

Mortgage Debt, Consumption, and Illiquid Housing Markets in the Great Recession

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Abstract

This paper explores the contribution of housing and mortgage debt to the macroeconomic performance of the United States economy during the Great Recession, with a particular eye toward consumption. The importance of housing is evaluated using a quantitative, heterogeneous agent model with search frictions in the housing market and equilibrium mortgage default. The model successfully replicates key features of the U.S. economy prior to the Great Recession and can rationalize the dynamics of housing, debt, and consumption during the crisis. The increase in labor market risk and deterioration in housing finance both play pivotal but different roles in explaining the steep recession and slow recovery. Endogenous housing illiquidity is necessary to explain the magnitude of the house price drop, the spike in foreclosures, the fall in consumption, and the evolution of homeownership. The model also substantiates and explains findings from the literature on the sensitivity of consumption to house price movements and how the degree of household indebtedness affects this relationship. Lastly, the Federal Reserve’s policy of Quantitative Easing is evaluated and found to have substantial effects on house price and consumption dynamics.

Keywords: Consumption; Housing; Liquidity; Debt; Default; Great Recession

JEL Classification Numbers: D31, D83, E21, E22, G11, G12, G21, R21, R31

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1 Introduction

From a macroeconomic perspective, the Great Recession has been characterized by a sizable and persistent decline in economic activity and spending patterns. While it is still not apparent what made this experience different from the traditional business cycle, it seems clear that housing markets and mortgage debt have been important contributors to the recent macroeconomic performance, not only in the United States, but in several countries in the European Union.

The mechanisms that connect housing behavior, mortgage finance, and the macroeconomy are still not well understood. This is particularly challenging because, traditionally, the empirical literature has argued that shocks to the household balance sheet should have very small aggregate effects. While this might be the case in the traditional business cycle frequency where house prices move relatively little from an aggregate perspective, the Great Recession appears to be the result of a very substantial increase in housing valuation and mortgage debt. During the housing boom, the low mortgage rates, access to home equity, and the ability to collateralize made homes a very attractive asset for many households that previously rented. The collapse of the housing market wiped out the home equity of many home owners but also reduced the liquidity properties of the house. As a result, a significant number of households exited the owner-occupied housing market, via selling or defaulting, and had to adjust their consumption expenditures. Given the special circumstances of this episode, it is unclear what are the microeconomic and macroeconomic implications of a shock of this magnitude on the households balance sheet.

The objective of the paper is to develop some understanding in the mechanisms that relate the housing market and mortgage finance with relevant macroeconomic variables, in particular consumption spending. In particular, the goal of this paper is to develop a framework that can deliver endogenously the dynamics of the housing market (i.e., house prices, home ownership, mortgage defaults, and selling time). The model developed in this paper considers a two-sector economy (consumption and

housing goods) with open capital flows. There is a continuum of individuals that, in the tradition of models with incomplete markets, face uninsurable income risk. Housing provides service flows, but is also an investment good that can be financed using a long-term mortgage loan with a default option. Households can refinance their mortgage and withdraw home equity, but this is costly. The housing market is subject to search frictions, and as a result, the liquidity properties of the housing stock are endogenously determined. This feature allows for the capturing of extreme liquidity (or very low time in the market) during the peak of the housing market and the illiquidity during the Great Recession. In equilibrium, the house price-to-rent ratio deviates from one because housing provides partial insurance against large and persistent income shocks and because its transaction is subject to endogenous trading frictions that limit the home owners ability to sell a house relatively quickly. In this economy, banks borrow funds from the capital markets and provide long-term mortgages. The banks also hold inventories of foreclosed properties and decide when to sell them in the market.

The baseline version of the model is calibrated to replicate key features of the United States economy prior to the Great Recession (2003–2005). The calibration puts heavy emphasis on matching key housing moments related to sales, time on the market, and foreclosures, but also important dimensions of the joint distribution of assets, housing wealth, and mortgage debt. To simulate the Great Recession, the baseline model is exposed to a series of unexpected events in the labor and housing finance markets starting in 2006, and the perfect foresight transition path is calculated.

The model can rationalize the performance of the housing market during the Great Recession, replicating the dynamics and magnitude of house prices, homeownership rates, housing defaults, and endogenous housing liquidity measured in terms of time-on-the-market (TOM). Analyzing the Great Recession through the lens of the model provides some important lessons in terms of the quantitative importance of the various

mechanisms at play.

The model suggests that the increase of downside labor market risk and the tightening of loan-to-value (LTV) constraints have the largest effects on house prices, consumption, and foreclosures. The increase in labor market risk is essential to generate the slow and pronounced decline in homeownership. Without this feature a decline in house prices generates a counterfactual increase of the home ownership rate. The foreclosure rate responds non-linearly to changes in house prices and income. A modified version of the double trigger hypothesis that includes the effects of housing illiquidity is necessary to explain default behavior. Decreased access to credit plays a major role in generating increased debt overhang (measured by time on the market) and foreclosure activity. The drop in total factor productivity (TFP) and increase in interest rates have modest effects on house prices and consumption; however, the TFP drop contributes significantly to higher foreclosures and the interest rate increase contributes to debt overhang.

The model suggests that endogenizing the liquidity properties of housing, as opposed to a standard transaction cost model, generate three striking differences: 1) it amplifies the aggregate default rates because some home owners that cannot sell the house in the market are forced to turn the property to the bank, 2) the endogenous illiquidity magnifies the drop in house prices and consumption relative to the model with exogenous illiquidity (transaction costs), and 3) the predicted number of home owners increases, as the housing market deteriorates, a feature that is not consistent with the observed decline in the home ownership rate.

1.1 Related Literature

There is a growing literature that relates aspects of financial crises with the Great Recession. While there are some important connections with this paper, the main objective of this section is to relate our research with different strands of the macro-housing literature.

There is a growing literature that emphasizes the connection between the housing market and the macroeconomy. Some examples include Iacoviello (2005), Davis and Heathcote (2005), Leamer (2007), and an extensive summary of the literature is provided by Davis and Van Nieuwerburgh (2015). While these papers measure the contribution of housing to the traditional business cycle, none of them specifically addresses the episode of the Great Recession.

One of the main challenges to understand this episode was the dramatic boom-bust in valuation of the housing stock and leverage cycle of mortgage debt. In this regard, traditional macroeconomic models of housing have serious difficulties replicating the observed patterns of prices and quantities during this episode. As a result, the majority of the research on the Great Recession is making advances by analyzing different aspects of this event.

To understand the dynamics of house prices during the boom and the bust Garriga, Manuelli, and Peralta-Alva (2012) develop a stylized macroeconomic model of market segmentation that generates sizable movement in house values, about 50 percent, driven by changes in housing finance. In their economy, the collapse of house prices induces a large and persistent recession through the deleveraging process and decline in non-housing consumption. This paper shares similar features in the process of engineering a housing crisis as unanticipated set of events, but the mechanisms are different. The most important is the presence of search frictions in the housing market that endogenizes the liquidity of homes, thereby introducing an amplification mechanism relative to a framework with exogenous transaction costs. In addition, the presence of household heterogeneity and tenure choice allows for exploring the differential response of homeowners and renters. In addition, homeowners can choose to deleverage by repaying the loan or defaulting. The choice to deleverage has important implications for the path of consumption of the home owners.

One can interpret the decline in house prices as a shock to households net worth. There is also an extensive literature that analyzes the response of consumption to

negative shocks to income or household balance sheets. For example, Iacoviello and Pavan (2013) argue that a tightening of households budgets, due to the drop in real estate wealth, can generate a sharp decline in aggregate consumption. Huo and Ros-Rull (2016) also analyze this issue in an economy with a continuum of agents and frictions in the goods market. In their economy, goods are produced in a market with frictions and, as a result, a negative wealth effect effectively reduces aggregate demand, generating a significant decline in consumption and output. However, households can readjust their portfolios instantly without incurring a cost and the houses are not subject to any form of transaction costs.

To amplify the response to shocks, Kaplan and Violante (2014) have argued that in the presence of illiquid assets, the response of consumption to unanticipated shocks can be substantially larger. When households have a substantial fraction of their wealth tied up in an illiquid asset, they behave as wealthy hand-to-mouth agents with relatively high marginal propensities to consume. This sensitivity affects income shocks but also shocks to interest rates, as discuss by Kaplan, Moll and Violante (2016). The notion of liquidity in these models is not tied to the macroeconomic performance, however, but instead shows up as exogenous transaction costs. In this paper, a decline in the house price endogenously reduces the liquidity properties of some assets, in this case homes. This mechanism significantly amplifies the response of consumption to house price shocks.

There is an important literature that explores the increase in foreclosure dynamics during the Great Recession. To simplify the problem, a number of papers consider an exogenous change in house prices to analyze the dynamics of defaults (i.e. Such as Guler (2014), Corbae and Quintin (2014), Campbell and Cocco (2014), and Hatchondo et. al. (2014)). Other papers endogenize prices, such as Garriga and Schlagenghauf (2009), Chatterjee and Eyigungor (2014), and Arsland, Guler, and Temel (2015), but housing liquidity is exogenous.

The heterogeneity in the model has clear testable data implications. The ability

of the model to match the empirical counterparts as suggested by the works of Mian, Rao, and Sufi (2013), Mian and Sufi (2014), Petev, Pistaferri, and Eksten (2011), and Parker and Vissing-Jorgensen (2009) among other is discussed in the results section. It is worth mentioning that there is also an extensive literature that explores the role of financial conditions as drivers of the Great Recession using quantitative dynamic macroeconomic models (i.e., Black (1995); Bloom (2009); Christiano et al. (2010); Arellano et al. (2010); Gertler and Karadi (2011); Hall (2011); Kocherlakota (2012); Jermann and Quadrini (2012); Brunnermeier and Sannikov (2013); He and Krishnamurthy (2014); Gertler and Kiyotaki (2015), Navarro (2015), among others). However, most of this research focuses on firms investment and private employment, but the literature makes no attempt to measure the specific role of housing and construction and in the Great Recession.

2 The Model

This section constructs a discrete time, infinite horizon, open economy model with the following features: 1) two production sectors (numeraire good; housing construction), 2) uninsurable, idiosyncratic earnings risk, 3) long-term mortgage contracts, and 4) endogenous credit constraints with equilibrium mortgage default.

2.1 Households

2.1.1 Endowments

Households are infinitely lived and inelastically supply a stochastic labor endowment $e \cdot s$ to the labor market. The persistent component $s \in S$ follows a finite state Markov chain with transitions $\pi_s(s'|s)$, and households draw the transitory component $e \in E \subset \mathbb{R}_+$ from the cumulative distribution function $F(e)$. Households receive their initial s from the invariant distribution $\Pi_s(s)$.

2.1.2 Preferences

Households discount the future at the rate β and have preferences over consumption c and housing services c_h . Households obtain housing services either by owning and occupying a house or by residing in an apartment. Apartment-dwellers, or “renters,” purchase apartment space $a \leq \bar{a}$ each period at a cost of r_h per unit. Each unit of apartment space generates one unit of housing services. Agents become homeowners by purchasing a house $h \in H = \{\underline{h}, h_2, h_3\}$ in the decentralized housing market. House h generates $c_h = h$ units of housing services each period. Homeowners are not permitted to own multiple houses or to rent out their house to a tenant. Furthermore, the largest apartment is smaller than the smallest house, i.e. $\bar{a} \leq \underline{h}$, which implies that all owners choose to occupy their house.

2.2 Technology

2.2.1 Composite Consumption

A representative firm produces the composite good using labor N_c as the sole input,

$$Y_c = A_c N_c.$$

Total factor productivity A_c is constant in the steady state but varies during the Great Recession. The cost of labor is w per unit of labor efficiency.

The profit maximization condition of the composite good firm is

$$w = A_c. \tag{1}$$

2.2.2 Apartments

Landlords operate a linear, reversible technology that converts each unit of the composite good into A_h units of apartment space, which they sell at price r_h .

The profit maximization condition of landlords is

$$r_h = \frac{1}{A_h} \tag{2}$$

2.2.3 Housing Construction

Home builders construct new houses using a constant returns to scale production function with land L , structures S_h , and labor N_h ,

$$Y_h = F_h(L, S_h, N_h).$$

Builders purchase new land permits from the government at price p_l , pay wage w , and purchase structures S_h from the consumption good sector. As in [Favilukis, Ludvigson and Van Nieuwerburgh \(2016\)](#), the government supplies a fixed amount $\bar{L} > 0$ of new

permits each period, and all revenues go to government consumption. Home builders do not experience construction lags and sell directly to real estate brokers at price p_h per unit of housing. Individual houses depreciate stochastically with probability δ_h . In the aggregate, the housing stock evolves according to

$$H' = (1 - \delta_h)H + Y'_h$$

The relevant profit maximization conditions of home builders are

$$1 = p_h \frac{\partial F_h(\bar{L}, S_h, N_h)}{\partial S_h} \quad (3)$$

$$w = p_h \frac{\partial F_h(\bar{L}, S_h, N_h)}{\partial N_h}. \quad (4)$$

2.3 Housing Market

Real estate brokers intermediate all trades in the decentralized housing market. First, owners (owner-occupiers or banks with foreclosed properties) choose a list price x_s to attract seller-brokers willing to purchase their house at that price. Meanwhile, buyers choose a desired house type $h \in H$ and purchase price x_b and direct their search for a buyer-broker willing to sell said house at said price. The market “clears” as seller-brokers, buyer-brokers, and home builders trade housing frictionlessly with each other at the *shadow housing price* p_h . Brokers are not permitted to carry housing inventories into future periods, but inventories *do* arise in equilibrium from the portion of the housing stock that owners put on the market but fail to sell.

2.3.1 Directed Search in the Housing Market

Buyers Prospective buyers direct their search for houses by choosing a desired price $x_b \geq 0$ and a house size $h \in H$. Formally, buyers enter submarket $(x_b, h) \in \mathbb{R}_+ \times H$. With probability $p_b(\theta_b(x_b, h))$, a buyer matches with and purchases a house from a buyer-broker, where $\theta_b(x_b, h)$ is the ratio of brokers to buyers, i.e. the market tightness

of submarket (x_b, h) . The probability that a broker finds a buyer is $\alpha_b(\theta_b(x_b, h)) = \frac{p_b(\theta_b(x_b, h))}{\theta_b(x_b, h)}$. The function $p_b : \mathbb{R}_+ \rightarrow [0, 1]$ is continuous and strictly increasing with $p_b(0) = 0$; α_b is strictly decreasing. It is possible that $\alpha_b > 1$, in which case the same broker finds multiple buyers, to which the broker sells one house each.

Successful buyers immediately move into their house and switch from apartment-dweller (“renter”) status to homeowner status. Unsuccessful buyers remain as renters until the next period. Each broker in submarket (x_b, h) incurs an entry cost $\kappa_b h$, and both sides of the market take $\theta_b(x_b, h)$ parametrically.

Sellers Sellers of existing houses, which includes homeowners and lenders selling foreclosed properties, simply choose a list price $x_s \geq 0$ *each period* that they commit to honoring if they match with a seller-broker. In the parlance of directed search, sellers enter submarket (x_s, h) , where h is the size of house they are selling. With probability $p_s(\theta_s(x_s, h))$, a seller successfully matches and sells the house, *provided that they have the ability to pay off any outstanding mortgage debt*. Brokers find sellers with probability α_s , where p_s and α_s are analogous to p_b and α_b , respectively. Each broker incurs an entry cost $\kappa_s h$, and owners that try and fail to sell pay a small utility cost ξ . Both sides of the market take $\theta_s(x_s, h)$ parametrically.

The profit maximization conditions of the real estate brokers are

$$\kappa_b h \geq \overbrace{\alpha_b(\theta_b(x_b, h))}^{\text{prob of match}} \overbrace{(x_b - p_h h)}^{\text{broker revenue}} \quad (5)$$

$$\kappa_s h \geq \underbrace{\alpha_s(\theta_s(x_s, h))}_{\text{prob of match}} \underbrace{(p_h h - x_s)}_{\text{broker revenue}} \quad (6)$$

with $\theta_b(x_b, h) \geq 0$, $\theta_s(x_s, h) \geq 0$, and complementary slackness holding.

The revenue to a seller-broker that purchases a house from a seller is $p_h h - x_s$. Therefore, brokers continue to enter submarket (x_s, h) until the cost $\kappa_s h$ exceeds the expected revenue. An analogous process occurs for buyer-brokers.

2.3.2 Block Recursivity

As the above analysis shows, the menu of market tightnesses does not depend directly on the distribution of households over income, assets, and debt. Instead, $\theta_s(x_s, h)$ and $\theta_b(x_b, h)$ depend only on p_h :

$$\theta_b(x_b, h) = \alpha_b^{-1} \left(\frac{\kappa_b h}{x_b - p_h h} \right) \quad (7)$$

$$\theta_s(x_s, h) = \alpha_s^{-1} \left(\frac{\kappa_s h}{p_h h - x_s} \right) \quad (8)$$

Block recursivity greatly simplifies and speeds up the computation without altering the substance of the frictional buying and selling problems of the households. As a result, solving for the dynamics of the market tightnesses reduces to finding the equilibrium path of p_h and then substituting into (7) – (8).

2.4 Financial Markets

Households save through the use of one period real bonds that trade at price $q_b = \frac{1}{1+r}$, where r is the (exogenous) risk-free rate. In addition, homeowners can borrow in the form of long term, fixed rate mortgage contracts.

2.4.1 Mortgages

Banks price default risk into new mortgage contracts. Specifically, when a borrower with bonds b' , house h , and persistent labor efficiency s takes out a mortgage of size m' at rate r_m , the bank delivers $q_m^0((q_m, m'), b', h, s)m'$ units of the composite consumption good to the borrower at origination, where $q_m \equiv \frac{1}{1+r_m}$ remains fixed for the duration of the loan. Perfect competition assures zero ex-ante profits loan-by-loan. For the duration of the paper, q_m denotes the current market (inverse) fixed rate for new mortgages while $\overline{q_m}$ denotes the rate for an individual existing borrower. No meaningful distinction exists in the steady state.

Mortgages in this paper have no predefined maturity date, which allows them to act as a stand-in for all forms of mortgage debt (i.e. not just a 30-year first lien). As a result, homeowners gradually accumulate equity at their own pace. However, homeowners that want to tap into their equity must refinance into a new contract.

Banks incur an origination cost ζ and servicing costs ϕ over the life of each mortgage. During repayment, banks have exposure to two risks. First, if the house depreciates, the bank must forgive the loan.¹ Second, homeowners can default in a given period by not making a payment. In this situation, the lender forecloses on the borrower with probability φ and repossesses the house. With probability $1 - \varphi$, the lender ignores the skipped payment until the next payment comes due.

Banks front-load all borrower-specific default risk into the price q_m^0 borrowers receive at origination, but the fixed rate $\bar{q}_m$ reflects depreciation risk. To summarize, a borrower with contract $(\bar{q}_m, m)$ that chooses a new balance of m' owes $m - \bar{q}_m m'$ if $m' \leq m$, or else $m - q_m^0((q_m, m'), b', h, s)m'$ if $m' > m$.

The fixed rate r_m set at origination satisfies $1 + r_m = \underbrace{\left(\frac{1 + \phi}{1 - \delta_h}\right)}_{\text{spread}} \underbrace{(1 + r^*)}_{\text{long-run risk-free rate}}$.

Mortgage prices for contract $(\bar{q}_m, M')$ satisfy the following recursive relationship:

$$\begin{aligned}
q_m^0((\bar{q}_m, m'), b', h, s)m' &= \frac{1 - \delta_h}{(1 + \zeta)(1 + \phi)(1 + r)} \mathbb{E} \left\{ \underbrace{p_s(\theta_s(x'_s, h))m'}_{\text{sell + repay}} + \underbrace{[1 - p_s(\theta_s(x'_s, h))]}_{\text{no sale (do not try/fail)}} \right. \\
&\times \left[\underbrace{d'\varphi \min\{J_{REO}(h), m'\}}_{\text{default + repossession}} + \underbrace{d'(1 - \varphi)}_{\text{no repossession}} \left(-\phi m' + \underbrace{(1 + \zeta)(1 + \phi)q_m^0((\bar{q}_m, m'), b'', h, s')m'}_{\text{continuation value of current } m'} \right) \right. \\
&\left. \left. + (1 - d') \left(\underbrace{m' - (1 + \phi)\bar{q}_m m'' \mathbf{1}_{[m'' \leq m']}}_{\text{borrower payment net of servicing costs}} + \underbrace{(1 + \zeta)(1 + \phi)q_m^0((\bar{q}_m, m''), b'', h, s')m'' \mathbf{1}_{[m'' \leq m']}}_{\text{continuation value of new } m''} \right) \right] \right\} \quad (9)
\end{aligned}$$

where x'_s , d' , b'' , and M'' are the policy functions for list price, mortgage default ($\in \{0, 1\}$), bonds, and new mortgage balance next period, respectively.

¹This assumption prevents the model from generating artificially high foreclosure rates.

2.4.2 Foreclosure Process

In the event of foreclosure, borrowers lose their house, have their debt erased, and receive a flag $f = 1$ on their credit record. Borrowers with a credit flag lose access to the mortgage market. Flags persist to next period with probability $\gamma_f \in (0, 1)$.

Banks sell repossessed houses (REO properties) in the decentralized housing market. Banks lose a proportion χ of sales revenue to the various costs of selling foreclosed houses. The bank absorbs all losses but must pass along profits to the borrower in the unlikely event that sales revenues exceed the remaining mortgage balance.

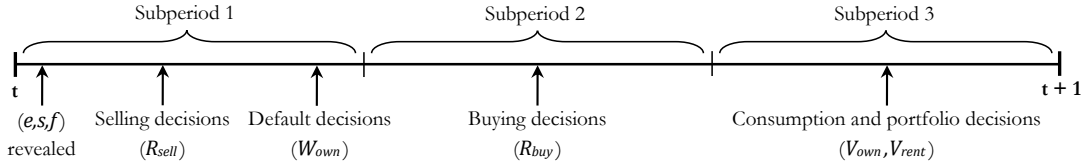
The value to a lender in repossessing a house h is

$$J_{REO}(h) = R_{REO}(h) - \eta h + \frac{1 - \delta_h}{1 + r} J_{REO}(h)$$

$$R_{REO}(h) = \max \left\{ 0, \max_{x_s \geq 0} p_s(\theta_s(x_s, h)) \left[(1 - \chi)x_s - \left(-\eta h + \frac{1 - \delta_h}{1 + r} J_{REO}(h) \right) \right] \right\} \quad (10)$$

where η is the cost of holding onto the house (maintenance, property taxes, etc.) and $R_{REO}(h)$ is the option value of trying to sell the house.

2.5 Household Problem



Each period contains three subperiods. At the beginning of subperiod 1, households learn their labor efficiency components, e and s , and their credit score $f \in \{0, 1\}$. The individual state of a homeowner is cash at hand y , inverse mortgage rate $\bar{q}_m$ and balance m , house h , and persistent labor component s . The individual state of a renter is simply (y, s, f) . Working backwards, the household problem is as follows:

2.5.1 Consumption/Saving

End-of-period homeowner expenditures consist of the consumption good, bond purchases, and mortgage payments. Homeowners face the following constraint:

$$c + \eta h + q_b b' + m - \widetilde{q}_m m' \leq y$$

where $\widetilde{q}_m = \overline{q}_m \mathbf{1}_{[m' \leq m]} + q_m^0((q_m, m'), b', h, s) \mathbf{1}_{[m' > m]}$.

In the stationary environment, owners with good credit have value function

$$V_{own}(y, (\overline{q}_m, m), h, s, 0) = \max_{m', b', c \geq 0} u(c, h) + \beta \mathbb{E} \left[\begin{array}{l} (1 - \delta_h)(W_{own} + R_{sell})(y', (\overline{q}_m, m'), h, s', 0) \\ + \delta_h(V_{rent} + R_{buy})(y', s', 0) \end{array} \right]$$

subject to

$$c + \eta h + q_b b' + m - \widetilde{q}_m m' \leq y$$

$$q_m^0((q_m, m'), b', h, s) m' \mathbf{1}_{[m' > m]} \leq \vartheta p_h$$

$$y' = w e' s' + b'$$
(11)

where ϑ is the loan-to-value limit for new loans. The terms $W_{own} + R_{sell}$ and $V_{rent} + R_{buy}$ are subperiod 1 utilities for homeowners and apartment-dwellers, respectively.

The problem for homeowners with bad credit is analogous, except that they lack access to the mortgage market. Apartment-dwellers replace mortgage payments with period-by-period purchases of apartment space $a \leq \bar{a}$. Therefore, apartment-dwellers face the following constraint:

$$c + r_h a + q_b b' \leq y.$$

2.5.2 House Buying

Prospective buyers (including successful home sellers from subperiod 1) direct their search to a submarket (x_b, h) of their choice. Buyers with bad credit are bound by the constraint $y - x_b \geq 0$, while buyers with good credit are bound by the constraint $y - x_b \geq \underline{y}(s, (h, 1))$, where $\underline{y} < 0$ captures the ability of new buyers to take out a mortgage in subperiod 3. The option value R_{buy} of attempting to buy is as follows:

$$R_{buy}(y, s, 0) = \max\{0, \max_{\substack{h \in H, \\ x_b \leq y - \underline{y}}} p_b(\theta_b(x_b, h)) [V_{own}(y - x_b, 0, h, s, 0) - V_{rent}(y, s, 0)]\} \quad (12)$$

$$R_{buy}(y, s, 1) = \max\{0, \max_{\substack{h \in H, \\ x_b \leq y}} p_b(\theta_b(x_b, h)) [V_{own}(y - x_b, 0, h, s, 1) - V_{rent}(y, s, 1)]\} \quad (13)$$

2.5.3 Mortgage Default

The value function for a homeowner deciding whether to default is

$$\begin{aligned} W(y, (\overline{q_m}, m), h, s, 0) = & \max \{ \varphi(V_{rent} + R_{buy})(y + \max\{0, J_{REO}(h) - m\}, s, 1) \\ & + (1 - \varphi)V_{own}^d(y, (\overline{q_m}, m), h, s, 0), V_{own}(y, (\overline{q_m}, m), h, s, 0) \} \end{aligned} \quad (14)$$

where the value function associated with defaulting but not being foreclosed on is

$$\begin{aligned} V_{own}^d(y, (\overline{q_m}, m), h, s, 0) = & \max_{b', c \geq 0} u(c, h) + \beta \mathbb{E} \left[\begin{aligned} & (1 - \delta_h)(W_{own} + R_{sell})(y', (\overline{q_m}, m), h, s', 0) \\ & + \delta_h(V_{rent} + R_{buy})(y', s', 0) \end{aligned} \right] \\ & \text{subject to} \\ & c + \eta h + q_b b' \leq y \\ & y' = we' s' + b' \end{aligned} \quad (15)$$

2.5.4 House Selling

Owners of house size h who want to sell choose a list price x_s and direct their search to submarket (x_s, h) . The option value R_{sell} for a homeowner with good credit is

$$R_{sell}(y, (\overline{q_m}, m), h, s, 0) = \max\{0, \max_{x_s} p_s(\theta_s(x_s, h)) [(V_{rent} + R_{buy})(y + x_s - m, s, 0) - W_{own}(y, (\overline{q_m}, m), h, s, 0)] + [1 - p_s(\theta_s(x_s, h))](-\xi)\} \text{ subject to } y + x_s \geq m \quad (16)$$

where the constraint reflects the mortgage repayment requirement.

3 Model Parametrization

The model is calibrated to replicate key features of the United States economy during 2003 – 2005, prior to the Great Recession. The calibration puts heavy emphasis on matching key housing moments related to sales, time on the market, and foreclosures, as well as important dimensions of the joint distribution of assets, housing wealth, and mortgage debt. Some parameters are drawn from the literature or from external sources, but the remainder are determined jointly within the model.

3.1 Independent Parameters

Households Following [Storesletten, Telmer and Yaron \(2004\)](#), the log of the persistent component of labor efficiency follows an AR(1) process, while the transitory component is log-normal.² The persistent component is discretized using a 3-state Markov chain.

For preferences, households have CES period utility with an intratemporal elasticity of substitution of $\nu = 0.13$. Risk aversion is set to $\sigma = 2$, while the consumption share ω and discount factor β are determined in the joint calibration.

²The appendix explains the procedure to convert the annual estimates from [Storesletten et al. \(2004\)](#) to quarterly values.

Technology Steady state TFP in the consumption good sector is set to normalize mean quarterly earnings to 0.25. Meanwhile, housing construction is Cobb-Douglas with a structures share of $\alpha_S = 0.3$ and a land share of $\alpha_L = 0.33$, based on data from the Lincoln Institute of Land Policy. Housing depreciates at an annual rate of 1.4%. Lastly, the apartment technology A_h is set to generate an annual rent-price ratio of 3.5%, consistent with [Sommer, Sullivan and Verbrugge \(2013\)](#).

Housing Market Matching is Cobb Douglas, i.e. $p_s(\theta_s) = \min\{\theta^{\gamma_s}, 1\}$ and $p_b(\theta_b) = \min\{\theta^{\gamma_b}, 1\}$. Substituting in (7) and (8) gives

$$p_s(\theta_s) = \begin{cases} 0 & \text{if } x_s > p_h h \\ \left(\frac{p_h h - x_s}{\kappa_s h}\right)^{\frac{\gamma_s}{1-\gamma_s}} & \text{if } (p_h - \kappa_s)h \leq x_s \leq p_h h \\ 1 & \text{if } x_s < (p_h - \kappa_s)h \end{cases} \quad p_b(\theta_b) = \begin{cases} 1 & \text{if } x_b > (p_h + \kappa_b)h \\ \left(\frac{x_b - p_h h}{\kappa_b h}\right)^{\frac{\gamma_b}{1-\gamma_b}} & \text{if } p_h h \leq x_b \leq (p_h + \kappa_b)h \\ 0 & \text{if } x_b < p_h h \end{cases}$$

The joint calibration determines the parameters κ_b , κ_s , γ_s , γ_b , and disutility ξ . Holding costs (maintenance, property taxes, etc.) are $\eta = 0.007$.

Financial Markets To match values in the U.S. during 2003 – 2005, the real risk-free rate is set to -1% , and the mortgage origination cost is 0.4% . The mortgage servicing cost ϕ is set to equate the real mortgage rate to 3.6% . Lastly, the exogenous LTV limit is $\vartheta = 1.25$ (125%), which makes it *non-binding* in the steady state.³ Lastly, the persistence of bad credit flags is $\gamma_f = 0.95$, and the REO discount χ is determined in the joint calibration.

3.2 Joint Calibration and Model Fit

The joint calibration determines the remaining parameters. First, the calibration targets select household portfolio moments calculated from the 2004 Survey of Consumer Finances (SCF). Specifically, the calibration aims to match average housing

³At the peak of the housing boom in 2005, the popularity of cash-out refinancing led to many instances of new mortgages with loan-to-value ratios in excess of 100%. See [Herkenhoff and Ohanian \(2015\)](#).

wealth and the proportion of borrowers with leverage exceeding 90%, because these households have the highest likelihood of ending up underwater on their mortgages and in danger of foreclosure during the Great Recession.⁴ The calibration also targets certain key moments of the housing market such as sales volume, average search duration for buyers and mismatched sellers, and maximum price spreads. Lastly, the model is calibrated to match foreclosure starts and the average foreclosure discount.

Table 1 shows that the model successfully matches the targets and nearly replicates other untargeted portfolio statistics from the 2004 SCF. Notably, the model matches median liquid assets and reasonably approximates the distribution of mortgage debt.

4 Results

This section undertakes four major tasks. First, the determinants of the Great Recession are categorized and quantified in terms of relative importance. Second, results are presented that highlight the importance of *endogenous housing liquidity* in explaining the dynamics of key housing variables, mortgage default, and consumption during the Great Recession. Next, the transmission of house price movements into consumption is analyzed, with particular attention paid to the role of illiquidity and indebtedness. The last task evaluates the macroeconomic effects of Quantitative Easing and provides insight into how interest rate movements affect consumption dynamics.

4.1 Replicating and Decomposing the Great Recession

To simulate the Great Recession, the model is hit with a combination of unanticipated shocks starting in 2006, and the perfect foresight transition path is calculated. In other words, households and banks are surprised by the onset of the recession but have rational expectations about the progression of the recession and recovery.

⁴Only includes households that are in the bottom 95% of the earnings *and* net worth distributions. Net worth = liq assets + housing – mortgages. Liq assets = financial wealth – quasi-liq retirement.

Table 1: Model Calibration

Description	Parameter	Value	Target	Model	Source/Reason
Calibration: Independent Parameters					
Autocorrelation	ρ	0.952			Storesletten et al. (2004)
SD of Persistent Shock	σ_ϵ	0.17			Storesletten et al. (2004)
SD of Transitory Shock	σ_e	0.49			Storesletten et al. (2004)
Intratemp. Elas. of Subst.	ν	0.13			Flavin and Nakagawa (2008)
Risk Aversion	σ	2			Various
Structure Share	α_S	30%			Favilukis et al. (2016)
Land Share	α_L	33%			Lincoln Inst Land Policy
Holding Costs	η	0.7%			Moody's
Depreciation (Annual)	δ_h	1.4%			BEA
Rent-Price Ratio (Annual)	r_h	3.5%			Sommer et al. (2013)
Risk-Free Rate (Annual)	r	-1.0%			Federal Reserve Board
Servicing Cost (Annual)	ϕ	3.2%			3.2% Real Mortgage Rate
Mortgage Origination Cost	ζ	0.4%			FHFA
Maximum LTV	ϑ	125%			Fannie Mae
Prob. of Repossession	φ	0.5			2008 OCC Mortgage Metrics
Credit Flag Persistence	λ_f	0.9500			Fannie Mae
Calibration: Jointly Determined Parameters					
Homeownership Rate	$\bar{a}$	3.2840	69.0%	68.9%	Census
Starter House Value	h_1	2.7100	2.75	2.75	Corbae and Quintin (2015)
Housing Wealth (Owners)	ω	0.8159	3.99	3.99	2004 SCF
Borrowers with $LTV \geq 90\%$	β	0.9749	11.40%	11.28%	2004 SCF
Months of Supply*	ξ	0.0013	4.90	4.89	Nat'l Assoc of Realtors
Avg. Buyer Search (Weeks)	γ_b	0.0940	10.00	10.04	Nat'l Assoc of Realtors
Maximum Bid Premium	κ_b	0.0209	2.5%	2.5%	Gruber and Martin (2003)
Maximum List Discount	κ_s	0.1256	15%	15%	RealtyTrac
Foreclosure Discount	χ	0.1370	20%	20%	Pennington-Cross (2006)
Foreclosure Starts (Annual)	γ_s	0.6550	1.20%	1.29%	Nat'l Delinquency Survey
Model Fit					
Borrowers with $LTV \geq 80\%$			21.90%	27.2%	2004 SCF
Borrowers with $LTV \geq 95\%$			7.10%	7.25%	2004 SCF
Median Owner Liq. Assets			0.19	0.22	2004 SCF

*Months of supply is inventories divided by the sales rate and proxies for time on the market.

4.1.1 Categorizing the Shocks

Labor Market Conditions The first category of shocks used to simulate the Great Recession affect the labor market. First, total factor productivity (TFP) drops by 5% and remains at that level for 3 years before reverting. Although the Great Recession did not officially begin until the end of 2007, evidence from [Fernald \(2014\)](#) indicates that TFP started dropping beforehand. In the model, this drop in TFP translates directly into a 5% cut in wages for all households.

Second, a temporary increase in labor market risk is engineered to generate a gradual 6.2% drop in aggregate labor consistent with the deterioration in employment from 2007 to 2010. Specifically, the labor efficiency transition matrix π_s is replaced with new transition probabilities $\tilde{\pi}_s^{recession}(s'|s)$.⁵

Financial Conditions Many analysts have also pointed to the importance of credit market disruptions in creating and exacerbating the Great Recession. This tightening of credit is captured in two ways for the simulation. First, the real risk free rate r jumps from -1% to 3% for eight quarters, corresponding to the hike in the Federal Funds Rate in 2006 and 2007. However, given the long horizon of mortgages, the adjustment in the mortgage market takes place through changes in mortgage prices $q_m^0((q_m, m'), b', h, s)$ rather than in the continuation q_m . Furthermore, existing borrowers in fixed rate contracts do not experience any change in rates. Second, the loan-to-value constraint on new mortgages is tightened from 125% to 90%, and the origination cost is increased from 0.4% to 1.2%⁶

Lastly, two temporary changes in bank behavior are implemented to reflect increased delays in foreclosure processing and the heightened propensity of banks to seek deficiency judgments: the probability of repossession φ decreases from 50% to 20%, and the probability of seeking a deficiency judgment increases from 0% to 50%.

⁵Details: $\tilde{\pi}_s^{recession}(s_2|s) = (1 - 0.026)\pi_s(s_2|s)$ for all s , $\tilde{\pi}_s^{recession}(s_j|s) = \pi_s(s_j|s)$ for all s and $j = 2, 3$, and $\tilde{\pi}_s^{recession}(s_1|s)$ is increased sufficiently to ensure $\sum_{s'} \tilde{\pi}_s^{recession}(s'|s) = 1$ for all s .

⁶Source: Monthly Interest Rate Survey.

The chronological summary of the shocks is as follows:

- *The Crash (3 Years)*

1. The real risk-free rate r increases from -1% to 3% for 8 quarters.
2. TFP A_c decreases by 5% .
3. Deteriorating transitions $\pi_s(s'|s)$ gradually reduce labor supply by 6.2% .
4. The maximum LTV ϑ drops from 125% to 90% and the origination cost ζ increases from 0.4% to 2% .
5. The probability of repossession φ decreases from 50% to 20% .
6. The probability of a deficiency judgment increases from 0% to 50% .

- *The Slow Recovery (4 Years)*

1. The real risk-free rate, TFP, and the probability of repossession revert.
2. Labor supply gradually recovers because of an improvement in $\pi_s(s'|s)$.

- *Return to Normalcy*

1. All exogenous variables revert to their initial steady state values.

4.1.2 Simulating the Great Recession

Figure 1 shows the response of the model economy to all of the shocks. Just as in the data, house prices drop precipitously and average time on the market skyrockets. Quantitatively, both the 24% drop in house prices and the surge in time on the market from 23 to 51 weeks in the model are almost identical to their empirical counterparts. Furthermore, the surge in the foreclosure rate to 4.3% compares well to the 5.2% peak reported in 2009 by the Mortgage Bankers Association.

Declining economic conditions, tighter credit, and a surge in foreclosures all combine to cause a gradual but temporary shift from homeownership to renting. The

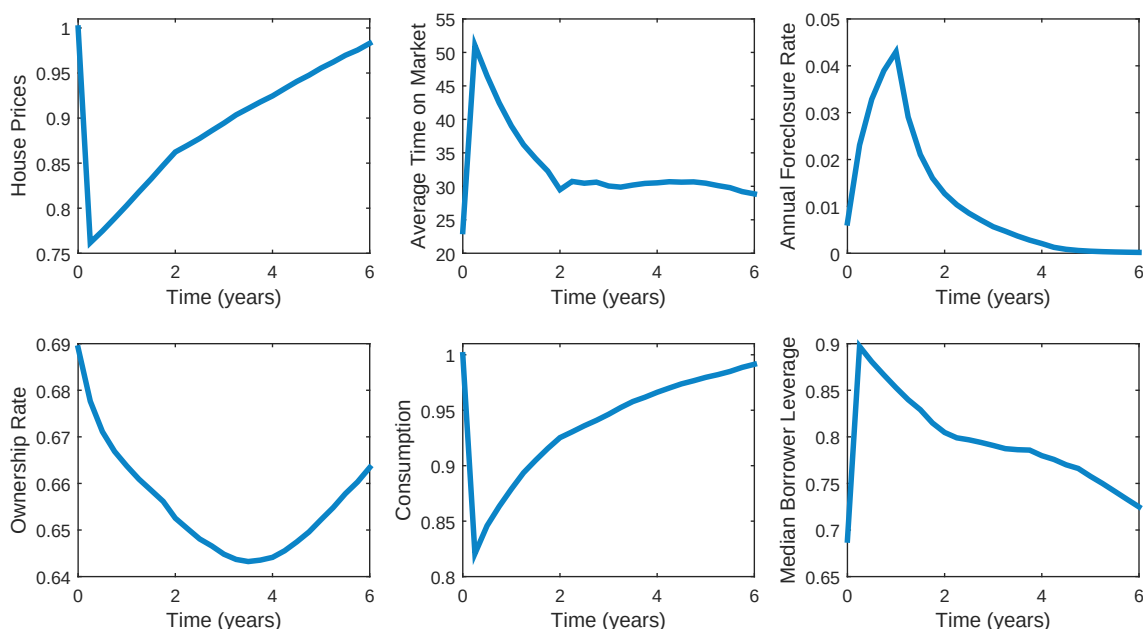


Figure 1: The simulated Great Recession: (TL) house prices, (TM) time on the market, (TR) foreclosure starts, (BL) ownership rate, (BM) consumption, (BR) leverage.

model generates a drop in homeownership from 69% to just over 64%, which accords with the observed national decline since 2006. In response to the collapse in house prices, the model generates an initial *spike* in leverage followed by a slow deleveraging, just as described by Mian, Rao and Sufi (2013). Lastly, household consumption exhibits a sharp drop in the recession and a slow recovery. While perhaps exaggerated, the model is consistent with evidence of a strong decline in consumption presented in Ríos-Rull and Huo (2016) and Pistaferri (2015).

The remainder of this section disentangles the effects of each shock and explains the mechanisms generating the Great Recession in the model.

4.1.3 Measuring the Impact of Labor Market Shocks

To bound the impact of the labor market shocks, two counterfactuals are simulated. First, the recession is re-computed with all but one of the shocks present. Next, the recession is re-computed with only one shock present at a time.

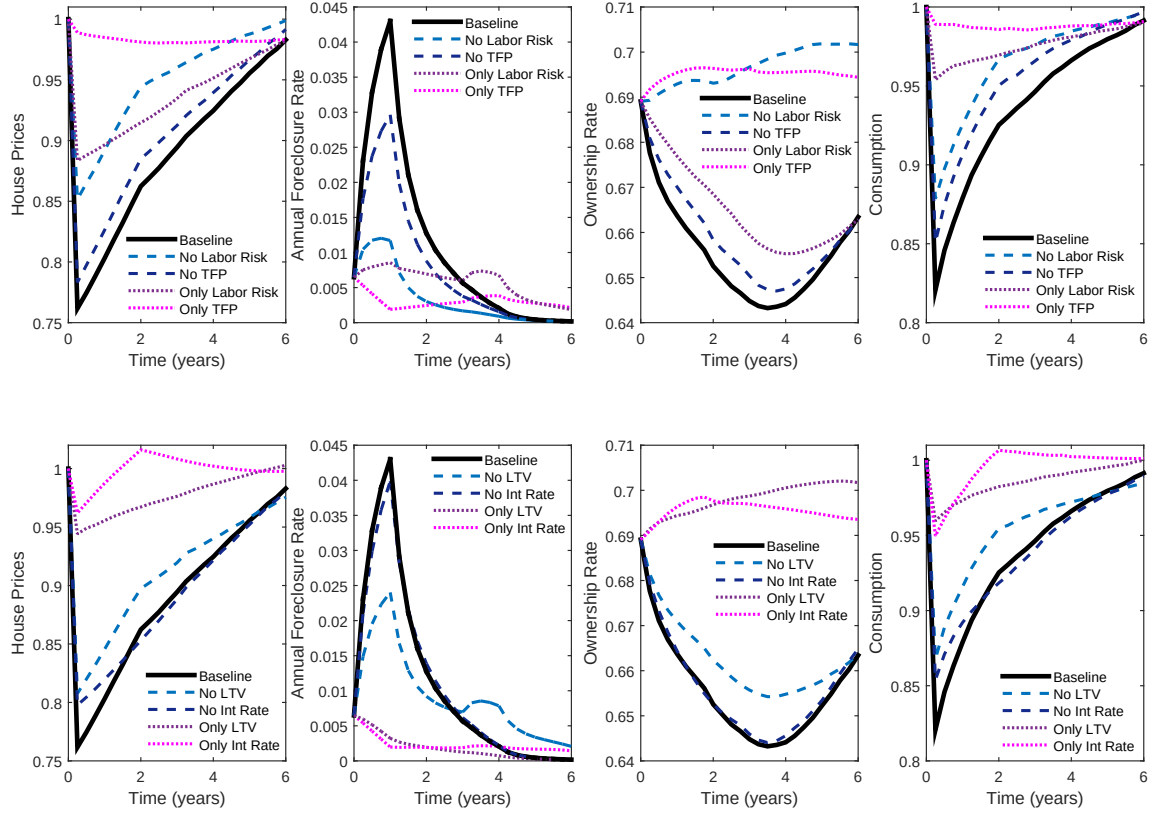


Figure 2: Top: disentangling the effects of labor market shocks. Bottom: disentangling the effects of financial shocks.

Higher Downside Labor Risk Recall that downside labor market risk temporarily increases in the baseline simulation and causes a gradual reduction in aggregate labor. Although the direct impact on earnings is delayed, the top row of figure 2 shows an immediate and substantial impact on house prices, foreclosures, homeownership, and consumption. Absent the increase in labor risk, house prices only fall by 15% instead of 24%. Furthermore, with *only* the increase in labor risk, house prices drop by almost 12%. Together, these two numbers place relatively tight bounds of [9.0%, 11.6%] on the impact of labor risk on house prices.

However, these tight bounds disappear when it comes to the impact of labor risk on the foreclosure rate. Removing the labor shock causes the peak foreclosure rate to plummet from 4.3% to only 1.2%, which represents over a 3 percentage point decline. However, hitting the steady state with *only* the labor risk shock causes a more modest 1.5 percentage point increase in foreclosures. Two lessons jump out. First, foreclosure decisions are highly **non-linear**. A 10% drop in house prices from the initial steady state has a relatively minimal effect on foreclosures, but an *additional* 10% drop in house prices from 15% to 25% below steady state causes a surge in foreclosures. Secondly, foreclosure depends on the **double trigger** of reduced house prices *and* a drop in income. Even though household income still falls absent the labor risk shock, the insufficient drop in house prices mitigates foreclosure activity.

The labor risk shock also has a profound and non-linear impact on the dynamics of the homeownership rate. Even with all other shocks present, the absence of higher labor risk causes the homeownership rate to *increase* during the Great Recession, rather than decrease. Absent higher uncertainty, the sharp drop in house prices increases affordability and encourages homeownership. As a result, the labor market deterioration is key to generate the shift from ownership to renting.

Lastly, table 2 shows that labor risk impacts consumption by anywhere from 4.6% to 5.7% and changes time on the market by anywhere from 9.6 to 12.2 weeks. The importance of endogenous housing liquidity is addressed in more detail in section 4.2.

Table 2: Measuring the Impact of Labor Market and Financial Shocks

	Baseline	Excluded	Alone	Bounds
Labor Market Shocks				
<i>Labor Risk</i>				
House Price Trough	−23.8%	−14.8%	−11.6%	[9.0%,11.6%]
Consumption Trough	−17.9%	−12.2%	−4.6%	[4.6%,5.7%]
Peak Foreclosure Rate	4.3%	1.2%	1.5%	[0.9pp,3.1pp]
Peak TOM (Weeks)	51.0	38.8	32.8	[9.6,12.2]
<i>TFP Drop</i>				
House Price Trough	−23.8%	−21.7%	−2.0%	[2.0%,2.1%]
Consumption Trough	−17.9%	−14.9%	−1.5%	[1.5%,3.0%]
Peak Foreclosure Rate	4.3%	3.0%	1.7%	[1.1pp,1.3pp]
Peak TOM (Weeks)	51.0	47.3	25.7	[2.5,3.7]
Financial Shocks				
<i>Tighter Credit Access</i>				
House Price Trough	−23.8%	−19.2%	−5.6%	[4.6%,5.6%]
Consumption Trough	−17.9%	−13.2%	−4.0%	[4.0%,4.7%]
Peak Foreclosure Rate	4.3%	2.4%	0.7%	[0.1pp,1.9pp]
Peak TOM (Weeks)	51.0	40.1	25.1	[1.9,10.9]
<i>Interest Rate Increase</i>				
House Price Trough	−23.8%	−20.2%	−3.8%	[3.6%,3.8%]
Consumption Trough	−17.9%	−14.6%	−5.0%	[3.3%,5.0%]
Peak Foreclosure Rate	4.3%	4.0%	1.2%	[0.3pp,0.6pp]
Peak TOM (Weeks)	51.0	44.2	27.2	[4.0,6.8]

To quantify each shock, two differences are calculated: (1) excluded vs. baseline, and (2) alone vs. steady state (zero by construction, except for foreclosures).

The Drop in TFP/Wages Isolating the effect of the drop in TFP (and, thus, wages) reveals much more modest effects on all but foreclosures. Table 2 shows an approximate 2% effect on house prices and 1.5% – 3.0% effect on consumption. However, absent the TFP drop, the peak foreclosure rate only reaches 3% instead of 4.3%, even with more or less the same fall in house prices. This result reinforces the importance of non-linearity and the double trigger in explaining foreclosure activity. However, contrary to the standard explanation of the double trigger, *negative* equity is not required for default. Instead, equity and illiquidity interact in a rich manner that sheds light on the default decision. Section 4.2 expounds on this point.

4.1.4 Measuring the Impact of Financial Shocks

Tighter Credit Access The tightening of the loan-to-value constraint from 125% to 90% and the increase in origination costs both curtail access to credit. Recall that the initial steady state matches several key statistics of the leverage distribution, including the fact that a relatively modest 11% of borrowers have leverage above 90% and 7% have leverage above 95%. As a result, imposing a 90% LTV constraint should have relatively minimal long-run effects.

However, when house prices fall precipitously in the Great Recession, thereby mechanically driving up leverage, the tighter borrowing constraint makes it impossible for many homeowners to refinance. In response, many of these homeowners are forced to either sell their house or go into foreclosure. To see the magnitude of this channel, note that the peak foreclosure rate falls from 4.3% to 2.4% when the tightening of borrowing constraints is removed, and time on the market falls by over *two and a half months* from 51 weeks to 40 weeks. Without access to additional credit, highly indebted homeowners who put their house on the market face long selling delays and a higher likelihood of entering foreclosure due to a failure to sell. By contrast, the ability to refinance mitigates this debt overhang and default.

The surge of owner-occupied and foreclosure properties that hit the market from the tightening of credit causes house prices to fall by 5% more than they would have otherwise. Furthermore, in the simulation with *only* the tighter LTV constraint, prices fall by almost 6% from steady state. These two experiments place relatively tight bounds of 5 – 6% on the negative impact of tighter LTV constraints on house prices. Inspection of 2 reveals a similar impact of approximately 4 – 5% on consumption.

Temporary Increase in Interest Rates The temporary increase in interest rates (reflecting the tightening of monetary policy in the run up to the Great Recession) has far more modest effects relative to the tightening in the LTV constraint. The jump in interest rates pushes house prices down by 4%, accounts for 0.3 – 0.6 percentage

points of the higher foreclosure rate, and affects consumption by anywhere from 3.3% – 5.0% using the two methods of decomposition. Section 4.4 explores in much greater detail the effects of interest rates on consumption and touches upon the asymmetry between rate increases and decreases, the effects of quantitative easing, and the role of fixed rate vs. adjustable rate mortgages.

4.1.5 Summary of Decomposition

The main lessons from the decomposition can be summarized as follows:

- The increase in downside labor market risk and the tightening of LTV constraints have the largest effects on house prices, consumption, and foreclosures.
- The increase in labor market risk is essential to generate the slow and pronounced decline in homeownership.
- The foreclosure rate responds non-linearly to changes in house prices and income. A modified version of the double trigger hypothesis that includes the effects of housing illiquidity is necessary to explain default behavior.
- *Decreased* access to credit plays a major role in generating *increased* debt overhang (measured by time on the market) and foreclosure activity.
- The drop in TFP and increase in interest rates have modest effects on house prices and consumption; however, the TFP drop contributes significantly to higher foreclosures and the interest rate increase contributes to debt overhang.

4.2 The Importance of Endogenous Housing Illiquidity

Recently, [Kaplan and Violante \(2014\)](#) have illustrated the importance of illiquid assets in the response of consumption to unanticipated shocks. When households have a substantial fraction of their wealth tied up in an illiquid asset, they behave as

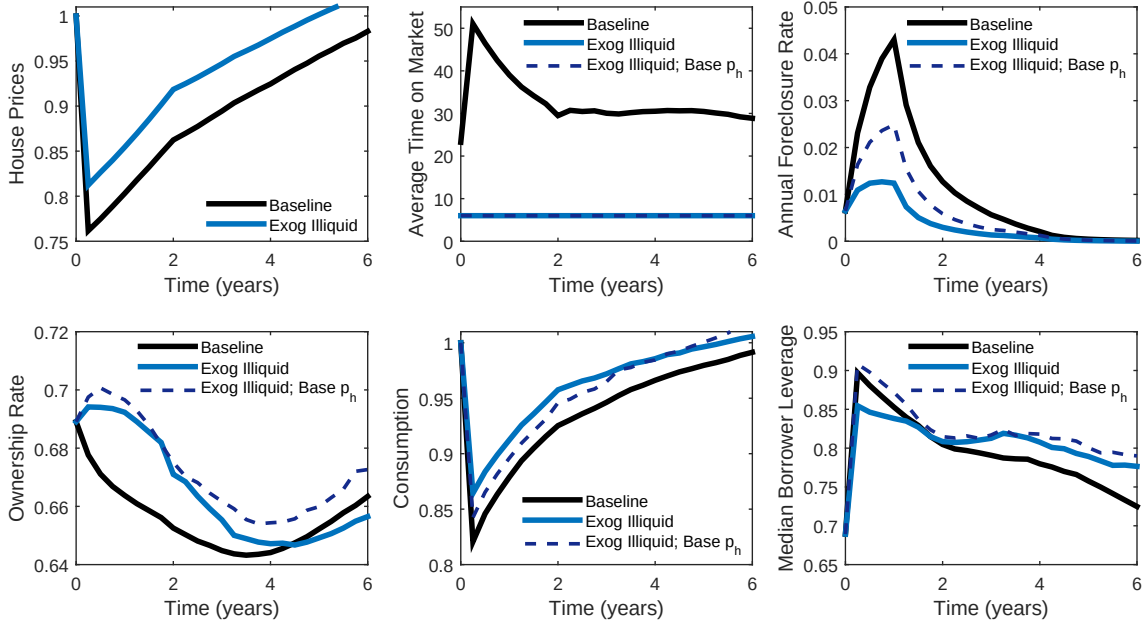


Figure 3: Baseline vs. exogenous illiquidity (no search; transaction costs only) with and without recomputing the path of equilibrium house prices

“wealthy hand-to-mouth” agents with relatively high marginal propensities to consume. As follow up, [Kaplan, Moll and Violante \(2016\)](#) analyze the role of illiquid assets in monetary policy by implicitly treating the illiquid wealth as housing subject to exogenous transaction costs. By contrast, this section shows the importance of analyzing housing *explicitly* and allowing for *endogenous* liquidity and house prices.

Figure 3 compares the Great Recession in the baseline model to that in a model with purely *exogenous* illiquidity, namely, one with Walrasian housing markets and a 6% selling cost. Both economies are initialized at the same distribution to control for the effect of wealth and debt on economic dynamics. Three striking differences stand out. First, foreclosure activity is much greater in the model with endogenous illiquidity (search frictions). Second, endogenous illiquidity magnifies the drop in house prices and consumption relative to the model with exogenous illiquidity. Lastly, the homeownership rate behaves rather differently at the beginning of the recession depending on whether housing markets are Walrasian or not.

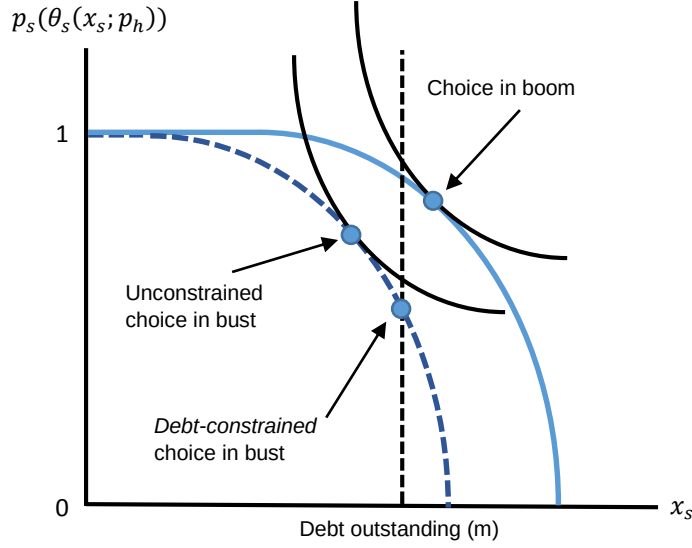


Figure 4: Optimal choice of list price x_s and selling probability p_s in boom and bust housing markets, with and without outstanding debt.

4.2.1 Illiquidity, Debt Overhang, and Default

Debt Overhang Absent search frictions, houses always sell without delay in the period of listing, which corresponds to 6 weeks time on the market. This selling time is invariant to housing market conditions and the equity position of the homeowner, as long as the homeowner is able to pay off the mortgage upon selling. However, search frictions cause time on the market, and thus illiquidity, to be *endogenous* and sensitive to both market and individual conditions. Figure 4 gives insight into the relationship between the housing market, debt, and individual selling experiences.

During “boom” times, the shadow price of housing is high, and homeowners face a favorable schedule of list price and selling probabilities $\{p_s(\theta_s(x_s; p_h))\}$ to choose from whenever they put their house on the market. However, in a housing bust, the shadow price of housing falls, and homeowners face a worsening of the price-probability schedule. Absent any constraints, homeowners prefer to adjust along *both* the price and selling time margins. Therefore, houses tend to sell for less *and* sit on

the market longer in busts, which translates to an *increase* in illiquidity. Conventional models of exogenously illiquid housing miss this dynamic.

However, the story does not end there. Figure 4 also shows how excessive mortgage debt distorts the list price decision. Because homeowners must pay off their mortgage upon selling, they face a lower bound to their price choice x_s : $x_s \geq m - y$, where m is outstanding debt and y is cash at hand. During boom times, this constraint is unlikely to bind. However, during busts, highly indebted homeowners are forced to post a higher price than they would normally post, which leads to even longer time on the market and worse illiquidity.⁷ The increase in time on the market from 23 to 51 weeks in figure 3 underscores the magnitude of this debt overhang. Such homeowners, if they fail to sell, still have to deal with mortgage payments. Depending on the exact circumstances of the homeowner, this *debt overhang* either results in a dramatic drop in consumption—which 4.3 explores more in detail—or in the decision to default.

Mortgage Default The top right panel of figure 3 shows that removing search frictions causes the peak in the foreclosure rate to fall from 4.3% to 1.3%. Undoubtedly, part of the attenuated response comes from the muted decline in house prices. However, even when the path of house prices is held at its baseline trajectory, the peak in the foreclosure rate still only hits 2.5%. Clearly, search-induced illiquidity has a sizable effect on the spike in foreclosure activity during deep recessions.

Consistent with findings in Gerardi, Herkenhoff, Ohanian and Willen (2015) and Schelkle (2015), negative equity is not a sufficient condition to generate foreclosures. Instead, the standard “double trigger” hypothesis states that both negative equity *and* a negative income shock are necessary for default. This paper proposes a modified version: the *stochastic liquidity-adjusted double trigger (SLADT)*. Under the basic double trigger hypothesis, homeowners know with probability 1 what they can sell their house for, and conditional on not being able to pay off their debt with the proceeds, they default if their cash at hand is sufficiently low.

⁷Hedlund (2015a) contains an extended discussion of this relationship.

Table 3: Amplification and Endogenous Housing Illiquidity

	Baseline	Exogenous Illiquidity	Amplification
House Price Trough	−23.8%	−18.8%	26.6%
Consumption Trough	−17.9%	−13.6%	31.6%
Peak Foreclosure Rate	4.3%	1.3%	428.6%

Comparing the severity of the recession with endogenous (baseline) vs. exogenous illiquidity (no search; transaction costs only).

Under SLADT, if highly-leveraged homeowners know they have a zero probability of selling at a price high enough to pay off their debt, their decision to default is the same as in the basic double trigger case. However, there is a wide range of *positive* equity (in many cases, up to 20% equity) where outstanding debt can distort the selling price and cause increased selling delays. In this case, homeowners first post a price and learn the stochastic selling outcome. Then, if they fail to sell, they decide whether to default based on their cash at hand and expectations of future liquidity.

In short, the basic double trigger hypothesis assumes that equity on paper translates immediately to realized selling outcomes. However, search-induced endogenous illiquidity breaks this deterministic relationship and introduces stochastic selling outcomes that are influenced by the magnitude of outstanding debt.

4.2.2 Illiquidity and Amplification

As demonstrated in figure 3, the baseline economy reacts more strongly to the shocks inducing the Great Recession than does the economy with Walrasian housing and exogenous illiquidity. Table 3 provides the magnitude of this search-induced amplification. In the exogenous illiquidity economy, house prices fall by 18.8%, whereas they fall by 23.8% in the baseline economy with search frictions. This additional 5 percentage point drop represents an amplification of almost 27% in the house price response. Similarly, consumption falls by 17.9% in the baseline compared to only 13.6% in the economy with exogenous illiquidity, which represents an amplification of almost 32%. Also, note that even when the path of house prices is fixed at the

baseline trajectory, consumption falls more with endogenous illiquidity than in the model where illiquidity comes only from exogenous transaction costs.

Two mechanisms cause the amplification in the house price and consumption response. First, falling house prices cause extended selling delays which depress liquidity and increase foreclosures, thereby causing banks to curtail lending. The reduced availability of credit, in turn, puts further downward pressure on house prices. These *liquidity spirals* have been shown in Hedlund (2015b) to generate substantial amplification in house price dynamics. The amplified consumption drop comes in part from the larger fall in house prices and partly from the direct impact of housing illiquidity on consumption. Section 4.3 discusses this decomposition more in-depth.

This first mechanism depends on the link between illiquidity, mortgage default, and endogenous credit constraints that adjust in response to default risk. However, search-induced endogenous illiquidity magnifies house price and consumption dynamics even in the absence of households' ability to default. From a pure asset pricing perspective, equilibrium house prices are influenced positively by the future ability to sell quickly. When house prices decline, selling probabilities $\{p_s(\theta_s(x_s; p_h))\}$ deteriorate, which makes housing less appealing and further depresses prices.

4.2.3 Homeownership Dynamics

As discussed in section 4.1.3, the increase in labor risk is necessary to generate the large decline in homeownership during the Great Recession. However, figure 3 shows that, even with the increase in labor risk, the model with Walrasian housing and exogenous illiquidity generates counterfactual homeownership dynamics. In the Walrasian model, the steep drop in house prices makes purchasing a house more appealing, both because of greater affordability and because of higher expected appreciation as house prices rebound. As a result, homeownership *increases* early in the Great Recession before falling in response to the combination of rising prices and worse labor risk. However, in the baseline model, the initial decline in house prices is accompanied by

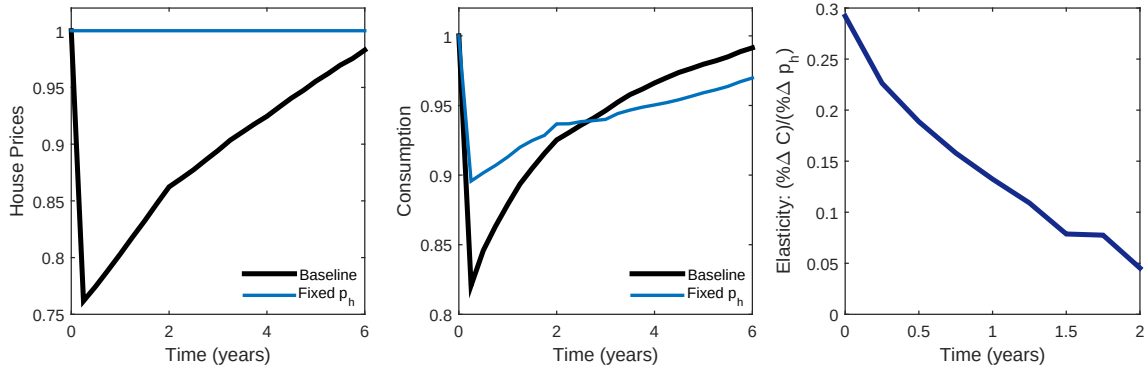


Figure 5: Consumption sensitivity to house prices. The elasticity is % change in consumption between “baseline” and “fixed p_h ” divided by % change in p_h .

a sharp increase in illiquidity, which makes housing far more risky. Even with the increased affordability and expected appreciation, the declining liquidity of housing induces a shift from homeownership to renting consistent with the data.

4.3 Consumption and Housing

In influential work, [Mian et al. \(2013\)](#) assert that the housing decline directly contributed to the large decline in consumption during the Great Recession. They estimate a large elasticity of consumption to house price changes, and they present evidence that consumption responded most strongly among poorer and more levered households. This section undertakes two tasks. First, new insights are presented pertaining to how house price movements impact consumption dynamics. Second, panel data is simulated to analyze how consumption dynamics vary by ownership status, household indebtedness, and by foreclosure status.

4.3.1 The Sensitivity of Consumption to House Price Movements

Figure 5 shows the baseline drop in house prices and consumption, and the middle panel shows the behavior of consumption in the counterfactual house prices are held fixed. With fixed house prices, consumption only falls by 10% instead of over 17% in the baseline. Because the same shocks are present in both cases, the divergent

consumption responses reflect only the effect of house prices.

The third panel of figure 5 plots the elasticity of consumption to house prices during the first two years of the recession. Upon impact, this elasticity is approximately 0.3, which closely matches estimates reported by Mian et al. (2013), Berger, Guerrieri, Lorenzoni and Vavra (2015), and Kaplan, Mitman and Violante (2015). However, rather than a sufficient statistic, the sensitivity of consumption to house prices is *nonlinear, dynamic, and depends on the shocks hitting the economy*.

Regarding the first point, the consumption elasticity peaks at 0.3 but gradually falls during the first two years of the recession. In fact, the elasticity even becomes briefly negative during the latter stages of the recovery due to the exaggerated drop in homeownership in the fixed price simulation. Whereas the homeownership rate falls from 69% to 64% in the baseline economy, the ownership rate falls all the way to 56% when house prices remain elevated. Because of the complementarity between housing and non-housing consumption, the resulting reduction in housing services temporarily depresses consumption.

Figures 8 and 9 in the appendix show the sensitivity of consumption to house prices under different scenarios for which shocks hit the economy. For each experiment, consumption is simulated with and without taking into account the endogenous response of house prices and with fixed house prices. Figure 8 shows that when only the labor risk shock hits the economy, the consumption elasticity to house price movements is only between 0.12 and 0.21, depending on whether one uses the fixed house price simulation as the reference point or the simulation which feeds in the baseline trajectory of house prices. In other words, the elasticity is **nonlinear**. When only the TFP shock hits the economy, the elasticity changes dramatically and ranges anywhere from 0.08 to over 0.5. Lastly, when only the credit constraints tighten, the elasticity of consumption to house price changes falls between 0.25 and 0.35.

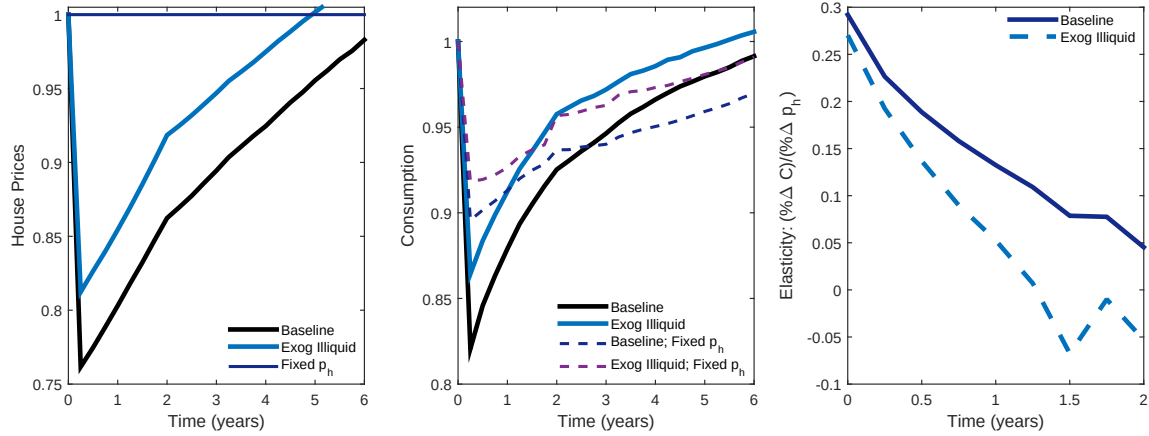


Figure 6: Effect of endogenous illiquidity on consumption sensitivity to house prices.

4.3.2 Consumption, House Prices, and Endogenous Illiquidity

Several economic mechanisms account for the impact of house prices on consumption. As in [Berger et al. \(2015\)](#), a change in house prices induces both an endowment and a collateral effect. For example, a drop in house prices changes the value of homeowners' housing endowments that induces a portfolio reallocation and cutback in consumption. Furthermore, lower house prices reduce the value of housing collateral and tighten the exogenous component of borrowing constraints. However, the model with endogenous illiquidity introduces a new, important link between house prices and consumption: the *liquidity effect*.

Figure 6 compares the response of consumption in the baseline economy to that in the Walrasian economy with exogenous illiquidity. The middle panel shows that consumption falls over 30% further with endogenous illiquidity. However, panel 1 shows that house prices also respond more strongly, which raises the possibility that the steeper consumption decline simply reflects the larger drop in house prices. To remove the house price response, consumption dynamics are compared in the two economies while fixing house prices. In the baseline economy, consumption drops by approximately 11.5%, whereas the exogenous illiquidity case exhibits only an 8% fall.

With exogenous illiquidity, all homeowners with sufficient equity to cover the 6%

transaction cost have the ability to immediately sell and get out from underneath their debt. By contrast, with endogenous illiquidity, selling delays force indebted homeowners to significantly reduce their consumption to keep making mortgage payments while their house sits on the market. When house prices fall, illiquidity worsens and the negative liquidity effect on consumption strengthens. Furthermore, the endogenous contraction in credit arising from the illiquidity-induced higher foreclosure risk magnifies this response.

The third panel of 6 shows that both the endogenous and exogenous illiquidity models deliver the same elasticity of consumption to house prices *on impact*. However, two remarks are in order. First, the magnitude of the house price and consumption drops are both larger in the endogenous illiquidity model, as has been discussed. Secondly, the *persistence* of the consumption response to house prices is greater with endogenous illiquidity. For example, one year into the recession, the consumption elasticity in the baseline model is still approximately 0.15, whereas it falls all the way below 0.05 with exogenous illiquidity.

4.3.3 Consumption Panel Dynamics

Recall that Mian et al. (2013) emphasize the role of the housing bust in explaining the consumption decline during the Great Recession, and they assert that consumption dropped the most for heavily indebted homeowners. To test these findings within the model, a panel of 10,000 households is simulated that allows for consumption dynamics to be disaggregated by ownership status, indebtedness, and default status.

The left column of panels in figure 7 shows consumption dynamics for renters and homeowners based on ownership status upon the onset of the recession. The top panel shows that homeowners experience a steep drop in consumption of over 15% followed by a slow recovery. By contrast, renter consumption only falls by 5% and rapidly recovers. The bottom left panel plots the distribution of consumption changes between two periods. In the steady state, the consumption change distributions

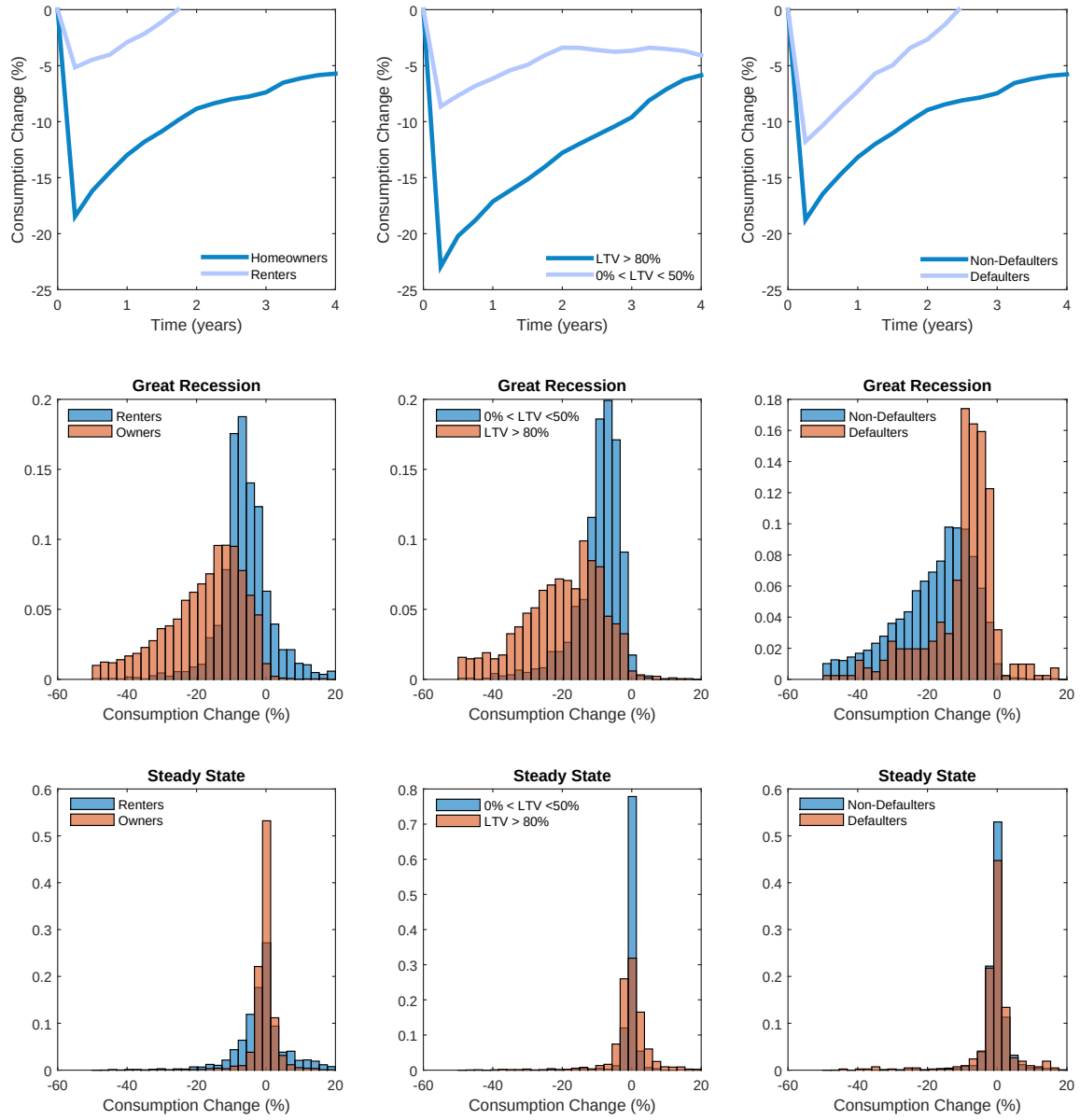


Figure 7: Consumption dynamics by ownership status, leverage, and default status.

are symmetric, but renter consumption has wider variance. In other words, during normal times, homeowners are better able to insure shocks. Part of this insurance is likely a selection effect—homeowners have more buffer savings and better income realizations—but in addition, homeowners can extract equity out of their houses to smooth shocks. However, the middle left panel shows how fortunes change in the Great Recession. Upon impact of the recession, the consumption change distribution for renters has a mean below zero but is symmetric and has moderate variance. However, the consumption change distribution for homeowners exhibits a strong left skew with some homeowners experiencing more than a 40% drop in consumption.

The second column of panels compares homeowner consumption dynamics by degree of indebtedness. Consistent with [Mian et al. \(2013\)](#), consumption falls much more for homeowners with high leverage. It is precisely these homeowners who are shut out from refinancing and who have the greatest difficulty selling their houses. Note that indebted homeowners exhibit higher consumption variance, even in the steady state, as shown in the bottom middle panel.

Lastly, the third column shows consumption behavior for *borrowers* who default at the beginning of the recession compared to those who do not. Even though defaulters are more likely to have the highest amount of debt and the lowest income realizations, their consumption actually falls *less* than that of non-defaulters. While perhaps counterintuitive at first sight, recall that default is a form of insurance against bad shocks. As such, defaulting *should* mediate the drop in consumption, though this insurance comes at the cost of house repossession and a temporary exclusion from borrowing in the mortgage market.

In all, the model confirms the message in [Mian et al. \(2013\)](#) that housing greatly exacerbated the consumption decline in the Great Recession. Furthermore, there is rich heterogeneity in the consumption response of households based on their ownership status, leverage, and decisions to default on their debt.

4.4 Consumption, Interest Rates, and Quantitative Easing

[TO BE COMPLETED]

5 Conclusion

[TO BE COMPLETED]

References

- Berger, David, Veronica Guerrieri, Guido Lorenzoni, and Joseph Vavra, “House Prices and Consumer Spending,” 2015. Working Paper.
- Corbae, Dean and Erwan Quintin, “Leverage and the Foreclosure Crisis,” *Journal of Political Economy*, 2015, 123, 1–65.
- Favilukis, Jack, Sydney C. Ludvigson, and Stijn Van Nieuwerburgh, “The Macroeconomic Effects of Housing Wealth, Housing Finance, and Limited Risk-Sharing in General Equilibrium,” *Journal of Political Economy*, Forthcoming 2016.
- Fernald, John, “Productivity and Potential Output Before, During, and After the Great Recession,” June 2014. NBER Working Paper 20248.
- Flavin, Marjorie and Shinobu Nakagawa, “A Model of Housing in the Presence of Adjustment Costs: A Structural Interpretation of Habit Persistence,” *American Economic Review*, Mar. 2008, 98 (1), 474–495.
- Gerardi, Kristopher, Kyle F. Herkenhoff, Lee E. Ohanian, and Paul S. Willen, “Can’t Pay or Won’t Pay? Unemployment, Negative Equity, and Strategic Default,” 2015. Working Paper.

- Gruber, Joseph and Robert F. Martin**, “The Role of Durable Goods in the Distribution of Wealth: Does Housing Make Us Less Equal?,” 2003. Working Paper.
- Hedlund, Aaron**, “Illiquidity and its Discontents: Trading Delays and Foreclosures in the Housing Market,” June 2015. Working Paper.
- , “The Cyclical Dynamics of Illiquid Housing, Debt, and Foreclosures,” *Quantitative Economics*, 2015. Forthcoming.
- Herkenhoff, Kyle and Lee Ohanian**, “Foreclosure Delay and U.S. Unemployment,” 2015. Working Paper.
- Kaplan, Greg and Giovanni L. Violante**, “A Model of the Consumption Response to Fiscal Stimulus Payments,” *Econometrica*, 2014, 82 (4), 1199–1239.
- , **Benjamin Moll, and Giovanni L. Violante**, “Monetary Policy According to HANK,” 2016. Working Paper.
- , **Kurt Mitman, and Giovanni L. Violante**, “Consumption and House Prices in the Great Recession: Model Meets Evidence,” 2015. Working Paper.
- Mian, Atif, Kamalesh Rao, and Amir Sufi**, “Household Balance Sheets, Consumption, and the Economic Slump,” *Quarterly Journal of Economics*, 2013, 128 (4), 1687–1726.
- Pennington-Cross, Anthony**, “The Value of Foreclosed Property,” *JRER*, 2006, 28 (2), 193–214.
- Pistaferri, Luigi**, “Household Consumption: Research Questions, Measurement Issues, and Data Collection Strategies,” *Journal of Economic and Social Measurement*, 2015.

Ríos-Rull, José-Víctor and Zhen Huo, “Financial Frictions, Asset Prices, and the Great Recession,” 2016. Working Paper.

Schelkle, Thomas, “Mortgage Default during the U.S. Mortgage Crisis,” 2015. Working Paper.

Sommer, Kamila, Paul Sullivan, and Randal Verbrugge, “The Equilibrium Effect of Fundamentals on House Prices and Rents,” *Journal of Monetary Economics*, 2013, *60* (7), 854–870.

Storesletten, Kjetil, Chris I. Telmer, and Amir Yaron, “Cyclical Dynamics in Idiosyncratic Labor Market Risk,” *Journal of Political Economy*, June 2004, *112* (3), 695–717.

A Supplementary Figures

A.1 Consumption Response to House Price Movements

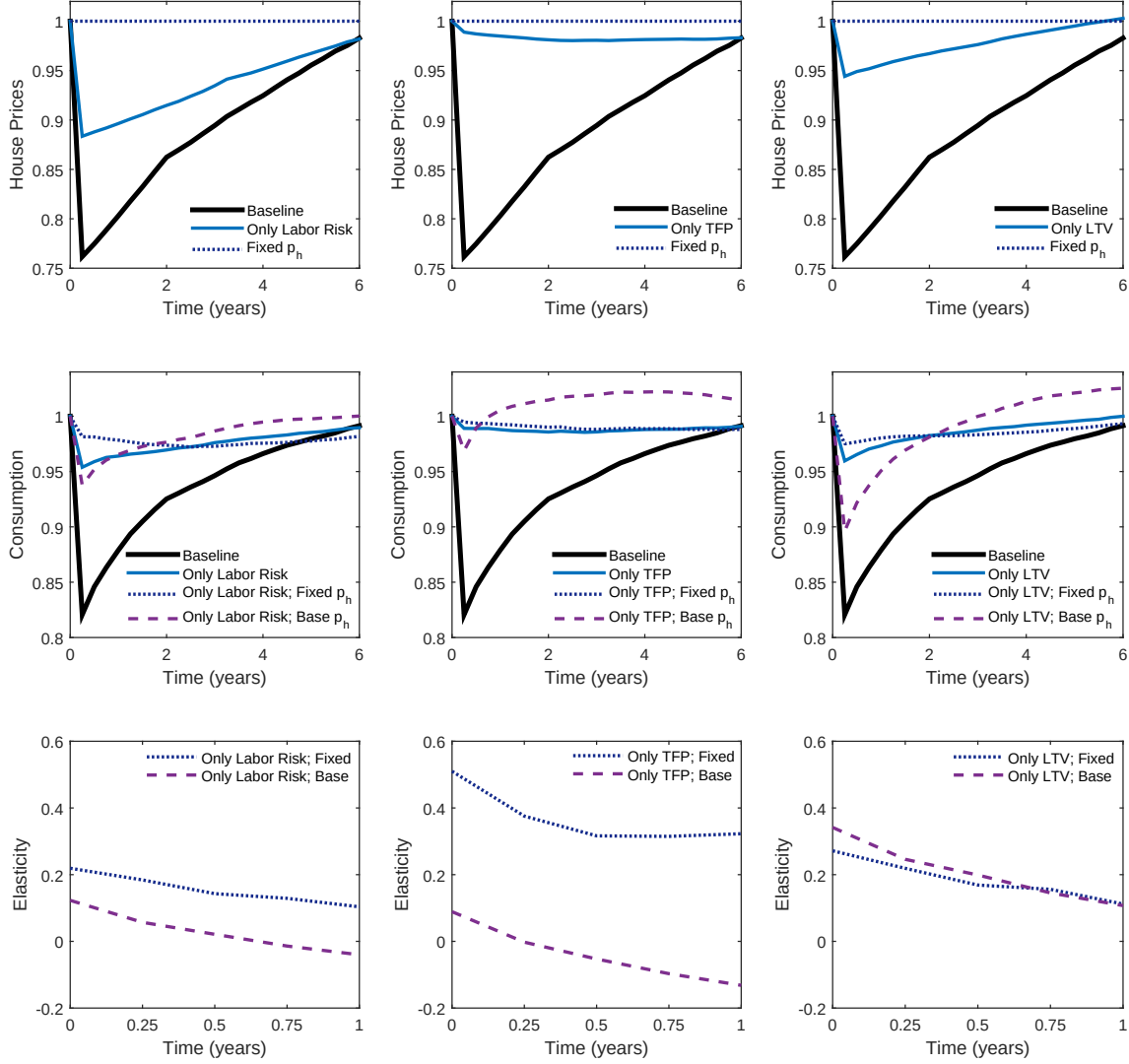


Figure 8: Consumption response to house price movements conditional on only one shock hitting the economy. Top: house prices; middle: consumption; bottom: elasticity of consumption to house prices. The “fixed” elasticity uses the “fixed p_h ” house price trajectory as the reference, whereas the “baseline” elasticity uses the “baseline p_h ” house price trajectory as the reference.

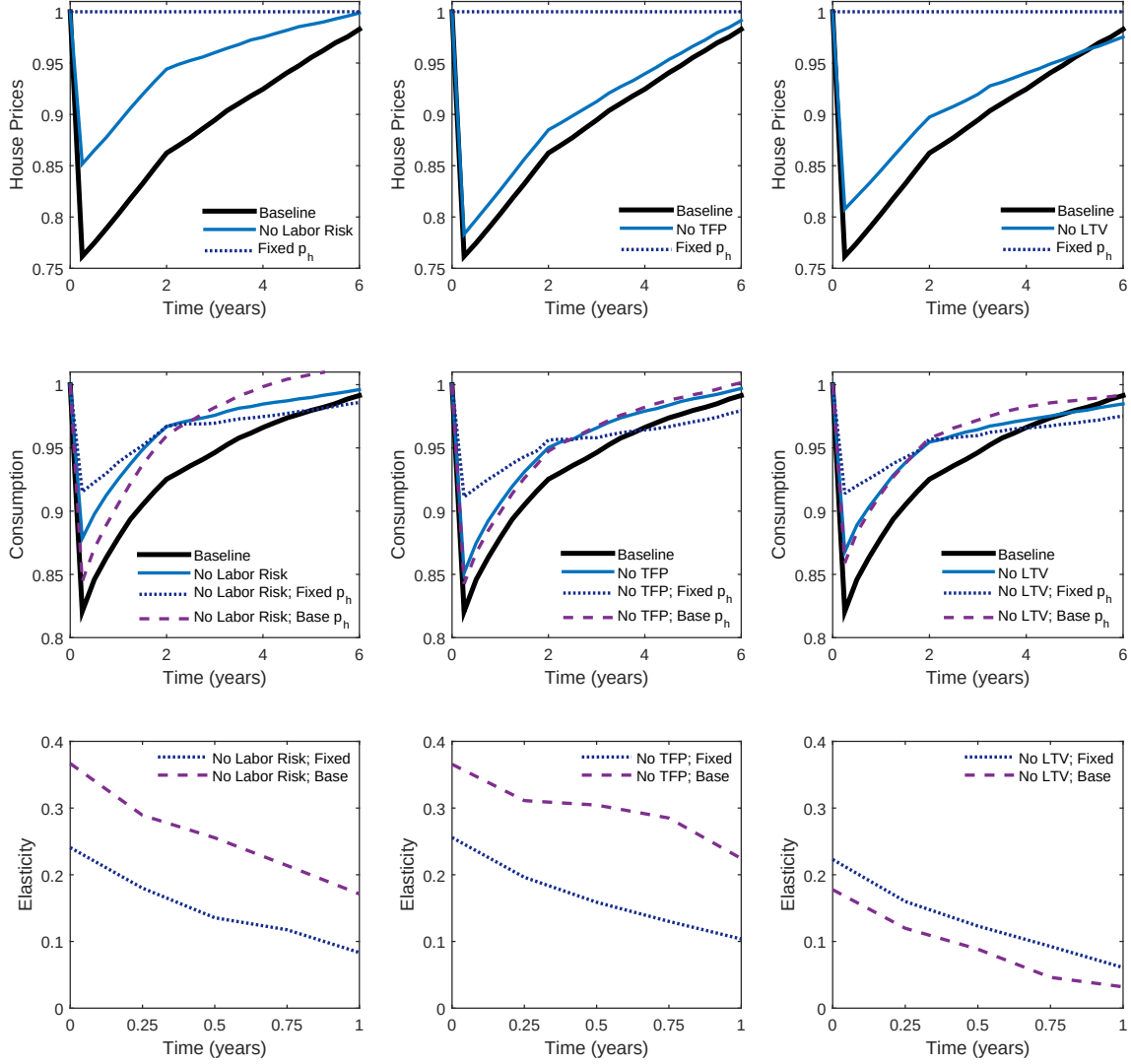


Figure 9: Consumption response to house price movements conditional on all but one shock hitting the economy. Top: house prices; middle: consumption; bottom: elasticity of consumption to house prices. The “fixed” elasticity uses the “fixed p_h ” house price trajectory as the reference, whereas the “baseline” elasticity uses the “baseline p_h ” house price trajectory as the reference.