_L), rental properties (p_r), loans (r_ℓ, q^m), taxes (τ), and a stationary distribution (Γ) such that

1. Given prices and taxes, policy functions for households solve households' problems in equations B.1-B.5, and V^o are the associated value functions for households.

2. Given prices, firms' policy functions (K, N_g, u) solve firms' problem in equation 2.

3. Given prices, construction firms' policy functions (L_p, N_h, I_h) solve construction firms' problem in equation 3.

4. Given prices, real estate companies' policy function (H_r) solves equation 4.

5. Given prices, banks' policy functions(c_B, L, B) solve equation 6.

6. q^m solves equation 10. Given stationary distribution Γ, markets clear:

$$\text{asset market: } \int a d\Gamma(\theta) = A = K + V^{rc}(H_r)$$
$$\text{labor market: } N_g + N_h = 1$$
$$\text{housing market: } \int s d\Gamma(\theta) = H$$
$$\text{credit market:} L_k + \int_\theta p_\ell(\theta)\,\ell(\theta) = L$$
$$\text{rental market: } \int s d\Gamma(\theta, o \in \{r, e\}) = H_r$$
$$\text{land permit market: } L_p = \bar{L_p}$$

where $\delta_h H = I_h$, $L_k = \mu w(\bar{w}, u) N_g$ is the firm's borrowing, $\ell(\theta) = \Gamma(\theta)$, i.e. banks' mortgage holding is equal to the demand for mortgages by households, p_ℓ is given by $p_\ell(\theta) = \frac{1}{1+r'_\ell} \int_{\theta'} (m_\ell(\theta') + p_\ell(\theta'))\, \Pi(\theta'|\theta)$.

7. Given stationary distribution Γ, the government runs a balanced budget, i.e. τ solves equation B.6

8. The distribution Γ is stationary and consistent with the policy functions of households:

$$\Gamma = G(\Gamma)$$

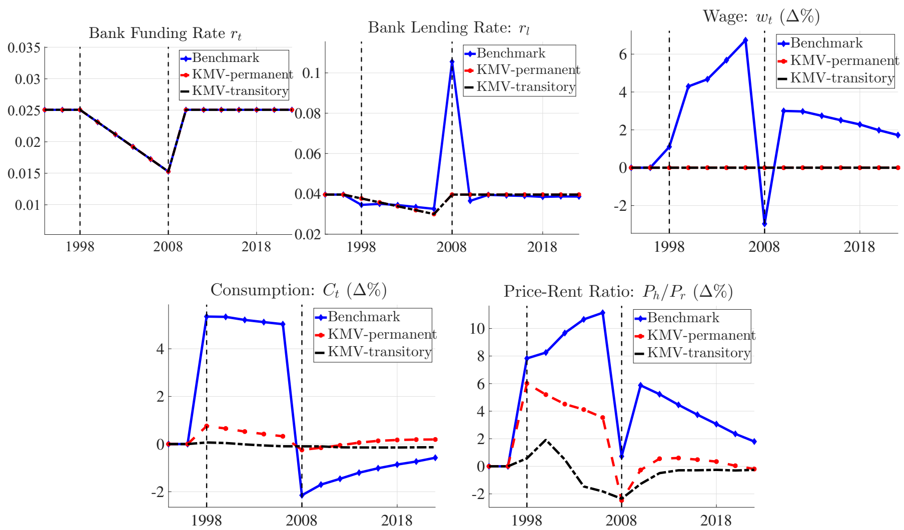
where the mapping G is obtained through the policy functions of households and evolution of exogenous states.

C Comparison to Kaplan et al. (2020)

C.1 Significance of Bank Balance Sheet and Wage Channels

In this section, we use our model to clarify why credit supply shocks have substantially larger aggregate effects in our framework than in Kaplan et al. (2020) (henceforth KMV). We focus on three differences between the two frameworks. First, changes in banks' funding conditions affect bank balance sheets and therefore need not translate one-for-one into bank lending rates. Second, changes in bank lending rates affect firms' borrowing costs and hence labor demand and wages, creating an additional transmission channel to household consumption and housing demand. Third, the credit supply shocks in our benchmark exercise are perceived as permanent, whereas KMV emphasize transitory shocks.

Figure C.1 – Model Dynamics with Credit Supply versus KMV



Notes: The graph plots dynamics when 100bp bank funding rate boom-bust is fed into the model. The "Benchmark" line shows the full model response. "KMV-permanent" line shows the KMV model response with the same shock. "KMV-transitory" line shows the KMV model response when shocks are transitory.

Because our benchmark credit supply shock operates through banks' leverage constraint, it does not have a direct counterpart in KMV, which does not model a bank leverage constraint. We therefore consider a bank funding-rate shock similar to the credit supply experiment in Section V.B of KMV. Beginning unexpectedly in 1998, the bank funding rate declines linearly by 100 basis points over the following ten years. In 2008, the shock is unexpectedly reversed and the funding rate returns toward its initial steady-state level. The resulting path of the funding rate is shown in the upper-left panel of Figure C.1.

Figure C.1 compares three experiments. The Benchmark specification uses our full model, allowing the funding-rate shock to affect bank balance sheets, the equilibrium bank lending rate, firms' borrowing costs, and wages. The KMV-permanent specification removes the bank-balance-sheet and wage channels: as in KMV, the funding rate is transmitted one-for-one to the bank lending rate, while wages and the return on capital are held fixed at their steady-state values. In both of these experiments, the initial decline in the funding rate is perceived as permanent until its unexpected reversal in 2008. Finally, the KMV-transitory specification also removes the bank-balance-sheet and wage channels but, following KMV, allows households to foresee the entire subsequent path of the funding rate. Thus, comparing the first two specifications isolates the importance of the bank-balance-sheet and wage channels, while comparing the latter two isolates the additional importance of shock persistence.

The results show that all three features matter. When the bank-balance-sheet and wage channels are shut down and the funding-rate shock is transitory, the effects on the price-rent ratio and consumption are very small, consistent with KMV. Making the shock permanent increases these responses, but only moderately. Allowing the funding-rate shock to operate through bank balance sheets and wages produces substantially larger effects.

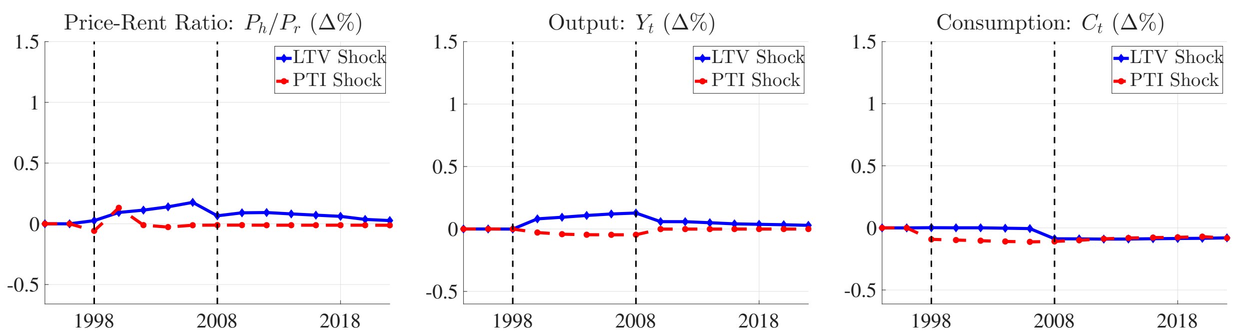
The bank-balance-sheet channel is particularly important during the bust. It has only a modest additional effect on the lending rate during the boom but generates a sharp increase in the lending rate when the funding shock is reversed. Because firms rely on bank credit to finance part of their wage bill, these movements in the lending rate also generate sizable movements in wages. The resulting combination of changes in household borrowing costs and labor income substantially amplifies the responses of housing and consumption. In the full model, the price-rent ratio rises by almost 12 percent during the boom and falls by about 10 percent during the bust, while consumption rises by about 4 percent and subsequently falls by about 6 percent.

C.2 LTV-PTI shocks

KMV also consider changes in maximum loan-to-value (LTV) and payment-to-income (PTI) limits as alternative credit supply shocks. We conduct analogous experiments in our model. In the benchmark calibration, the maximum LTV ratio is 95 percent. To generate a boom, we unexpectedly increase this limit to 110 percent in 1998, as in KMV, and then unexpectedly restore it to 95 percent in 2008. In a separate experiment, we generate the same boom-bust timing by relaxing the maximum PTI ratio from 25 percent to 45 percent in 1998 and unexpectedly restoring it to its initial level in 2008. Figure C.2 reports the resulting dynamics.

Both shocks have very small aggregate effects. The reason is that the statutory LTV and PTI limits are not binding for household borrowing in the benchmark economy. Given default risk and endogenous mortgage pricing, households face effective borrowing limits that are tighter than the imposed 95 percent LTV and 25 percent PTI ceilings. Relaxing these regulatory limits therefore does not materially change the mortgage terms available to households and consequently has little effect on housing demand, consumption, or output. Figure C.2 illustrates this near-neutrality result.

FIGURE C.2 – LTV and PTI Boom-Bust Experiments



Notes: This figure plots the model dynamics where LTV and PTI constraints are unexpectedly relaxed in 1998 and again unexpectedly restored to their original values in 2008. LTV constraint is relaxed from 95% to 110% and PTI constraint is relaxed from 25% to 45%.

D Data for Empirical Analysis

We combine several data sets for our analysis.

CoreLogic: From CoreLogic, we use the Loan-Level Market Analytics (LLMA) originations data set, which contains detailed loan-level data on individual residential mortgage loans in the United States. The data set provides information about loan and borrower characteristics at origination, such as interest rates, loan amounts, loan-to-value ratios, property ZIP code and appraisal value, borrower FICO scores, and loan types (ARM or FRM).

We calculate county-level yearly averages of key mortgage variables from 1998 to 2011. In particular, for each county and year, we calculate the averages of mortgage interest rates, loan amounts, combined loan-to-value ratios, appraised values (we use these instead of sales price since the data are more available), and the share of FRMs in a county at origination.

We use county-level variation in mortgage interest rates to evaluate whether the data exhibit the comovements implied by the model's credit supply mechanism. In our quantitative model, an increase in credit supply lowers interest rates, which increases lending to firms and households. Since firms can finance at a lower rate, labor demand and wages increase. For each county, we calculate the changes in mortgage interest rates from 1998 to 2006 (boom), and from 2006 to 2011 (bust), and use these county-level changes in interest rates as measures of changes in credit supply conditions during the boom and bust periods. We control for the average FICO score on mortgages in each county since this might affect the level of mortgage interest rates.

Table D.1 gives summary statistics of these data. During the boom period (1998-2006), counties experienced significant increases in lending and asset values, with mortgage volume growing by an average of 98.6 percent and small business lending surging by 117.6 percent. House values appreciated, on average, 60.4 percent in nominal terms. This period was characterized by declining mortgage interest rates (average decrease of 1.02 percentage points) and favorable labor market conditions, with a slight decrease in unemployment (-0.25 percentage points) and substantial growth in per-capita income (37 percent). Loan-to-value ratios increased from an average of 77.1 percent in 1998 to 81.3 percent in 2006, suggesting higher leverage during the boom period. The bust period (2006-2011) saw a reversal: unemployment rose sharply (average increase of 3.87 percentage points), mortgage volumes contracted by 33 percent, and small business lending fell by 31.7 percent.

Community Reinvestment Act (CRA): The Community Reinvestment Act (CRA) requires that large banks annually report small business lending data at the county level. This helps us study credit to (relatively small) firms at the county-level.

Other data: To study the effect of credit supply on the labor market, we use county-level per-capita income and unemployment data from the BLS. To control for firm loan demand at the county level, we construct a county external financial dependence measure for each county following Arslan et al. (2025).

US Call Reports: The bank balance sheet data come from the Call Reports, which are submitted by banks subject to regulation by the Federal Reserve System, Federal Deposit Insurance Corporation, and the Comptroller of the Currency. We obtain the data from Drechsler et al. (2021), and complement it with additional data from Wharton Research Data Services (WRDS). We drop the smallest 10 percent of the banks.[42]

For the boom (1998 to 2006) and the bust (from 2006 to 2011) periods, we calculate the changes in risk-weighted capital ratio, which is our main explanatory variable.[43] We also construct a set of additional control variables. Consistent with existing literature on bank lending behavior, we include the bank liquidity ratio (normalized by bank assets) and bank size (the logarithm of bank assets), and the shares (relative to total assets) of C&I loans, mortgages, personal loans, deposits, and cash, in the balance sheets of the banks at the beginning of the boom and bust periods. For each bank, we construct multiple dependent variables: log changes in C&I loans, total loans, and mortgages; and changes in interest income on loans (relative to loans); and net interest income (relative to loans).

[42]As of 2006, this corresponds to banks with assets greater than about 11 million USD.

[43]The results are robust to using total assets.

Table D.1

Panel A: 1998-2006 Period	Observations	Mean	Median	Std. Dev.	Min	Max
Dependent Variables						
Change in Unemployment Rate (1998-2006). Source: BLS	2733	-0.25	0.20	2.35	-19.40	7.70
% Change in per-capita income (1998-2006). Source: BLS	2697	37.01	35.67	14.11	-16.67	284.09
% Change in appraised house value (1998-2006). Source: CoreLogic	2709	60.38	51.14	54.40	-64.04	1280.30
% Change in mortgage volume (1998-2006). Source: CoreLogic	2712	98.57	63.90	155.39	-90.34	3622.71
% Change in lending to small firms (1998-2006). Source: CRA	2740	117.60	67.53	349.16	-84.88	9602.53
Control Variables						
Change in average mortgage interest rate in a county (1998-2006). Source: CoreLogic	2712	-1.02	-0.87	0.71	-10.35	2.81
Average FICO score in 1998. Source: CoreLogic	2710	684.10	686.62	28.29	541.20	798.00
Unemployment rate in 1998. Source: BLS	2740	5.49	4.60	3.40	1.00	30.10
Average appraised house value in 1998. Source: CoreLogic	2719	122551.21	108701.62	64162.73	18034.00	1497679.11
Average combined LTV in 1998. Source: CoreLogic	2719	77.14	77.61	5.26	17.00	107.02
Share of FRMs in 1998 (originations). Source: CoreLogic	2707	0.89	0.90	0.08	0.00	1.00

Panel B: 2006-2011 Period	Observations	Mean	Median	Std. Dev.	Min	Max
Control Variables						
Change in Unemployment Rate (2006-2011). Source: BLS	3013	3.87	3.60	2.04	-3.70	14.30
% Change in per-capita income (2006-2011). Source: BLS	2973	21.61	18.59	15.92	-47.89	198.91
% Change in appraised house value (2006-2011). Source: CoreLogic	2931	11.99	11.42	25.17	-76.41	176.28
% Change in mortgage volume (2006-2011). Source: CoreLogic	2945	-32.97	-36.68	32.02	-99.32	387.64
% Change lending to small firms (2006-2011). Source: CRA	3025	-31.68	-36.55	35.69	-94.43	327.46
Control Variables						
Change in average mortgage interest rate in a county (2006-2011). Source: CoreLogic	2945	-2.62	-2.64	0.50	-6.75	4.36
Average FICO score in 2006. Source: CoreLogic	2992	680.25	680.38	20.68	515.50	775.67
Unemployment rate in 2006. Source: BLS	3016	5.21	4.80	2.12	1.60	20.70
Average appraised house value in 2006. Source: CoreLogic	2990	191119.12	155903.33	121935.21	36850.00	1964071.54
Average combined LTV in 2006. Source: CoreLogic	2955	81.30	82.00	5.87	37.69	107.37
Share of FRMs in 2006 (originations). Source: CoreLogic	2989	0.78	0.80	0.12	0.00	1.00

We report descriptive statistics in Table D.2. During the boom (1998-2006), banks experienced strong loan growth across all categories, with total loans increasing by 59.4 percent, C&I loans growing by 53.8 percent, and first-lien residential mortgages expanding by 43.7 percent. Interest income on loans relative to total loans decreased by 0.4 percentage points. The bust period (2006-2011) showed significantly slower loan growth: total loans grew by 23.9 percent, C&I loans by 13 percent, and residential mortgages by 31.7 percent. Banks' risk-weighted capital ratios decreased during the boom (-1.6 percentage points) and increased during the bust (0.3 percentage points).[44]

[44] The increase in bank equity ratios becomes significantly larger in later years.

Table D.2

Panel A: 1998-2006 Period	Observations	Mean	Median	Std. Dev.	Min	Max
Dependent Variables						
Log Change in Commercial and Industrial Loans.	7084	0.538	0.426	0.820	-1.605	3.304
Log Change in Total Loans.	7313	0.594	0.495	0.632	-0.739	2.934
Log Change in First-Lien Residential Mortgages.	6929	0.437	0.322	0.687	-1.208	3.073
Change in Interest on Loans/Total Loans.	7044	-0.004	-0.004	0.002	-0.012	0.000
Change in Net Interest Income/Average Loans.	7044	-0.003	-0.002	0.006	-0.043	0.010
Control Variables						
Change in Risk-Weighted Capital Ratio.	7215	-0.016	-0.004	0.061	-0.293	0.165
Log of Total Assets in 1998.	6138	11.501	11.282	1.190	9.526	19.511
Liquidity Ratio in 1998.	6138	0.347	0.333	0.142	0.015	0.794
Cash to Assets Ratio in 1998.	6138	0.065	0.050	0.064	0.000	1.000
Personal Loans to Assets Ratio in 1998.	5928	0.088	0.072	0.080	0.000	1.015
Commercial and Industrial Loans to Assets Ratio in 1998.	6138	0.111	0.089	0.103	0.000	1.007
Securities to Assets Ratio in 1998.	6138	0.293	0.280	0.145	0.000	0.986
Real Estate Loans to Assets Ratio in 1998.	5928	0.179	0.154	0.129	0.000	0.613

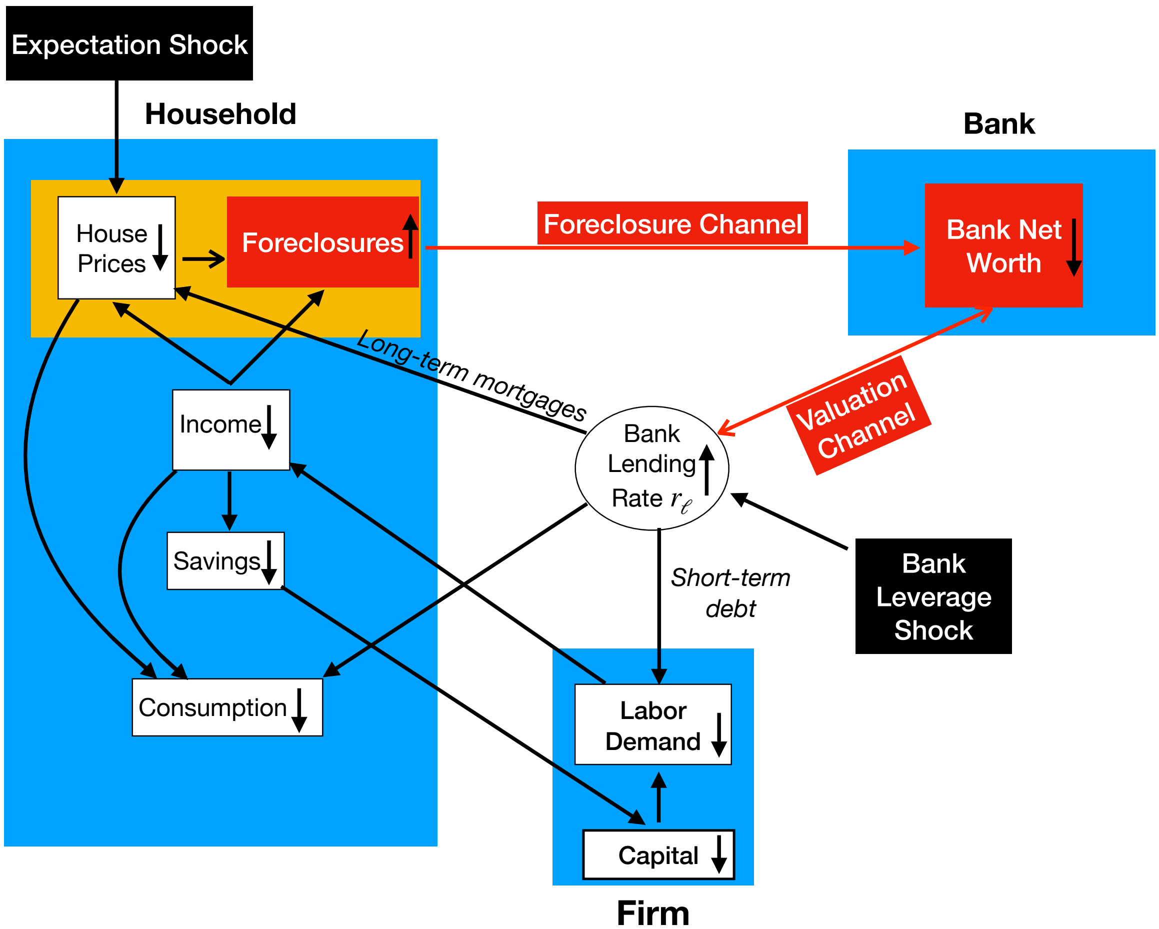
Panel B: 2006-2011 Period	Observations	Mean	Median	Std. Dev.	Min	Max
Dependent Variables						
Log Change in Commercial and Industrial Loans.	6164	0.130	0.051	0.678	-1.617	2.642
Log Change in Total Loans.	6306	0.239	0.153	0.475	-0.661	2.493
Log Change in First-Lien Residential Mortgages.	5997	0.317	0.187	0.626	-0.920	3.093
Change in Interest on Loans/Total Loans.	6062	-0.005	-0.004	0.003	-0.016	0.000
Change in Net Interest Income/Average Loans.	6063	-0.003	0.000	0.017	-0.150	0.011
Control Variables						
Change in Risk-Weighted Capital Ratio.	6148	0.003	0.012	0.080	-0.502	0.179
Log of Total Assets in 2006.	6013	12.046	11.813	1.309	9.950	20.873
Liquidity Ratio in 2006.	5989	0.285	0.258	0.159	0.010	0.847
Cash to Assets Ratio in 2006.	6005	0.056	0.040	0.063	0.000	0.991
Personal Loans to Assets Ratio in 2006.	5791	0.056	0.040	0.075	0.000	1.024
Commercial and Industrial Loans to Assets Ratio in 2006.	5989	0.114	0.092	0.099	0.000	0.993
Securities to Assets Ratio in 2006.	5989	0.238	0.211	0.158	0.000	0.998
Real Estate Loans to Assets Ratio in 2006.	5791	0.156	0.131	0.116	0.000	0.562

Notes: Summary statistics are based on the quarterly US Call Reports restricted to US banks.

INTERNET APPENDIX

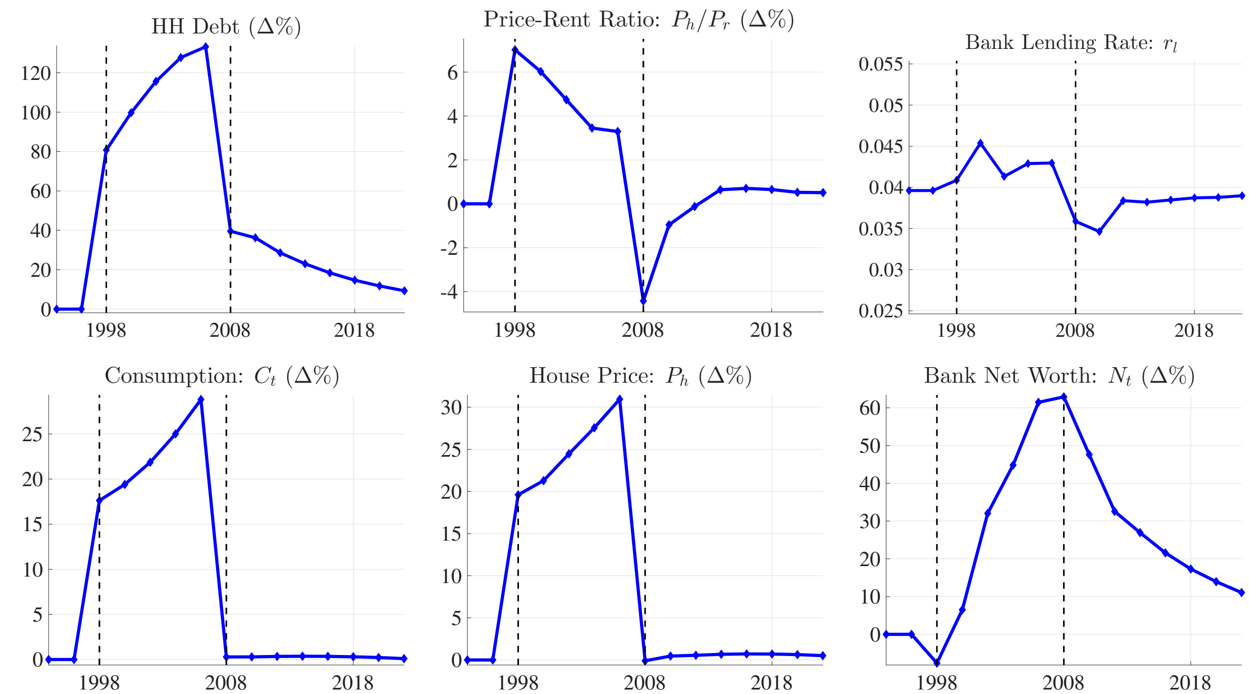
E Linkages across sectors

Figure E.1 – Linkages across sectors and amplification channels during the bust



F Model Dynamics with only Productivity Shocks

Figure F.1 – Model Dynamics with Productivity Shocks



Notes: The graph plots the dynamics of key aggregate variables during the boom-bust episode in an economy with only a productivity shock. The size of the shock is chosen to generate a similar increase in house prices compared to demand and leverage shocks.

G Robustness

For all robustness analyses, we recalibrate the initial steady state of the model. Then we feed into the economy the **same shocks from our benchmark**. We report our results in Figure G.1.

For some of the exercises below, we adopt the following Epstein-Zin (Epstein and Zin, 1989) recursive utility formulation for household preferences:

$$V_j = \left(\left(e_j \left((1-\gamma) c^{1-\epsilon} + \gamma s^{1-\epsilon} \right) \right)^{\frac{1-\rho}{1-\epsilon}} + \beta E_j \left(V_{j+1}^{1-\sigma} \right)^{\frac{1-\rho}{1-\sigma}} \right)^{\frac{1}{1-\rho}},$$

where E is the expectations operator, β is the discount factor, c is consumption, and s is housing services. When $\rho = \sigma$, this specification collapses to standard CRRA preferences over the intratemporal consumption-housing composite. We conduct robustness analyses with respect to the risk aversion parameter, σ, and the parameter governing elasticity of intertemporal substitution, $1/\rho$, independently. In addition, the Epstein-Zin formulation facilitates a more accurate numerical computation of the quantitative model.

The boom-bust dynamics are not different enough for different parameterizations to change our substantive conclusions.

FIGURE G.1 – The two-shock boom-bust dynamics with alternative parameterizations (1)

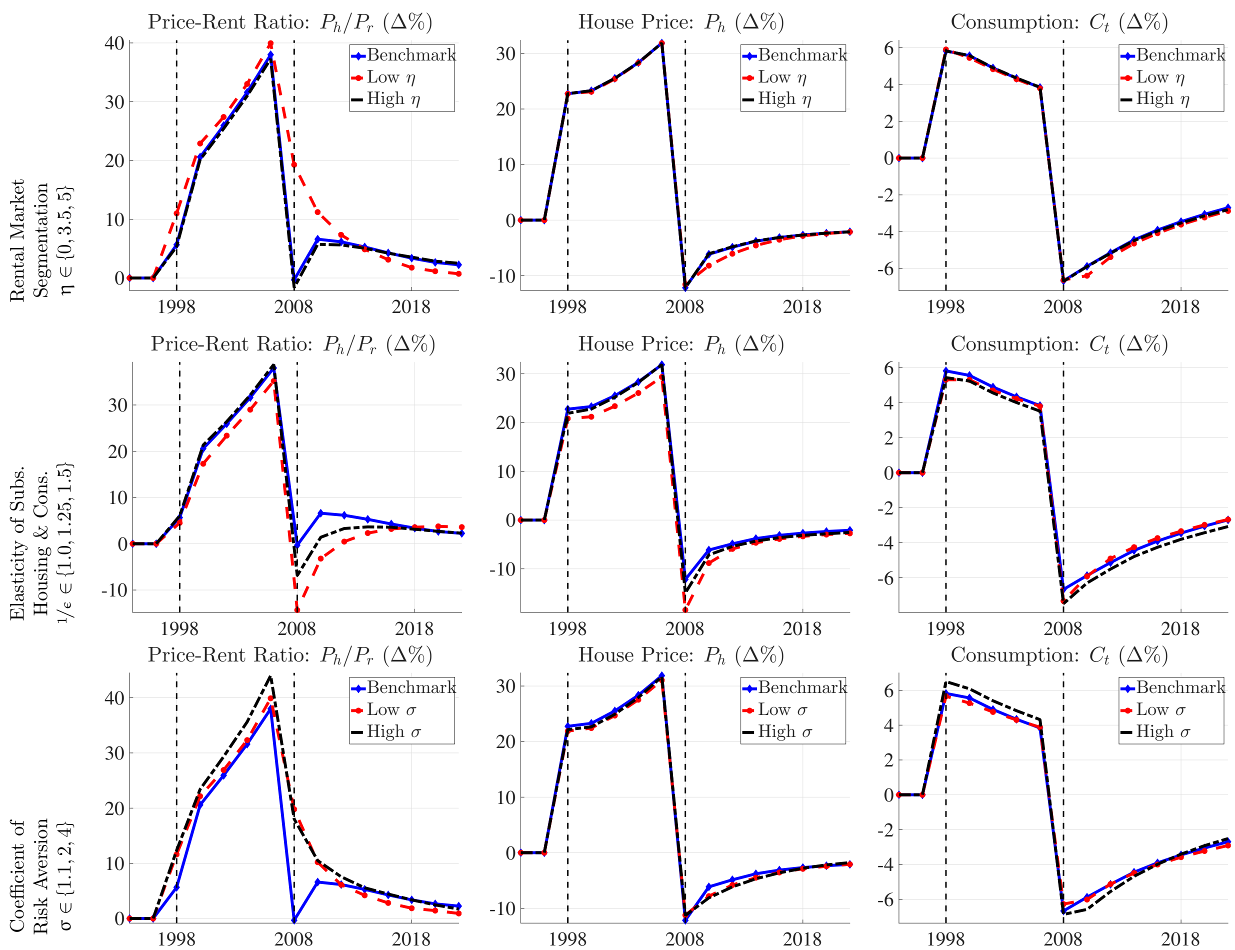
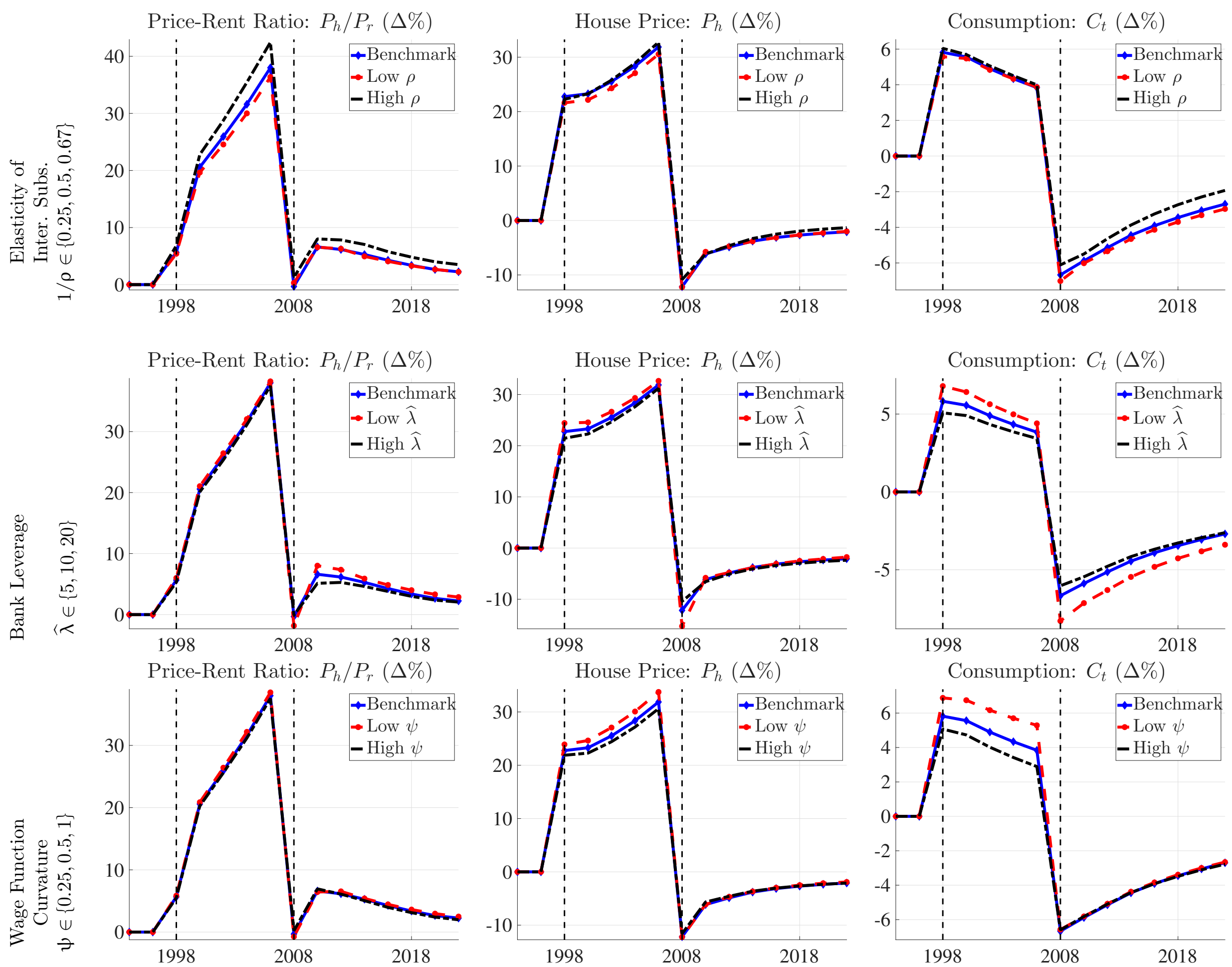


Figure G.2 – The two-shock boom-bust dynamics with alternative parameterizations (2)



H Equivalence of GHH preferences and Labor Utilization

Consider the following simplified static model. Households supply labor to firms and consume the labor income. Firms hire workers, pay market wages and produce output. Output is only produced by labor. Below we show that the model with labor utilization in the firm's problem and inelastic labor supply for households is equivalent to the model without labor utilization on firm's problem and flexible labor supply on households when their preferences are GHH form.

H.1 Static Model with Labor Utilization

Households derive utility only from consumption and labor supply is inelastic. Then, the household's problem becomes:

$$\max_{c} \frac{c^{1-\sigma}}{1-\sigma}$$

subject to

$$c = w(u)$$

$w(u)$ is their labor income.

Firms produce output using only labor, but they can choose the utilization rate of labor, u, subject to convex wage payments as a function of utilization representing overtime payments. Then, the firm's problem becomes:

$$\max_{n,u} \{znu - w(u)\, n\}$$

where

$$w(u) = \bar{w} + \chi \frac{u^{1+\psi}}{1+\psi}$$

First-order conditions to the firm's problem imply:

$$z = w'(u)$$
$$zu = w(u)$$

Using the FOC with respect to u and imposing the market clearing condition of $n = 1$, we get:

$$z = w'(u) = \chi u^{\psi}$$

which results

$$u = \left(\frac{z}{\chi}\right)^{\frac{1}{\psi}}$$

The FOC w.r.to n implies (when $n = 1$):

$$w(u) = zu = \left(\frac{z^{1+\psi}}{\chi}\right)^{\frac{1}{\psi}}$$
$$c = w(u) = \left(\frac{z^{1+\psi}}{\chi}\right)^{\frac{1}{\psi}}$$

H.2 Static Model with GHH preferences

Household's problem can be written as:

$$\max_{c,n} \frac{\left(c - \chi \frac{n^{1+\psi}}{1+\psi}\right)^{1-\sigma}}{1-\sigma}$$

subject to

$$c = wn$$

First-order conditions to the household's problem yield:

$$\chi n^{\psi} = w$$

which results in the following labor supply schedule:

$$n^{s} = \left(\frac{w}{\chi}\right)^{\frac{1}{\psi}}$$

Firms' problem can be written as:

$$\max_{n} \{zn - wn\}$$

First-order condition to the firm's problem results:

$$z = w$$

Substituting this into the household's problem we get

$$c = wn = \left(\frac{z^{1+\psi}}{\chi}\right)^{\frac{1}{\psi}}$$

which yields the exact same allocation as in the model with labor utilization.

I Characterization of the Bank's Problem

In this section, we will provide proofs for the characterization of the bank's problem. We will start with the steady-state value functions and decision rules and continue obtaining value functions in the transition by iterating backward from the steady state.

The bank's problem is given as

$$\Psi_t \left(L_t, B_t\right) = \max_{B_{t+1}, L_{t+1}, c_t^B} \left\{\log\left(c_t^B\right) + \beta_L \Psi_{t+1}\left(L_{t+1}, B_{t+1}\right)\right\}$$

subject to

$$\begin{aligned} c_t^B + L_{t+1} &= \left(1 + r_{\ell,t}\right) L_t - \left(1 + r_t\right) B_t + B_{t+1} \\ \Psi_{t+1}\left(L_{t+1}, B_{t+1}\right) &\geqslant \tilde{\Psi}_{t+1}^{D}\left(\xi\left(1 + r_{\ell,t+1}\right) L_{t+1}\right), \end{aligned}$$

where $\tilde{\Psi}_t^D(W) = \max_{W'} \log(W - W') + \beta_L \tilde{\Psi}_{t+1}^D((1+r_{t+1})W')$.

I.1 Steady State with $r_\ell > r$

We will characterize the case $r_\ell > r$ and leave the cases for $r_\ell \leqslant r$ for brevity. We will start with the value function of the bank when it defaults.

Since the bank can divert a fraction ξ of assets after the return has been realized and can continue saving at interest rate r, the bank's problem in the period of default is given as

$$\tilde{\Psi}^D\left(\xi L'\right) = \max_{s'} \log\left(\xi L' - W'\right) + \beta_L \Psi^D\left((1+r)W'\right),$$

and after default, it becomes

$$\tilde{\Psi}^D(W) = \max_{s'} \log\left(W - W'\right) + \beta_L \Psi^D\left((1+r)W'\right).$$

Lemma 1. $\tilde{\Psi}^D(W)$ *is given as*

$$\tilde{\Psi}^D(W) = \frac{1}{1-\beta_L}\log(W) + \frac{\beta_L}{(1-\beta_L)^2}\log(\beta_L(1+r)) + \frac{\log(1-\beta_L)}{1-\beta_L}.$$

The bank's problem in the no-default state solves

$$\Psi(L,B) = \max_{L',B'} \log\left((1+r_\ell)L - (1+r)B + B' - L'\right) + \beta_L \Psi\left(L', B'\right)$$

subject to

$$\Psi\left(L', B'\right) \geqslant \tilde{\Psi}^D\left(\xi(1+r_\ell)L'\right).$$

Proposition 1. *The solution to the bank's problem is given as follows:*

1. Value function:

$$\begin{aligned}
\Psi(L,B) &= \frac{1}{1-\beta_L}\log\left((1+r_\ell)L - (1+r)B\right) \\
&+ \frac{\beta_L}{(1-\beta_L)^2}\log\left(\frac{(1+r)(1+r_\ell)\beta_L\phi}{1+r-(1+r_\ell)(1-\phi)}\right) + \frac{\log(1-\beta_L)}{1-\beta_L}.
\end{aligned}$$

2. The no-default constraint can be written as

$$(1+r_\ell)(1-\phi)L' \geqslant (1+r)B'$$

   where ϕ is given as

$$\phi = \xi^{1-\beta_L}\left(\frac{1+r}{1+r_\ell} - (1-\phi)\right)^{\beta_L}.$$

3. The bank's solution satisfies the following expression regardless of whether or not the no-default constraint binds:
$$L' - B' = \beta_L \left((1+r_\ell)L - (1+r)B\right).$$

4. The decision rules when the no-default constraint is binding (if $r_\ell > r$):

$$\begin{aligned} L' &= \frac{(1+r)}{1+r-(1-\phi)(1+r_\ell)} \beta_L \left((1+r_\ell)L - (1+r)B\right) \\ B' &= \frac{(1-\phi)(1+r_\ell)}{1+r-(1-\phi)(1+r_\ell)} \beta_L \left((1+r_\ell)L - (1+r)B\right). \end{aligned}$$

Proof. (Proposition 1) We will use the expressions for value functions and verify the claims above. First, derive the capital requirement constraint:

$$\Psi\left(L', B'\right) \geqslant \tilde{\Psi}^D\left(\xi(1+r_\ell)L'\right).$$

$$\frac{1}{1-\beta_L}\log\left((1+r_\ell)L' - (1+r)B'\right) + \frac{\beta_L}{(1-\beta_L)^2}\log\left(\frac{(1+r_\ell)(1+r)\beta_L\phi'}{(1+r)-(1+r_\ell)(1-\phi')}\right) \geqslant \frac{1}{1-\beta_L}\log(\xi(1+r_\ell)L') + \frac{\beta_L}{(1-\beta_L)^2}\log(\beta_L(1+r)),$$

where ϕ' is the capital requirement constraint in the next period. The expression above gives

$$\log\left(\frac{(1+r_\ell)L' - (1+r)B'}{\xi(1+r_\ell)L'}\right) \geqslant \frac{\beta_L}{1-\beta_L}\log\left(\frac{\beta_L\left((1+r)-(1+r_\ell)(1-\phi')\right)}{(1+r_\ell)\beta_L\phi'}\right)$$

$$\frac{(1+r_\ell)L' - (1+r)B'}{(1+r_\ell)L'} \geqslant \xi\left(\frac{((1+r)-(1+r_\ell)(1-\phi'))}{(1+r)\phi'}\right)^{\frac{\beta_L}{1-\beta_L}}.$$

We will show below that the solution of ϕ' is the fixed point of

$$\phi = \xi\left(\frac{((1+r)-(1+r_\ell)(1-\phi'))}{(1+r)\phi'}\right)^{\frac{\beta_L}{1-\beta_L}}.$$

Then this constraint can be written as

$$(1+r_\ell)(1-\phi)L' \geqslant (1+r)B'.$$

Now, we can solve the bank's problem:

$$\begin{aligned}
\Psi(L,B) &= \max_{L',B'} \log\left((1+r_\ell)L-(1+r)B+B'-L'\right)+\beta_L\Psi\left(L',B'\right)\\
&= \max_{L',B'} \log\left((1+r_\ell)L-(1+r)B+B'-L'\right)\\
&+ \frac{\beta_L}{1-\beta_L}\log\left((1+r_\ell)L'-(1+r)B'\right)\\
&+ \frac{\beta_L^2}{(1-\beta_L)^2}\log\left(\frac{(1+r_\ell)(1+r)\beta_L\phi'}{(1+r)-(1+r_\ell)(1-\phi')}\right)+\frac{\beta_L\log(1-\beta_L)}{1-\beta_L}
\end{aligned}$$

subject to

$$(1+r_\ell)(1-\phi)L' \geqslant (1+r)B'.$$

Imposing the balance sheet constraint, we obtain

$$\begin{aligned}
\Psi(L,B) &= \max_{L',B'} \log\left((1+r_\ell)L-(1+r)B+\frac{(1+r_\ell)(1-\phi)L'}{1+r}-L'\right)\\
&+ \frac{\beta_L}{1-\beta_L}\log\left((1+r_\ell)L'-(1+r)\frac{(1+r_\ell)(1-\phi)L'}{1+r}\right)\\
&+ \frac{\beta_L^2}{(1-\beta_L)^2}\log\left(\frac{(1+r_\ell)(1+r)\beta_L\phi'}{(1+r)-(1+r_\ell)(1-\phi')}\right)+\frac{\beta_L\log(1-\beta_L)}{1-\beta_L}
\end{aligned}$$

$$\begin{aligned}
\Psi(L,B) &= \max_{L'} \log\left((1+r_\ell)L-(1+r)B-\frac{(1+r)-(1+r_\ell)(1-\phi)}{1+r}L'\right)\\
&+ \frac{\beta_L}{1-\beta_L}\log\left((1+r_\ell)\phi L'\right)\\
&+ \frac{\beta_L^2}{(1-\beta_L)^2}\log\left(\frac{(1+r_\ell)(1+r)\beta_L\phi'}{(1+r)-(1+r_\ell)(1-\phi')}\right)+\frac{\beta_L\log(1-\beta_L)}{1-\beta_L}.
\end{aligned}$$

The first-order condition is

$$\frac{\frac{(1+r)-(1+r_\ell)(1-\phi)}{1+r}}{(1+r_\ell)L-(1+r)B-\frac{(1+r)-(1+r_\ell)(1-\phi)}{1+r}L'}=\frac{\beta_L}{1-\beta_L}\frac{1}{L'},$$

which gives

$$\begin{aligned}
L' &= \frac{\beta_L(1+r)}{(1+r)-(1-\phi)(1+r_\ell)}\left((1+r_\ell)L-(1+r)B\right)\\
B' &= \frac{\beta_L(1-\phi')(1+r_\ell)}{(1+r)-(1-\phi')(1+r_\ell)}\left((1+r_\ell)L-(1+r)B\right).
\end{aligned}$$

Given these decision rules, the value function is given by

$$\begin{aligned}\Psi(L,B) &= \frac{1}{1-\beta_L}\log\left((1+r_\ell)L-(1+r)B\right)\\ &+ \frac{\beta_L}{1-\beta_L}\log\left(\frac{(1+r_\ell)(1+r)\beta_L\phi}{(1+r)-(1+r_\ell)(1-\phi')}\right)\\ &+ \frac{\beta_L^2}{(1-\beta_L)^2}\log\left(\frac{(1+r_\ell)(1+r)\beta_L\phi'}{(1+r)-(1+r_\ell)(1-\phi')}\right)+\frac{\log(1-\beta_L)}{1-\beta_L}.\end{aligned}$$

Equating this expression to our initial guess,

$$\frac{1}{1-\beta_L}\log\left((1+r_\ell)L-(1+r)B\right)+\frac{\beta_L}{(1-\beta_L)^2}\log\left(\frac{(1+r_\ell)(1+r)\beta_L\phi}{(1+r)-(1+r_\ell)(1-\phi)}\right)+\frac{\log(1-\beta_L)}{1-\beta_L},$$

we obtain

$$\begin{aligned}\frac{\beta_L}{(1-\beta_L)^2}\log\left(\frac{(1+r_\ell)(1+r)\beta_L\phi}{(1+r)-(1+r_\ell)(1-\phi)}\right) &= \frac{\beta_L}{1-\beta_L}\log\left(\frac{(1+r_\ell)(1+r)\beta_L\phi}{(1+r)-(1+r_\ell)(1-\phi)}\right)\\ &+ \frac{\beta_L^2}{(1-\beta_L)^2}\log\left(\frac{(1+r_\ell)(1+r)\beta_L\phi'}{(1+r)-(1+r_\ell)(1-\phi')}\right),\end{aligned}$$

which gives

$$\frac{\phi}{(1+r)-(1+r_\ell)(1-\phi)}=\frac{\phi'}{(1+r)-(1+r_\ell)(1-\phi')}.$$

Since these expressions are monotone (and declining) in ϕ, they imply that $\phi=\phi'$. By imposing this into

$$\phi=\xi\left(\frac{1+r-(1+r_\ell)(1-\phi')}{(1+r)\phi'}\right)^{\frac{\beta_L}{1-\beta_L}}.$$

we obtain

$$\phi=\xi^{1-\beta_L}\left(\frac{1+r-(1+r_\ell)(1-\phi)}{(1+r_\ell)}\right)^{\beta_L}.$$

□

I.2 Transition

Assume that the last period of the transition is period T and the economy is in steady state with r_ℓ and r from period $T+1$ and onward. The following proposition characterizes the bank's solution in the transition, where all prices $r_{\ell,t}$ and r_t are potentially changing.

Proposition 2. *The solution to the bank's problem is given as follows:*

1. The value function:

$$\Psi_t(L_t,B_t)=\frac{1}{1-\beta_L}\log\left((1+r_{\ell,t})L_t-(1+r_t)B_t\right)+\Omega_t+\frac{\log(1-\beta_L)}{1-\beta_L},$$

where

$$\Omega_t = \frac{\beta_L}{1-\beta_L} \log\left(\frac{\beta_L \phi_{t+1}(1+r_{t+1})\left(1+r_{\ell,t+1}\right)}{1+r_{t+1}-\left(1-\phi_{t+1}\right)\left(1+r_{\ell,t+1}\right)}\right) + \beta_L \Omega_{t+1};$$

$$\Omega_T = \Omega = \frac{\beta_L}{(1-\beta_L)^2} \log\left(\frac{\beta_L \phi(1+r)\left(1+r_\ell\right)}{1+r-(1-\phi)\left(1+r_\ell\right)}\right);$$

$$\phi_t = \xi^{1-\beta_L}\left(\frac{1+r_{t+1}}{1+r_{\ell,t+1}} - \left(1-\phi_{t+1}\right)\right)^{\beta_L};$$

and

$$\phi_T = \phi.$$

2. The no-default constraint in period t can be written as

$$\left(1+r_{\ell,t+1}\right)\left(1-\phi_{t+1}\right) L_{t+1} \geqslant \left(1+r_{t+1}\right) B_{t+1}.$$

3. The bank's solution satisfies the following expression regardless of whether or not the no-default constraint binds:

$$L_{t+1} - B_{t+1} = \beta_L \left((1+r_{\ell,t})L_t - (1+r_t)B_t\right).$$

4. The decision rules when the no-default constraint is binding (if $r_{\ell,t+1} > r_{t+1}$):

$$\begin{aligned} L_{t+1} &= \frac{\beta_L(1+r_{t+1})}{1+r_{t+1}-(1-\phi_{t+1})(1+r_{\ell,t+1})}\left((1+r_{\ell,t})L_t - (1+r_t)B_t\right) \\ B_{t+1} &= \frac{\beta_L(1-\phi_{t+1})(1+r_{\ell,t+1})}{1+r_{t+1}-(1-\phi_{t+1})(1+r_{\ell,t+1})}\left((1+r_{\ell,t})L_t - (1+r_t)B_t\right). \end{aligned}$$

5. The decision rules when the no-default constraint is not binding (if $r_{\ell,t+1} \leqslant r_{t+1}$):

$$B_{t+1} = \begin{cases} \in \left[0, \frac{\beta_L(1-\phi_{t+1})(1+r_{\ell,t+1})}{1+r_{t+1}-(1-\phi_{t+1})(1+r_{\ell,t+1})}\left((1+r_{\ell,t})L_t - (1+r_t)B_t\right)\right] & \text{if } r_{\ell,t+1} = r_{t+1} \\ 0 & \text{if } r_{\ell,t+1} < r_{t+1} \end{cases}$$

and

$$L_{t+1} = B_{t+1} + \beta_L \left((1+r_{\ell,t})L_t - (1+r_t)B_t\right).$$

Proof. We are going to solve the problem backward starting from period T.

Period T:

$$\begin{aligned} \Psi_T\left(L_T, B_T\right) &= \max_{L_{T+1}, B_{T+1}} \log\left((1+r_{\ell,T})L_T - (1+r_T)B_T - (L_{T+1} - B_{T+1})\right) \\ &+ \frac{\beta_L}{1-\beta_L} \log\left((1+r_\ell)L_{T+1} - (1+r)B_{T+1}\right) \\ &+ \left(\frac{\beta_L}{1-\beta_L}\right)^2 \log\left(\frac{\beta_L \phi(1+r_\ell)(1+r)}{1+r-(1-\phi)(1+r_\ell)}\right) + \frac{\beta_L}{1-\beta_L}\log(1-\beta_L) \\ &\text{s.t.} \\ (1-\phi)(1+r_\ell)L_{T+1} &\geqslant (1+r)B_{T+1}. \end{aligned}$$

The decision rules of this problem are given as

$$\begin{aligned}
L_{T+1} &= \frac{\beta_L(1+r)}{1+r-(1-\phi)(1+r_\ell)}\left((1+r_{\ell,T})L_T-(1+r_T)B_T\right)\\
B_{T+1} &= \frac{\beta_L(1-\phi)(1+r_\ell)}{1+r-(1-\phi)(1+r_\ell)}\left((1+r_{\ell,T})L_T-(1+r_T)B_T\right)\\
L_{T+1}-B_{T+1} &= \beta_L\left((1+r_{\ell,T})L_T-(1+r_T)B_T\right)\\
(1+r_\ell)L_{T+1}-(1+r)B_{T+1} &= \frac{\beta_L\phi(1+r_\ell)(1+r)}{1+r-(1-\phi)(1+r_\ell)}\left((1+r_{\ell,T})L_T-(1+r_T)B_T\right)
\end{aligned}$$

which give

$$\begin{aligned}
\Psi_T\left(L_T,B_T\right) &= \frac{1}{1-\beta_L}\log\left((1+r_{\ell,T})L_T-(1+r_T)B_T\right)\\
&+ \frac{\beta_L}{(1-\beta_L)^2}\log\left(\frac{\beta_L\phi(1+r_\ell)(1+r)}{1+r-(1-\phi)(1+r_\ell)}\right)+\frac{1}{1-\beta_L}\log(1-\beta_L).
\end{aligned}$$

The value function when the bank defaults is

$$\tilde{\Psi}_T^D\left(\xi(1+r_{\ell,T})L_T\right)=\frac{1}{1-\beta_L}\log\left(\xi(1+r_{\ell,T})L_T\right)+\frac{\beta_L}{(1-\beta_L)^2}\log(\beta_L(1+r))+\frac{\log(1-\beta_L)}{1-\beta_L}.$$

The no-default condition in period T can be written as

$$(1-\phi_T)(1+r_{\ell,T})L_T\geqslant(1+r_T)B_T,$$

where

$$\phi_T=\xi^{1-\beta_L}\left(\frac{1+r}{1+r_\ell}-(1-\phi)\right)^{\beta_L}.$$

Period $T-1$:

$$\begin{aligned}
\Psi_{T-1}\left(L_{T-1},B_{T-1}\right) &= \max_{L_T,B_T}\log\left((1+r_{\ell,T-1})L_{T-1}-(1+r_{T-1})B_{T-1}-(L_T-B_T)\right)\\
&+ \frac{\beta_L}{1-\beta_L}\log\left((1+r_{\ell,T})L_T-(1+r_T)B_T\right)\\
&+ \left(\frac{\beta_L}{1-\beta_L}\right)^2\log\left(\frac{\beta_L\phi(1+r_\ell)(1+r)}{1+r-(1-\phi)(1+r_\ell)}\right)+\frac{\beta_L}{1-\beta_L}\log(1-\beta_L)\\
&\text{s.t.}\\
(1-\phi_T)(1+r_{\ell,T})L_T &\geqslant (1+r_T)B_T.
\end{aligned}$$

The decision rules for this problem are given as

$$\begin{aligned}
L_T &= \frac{\beta_L(1+r_T)}{1+r_T-(1-\phi_T)(1+r_{\ell,T})}\left((1+r_{\ell,T-1})L_{T-1}-(1+r_{T-1})B_{T-1}\right) \\
B_T &= \frac{\beta_L(1-\phi_T)(1+r_{\ell,T})}{1+r_T-(1-\phi_T)(1+r_{\ell,T})}\left((1+r_{\ell,T-1})L_{T-1}-(1+r_{T-1})B_{T-1}\right) \\
L_T-B_T &= \beta_L\left((1+r_{\ell,T-1})L_{T-1}-(1+r_{T-1})B_{T-1}\right) \\
(1+r_{\ell,T})L_T-(1+r_T)B_T &= \frac{\beta_L\phi_T(1+r_{\ell,T})(1+r_T)}{1+r_T-(1-\phi_T)(1+r_{\ell,T})}\left((1+r_{\ell,T-1})L_{T-1}-(1+r_{T-1})B_{T-1}\right),
\end{aligned}$$

which give

$$\begin{aligned}
\Psi_{T-1}\left(L_{T-1},B_{T-1}\right) &= \frac{1}{1-\beta_L}\log\left((1+r_{\ell,T-1})L_{T-1}-(1+r_{T-1})B_{T-1}\right) \\
&+ \frac{\beta_L}{1-\beta_L}\log\left(\frac{\beta_L\phi_T(1+r_{\ell,T})(1+r_T)}{1+r_T-(1-\phi_T)(1+r_{\ell,T})}\right) \\
&+ \frac{\beta_L^2}{(1-\beta_L)^2}\log\left(\frac{\beta_L\phi(1+r_\ell)(1+r)}{1+r-(1-\phi)(1+r_\ell)}\right)+\frac{1}{1-\beta_L}\log(1-\beta_L).
\end{aligned}$$

The value function when the bank defaults is

$$\begin{aligned}
\tilde{\Psi}^D_{T-1}\left(\xi(1+r_{\ell,T-1})L_{T-1}\right) &= \frac{1}{1-\beta_L}\log\left(\xi(1+r_{\ell,T-1})L_{T-1}\right)+\frac{\beta_L}{1-\beta_L}\log(\beta_L(1+r_T^D)) \\
&+ \frac{\beta_L^2}{(1-\beta_L)^2}\log(\beta_L(1+r^D))+\frac{\log(1-\beta_L)}{1-\beta_L}.
\end{aligned}$$

The no-default condition in period $T-1$ can be written as

$$(1-\phi_{T-1})(1+r_{\ell,T-1})L_{T-1}\geqslant(1+r_{T-1})B_{T-1},$$

where

$$\phi_{T-1}=\xi^{1-\beta_L}\left(\frac{1+r_T}{1+r_{\ell,T}}-(1-\phi_T)\right)^{\beta_L}.$$

Period $T-2$:

$$
\begin{aligned}
\Psi_{T-2}\left(L_{T-2},B_{T-2}\right) &= \max_{L_{T-1},B_{T-1}} \log\left((1+r_{\ell,T-2})L_{T-2}-(1+r_{T-2})B_{T-2}-(L_{T-1}-B_{T-1})\right) \\
&+ \frac{\beta_L}{1-\beta_L}\log\left((1+r_{\ell,T-1})L_{T-1}-(1+r_{T-1})B_{T-1}\right) \\
&+ \frac{\beta_L^2}{1-\beta_L}\log\left(\frac{\beta_L\phi_T(1+r_{\ell,T})(1+r_T)}{1+r_T-(1-\phi_T)(1+r_{\ell,T})}\right) \\
&+ \frac{\beta_L^3}{(1-\beta_L)^2}\log\left(\frac{\beta_L\phi(1+r_\ell)(1+r)}{1+r-(1-\phi)(1+r_\ell)}\right)+\frac{\beta_L}{1-\beta_L}\log(1-\beta_L) \\
\text{s.t.} \\
(1-\phi_{T-1})(1+r_{\ell,T-1})L_{T-1} &\geqslant (1+r_{T-1})B_{T-1}.
\end{aligned}
$$

The decision rules of this problem are given as

$$
\begin{aligned}
L_{T-1} &= \frac{\beta_L(1+r_{T-1})}{1+r_{T-1}-(1-\phi_{T-1})(1+r_{\ell,T-1})}\omega_{T-2} \\
B_{T-1} &= \frac{\beta_L(1-\phi_{T-1})(1+r_{\ell,T-1})}{1+r_{T-1}-(1-\phi_{T-1})(1+r_{\ell,T-1})}\omega_{T-2} \\
L_{T-1}-B_{T-1} &= \beta_L\omega_{T-2} \\
(1+r_{\ell,T-1})L_{T-1}-(1+r_{T-1})B_{T-1} &= \frac{\beta_L\phi_{T-1}(1+r_{\ell,T-1})(1+r_{T-1})}{1+r_{T-1}-(1-\phi_{T-1})(1+r_{\ell,T-1})}\omega_{T-2}, \\
\omega_{T-2} &= \left((1+r_{\ell,T-2})L_{T-2}-(1+r_{T-2})B_{T-2}\right),
\end{aligned}
$$

which give

$$
\begin{aligned}
\Psi_{T-2}\left(L_{T-2},B_{T-2}\right) &= \frac{1}{1-\beta_L}\log\left((1+r_{\ell,T-2})L_{T-2}-(1+r_{T-2})B_{T-2}\right) \\
&+ \frac{\beta_L}{1-\beta_L}\log\left(\frac{\beta_L\phi_{T-1}(1+r_{\ell,T-1})(1+r_{T-1})}{1+r_{T-1}-(1-\phi_{T-1})(1+r_{\ell,T-1})}\right) \\
&+ \frac{\beta_L^2}{1-\beta_L}\log\left(\frac{\beta_L\phi_T(1+r_{\ell,T})(1+r_T)}{1+r_T-(1-\phi_T)(1+r_{\ell,T})}\right) \\
&+ \frac{\beta_L^3}{(1-\beta_L)^2}\log\left(\frac{\beta_L\phi(1+r_\ell)(1+r)}{1+r-(1-\phi)(1+r_\ell)}\right)+\frac{1}{1-\beta_L}\log(1-\beta_L).
\end{aligned}
$$

The value function when the bank defaults is

$$
\begin{aligned}
\tilde{\Psi}^D_{T-2}\left(\xi(1+r_{\ell,T-2})L_{T-2}\right) &= \frac{1}{1-\beta_L}\log\left(\xi(1+r_{\ell,T-2})L_{T-2}\right)+\frac{\log(1-\beta_L)}{1-\beta_L} \\
&+ \frac{\beta_L}{1-\beta_L}\log(\beta_L(1+r_{T-1}))+\frac{\beta_L^2}{1-\beta_L}\log(\beta_L(1+r_T)) \\
&+ \frac{\beta_L^3}{(1-\beta_L)^2}\log(\beta_L(1+r)).
\end{aligned}
$$

The no-default condition in period $T-2$ can be written as

$$(1-\phi_{T-2})(1+r_{\ell,T-2})L_{T-2} \geqslant (1+r_{T-2})B_{T-2},$$

where

$$\phi_{T-2} = \xi^{1-\beta_L}\left(\frac{1+r_{T-1}}{1+r_{\ell,T-1}} - (1-\phi_{T-1})\right)^{\beta_L}.$$

The derivations suggest that the value functions and decision rules have the same pattern. Thus, they will take the same form as in the previous period. □

I.3 Bank's solution

Given the collateral constraint the bank is facing, we can explicitly solve for the bank's problem, which is summarized in the following proposition.

Proposition 3. *The decision rules when the no-default constraint binds (if $r_{\ell,t+1} > r_{t+1}$) are*

$$\begin{aligned} L_{t+1} &= \frac{(1+r_{t+1})}{1+r_{t+1}-(1-\phi_{t+1})(1+r_{\ell,t+1})}\beta_L\omega_t \\ B_{t+1} &= \frac{(1-\phi_{t+1})(1+r_{\ell,t+1})}{1+r_{t+1}-(1-\phi_{t+1})(1+r_{\ell,t+1})}\beta_L\omega_t, \end{aligned}$$

where $\omega_t = (1+r_{\ell,t})L_t - (1+r_t)B_t$.

The decision rules when the no-default constraint does not bind (if $r_{\ell,t+1} \leqslant r_{t+1}$) are:

$$B_{t+1} = \begin{cases} \in \left[0, \frac{\beta_L(1-\phi_{t+1})(1+r_{\ell,t+1})}{1+r_{t+1}-(1-\phi_{t+1})(1+r_{\ell,t+1})}\omega_t\right] & \textit{if } r_{\ell,t+1} = r_{t+1} \\ 0 & \textit{if } r_{\ell,t+1} < r_{t+1} \end{cases}$$

and

$$L_{t+1} = B_{t+1} + \beta_L\left((1+r_{\ell,t})L_t - (1+r_t)B_t\right).$$

I.4 Characterization of the Bank's Problem in Stationary Equilibrium

We can further characterize the bank's problem under stationarity. Throughout the paper, we will focus on stationary equilibria where the capital requirement constraint is binding. If it did not bind, then bank balance sheets would not have any impact on the economy. However, we do not rule out the case that there might be some periods in the transition where this constraint becomes slack. Using the general formula capturing both the exogenous and endogenous capital requirement constraint, we have the following decision rules when the constraint binds:

$$L_{t+1} = \beta_L\widehat{\lambda}_t\omega_t \quad \text{and} \quad B_{t+1} = \beta_L\left(\widehat{\lambda}_t - 1\right)\omega_t,$$

where

$$\widehat{\lambda}_t = \frac{(1+r_{t+1})}{1+r_{t+1}-(1-\phi_{t+1})(1+r_{\ell,t+1})}. \tag{I.1}$$

Then the law of motion for net worth is given as

$$\omega_{t+1} \quad = \quad L_{t+1}\left(1+r_{\ell,t+1}\right) - B_{t+1}\left(1+r_{t+1}\right).$$

Then, we can obtain the next period's net worth as

$$\omega_{t+1} \quad = \quad \beta_L\left(\widehat{\lambda_t}\left(1+r_{\ell,t+1}\right) - \left(\widehat{\lambda_t}-1\right)\left(1+r_{t+1}\right)\right)\omega_t.$$

Imposing steady state $\omega_{t+1} = \omega_t$ and $\widehat{\lambda_t} = \widehat{\lambda}$ gives

$$r_\ell - r = \frac{1-\beta_L(1+r)}{\widehat{\lambda}\beta_L},$$

where $r_\ell - r$ is the premium due to the bank capital constraint. If $\beta_L(1+r) < 1$ and $\widehat{\lambda} < \infty$, then $r_\ell - r > 0$. Thus, the capital constraint will be binding in the stationary equilibrium. To understand this point, assume that $\beta_L(1+r) < 1$ but the bank starts with a high net worth so that the capital requirement constraint is not binding. In that case, $r_{\ell,t+1} = r$ and the bank's decision rule is $L_{t+1} - B_{t+1} = \beta_L\omega_t$. Using that, we can show that $\omega_{t+1} = (1+r)\,\beta_L\omega_t < \omega_t$. Thus, the bank consumes from its net worth until the capital constraint starts to bind. Thus, the economy will converge to a stationary equilibrium where it actually binds.

J Computational Appendix

Denote the state variable of the household as $\theta = (a, h, d, z, j, o)$ where o is the housing tenure, j is the age of the household, z is the income efficiency shock, d is the ratio of mortgage debt to initial house price level, h is the size of the owner-occupied unit, and a is the financial wealth. For active/inactive renters ($o \in \{r, e\}$) $h = d = 0$. We discretize a into 120 and d into 36 exponentially spaced points. The age j runs from 1 to 30, and h is linearly discretized into 5 points. Income shock z is discretized into 15 points, and grid points and transition probabilities are computed using the method of Tauchen (1986). Since this is a life-cycle model, the grid points for income shocks are age dependent to better approximate the AR(1) process with a Markov process. We approximate the US retirement system following Guvenen and Smith (2014). We adjust the retirement income level such that working-age households pay 12 percent tax.[45]

J.1 Steady-State Computation

The steady state of the model is computed as follows:

1. From the bank's problem, the lending rate at the steady state is $r_\ell = r + \frac{1-\beta_L(1+r)}{\widehat{\lambda}\beta_L}$.

2. Make a guess on K and H.

[45]The calibration of the model is done using the global optimization algorithm Controlled Random Search with local mutation in NLOPT (https://nlopt.readthedocs.io/en/latest/NLopt_Algorithms/). The objective function is the sum of squared differences between the data and model-simulated moments. During the calibration stage, we impose the market clearing conditions for the asset and housing market and replace the two moments (capital-output ratio and share of housing services in GDP) with the two market clearing conditions.

3. Using the condition of free mobility of labor across sectors, we can compute N_h:

$$N_h = \left(\frac{\delta_h H}{\bar{L}^{\theta_h}}\right)^{\frac{1}{1-\theta_h}}$$

4. Using the labor market clearing condition, we can solve for N_g:

$$N_g = 1 - N_h$$

5. Given these guesses, using the firm's problem, compute w and u:

$$\begin{aligned} u &= \left(\frac{(1-\alpha)\left(\frac{K}{N_g}\right)^{\alpha}}{(1+\mu r_\ell)\vartheta}\right)^{\frac{1}{\alpha+\psi}} \\ w &= \vartheta^{\frac{\alpha-1}{\alpha+\psi}}\left(\frac{(1-\alpha)\left(\frac{K}{N_g}\right)^{\alpha}}{(1+\mu r_\ell)}\right)^{\frac{1+\psi}{\alpha+\psi}} \\ r_k &= \alpha\left(\frac{K}{N_g u}\right)^{\alpha-1} - \delta \end{aligned}$$

6. Using construction companies' problem, we can solve for p_h:

$$p_h = \frac{w}{(1-\theta_h)\left(\frac{\bar{L}}{N_h}\right)^{\theta_h}}$$

7. Using the rental companies' problem, compute the rent price:

$$p_r = \kappa + \frac{r_k + \tau_h + \delta_h}{1 + r_k} p_h$$

8. Given all these prices, solve the household's problem recursively:
   (a) Solve the terminal period problem where all dynamic choices are set to 0: $a' = d' = 0$. This gives the value for the household, $V_J(\theta)$, and the continuation value of the mortgage contract, $v_J^l(\theta)$.
   (b) Given $V_j(\theta)$ and $v_j^l(\theta)$, solve $V_{j-1}(\theta)$ and $v_{j-1}^l(\theta)$:
      i. Given $V_j(\theta)$ and $v_j^l(\theta)$, first solve the expected continuation values $EV_j(\theta)$ and $Ev_j^l(\theta)$.
      ii. Solve for mortgage prices at the origination, $q^m(\theta)$.
      iii. The solutions to the problems for the inactive renter and the active renter who decides to become a renter are straightforward. Their choices are housing services, consumption, and saving. We interpolate the expected value of the continuation value using linear interpolation, and to choose the optimal saving level, we first

search globally over a finer discrete space for a' to bracket the maximum.[46] Once the maximum is bracketed, we solve for the optimum using Brent's method. Given the saving choice, we compute the optimal housing services using the analytical expression for it.[47] Then, we use the budget constraint to compute the consumption.

iv. The most complex and time-consuming problem is the problem of the renter who decides to purchase a house. This household chooses consumption, saving, house size, and mortgage debt. We restrict the choice of down payment and house size to finite sets. For down payment, the grid points for d are the choices, and for house size the grid points for h are the choices.[48] For each down payment and house size choices, we solve the household's objective function, $V_{j-1}^{d,h}$, by finding the optimal saving level, as we discussed in point 8(b)iii. Given all household choices, we can obtain $q^m(\theta)$. We use linear interpolation for the points off the grid. Also given the choice of d and h, the mortgage debt becomes $dp_h^* h$ where p_h^* is the equilibrium price level at the initial steady state. Once the objective function is solved for a given down payment and house size choice, we set $V_{j-1}(\theta) = \max_{d,h} \left\{ V_{j-1}^{d,h} \right\}$.

v. The solution of the homeowner's problem:

A. Stayer: The stayer's problem is simple since the household only chooses consumption and saving. We solve it similarly to the inactive renter's problem. The only exception is that in the continuation value, the variable keeping track of the principal amount d will be adjusted. Given current d, $d' = (d - m)(1 + r_\ell)$ where $m(d) = d\frac{r_\ell (1+r_\ell)^{J-j}}{(1+r_\ell)^{J-j+1} - 1}$. We use linear interpolation over d' to compute the expected continuation value for the household.

B. Seller: The seller's problem is the same as the problem of an active renter except that in the budget constraint, the household will have the term due to the proceeds from the sale of the house: $p_h h(1 - \varphi_s - \tau_h) - dhp_h^*$

C. Refinancer: The refinancer's problem is the same as the problem of a renter who purchases a house except that she is restricted to purchasing the same house.

D. Defaulter: The defaulter's problem is similar to the inactive renter's problem.

vi. Solving the homeowner's problem also gives us the mortgage payment for each type of mortgage contract and allows us to compute the continuation of the mortgage contract, $v_j^l(\theta)$[49]:

$$v_{j-1}^l(\theta) = m(\theta) + \frac{1}{1 + r_\ell} \int_{\theta'} v_j^l(\theta') \Pi(\theta'|\theta),$$

[46]For saving choice, we use 120 grid points.

[47]Since the utility function is CES in consumption and housing services, we can obtain an analytical expression for optimal housing services.

[48]Increasing the number of grid points for d and h beyond the levels we set does not noticeably change the results.

[49]$v_j^l(\theta) = 0$ if the mortgage is terminated upon house sale or mortgage default.

where

$$m(\theta) = \begin{cases} dhp_h^* & \text{if } o \in \{hr, hf\} \\ p_h h (1-\varphi_e) & \text{if } o = he \\ \frac{r_\ell (1+r_\ell)^{J-j}}{(1+r_\ell)^{J-j+1}-1} dhp_h^* & \text{if } o = hh \end{cases}$$

(c) Repeat step (b) for each $j = \{J-1, ..., 1\}$.

9. Given the policy functions for the household, simulate an economy with $N = 20,000$ individuals for $J = 30$ periods. This gives us aggregate saving, A, aggregate housing demand, H^d, and aggregate rental demand, H^r. Given aggregate saving, we update the aggregate capital guess as $K = (1-\lambda_k) K + \lambda_k (A - V^{rc}(H^r))$ where $V^{rc} = \frac{p_r - \kappa - (\tau_h + \delta_h) p_h^0}{r_k} H^r$ is the value of rental companies. Given aggregate housing demand, we update the housing supply guess as $H = (1-\lambda_h) H + \lambda_h H^d$. We set $\lambda_k = \lambda_h = 0.1$. We continue this process until $\max\left(|A - V^{rc}(H^r) - K|, \left|H - H^d\right|\right) < \epsilon$ where $\epsilon = 10^{-4}$.

10. Once equilibrium prices and allocations are solved, we solve for bank-related variables: bank net worth, bank assets, and bank liabilities using the steady-state analytical equations for these variables.

J.2 Transition Algorithm

The transitional problem has two main differences. First, we need to solve for a path of equilibrium prices and allocations along the transition. Second, we need to adjust the algorithm to capture the fact that the risk-free mortgage interest rate can change along the transition. This second point is important because to avoid adding another state variable, we assume individuals pay points at the origination time to reduce the risk-adjusted mortgage interest rate to the risk-free mortgage interest rate. This allows us to eliminate the mortgage interest rate as an additional state variable. However, since shocks are permanent, this assumption can artificially distort the equilibrium. Consider a decline in the risk-free mortgage interest rate from 5 percent to 4 percent. If we still assume all new mortgages are priced at 5 percent, this would imply that banks would be paid more than the principal amount if they still use the same amortization schedule we use in the steady-state algorithm. That will result in q^m being significantly larger than 1, implying a substantial subsidy from banks to individuals. More importantly, if we also apply this new risk-free mortgage interest rate to existing mortgages, that would imply a reduction of all the existing mortgage payments: a positive wealth shock to all existing mortgage owners and a negative shock to banks.[50]

To tackle this issue without further complicating the solution algorithm, we assume that after the shock is realized, all new mortgages will be priced at the new risk-free mortgage rate, whereas all existing mortgages will still be paid using the old risk-free mortgage rate. We also include an additional state variable in the household's problem to keep track of whether the household purchased a house before or after the shock is realized. This allows us to compute the mortgage payments more accurately without substantially distorting the solution algorithm.

Given these modifications, the rest of the algorithm is as follows:

[50] Since we keep track of the principal balance as a state variable, we need to know the risk-free mortgage rate to compute the implied mortgage payments. Another formulation could be to keep track of the mortgage payments. However, in this case, we still need to know the risk-free mortgage rate in order to compute the implied principal amount since it affects the resources of homeowners in the event of selling/refinancing/defaulting.

1. Fix the time it takes for the transition to happen: T periods. We set $T = 60$ corresponding to 120 years.

2. Solve the initial steady state of the problem as outlined above. Store the initial steady-state distribution denoted as $\Gamma_0(\theta)$.

3. Given the boom shock, solve the final steady state of the problem as outlined above. Store $V_T(\theta)$ and $\nu_T^l(\theta)$.[51]

4. Guess the path of aggregate capital stock, housing stock, rental demand, and lending rate: $\left\{K_{t+1}, H_t, H_t^{r,0}, r_{\ell,t+1}^0\right\}_{t=1}^{T-1}$.

5. Given these guesses, compute $\left\{w_t, r_{k,t+1}, p_t^h, p_t^r\right\}$ using the goods-producing firms', construction firms' and rental companies' problems. Compute V_t^{rc} using the rental companies' problem.

6. Solve each cohort's problem for each period they are alive, starting from the cohort born in period $-J+2$ until the cohort born in period $T-1$[52]:

   (a) For each generation, given prices, solve the household's problem and the continuation value of the contract as in the steady-state problem above. The only difference is that for new mortgage buyers, the risk-free mortgage interest rate is the final steady-state risk-free mortgage interest rate, whereas for existing mortgage owners, it is the initial steady-state risk-free mortgage interest rate. This also affects the continuation value for households and mortgage contracts since we need to keep track of whether a mortgage originated before or after the shock.

   (b) Given the policy functions for each generation, simulate the economy starting from the initial steady-state distribution $\Gamma_0(\theta)$ for T periods. We fix the same random numbers for the idiosyncratic shocks to households.

   (c) Using the simulated path, compute the aggregates: $A_{t+1}, H_t^{r,1}, H_t^d$, $M_t = \frac{1}{1+r_t^\ell}\int \nu_t^l(\theta)$.

   (d) Update guesses:

$$
\begin{aligned}
K_{t+1} &= (1-\lambda_k) K_{t+1} + \lambda_k \left(A_{t+1} - V_{t+1}^{rc}\left(H_{t+1}^r\right)\right) \\
H_t &= (1-\lambda_h) H_t + \lambda_h H_t^d \\
H_t^r &= (1-\lambda_{rc}) H_t^{r,0} + \lambda_{rc} H_t^{r,1} \\
r_{\ell,t+1}^0 &= (1-\lambda_r) r_{\ell,t+1}^0 + \lambda_r r_{\ell,t+1}^1
\end{aligned}
$$

   where $r_{\ell,t+1}$ solves

$$
L_{t+1} = \frac{(1+r_{t+1})}{1 + r_{t+1} - (1-\phi_{t+1})(1+r_{\ell,t+1})} \beta_L \omega_t
$$

[51] The transition to the bust is solved separately after the boom transition is solved. The distribution of the households obtained during the boom transition will be the input for the bust transition solution.

[52] A household of age j belonging to a cohort born in period $g \in \{-J+2, ..., T-1\}$ will be subject to prices p_{g+j-1}.

where $L_{t+1} = M_{t+1} + \mu w_{t+1}(\bar{w}, u_{t+1}) N^{g}_{t+1}$ and

$$\omega_t = \begin{cases} L_t\left(1 + r_{\ell,t}\right) - B_t\left(1 + r_t\right) & \text{if } t = 1 \\ \left(1 + r^0_{\ell,t}\right)\phi_t L_t & \text{if } t > 1. \end{cases}$$

(e) Iterate this process until convergence occurs on guesses. The convergence criteria are defined as $\max\left|K_{t+1} + V^{rc}_{t+1}\left(H^r_{t+1}\right) - A_{t+1}\right| < \epsilon_k$, $\max\left|H^{r,1}_t - H^{r,0}_t\right| < \epsilon_h$, $\max\left|H^d_t - H_t\right| < \epsilon_h$, and $\max\left|r^1_{\ell,t} - r^0_{\ell,t}\right| < \epsilon_r$ where $\epsilon_k = \epsilon_h = 10^{-3}$ and $\epsilon_r = 10^{-4}$.