



Illiquidity and its discontents: Trading delays and foreclosures in the housing market



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ABSTRACT

The macroeconomic effects of housing illiquidity are analyzed using a novel directed search model of housing with long-term debt and default. Debt overhang emerges when highly leveraged sellers are forced to post high prices that produce long selling delays. These delays increase foreclosures, raise default premia, and curtail credit. Cheaper credit fuels temporarily higher house prices, faster sales, and fewer foreclosures, but the borrowing surge facilitates future debt overhang and default. More stringent foreclosure punishments also expand credit and, therefore, either generate higher foreclosures or more debt overhang. Leverage caps avoid this conundrum but reduce welfare by restricting borrowing.

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1. Introduction

“Leverage, concentration, and illiquidity are the three things that can kill you.” Though he was referring to lessons learned from the market collapse in 2008, billionaire hedge fund manager Steven Cohen could just have well have uttered those words about recent housing market behavior. In fact, over the past *several decades*, the housing market has gone through recurrent episodes of illiquidity characterized by spikes in the amount of time houses sit on the market, such as the jump in selling time from 3 to 12 months during the Great Recession.

This paper uses a heterogeneous agent macroeconomic model with directed search in the housing market, endogenous supply of mortgage credit, and equilibrium default to ask three main questions: (1) How do search frictions affect the behavior of housing aggregates and selling behavior? (2) What impact do search frictions have on the availability of credit? (3) To what extent can policy interventions mitigate the effects of housing illiquidity?

First, the paper makes a methodological contribution by developing a tractable approach to computing equilibrium in a directed search framework with endogenous two-sided heterogeneity. In the model, buyers and sellers with different income, housing, and financial portfolios direct their search according to house type and price. Given that search behavior depends on the individual states of market participants, equilibrium trading probabilities would normally depend non-trivially on the infinite-dimensional heterogeneity. However, motivated by work in [Menzio and Shi \(2010\)](#), [Duffie et al. \(2005\)](#), and [Lagos and Rocheteau \(2009\)](#), I introduce passive real estate brokers that intermediate trades. The economics of buyer and seller decisions remains unchanged, but a block recursive structure arises that simplifies computation.

I establish several results regarding the importance of housing illiquidity. First, search frictions generate a positive relationship between leverage, list price, and time on the market, consistent with evidence in [Genesove and Mayer \(1997\)](#),

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2001). This relationship frequently results in *debt overhang*, in which high leverage causes houses to sit longer on the market. Sellers with ample equity have the flexibility to set prices that attract buyers and lead to prompt sales. However, if a seller is highly leveraged, their mortgage balance acts as a binding price floor that inflates time on the market. Quantitatively, mismatched sellers take an average of 26 weeks to sell when they have 90%+ LTV compared to 17 weeks otherwise, and instances exist of time on the market exceeding one year.

Extended selling delays cause some homeowners in financial distress to go into foreclosure, which brings up the second result: many foreclosures are caused by housing illiquidity and do not require negative equity. By contrast, in Walrasian models of housing, homeowners with even a penny of equity net of selling costs can instantly sell their house to avoid default. Instead, what matters here is not just paper equity but the ability to sell at a particular price in a reasonable time frame. Quantitatively, removing liquidity risk causes the foreclosure rate to drop from 1.21% to 0.26%. The spillover of liquidity risk into foreclosure risk also tightens credit constraints by substantially increasing default premia.

Third, expansions in credit cause short-run booms in house prices and liquidity, but over time, the cheaper credit fuels a leverage boom that generates future debt overhang and higher foreclosures. As owners increase their debt, time on the market doubles from 11 to over 22 weeks, and foreclosures increase to an annual rate of almost 3%.

Lastly, foreclosure penalties generate either *higher* foreclosures or *worse* debt overhang. The reduced propensity to default at given values of leverage stimulates credit supply and increases indebtedness. Moderate penalties cause distressed owners to default more frequently, whereas severe penalties force homeowners to spend longer time on the market avoiding default. Leverage caps avoid this trade-off but reduce welfare by restricting borrowing.

1.1. Related literature

This paper fits into a large body of work employing search models of housing. Earlier papers, such as Wheaton (1990) and Krainer (2001), use random search to model housing trades, as does more recent work by Novy-Marx (2009), Ngai and Tenreiro (2014), Burnside et al. (2016), Caplin and Leahy (2011), and others. However, Merlo et al. (2014) provide evidence that homeowners dynamically adjust their asking price to attract buyers, which motivates the use of a directed search model in this paper. Other directed search models of housing appear in Díaz and Jerez (2013), Albrecht et al. (2016), and Head et al. (2014), although these papers abstract from credit constraints and financial heterogeneity of buyers and sellers. As such, they are not suitable for investigating the link between illiquidity, foreclosures, and endogenous credit supply. Guren and McQuade (2015) develop a random search housing model with default and exogenous leverage, whereas I endogenize credit constraints and borrowing.

This paper also fits into the extensive literature on quantitative models of housing. Most directly, Garriga and Schlaggenhauf (2009), Mitman (2016), and Arslan et al. (2015) use structural models with long-term debt to analyze foreclosures. By introducing housing search frictions, this paper uncovers a quantitatively important link between housing illiquidity and access to credit in the mortgage market. Corbae and Quintin (2014) and Hatchondo et al. (2015) analyze the effectiveness of foreclosure penalties at reducing defaults in a Walrasian model with exogenous house prices, and they find significant welfare gains from the resulting expansion in credit. However, this paper shows that strict penalties also cause an endogenous housing illiquidity response that increases selling delays, forces owners to cut consumption while their house sits on the market, and reduces welfare.

Subsequently, Hedlund (2016) introduces aggregate shocks to the housing framework first developed here to study cyclical housing dynamics and to assess housing stabilization policies, and Garriga and Hedlund (2016) apply this framework to study the Great Recession.

2. The model

The model economy consists of multiple production sectors, a housing market subject to search frictions, a banking sector that issues long-term, defaultable mortgages, and a continuum of heterogeneous households that face uninsurable earnings risk.

2.1. Households

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 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 $F(e)$.

Preferences: Households have preferences over consumption c and housing services c_h and are either apartment-dwellers or homeowners. Apartment-dwellers purchase apartment space $a \leq \bar{a}$ each period at price r_h and receive $c_h = a$ housing services. Agents who purchase a house $h \in H = \{h_1, h_2, h_3\}$ in the decentralized housing market become owners. Upon purchase, house h generates a dividend $c_h = h$ of housing services each period. However, with probability p_ψ , owners become mismatched and receive housing service dividends of $c_h = \psi h < h$ until they move. Let $g = (h, \psi)$, $\psi \in \{\psi, 1\}$, denote the housing state.

2.2. Technology

Composite consumption: A representative firm uses capital K_c and labor N_c to produce the consumption good: $Y_c = F_c(K_c, N_c)$.

Apartments: Landlords operate a reversible technology that converts one unit of consumption into A_h units of apartment space to be sold at price r_h .¹

Housing construction: Home builders operate a constant returns to scale production function using land L , structures S_h , and labor N_h to construct houses: $Y_h = F_h(L, S_h, N_h)$. Builders purchase structures S_h from the consumption good sector, and as in Favilukis et al. (2016), the government supplies a fixed amount $\bar{L} > 0$ of new permits each period and spends the revenue on purchases. Houses depreciate stochastically with probability δ_h .² Thus, the evolution of the housing stock is $H' = (1 - \delta_h)H + Y_h'$.

2.3. Housing market

Absent is a centralized housing market, real estate brokers intermediate all trades. First, owners (or banks in possession of foreclosed properties) search on the basis of price for brokers willing to purchase their house at price x_s , while buyers direct their search on the basis of house type and price for brokers willing to sell them house $h \in H$ at price x_b . Brokers (who are not permitted to hold any inventories) frictionlessly trade housing with each other and with home builders at unit price p_h .

2.3.1. Directed search details

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 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.

Successful buyers immediately move into their house and switch from renter status to homeowner status with state $g = (h, \psi = 1)$. Unsuccessful buyers remain as renters until the next period. Each broker in submarket (x_b, h) incurs an entry cost $\kappa_b h$.

Sellers: Sellers of existing houses simply choose a list price $x_s \geq 0$ that they commit to honoring if they match with a 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 they are able to pay off any outstanding mortgage debt. Therefore, a homeowner with cash at hand y and mortgage debt m faces the following list price constraint: $x_s \geq m - y$. 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 .³ On both sides of the market, all participants take submarket tightnesses parametrically.

The profit maximization conditions of the real estate brokers are

$$\kappa_b h \geq \underbrace{\frac{\text{prob of match}}{\alpha_b(\theta_b(x_b, h))}}_{\text{broker revenue}} (x_b - p_h h) \quad \text{cost of building the house} \quad (1)$$

$$\kappa_s h \geq \underbrace{\frac{\alpha_s(\theta_s(x_s, h))}{\text{prob of match}}}_{\text{broker revenue}} (p_h h - x_s) \quad (2)$$

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

The revenue to a 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 brokers selling houses to buyers.

2.4. Financial markets

Households save using one-period bonds that trade at price $q_b = \frac{1}{1+r}$ (r is exogenous), and owners can borrow against their house using long-term, collateralized debt, i.e. mortgages.

¹ Owners cannot rent out their houses, and rents depend only on the apartment technology. Sommer et al. (2013) and Davis et al. (2008) report that real rents have remained mostly flat over the past 30 years, even while house prices have experienced swings.

² Complete depreciation averts the need to deal with situations where mortgaged homeowners suddenly find themselves underwater because a portion of their house depreciates. As I discuss in Section 2.4.1, I assume complete mortgage forgiveness in the low probability event that a house depreciates.

³ The utility cost prevents homeowners nearly indifferent about selling from fishing for buyers by posting unreasonably high prices that lead to inordinate time on the market.

2.4.1. Mortgages

Banks assess individual borrower risk when pricing new mortgage contracts. A borrower with assets b' , house $g = (h, \psi)$, and persistent labor efficiency s who takes out a mortgage of face value m' receives $q_m^0(m', b', g, s)m'$ in consumption units at origination, where $q_m^0(\cdot)$ is the mortgage price. Perfect competition assures zero profits for each loan type.

Mortgage contracts in the model have a flexible amortization schedule that allows homeowners to pay down principal at their own pace. However, homeowners who want to extract equity must refinance by paying off their old mortgage and taking out a new, re-priced mortgage. Specifically, a homeowner with balance m who chooses m' pays $m - \tilde{q}_m m'$, where $\tilde{q}_m = q_m \mathbf{1}_{[m' \leq m]} + q_m^0(q_m, m'), b', h, s) \mathbf{1}_{[m' > m]}$, $q_m = \frac{1}{1+r_m}$, and r_m is the fixed mortgage rate.

Banks incur a proportional origination cost ζ and servicing costs ϕ over the life of the contract. Banks face two sources of risk during repayment. First, if the house depreciates, the bank must forgive the loan balance.⁴ Second, homeowners can opt to default and not make any payment. Banks incorporate servicing costs and depreciation into the common rate, $1+r_m = \frac{1+\phi}{1-\delta_h}(1+r)$, but they price default risk into the borrower-specific $q_m^0(\cdot)$.

In the event of default, the bank forecloses on the borrower and repossesses their house. The foreclosure process erases the borrower's mortgage debt but places a flag $f=1$ on their credit record that prevents them from future borrowing. The credit flag is persistent and carries over to the following period with probability $\gamma_f \in (0, 1)$.

Houses repossessed by the bank become **REO (Real Estate Owned)** properties. Banks proceed to sell the house in the decentralized housing market, albeit with a reduced search efficiency $\lambda \in (0, 1)$ and subject to a selling price discount of χ .

The value to the bank of repossessing a house h is

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

$$R_{REO}(h) = \max \left\{ 0, \max_{x_s \geq 0} \lambda p_s(\theta_s(x_s, h)) \left[(1-\chi)x_s - \left(-\eta h + \frac{1-\delta_h}{1+r} J_{REO}(h) \right) \right] \right\} \quad (3)$$

where η is the cost of holding onto the house (maintenance, property taxes, etc.).

Mortgage prices satisfy the following recursive relationship:

$$q_m^0(m', b', h, s) = \frac{q_m}{1+\zeta} \mathbb{E}_{(e', s')} \left\{ \overbrace{p_s(\theta_s(x_s^{*'}, h))}^{\text{sell, repay}} + \overbrace{[1-p_s(\theta_s(x_s^{*'}, h))]}^{\text{borrower fails to sell}} \left[\overbrace{d^{*'} \min \left\{ 1, \frac{J_{REO}(h)}{m'} \right\}}^{\text{default + repossession}} \right. \right. \\ \left. \left. + (1-d^{*'}) \left(\overbrace{\frac{m' - (1+\phi)q_m m^{*'} \mathbf{1}_{[m^{*'} \leq m']}}{m'}}^{\text{payment - servicing cost}} + \overbrace{\frac{q_m^0(m^{*'}, b^{*'}, h, s')(1+\zeta)(1+\phi)m^{*'} \mathbf{1}_{[m^{*'} \leq m']}}{m'}}^{\text{continuation value}} \right) \right] \right\} \quad (4)$$

where $x_s^{*'}, m^{*'}, b^{*'},$ and $d^{*'}$ are the borrower's respective choices of list price, new mortgage balance, bonds, and whether to default.

A few cases are worth mentioning. First, the contract terminates successfully in the period after origination if the borrower either sells the house, refinances to a different loan, or simply pays off the entire balance. In each of these cases, the bank receives m' back in full and the mortgage effectively becomes a one-period loan with $q_m^0(\cdot) = \frac{q_m}{1+\zeta}$. On the opposite end of the spectrum, if the borrower never attempts to sell and never defaults, then $p_s(\theta_s(x_s^{*'}, h)) = 0$, $d^{*'} = 0$, and the mortgage pricing equation can be rewritten as

$$[q_m^0(m', b', h, s)(1+\zeta) - q_m]m' = (1+\phi) \mathbb{E}_{(e', s')} \left\{ [q_m^0(m^{*'}, b^{*'}, h, s')(1+\zeta) - q_m] m^{*'} \mathbf{1}_{[m^{*'} \leq m']} \right\} \quad (5)$$

In this case, mortgage prices again satisfy $q_m^0(\cdot) = \frac{q_m}{1+\zeta}$. Going back to the full mortgage pricing equation, only in regions where borrowers default with positive probability *after failing to sell* and where the value of repossession falls below the outstanding debt, $J_{REO}(h) < m'$, do mortgage prices incorporate a default premium, i.e. $\frac{1}{q_m^0(\cdot)} > (1+\zeta)(1+r_m)$. In particular, note that worse housing illiquidity, as measured by lower selling probabilities $p_s(\cdot)$, raises default premia and curtails the supply of credit.

2.4.2. Further discussion of mortgage design and pricing

This setup reflects key details of mortgage lending in the United States while striking a balance between realism and computational feasibility. In addition, the model is consistent with insights from the contracting literature. For example, Piskorski and Tchistyi (2010) and Piskorski and Tchistyi (2011) show the optimality of mortgages that feature flexible payments and default with repossession in some states of the world.

⁴ This assumption adds to the cost of borrowing but shuts down artificial foreclosure activity.

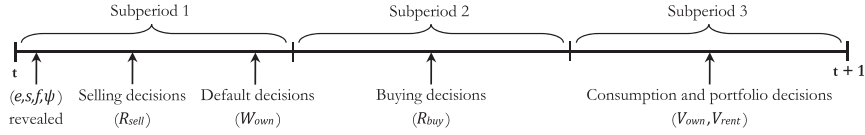


Fig. 1. Household timeline.

Flexible amortization schedule: The flexible amortization schedule acts as a stand-in for homeowners holding multiple liens against their house, such as second mortgages and home equity lines of credit. This approach endogenizes the speed of total deleveraging and simplifies computation by removing loan duration as a state variable.⁵

Consequences of mortgage default: Mortgages are a form of *collateralized* debt that pledge the borrower's house to the bank in the event of default. In the United States, the laws surrounding the foreclosure process and its consequences vary from state to state, as examined by Ghent and Kudlyak (2011) and Mitman (2016). In particular, some states require a court order before foreclosure proceedings commence, whereas non-judicial states do not. Furthermore, some states give recourse to banks to seek judgments against other assets of the borrower in the event that repossession and sale of the house does not cover the outstanding debt. However, Jones (1993) and Pence (2006) report on the rarity of deficiency judgments. As a result, I follow (Campbell and Cocco, 2014) and assume that banks have no recourse.

In addition to losing their house, borrowers suffer a decline in their credit score that effectively excludes them from mortgage borrowing for a period of time. This exclusion typically lasts for 5 years,⁶ but modeling a stochastic credit flag economizes on state variables.

Pricing of default risk: Typically, banks amortize all risks into the long-term rate paid by each borrower, which gets pinned down in perfect competition by the zero-profit condition. However, borrowers in the U.S. also have the option of paying discount points—either at closing or by wrapping them into the loan principal—to reduce the interest rate.

My formulation implicitly assumes that borrowers pay the requisite number of points determined by perfect competition—here, equal to the gap between $q_m^0(m', b', h, s)$ and $\frac{q_m}{1+\zeta}$ —to bring their interest rate down to r_m from the rate that would amortize default risk over the duration of the loan. In other words, for a given amount of resources delivered at origination, default risk gets embedded into higher principal instead of higher long-term rates. Computationally, this setup removes the individual-specific interest rate as a state variable and preserves the important feature that mortgages are long-term contracts that shield borrowers from continual re-pricing of their default risk.

2.5. Household problem

Each period contains three subperiods, as shown in Fig. 1. In subperiod 1, prospective sellers put their house on the market and default decisions are made. In subperiod 2, prospective buyers search for houses. In subperiod 3, households make consumption and portfolio choices. The individual state is cash at hand y , mortgage m , house $g = (h, \psi)$, labor shock s , and flag $f \in \{0, 1\}$.

Consumption/saving: Owners with good credit have value function

$$\begin{aligned}
 V_{own}(y, m, g, s, 0) &= \max_{m', b', c \geq 0} u(c, \psi h) + \beta \mathbb{E}_{(e', s', \psi')} \left[(1 - \delta_h)(W_{own} + R_{sell})(y', m', (h, \psi'), s', 0) \right. \\
 &\quad \left. + \delta_h(V_{rent} + R_{buy})(y', s', 0) \right] \\
 &\text{subject to} \\
 &c + \eta h + q_b b' + m - \widetilde{q}_m(m', b', g, s)m' \leq y \\
 &q_m^0(m', b', g, s)m' \mathbf{1}_{[m' > m]} \leq \vartheta p_h h \\
 &y' = w e' s' + b'
 \end{aligned} \tag{6}$$

where ϑ is an exogenous upper bound on LTV for new loans and 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 $a \leq \bar{a}$ and face the constraint $c + r_h a + q_b b' \leq y$.

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.

⁵ Chatterjee and Eyigungor (2015) and Hatchondo et al. (2015) use infinite duration contracts but assume geometrically declining payments. Their approach makes the speed of deleveraging exogenous and requires interpolation along the mortgage debt dimension during computation. As in this paper, default risk enters into the mortgage price at origination.

⁶ Fannie Mae waits five years before underwriting borrowers with foreclosure records. See https://www.fanniemae.com/content/fact_sheet/derogatory-credit-event-fact-sheet.pdf.

The option value R_{buy} of attempting to buy is as follows:

$$R_{buy}(y, s, 0) = \max \left\{ 0, \max_{\substack{h \in H, \\ x_b \leq y - \underline{y}}} p_b(\theta_b(x_b, h)) [V_{own}(y - x_b, 0, (h, 1), s, 0) - V_{rent}(y, s, 0)] \right\} \quad (7)$$

$$R_{buy}(y, s, 1) = \max \left\{ 0, \max_{\substack{h \in H, \\ x_b \leq y}} p_b(\theta_b(x_b, h)) [V_{own}(y - x_b, 0, (h, 1), s, 1) - V_{rent}(y, s, 1)] \right\} \quad (8)$$

Mortgage default: The value function for a homeowner deciding whether to default is

$$W(y, m, g, s, 0) = \max \{ V_{own}(y, m, g, s, 0), (V_{rent} + R_{buy})(y + \max \{ 0, J_{REO}(h) - m \}, s, 1) \} \quad (9)$$

House selling: Homeowners in subperiod 1 decide whether to try to sell their house. Prospective sellers choose a list price x_s and enter submarket (x_s, h) . The option value R_{sell} for a homeowner with good credit is

$$R_{sell}(y, m, (h, \psi), s, 0) = \max \left\{ 0, \max_{x_s} p_s(\theta_s(x_s, h)) [(V_{rent} + R_{buy})(y + x_s - m, s, 0) - W_{own}(y, m, (h, \psi), s, 0)] + [1 - p_s(\theta_s(x_s, h))](-\xi) \right\} \text{ subject to } y + x_s \geq m \quad (10)$$

where ξ is the disutility of trying and failing to sell, and the constraint $y + x_s \geq m$ reflects the requirement that sellers pay off their mortgage. When this constraint binds, sellers are forced to set a high price that leads to longer time on the market, i.e. debt overhang.

2.6. Block recursivity in the housing market

A major contribution of this paper centers on its development of a tractable solution for market tightnesses in a directed search framework with endogenous two-sided heterogeneity. The presence of passive real estate brokers gives rise to a *block recursive* housing equilibrium that resembles a hybrid of [Menzio and Shi \(2010\)](#) and [Lagos and Rocheteau \(2009\)](#). Without block recursivity, equilibrium submarket tightnesses $\theta_s(x_s, h)$ and $\theta_b(x_b, h)$ would normally depend nontrivially on the entire infinite dimensional distribution of households. However, Eqs. (11) and (12) show that active submarkets ($\theta > 0$) do not depend directly on the distribution of household characteristics but only on p_h (the shadow housing price):

$$\theta_b(x_b, h; p_h) = \alpha_b^{-1} \left(\frac{\kappa_b h}{x_b - p_h h} \right) \quad (11)$$

$$\theta_s(x_s, h; p_h) = \alpha_s^{-1} \left(\frac{\kappa_s h}{p_h h - x_s} \right) \quad (12)$$

Finding the menu of equilibrium trading probabilities reduces to finding one equilibrium p_h , just as one would do in a Walrasian model. This block recursivity result arises because of directed search and free entry of real estate brokers. Directed search pins down the terms of trade in each submarket before matching takes place, and the free entry of brokers into each submarket drives up market tightnesses until broker profits fall to zero. In subsequent work, [Hedlund \(2016\)](#) applies this framework to analyze housing business cycle dynamics.

2.7. Equilibrium

For a given interest rate r , a stationary equilibrium is a collection of value/policy functions for households and banks; market tightness functions θ_s and θ_b ; prices w , p_h , q_m^0 , q_m , q_b , and r_h ; and stationary distributions Φ of households and H_{REO} of REO housing stock that solve the relevant optimization problems and clear the markets for housing and factor inputs.⁷

3. Model calibration

The analysis in [Sections 4 and 5](#) depends on having a model that successfully matches 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. As elaborated on in [Section 4](#), housing market search frictions prove key to jointly matching foreclosure activity and the distribution of mortgage leverage. To avoid capturing the effects of the recent housing boom and bust, I calibrate the model to the U.S. economy in the late 1990s. The first phase of the calibration involves choosing parameters externally from the literature or from a priori information. I calibrate the remaining parameters using the model.

⁷ See the online appendix for more details.

Table 1
Model calibration.

Description	Parameter	Value	Target	Model	Source
<i>Calibration: Independent parameters</i>					
Autocorrelation	ρ	0.952			Storesletten et al. (2004)
SD of persistent shock	σ_e	0.17			Storesletten et al. (2004)
SD of transitory shock	σ_e	0.49			Storesletten et al. (2004)
IES	ν	0.13			Nakagawa and Mar (2008)
Risk aversion	σ	2			Various
Capital share	α_K	0.26			Díaz and Luengo-Prado (2010)
Structure share	α_S	0.3			Favilukis et al. (2016)
Land share	α_L	0.33			Lincoln Inst Land Policy
Capital depreciation (annual)	δ_K	10%			BEA
Housing depreciation (annual)	δ_h	1.4%			BEA
Holding costs	η	0.007			Moody's
Rent-price ratio (annual)	r_h	5.0%			Davis and Palumbo, 2008
Risk-free rate (annual)	r	4%			Federal Reserve Board
Mortgage servicing cost	ϕ	0.0038			1997 AHS
Mortgage origination cost	ζ	2.0%			FHFA
Maximum LTV	ϑ	125%			Fannie Mae
Persistence of credit flag	λ_f	0.9500			Fannie Mae
<i>Calibration: Jointly determined parameters</i>					
Homeownership rate	\bar{a}	2.0650	65.9%	65.9%	Census, 1998 data
Starter house/income	h_1	2.4600	1.75	1.75	1997 AHS
Median owner net worth	β	0.9653	1.40	1.40	1998 SCF
Owner housing wealth	ω	0.8131	2.49	2.49	1998 SCF
Annual sales rate	p_ψ	0.0105	10.00%	10.01%	Nat'l Assoc of realtors
Months of supply	ξ	0.0021	4.90	4.90	Nat'l Assoc of realtors
Average selling time (weeks)	ψ	0.4850	17.33	17.33	Nat'l Assoc of realtors
Average buyer search (weeks)	γ_b	0.1030	10.00	10.02	Nat'l Assoc of realtors
Maximum bid premium	κ_b	0.0178	2.5%	2.5%	Gruber and Martin (2003)
Maximum list discount	κ_s	0.1778	25%	25%	RealtyTrac
Foreclosure discount	χ	0.1170	0.21	0.21	Pennington-Cross (2006)
Mean REO selling time	λ	0.5580	52.00	52.03	RealtyTrac
Foreclosure rate (annual)	γ_s	0.5200	1.20%	1.21%	Nat'l delinquency survey

Table 1 summarizes the calibration, including listing the source for each externally calibrated parameter and the data source for each model target in the joint calibration.

3.1. Independent parameters

Households: Following Storesletten et al. (2004), I assume that the log of the persistent component of labor efficiency follows an AR(1) process, while the transitory component is log-normal.⁸ 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.

Technology: Production in both the composite good and the construction sector is Cobb-Douglas. Capital takes a share $\alpha_K = 0.26$ of non-housing production and depreciates at an annual rate of 10%. I calibrate TFP in the composite good sector to normalize mean quarterly earnings to 0.25. For housing construction, the structures share is $\alpha_S = 0.3$, and the land share is $\alpha_L = 0.33$. 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 5%.

Housing market: Matching is Cobb Douglas, i.e. $p_s(\theta_s) = \min\{\theta^{r_s}, 1\}$ and $p_b(\theta_b) = \min\{\theta^{r_b}, 1\}$. Substituting in (1) and (2) gives

$$p_s(\theta_s) = \min\left\{1, \max\left\{0, \left(\frac{p_h h - x_s}{\kappa_s h}\right)^{\frac{r_s}{1-r_s}}\right\}\right\}, \quad p_b(\theta_b) = \min\left\{1, \max\left\{0, \left(\frac{x_b - p_h h}{\kappa_b h}\right)^{\frac{r_b}{1-r_b}}\right\}\right\}$$

Holding costs are $\eta = 0.007$, while κ_b , κ_s , γ_s , γ_b , and ξ are determined jointly. Garriga and Schlagenhauf (2009) use data from the American Housing Survey to measure an idiosyncratic capital gains shock to housing, which is the deviation between the selling price of a house and its market value. They calculate that 90% of capital gains shocks fall in the range from -9.7% to 12.2%, which is a range of 21.9%. The 25% maximum discount is also consistent with evidence from pre-foreclosure sales price discounts reported by RealtyTrac. See Li et al. (2015) and Corbae and Quintin (2014) for more evidence.

⁸ The online appendix explains the conversion of their annual estimates to quarterly values.

Table 2
Model fit.

Statistic	Data	Model	Source
Median homeowner liquid assets	0.25	0.25	1998 SCF
Average mortgage payment/income	19.7%	20.7%	1997 AHS
Borrower leverage distribution			
Median LTV	62.9%	61.5%	1998 SCF
Share with LTV $\geq 70\%$	40.0%	39.4%	1998 SCF
Share with LTV $\geq 80\%$	25.0%	27.7%	1998 SCF
Share with LTV $\geq 90\%$	14.5%	10.8%	1998 SCF
Share with LTV $\geq 95\%$	9.2%	10.3%	1998 SCF

Table 3
Welfare effects of eliminating search frictions in the housing market.

Model	All (%)	Renters (%)	Owners (%)	LTV _{80–90%} (%)	LTV _{90–95%} (%)	LTV _{95%+} (%)
Baseline ₀	2.45	0.91	3.25	3.33	3.46	2.59
Fixed ^a q_m	2.02	0.69	2.71	2.75	2.78	2.23

^a q_m fixed at baseline level. The Walrasian model includes a 6% selling cost.

Financial markets: To match values in the U.S. during the 1990s, the risk-free rate is 4%, the origination cost is 2%, and the servicing cost ϕ is set to yield a 7.1% mortgage rate. The exogenous upper bound on leverage for new mortgages is set to a non-binding level of $\theta = 1.25$ (125%), and the persistence of bad credit flags is $\gamma_f = 0.95$. Lastly, the REO discount χ and search efficiency γ are determined in the joint calibration.

3.2. Joint calibration and model fit

I determine the remaining parameters to fit the model to certain aspects of U.S. macroeconomic data in the late 1990s. The first set of targets are select household portfolio moments calculated from the 1998 Survey of Consumer Finances.⁹ I also target certain key moments of the housing market such as sales volume, average search duration for buyers and mismatched sellers, and maximum price spreads. Lastly, I calibrate the model to match the average foreclosure price discount, REO time on the market, and the foreclosure rate.

Table 2 shows that the model also fits the untargeted leverage distribution,¹⁰ liquid assets, and the size of mortgage payments. As explained in Section 4, a meaningful interaction between search frictions and endogenous credit constraints emerges at high values of leverage. Therefore, matching the right tail of the leverage distribution is important. Without search, the model can either match the leverage distribution but generate too few foreclosures, or it can match foreclosures by overshooting the share of underwater borrowers.

4. Results

Search frictions make houses illiquid. In the aggregate, this illiquidity manifests as unsold houses that sit on the market for extended periods of time. At the individual level, illiquidity introduces the risk that sellers fail to sell (*liquidity risk*) and creates a trade-off between list price and expected selling time (*liquidity discounts*). With incomplete markets, housing illiquidity has significant welfare consequences. Table 3 reports that eliminating search frictions increases overall welfare by 2.45% in consumption-equivalent units. Owners gain by 3.25%, but renters who expect to be future homeowners also experience gains. Highly leveraged owners benefit the most, with the exception of the most heavily indebted borrowers who expect to default regardless of frictional house selling. Ignoring the positive effects on credit supply of eliminating search frictions mutes the welfare gains.

4.1. The anatomy of liquidity risk

Panel 1 of Fig. 2 shows listing price behavior as a function of mortgage leverage. For asset poor homeowners, listing price is a non-monotonic function of leverage. For low values of leverage, the listing price is almost invariant to small changes in loan-to-value. However, as leverage increases to moderate levels (70–80% LTV), asset poor homeowners become financially distressed from the burden of mortgage payments.

⁹ I include only households that are in the bottom 95% of the earnings and net worth distributions. Net worth is liquid assets + housing – mortgages. Liquid assets is financial wealth – quasi-liquid retirement.

¹⁰ An exception is the share of mortgagors, which is 78.7% in the data sample and 96.4% in the model.

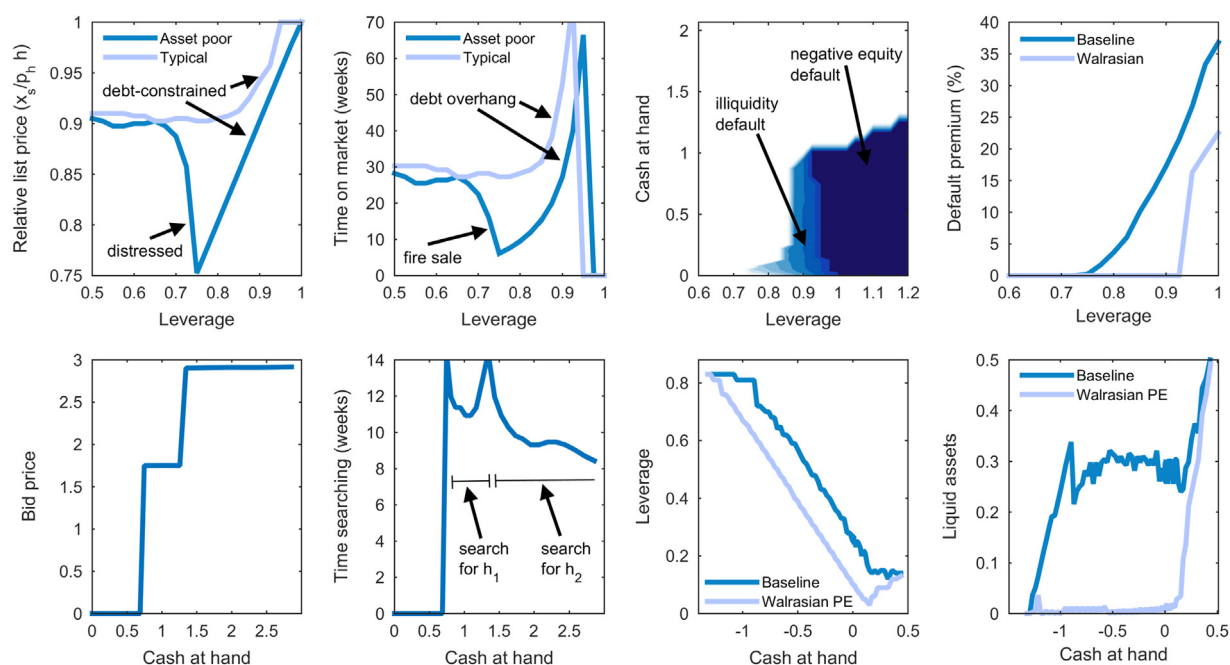


Fig. 2. (1) Seller list price; (2) Seller TOM; (3) Probability of mortgage default; (4) Default premia; (5) Buyer bid price; (6) Buyer search time; (7) Mortgage borrowing; (8) Liquid assets.

Distressed sales: In principle, low asset homeowners have two options: they can extract equity by refinancing, or they can try to quickly sell their house. However, the refinance option loses viability because banks recognize the high default risk of such homeowners and refuse to extend credit on favorable terms. As a result, these *distressed sellers* are forced to use their equity cushion to post low, *fire sale* prices that guarantee a rapid sale.

Debt overhang: For high values of leverage, the constraint $x_s + y \geq m$ starts to bind. As their equity cushion evaporates, *debt-constrained sellers* lose the flexibility to price their house to sell quickly. These homeowners experience *debt overhang* as their houses take longer to sell. Panel 2 of Fig. 2 plots time on the market, which rises to over one year for the most indebted sellers. The positive relationship between leverage, price, and time on the market—which holds for typical and asset poor sellers alike—was shown empirically by Genesove and Mayer (1997, 2001) and has not been accounted for, to date, by other models.

Risky housing, risky mortgages: Liquidity risk exacerbates debt overhang by inducing homeowners to take out additional risky, high LTV loans, as shown in Table 4. Though median LTV differs little between the baseline and Walrasian economies, the baseline economy features far more mortgages with high leverage. Two channels account for this result.

First, liquidity risk creates a precautionary motive for homeowners to shift wealth from housing equity to financial assets. To improve consumption smoothing, owners finance additional asset accumulation through increased borrowing. While repeated equity extraction can itself be used to smooth consumption, the origination costs and the lock-in effect of long-term mortgage rates makes constantly adjusting mortgage balances an undesirable way to insure against shocks. Quantitatively, homeowners hold 28% greater financial asset wealth in the baseline economy than in the Walrasian economy. Panels 7 and 8 of Fig. 2 graphically show the portfolio choice behavior of new homeowners in the two economies.¹¹

In addition to the precautionary motive, some homeowners take out high leverage mortgages because of financial duress and a temporary failure to sell. This “distressed borrowing” gives the homeowner funds to avoid insolvency and foreclosure while their house sits on the market. The longer the house takes to sell, the more debt homeowners accumulate. Ironically, this higher debt, by tightening the $x_s + y \geq m$ constraint and preventing the homeowner from lowering the list price, causes the house to take longer to sell.

4.2. Illiquidity and default

Debt-induced selling delays increase the probability of eventual foreclosure. In short, liquidity risk spills over into foreclosure risk. In standard Walrasian models of housing, negative equity is a necessary condition for default. As long as the

¹¹ The timing of the model causes most new owners to enter subperiod 3 with negative cash at hand. Buyers in subperiod 2 typically purchase a house with resources they actually receive at the end of the period through borrowing.

Table 4
Housing illiquidity: portfolio effects.

	Baseline	Walrasian PE ^a
Liquid assets	0.37	0.29
Median LTV	61.5%	63.5%
Share with LTV $\geq 80\%$	27.7%	35.1%
Share with LTV $\geq 90\%$	10.8%	2.8%
Share with LTV $\geq 95\%$	10.3%	1.7%

^a Partial equilibrium.

Table 5
Credit consequences of housing illiquidity.

	Baseline (%)	Walrasian (%)
Foreclosure rate	1.21	0.26
Average default premia		
All borrowers	0.42	0.16
LTV $\geq 80\%$	2.99	0.31
LTV $\geq 90\%$	7.66	0.40
LTV $\geq 95\%$	8.20	2.52

market clearing price suffices to pay off the mortgage liability, owners can sell their houses *instantly* to avoid default. However, with illiquid housing, the length of selling delays has a direct impact on foreclosure activity. Even if, *in principle*, a homeowner could sell their house at a sufficient price to pay off their debt, such a possibility loses relevance if it takes too long to do so. In other words, a difference exists between home equity *on paper* and equity as it pertains to selling at a particular price in a timely manner. Quantitatively, removing liquidity risk causes the foreclosure rate to plummet from 1.21% to just 0.26%.

Panel 3 of Fig. 2 plots contours for the probability of default—the binary default decision multiplied by the probability of not selling—as a function of leverage and cash at hand. In the Walrasian model, foreclosure only occurs in the dark blue region. Search frictions introduce a new, graduated region, which I label “illiquidity default.” Notice that, depending on an owner’s asset position, even having 6%, 10%, or 15% equity does not inoculate owners against the risk of default. Empirically, Pennington-Cross (2010) examines subprime mortgage data and finds repossession rates of 50% for delinquent mortgages with LTV ratios between 80–90% and 55% for delinquent mortgages with LTV ratios between 90% and 100%. In a Walrasian world, one would expect 0% repossession rates for such mortgages.

4.3. Illiquidity and credit supply

The heightened foreclosure risk that arises from housing illiquidity has a substantial effect on the supply of mortgage credit. Panel 4 of Fig. 2 plots sample default premia for new loans as a function of leverage. For clarity, a 10% default premium adds 10% to the cost of a loan over its lifetime. Default premia in the baseline economy with illiquid housing considerably exceed those in the Walrasian economy. Quantitatively, Table 5 shows that the average default premium for 80%+ LTV mortgages is 2.99% with liquidity risk and only 0.31% in the Walrasian economy. The corresponding quantities for 90% LTV mortgages are 7.66% and 0.40%, respectively, and for 95% mortgages are 8.20% and 2.52%, respectively.

4.4. The dynamic effects of cheaper credit

Now I consider the effects of an unanticipated, permanent decline in the risk-free rate from 4% to 1%, akin to what has occurred since 2003 (with a brief interlude between 2005 and 2007). Fig. 3 plots the response of house prices, time on the market, and foreclosures. Several observations stand out. First, house prices overshoot dramatically by increasing almost 60% before settling at 10% above their initial steady state. Second, time on the market drops from 17 weeks to 11 weeks before rising above its initial level to exceed 22 weeks. The foreclosure rate follows a similar pattern and ends at over twice its original level.

The initial drop in time on the market and foreclosures can be attributed to the surge in home equity created by the jump in house prices. Increased equity alleviates debt overhang and reduces foreclosures. However, the availability of cheap credit causes homeowners to gradually increase their leverage. Over time, this debt accumulation sows the seeds for future debt overhang and default. The Walrasian model completely misses this channel.

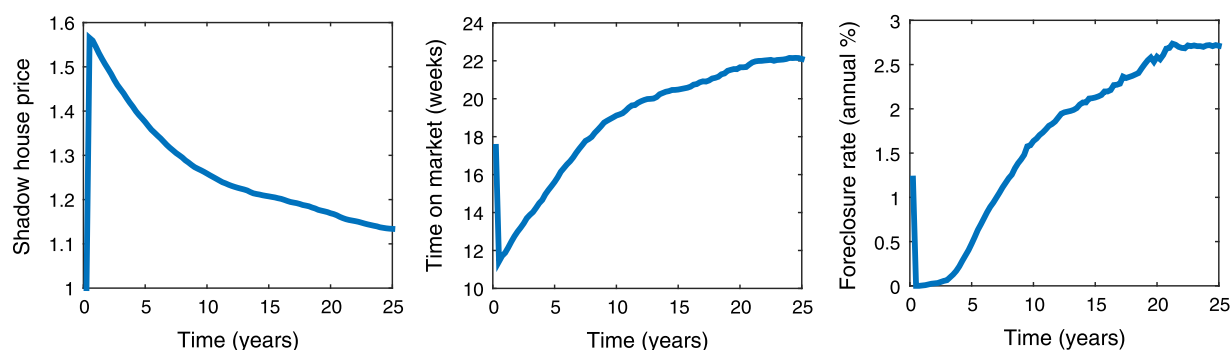


Fig. 3. The response of house prices, time on the market for mismatched sellers, and foreclosures to an unanticipated, permanent drop in the risk-free rate from 4% to 1%.

Table 6

Policy interventions: foreclosures and debt overhang.

	Foreclosure rate		Months of supply		TOM _{LTV ≥ 90%}	
	$r = 4\%$	$r = 1\%$	$r = 4\%$	$r = 1\%$	$r = 4\%$	$r = 1\%$
Baseline	1.21%	2.37%	4.90	5.78	26.3	26.0
Moderate recourse	1.92%	2.24%	5.09	6.07	28.9	32.4
Stringent recourse	0.16%	1.08%	5.58	7.01	36.0	42.0
LTV cap	0.39%	0.15%	4.88	6.07	—	—

5. Policy Analysis

In response to the recent foreclosure crisis, a flurry of debate has occurred over optimal foreclosure laws and default interventions. In some corners, the conventional wisdom is that no-recourse mortgages encourage borrower speculation and cause lenders to limit access to credit, in which case the solution is to increase default penalties. On the other hand, [Li et al. \(2016\)](#) point out that Nevada has moved in the opposite direction by formally abolishing deficiency judgments for all loans originated after October 1, 2009.

This section assesses the efficacy of two policy proposals designed to reduce foreclosure activity. I look first at reforms that increase the penalty of default, and then I analyze macroprudential policies that impose leverage limits at origination. Thus far, much of the analysis on foreclosure mitigation policies has focused on how policies alter the individual behavior of borrowers and lenders, such as in parallel work by [Hatchondo et al. \(2015\)](#) and [Mitman \(2016\)](#). This paper goes a step further by endogenizing the response of house prices and, most importantly, the change in housing illiquidity.

5.1. Foreclosure punishments

I consider two policy proposals that increase the degree of recourse available to lenders in the event of borrower default. The moderate recourse policy allows banks to seize up to 50% of the non-housing assets of the borrower, and the strict recourse policy allows seizure of up to 90% of assets. [Table 6](#) shows that foreclosure punishments face a stubborn trade-off between *increasing* either foreclosures or debt overhang. While the direct effect of foreclosure punishments is to decrease the demand for high leverage mortgages, such policies also lead to an expansion of credit because new mortgage prices reflect the reduced likelihood of default.

The credit expansion dominates under the moderate recourse policy as the share of 90%+ LTV mortgages jumps from 10.8% to 44.0%. [Table 6](#) shows that foreclosures actually *rise* from 1.21% to 1.92%, despite the increased reluctance to default on a given level of debt.

The stringent recourse policy *does* succeed at reducing foreclosures, but only at the cost of increased debt overhang, as months supply increases from 4.90 to 5.58. More strikingly, selling time for highly leveraged homeowners jumps from an average of 26 weeks to 36 weeks. Low interest rates magnify the deterioration, leading to months supply of 7.01 and time on the market of 42 weeks for homeowners with 90%+ LTV.

[Fig. 4](#) helps explain the heightened debt overhang. First, the expansion of credit affords owners greater patience in selling, as easier equity extraction delays financial duress. In short, not only does selling behavior affect the supply of credit—through its effect on eventual default probabilities—but the availability of credit also affects selling behavior. Second, by borrowing more heavily under the stringent recourse regime, homeowners end up more frequently in the debt overhang region. Lastly, the circled region in panel 3 shows that some owners who would have previously preferred to deleverage

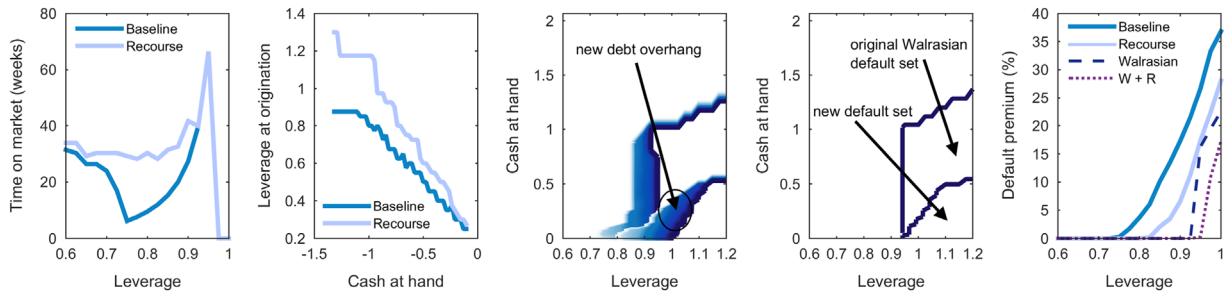


Fig. 4. The effects of stringent foreclosure punishments on (1) time on the market, (2) borrowing behavior, (3) default and debt overhang, (4) default in the Walrasian model, and (5) default premia.

immediately by defaulting instead attempt to sell—despite a low expectation of selling quickly. The Walrasian economy does not capture such an increase of debt overhang, as stringent recourse simply shrinks the default set. Panel 5 compares the shift in default premia between the two economies, with the baseline economy exhibiting a greater response to the policy because of the feedback from endogenous changes to housing liquidity.

5.2. Loan-to-value caps

Capping the LTV on new mortgages arises as a natural policy to avoid the trade-off between more foreclosures and worse debt overhang. In fact, an 80% LTV cap succeeds remarkably well by lowering foreclosures by 70% without adversely affecting months supply. However, an important caveat is in order. Although LTV caps are innocuous with regard to steady state debt overhang, they could have deleterious effects during a housing downturn. In the event of a drop in house prices, homeowners who suddenly find themselves with less than 20% equity would lose the ability to refinance. Those in financial distress would find themselves forced to try to sell their house, leading to an aggravation of debt overhang.

5.3. Welfare

Table 1 in the online appendix shows the welfare effects of the aforementioned policies. The recourse policies create a small welfare gain for the average homeowner but sizable losses for highly leveraged owners. In particular, the stringent recourse policy substantially reduces welfare of indebted owners by increasing selling delays and forcing them to cut their consumption to avoid default while their house sits on the market. By contrast, the absence of the endogenous illiquidity response significantly dampens these welfare losses in the Walrasian economy. The LTV cap, meanwhile, reduces welfare for all owners by restricting borrowing choices. In fact, LTV caps impose larger welfare losses in the Walrasian economy because they prevent borrowers from taking advantage of the greater access to credit created by the absence of housing illiquidity.

6. Conclusions

Search frictions in the housing market have quantitatively important effects on housing behavior, foreclosures, and the mortgage market. Liquidity risk spills over into higher foreclosure risk and creates a debt overhang problem characterized by financial distress and long selling delays. Credit expansions cause housing booms in the short run but debt overhang, longer selling delays, and higher foreclosures in the long run. Furthermore, foreclosure mitigation policies face difficult trade-offs that can either limit credit access or aggravate debt overhang and selling delays. The block recursive framework developed in this paper lends itself to other applications, including future work into other frictional markets with two-sided heterogeneity.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version at <http://dx.doi.org/10.1016/j.jmoneco.2016.08.005>.

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