Liquidity Constraints in the U.S. Housing Market*

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Abstract

We study the severity of liquidity constraints in the U.S. housing market using a life-cycle model with uninsurable idiosyncratic risks in which houses are illiquid, but agents have the option to extract home equity by refinancing their long-term mortgages. The model implies that three quarters of homeowners are liquidity constrained and willing to pay an average of 5 cents to extract an additional dollar of liquidity from their home. Most homeowners value liquidity for precautionary reasons, anticipating the possibility of income declines and the need to make mortgage payments in future periods. Mortgage assistance policies structured as credit lines to homeowners who experience a shortfall in income greatly reduce the severity of liquidity constraints.

Keywords: Home Equity Extraction, Liquidity Constraints, Mortgage Refinancing.

JEL classifications: E21, E30.

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1 Introduction

Housing wealth is the most important savings instrument for a large fraction of U.S. households. According to the Survey of Consumer Finances (SCF), about 70 percent of U.S. households own a home. Housing equity is by far the largest component of these individuals' balance sheets: it accounts for about 80% of the median homeowner's wealth. Housing is, however, a relatively illiquid asset because accessing home equity by selling or remortgaging a house involves considerable costs. Moreover, most mortgage contracts require homeowners to repay principal and build equity in their homes over time, thus exposing them to the risk of being unable to meet their mortgage obligations in the event of a transitory income loss. This risk is exacerbated by the presence of payment-to-income (PTI) constraints which preclude individuals with a temporary drop in income from tapping home equity and may lead to large swings in consumption in the face of transitory income shocks.

Our goal in this paper is to study how these institutional details of the U.S. housing market shape the homeowners' ability to smooth consumption in response to income shocks. In short, we ask: how liquid is housing wealth in the U.S.? The assumption that homeowners in the U.S. are liquidity constrained is at the heart of models capable of reproducing the high marginal propensities to consume in the cross-section of households, as in the work of Kaplan and Violante (2014) and Kaplan et al. (2014) on the wealthy hand-to-mouth, as well as to reproduce the response of macroeconomic aggregates to changes in household credit, as in the work of Mian and Sufi (2011) and Jones et al. (2017). Yet little direct evidence exists on the magnitude of the frictions that preclude homeowners from tapping home equity and the consequences of these frictions for their ability to smooth consumption.

We study this question using a quantitative life-cycle model with uninsurable idiosyncratic risks in which we explicitly model the key institutional details of the U.S. housing and mortgage markets. We parameterize the model to match salient characteristics of households' balance sheets, their income process, as well as the frequency of home equity withdrawals. Our model predicts that three quarters of homeowners are liquidity constrained, in that they would be better off if they could convert housing equity into liquid wealth. These homeowners are willing to pay 5 cents, on average, for every additional dollar of liquidity extracted from their homes. Liquidity constraints increase the average marginal propensity to consume out of a transitory income windfall by about 40% and reduce house prices by about 15%. Overall, our model predicts that frictions that prevent homeowners from tapping home equity are sizable.

What institutional features of the housing market are mostly responsible for the severity of liquidity constraints? We answer this question by removing, in isolation, each of the three key frictions homeowners in our model face: the costs of refinancing, the PTI constraint, and the requirement that mortgage borrowers gradually build equity in their homes. We find that the costs of refinancing play an important role. In our calibrated model these are equal to a fixed fee of $650 plus 1% of the value of one's loan, numbers in line with the evidence. Removing these costs would reduce the median homeowner's marginal propensity to consume out of transitory income shocks by about 40% and greatly increase the demand for housing, increasing the equilibrium price of housing by 8.6%. A payment-to-income constraint of 35% has, in contrast, a much smaller impact in our economy. Removing this constraint would leave marginal propensities to consume virtually unchanged and would only increase house prices by 1.6%. Intuitively, the presence of fixed costs of refinancing makes homeowners wary of borrowing too much even in the absence of the constraint, since they risk too much exposure to transitory income shocks. We confirm this intuition by showing that removing the costs of refinancing and the PTI constraint simultaneously would lead to a much larger 15% increase in house prices. The model therefore predicts an important interaction between these two frictions. Finally, we show that the requirement that borrowers build equity in their homes over time is a quite onerous one: in its absence house prices would increase by about 9.5%.

Motivated by these findings, we evaluate the effects of two types of mortgage assistance programs that provide relief to liquidity constrained homeowners. We show that mortgage forbearance policies must be much more generous than those currently in place to have a significant impact. Such policies currently limit the amount borrowers must make on their mortgage to about 30% of one's income. Since the majority of U.S. homeowners have payment-to-income ratios well below this amount, such policies do not provide relief for a sizable fraction of homeowners with small or no required mortgage payments. In contrast, the introduction of temporary lines of credit against one's home equity for homeowners experiencing a transitory income loss would have a strong impact since it would target exactly those homeowners who are most liquidity constrained.

Agents in our model face persistent and transitory income shocks and can save in a liquid asset at a relatively low interest rate. Consistent with the evidence in Guvenen et al. (2016), income shocks are drawn from a fat-tailed distribution, so that agents experience large declines in their income relatively infrequently. Households in our model can either rent or purchase housing subject to non-convex transaction costs. Homeowners can borrow against the value of their home, at a relatively high interest rate, and are subject to loan-to-value and payment-to-income constraints. Mortgage loans are long-term securities which require payment of interest and principal over time. Finally, agents can extract home equity by refinancing their mortgage. We think of this option as capturing both cash-out refinances and second-lien mortgage contracts, such as home equity loans.

We parameterize the model using data from the SCF on the poorest 80% of households and the Panel Study of Income Dynamics (PSID).[1] We show that data on household balance sheets and income processes are not sufficient to inform about the severity of liquidity constraints. If refinancing one's mortgage or other means of home equity extraction are relatively cheap, homeowners will purposefully choose to hold low amounts of the lower-return liquid asset and tap home equity whenever the need arises. We therefore require that our model reproduces the evidence, assembled by Bhutta and Keys (2016) using a large panel of consumer credit records, that about 8% of U.S. homeowners extract equity from their homes in any given year.

An additional factor that shapes the severity of liquidity constraints is the maturity of the mortgage contract. The shorter this maturity, the faster must agents repay the principal on their mortgage and accumulate home equity. Repaying principal may be quite costly for homeowners who experience a string of negative income shocks, a force that exacerbates liquidity constraints. We thus require that our model matches the duration of the most widely-used 30-year mortgage contracts in the U.S.

We define homeowners as liquidity constrained if they would be better off with a more liquid wealth portfolio. This group includes not only the hand-to-mouth homeowners who are at the kink in their Euler equation for liquid assets, but also marginal homeowners who pay a fixed cost to extract home equity and who would benefit from additional liquidity by exercising the option value of waiting. This group also includes homeowners who are not hand-to-mouth, yet keep their consumption low for precautionary reasons, anticipating the possibility of negative income shocks and the need to make mortgage payments in the future. In our model, only 25% of homeowners are hand-to-mouth, consistent with the findings of Kaplan and Violante (2014), while a much larger fraction of about 40% of homeowners value

[1] As we show below, agents in the top 20% of the wealth distribution have very large holdings of liquid assets and are unlikely to be liquidity constrained.

liquidity for precautionary reasons. These non-hand-to-mouth households are willing to pay 4 cents on average for every dollar of home equity that they are able to extract, and would consume about 10% of every dollar of equity extracted from their home.

We focus our analysis on studying the steady-state implications of liquidity constraints, and purposefully abstract from introducing aggregate dynamics. Although the question of how liquidity constraints vary over the business cycle is an important one, we do not pursue it here. Whether liquidity constraints bind more or less during a downturn accompanied by a large decline in house prices critically depends on the source of shocks triggering such dynamics. We have shown, in earlier versions of this paper,[2] that a decline in house prices may, in fact, trigger a relaxation of liquidity constraints since households reduce consumption due to a decline in their overall wealth.[3] Since generating realistic time-series variation in equilibrium returns on housing is a challenging task even in the absence of frictions on home equity extraction,[4] and since frictions on home equity extraction introduce important non-convexities that are challenging to handle even in our stationary environment, we leave such extensions for future work.

Related Work This paper is part of a wider research agenda, developed by Hurst and Stafford (2004), Khandani et al. (2013), and Beraja et al. (2016), among others, studying liquidity management in the housing market.

In addition to Kaplan and Violante (2014), our paper is most closely related to the work of Chen et al. (2013) and Kaplan et al. (2015). Both of these papers study models of the housing market in which houses are illiquid, mortgages have long durations and households can extract equity from of their homes. Unlike these papers, which study the comovement of consumption, house prices and income at business cycle frequencies, our work focuses solely on measuring the severity of liquidity constraints and the policies used to mitigate their effects in a stationary environment.

Our work is also related to a number of papers that study the housing market: Davis and Heathcote (2005), Ríos-Rull and Sánchez-Marcos (2008), Kiyotaki et al. (2011), Landvoigt et al. (2015), and Favilukis et al. (2017). In contrast to these papers, which typically assume one-period-ahead mortgage contracts and no costs of refinancing, our analysis explicitly introduces long-term mortgages that are costly to refinance and is thus more suitable

[2] Gorea and Midrigan (2015, 2017).

[3] See also Berger et al. (2017) who study the response of consumption to changes in house prices.

[4] See Favilukis et al. (2017).

for understanding the role of liquidity constraints. Chambers et al. (2009a,b) study rich models of the mortgage and housing market but unlike us focus on understanding changes in the homeownership rates and optimal mortgage choice, as do Campbell and Cocco (2003). Chatterjee and Eyigungor (2015) and Corbae and Quintin (2015) study models of the housing market with long-term mortgages but unlike us focus on understanding the foreclosure crisis. Finally, Greenwald (2015) proposes a tractable New Keynesian model of long-term fixed-rate mortgages and studies the aggregate implications of mortgage refinancing.

The rest of the paper is organized as follows. Section 2 presents some evidence that motivates our modeling choices. Section 3 describes the model. Section 4 discusses the data we have used and our empirical strategy. Section 5 studies the severity of liquidity constraints and discusses the relative importance of mortgage market frictions. Section 6 studies the impact of different mortgage assistance programs. Section 7 presents several robustness checks we have conducted. Section 8 concludes.

2 Motivating Evidence

We document, using data from the 2001 Survey of Consumer Finances (SCF), that a large fraction of U.S. homeowners hold most of their wealth in the form of housing equity. Though this fact has been documented elsewhere,[5] we report additional statistics on the distribution of housing equity and liquid assets that we then use to evaluate our quantitative model. We also summarize the evidence on the amount of home equity extraction.

2.1 Data

We use the 2001 SCF to compute measures of the various components of household wealth. Here we briefly discuss the variables we used.[6] Our measure of housing is the value of the primary residence owned by each household. We calculate mortgage debt by adding the outstanding principal on all mortgages secured by the primary residence, including home equity loans and other second-lien loans.

Our measure of liquid assets adds balances on all checking and savings accounts, money market deposits and mutual funds, certificates of deposit, directly held pooled investment funds, bonds, stocks, and secondary residential real estate. We subtract from these the

[5] See Kaplan and Violante (2014).

[6] See our Appendix for a more detailed description of our measures of wealth and disposable income.

amount owed on credit cards, installment loans, and debt secured by secondary properties. Our inclusion of secondary properties in our measure of liquid assets is motivated by the observation that these are transacted quite often and are thus relatively liquid.[7] Most households do not own such properties, so this choice does not greatly affect our results.

We define total wealth as the sum of liquid assets and housing, net of mortgage debt, thus excluding balances held in retirement accounts. We account for the latter in our model by directly subtracting transfers into and out of these accounts from the household's measure of disposable income. As Kaplan and Violante (2014) point out, retirement accounts make up less than 2% of the median household's wealth in the U.S., so our choice to exclude these from our definition of wealth does not change our statistics much.

2.2 Stylized Facts

Table 1 reports several key features of the data. We report statistics for the entire sample, as well as separately for those in the top 20% and bottom 80% of the wealth distribution.

The aggregate stock of liquid assets is quite high: its per-capita average is equal to $114,000, or about two-thirds of overall wealth and more than three times annual income.[8] This average masks, however, a great deal of heterogeneity in the households' portfolio composition. The richest 20% of households have an average stock of liquid assets of about $494,000, seven times their annual income. The poorest 80% of households, in contrast, have an average stock of liquid assets of only $13,000, less than half their average annual income.

The lower tail of the distribution of liquid assets reveals an even more striking pattern. The richest 20% of households have sizable amounts of liquid assets even at the low end of the distribution – the 10th percentile is equal to $23,700. In contrast, the poorest 80% of households have very few liquid assets. Among households in this group, the 10th percentile of liquid assets is equal to −$1,200, the 25th percentile is equal to zero, while the 50% percentile is equal to only $2,000, less then one-tenth of the average annual income of these households.

We find a similar pattern when we restrict our calculations to the sample of households who own a home. As Table 1 indicates, about 71% of all households own a home. Among those in the bottom 80% of the wealth distribution, 64% of households own a home. The

[7] See our Appendix for evidence on this.

[8] We have adjusted all variables for household size using the OECD equivalent scales. All numbers are expressed in 2001 USD.

25th percentile of liquid assets is equal to $278 for homeowners in this latter group, thus about 1% of their average income. The median liquid assets of these homeowners is also small, about $4,200.

Consider finally the share of housing equity (housing net of mortgage debt) in households' total wealth. Table 1 shows that for the sample of all homeowners, the median share of housing equity in total wealth is 77%. This pattern is even more pronounced when we focus on the poorest 80% of households: housing wealth accounts for 87% of all of the wealth of the median homeowner in this group.

Frequency of Housing Turnover and Home Equity Extraction. Whether housing wealth is liquid or not depends on the availability of opportunities to extract home equity. These include the option to sell a home, as well as to extract equity from an existing home.

Bhutta and Keys (2016) study a large, nationally representative panel of consumer credit records. They report that 8.5% of homeowners with positive mortgage debt who did not move extracted home equity in 1999 and 7.3% did so in 2000. Though the fraction of homeowners who extract equity increased in the subsequent years of the boom in the U.S. housing market (to a high of 18.4% in 2003), the frequency of home equity extraction returned to pre-2000 level by 2008. As for the frequency with which homeowners sell their homes, Berger and Vavra (2015) report that about 4.4% of the existing housing stock was sold in 2001.

3 Model

This is an overlapping generations endowment economy. Agents live for a finite number of periods, are subject to idiosyncratic income shocks, derive utility from consumption and housing, and can save using a one-period liquid asset or by purchasing a home. We assume a small open economy so the interest rates at which agents save and borrow are exogenously given and constant in our experiments. Agents can either rent or own their homes. Selling one's home entails a fixed transaction cost. Agents can borrow against their home by taking on a mortgage, but doing so entails a fixed cost. We next describe preferences, the income process, and the assets available for trade.

Preferences. Agents live for T periods, of which they work for the first J periods. The utility function is time-separable, with an inter-temporal elasticity of substitution equal to one, a preference weight on housing equal to α and a discount factor β. We let c denote the consumption of the endowment good and h denote the amount of housing the agent consumes. The life-time utility of an agent is

$$V_0 = \mathbb{E} \sum_{t=1}^{T} \beta^{t-1} \left((1-\alpha) \log c_t + \alpha \log h_t \right) + \beta^T \log w_{T+1},$$

where w_{T+1} is one's terminal wealth, which includes liquid assets and the equity in one's home in the last period of life.

Income. An agent i at age t receives endowment income

$$y_{i,t} = z_{i,t} e_{i,t},$$

where z is the persistent component of one's income and $e_{i,t}$ is the transitory component. The persistent component is drawn at birth from $\mathbb{N}\left(\mu_{0,z}, \sigma_{0,z}^2\right)$ and evolves over time according to an AR(1) process whose mean depends on whether one is employed or retired:

$$\log(z_{i,t+1}) = \rho_z \log(z_{i,t}) + \sigma_z \varepsilon_{i,t+1}, \quad \text{if} \quad t < J$$

and

$$\log(z_{i,t+1}) = (1-\rho_z)\mu_{R,z} + \rho_z \log(z_{i,t}) + \sigma_z \varepsilon_{i,t+1}, \quad \text{if} \quad t \geq J,$$

where σ_z determines the volatility of innovations, $\mu_{R,z}$ governs the rate at which income falls during retirement and ρ_z determines the persistence of one's income. The transitory component e is i.i.d. and drawn from a distribution with volatility σ_e.

We assume, motivated by the evidence in Guvenen et al. (2016), that shocks to the income process are leptokurtic. We capture this excess kurtosis by assuming that both transitory and persistent income shocks are drawn from the *Tukey gh* distribution. Specifically, letting ϵ be a draw from a standard normal, we use the transformation

$$\varepsilon = \epsilon \exp\left(\frac{\kappa}{2}\epsilon^2\right)$$

to model the income shocks, with the kurtosis increasing in the parameter $\kappa \geq 0$.[9] For simplicity, we assume that the distributions of both transitory and persistent shocks have the same kurtosis.

[9] See Headrick et al. (2008) for a detailed discussion of this distribution.

Assets. Agents can save using a one-period risk-free *liquid asset* at an interest rate r_l. We let a denote the amount of liquid assets an agent has and restrict these to be non-negative, $a' \geq 0$. In a working version of this paper, Gorea and Midrigan (2015, 2017), we have shown that all our results are robust to allowing agents access to unsecured credit at credit card borrowing rates, as long as we match the low fraction of homeowners with negative liquid asset holdings observed in the data.

We let h denote the amount of housing the agent owns and P the equilibrium price of housing. Housing is subject to transaction costs that are proportional to the value of one's home and equal to $f_s Ph$ units of the endowment good. These costs are incurred whenever one sells their home. We assume, in our computations, that the stock of houses is indivisible, but have chosen a grid size sufficiently large so that these indivisibilities do not have much impact on the agents' decision rules.

Mortgages. Agents can borrow against the value of their homes using mortgages. We follow Hatchondo and Martinez (2009) and Chatterjee and Eyigungor (2015) in assuming, for computational tractability, that mortgages are perpetuity contracts with geometrically decaying coupon payments. Let b denote the face value of the mortgage. The mortgage is characterized by an interest rate, $r_m > r_l$, as well as a parameter $\gamma \leq 1$ that determines the minimum fraction of principal that the borrower needs to repay each period. A borrower with a remaining mortgage debt of size b must make a minimum payment of $(1-\gamma+r_m)b$, of which a fraction is interest and the rest is principal. The higher γ is, the smaller the required principal payments, and thus the longer the duration of the mortgage contract.

There are no curtailment penalties in the model so borrowers can repay a greater fraction of the principal than stipulated by the mortgage contract.[10] Thus, a borrower who does not extract home equity chooses a new loan balance b' subject to the borrowing constraint

$$b' \leq \gamma b. \tag{1}$$

Mortgage Refinancing. We assume that agents who do not sell their homes have only one means of home equity extraction, which we refer to as *refinancing.* This option is costly to exercise, and allows homeowners to relax the borrowing constraint in (1) by increasing the

[10] Although some lenders do impose curtailment penalties, they typically apply them only in the first few years in the life of the mortgage and only if a borrower pre-pays more than 20% of the loan balance in any given year. McCollum et al. (2015) report that these limits rarely bind.

amount borrowed on the mortgage. In practice, homeowners in the U.S. have a number of means to extract home equity, by either cash-out refinancing, taking on a home equity loan, a home equity line of credit, or a second mortgage, among others. Since the details of how these alternative approaches vary are quite complex, here we purposefully chose to keep the model simple by assuming a single means of home equity extraction that stands in for all these alternatives. See our earlier work, Gorea and Midrigan (2015, 2017), in which we have explicitly modeled the distinction between home equity loans and cash-out refinances and found results similar to those here.

We assume that the cost of refinancing one's mortgage has two components, a fixed one, $f_{0,m}$, independent of how much one borrows, as well as a second one, $f_{1,m}b'$, proportional to the amount of the new loan, b'. These two components capture the closing costs (origination fees), a portion of which are independent of the amount borrowed, as well as the *discount points* which are often equal to a small fraction of the amount borrowed. We assume throughout most of our analysis that these costs are the same whether the agent finances the purchase of a new home by obtaining a new mortgage, or refinances an old mortgage on an existing home.

Agents who refinance a mortgage on an existing home or obtain a new mortgage to finance the purchase of a new home face two constraints on the amount they can borrow: a loan-to-value (LTV) constraint that restricts the total amount of debt below a fraction θ_m of the value of the home:

$$b' \leq \theta_m P h, \tag{2}$$

as well as a payment-to-income (PTI) constraint that requires that the minimum mortgage payment not exceed a fraction θ_y of the household's income:

$$(1 - \gamma + r_m) b' \leq \theta_y y. \tag{3}$$

This constraint only applies at mortgage origination – agents for whom income falls a lot during the life of a mortgage are not required to curtail it.

Rental Market. An agent who does not own a home can rent h units of housing services at a rental rate R. Rental housing is not subject to adjustment costs or indivisibilities. In our quantitative section we calibrate R in order to match the homeownership rates in the data. We interpret the difference between this rental rate and the user cost of owner-occupied housing as capturing a number of reasons that make ownership preferable to renting, including moral hazard problems that exacerbate maintenance costs of rental property.[11]

Housing Supply. We assume that the stock of owner-occupied housing is in fixed supply, and calculate the response of house prices to changes in the environment. Rental housing, in contrast, is perfectly elastically supplied, so its rental rate, R, is constant. There is no aggregate uncertainty and we focus solely on studying the model's implications in the ergodic steady state.

Budget Constraints. Consider an agent who enters the period with a house of size h, outstanding mortgage debt b, liquid assets a and income y. The budget constraint of the agent varies depending on whether she rents, purchases a new home or remains in the existing home, as well as on whether she chooses to extract home equity. Households can extract equity from their homes in two ways: (i) by selling their house and (ii) by refinancing their mortgage to a higher balance.

Agents who *rent* face the budget constraint

$$c + a' + Rh' = y + (1 + r_l)a - (1 + r_m)b + (1 - f_s)Ph. \tag{4}$$

The right-hand side represents the agent's liquid wealth after she sells the house, incurring the selling cost $f_s Ph$, repays the principal and interest on the outstanding mortgage debt, $(1 + r_m)b$, and receives income y and interest and principal on the liquid account, $(1 + r_l)a$. The left-hand side sums consumption, c, liquid savings, a', and rental spending, Rh'.

Agents who *purchase* a new home face

$$c + a' + Ph' - b' + (f_{0,m}\mathbb{I}_{b'>0} + f_{1,m}b') = y + (1 + r_l)a - (1 + r_m)b + (1 - f_s)Ph. \tag{5}$$

The right-hand side is identical to that of the renter. The left-hand side sums the agent's consumption and liquid savings, the cost of the new home, Ph', net of the new mortgage debt, b', if the agent chooses to borrow. If the agent does borrow, she incurs the fixed mortgage closing cost $f_{0,m}$ as well as a cost proportional to the amount borrowed, $f_{1,m}b'$, and faces the borrowing constraints in (2) and (3).

Inactive homeowners neither transact their house, nor extract home equity and face

$$c + a' = y + (1 + r_l)a - (r_m b + b - b'), \tag{6}$$

[11] See, for example, Chambers et al. (2009a,b).

as well as the requirement that they pay down a fraction γ of their existing loan balance, summarized by (1). These agents consume or save their income and the balance on their liquid account, net of the payments on their mortgage. These payments include interest, $r_m b$, as well as principal repayment, $b - b' \geq (1-\gamma)b$.

Finally, agents who *refinance* their mortgage face

$$c + a' - b' + (f_{0,m} + f_{1,m} b') = y + (1 + r_l)a - (1 + r_m)b. \tag{7}$$

These agents repay back the entire balance on their original mortgage, $(1 + r_m)b$, and take on a new mortgage b', the size of which is limited by the LTV and PTI constraints. For simplicity, we assume that mortgage refinancing entails the same cost as that required to obtain a mortgage on a new home.

Recursive Formulation. Let m denote an agent's total wealth, including liquid assets and the resale value of the home, net of the mortgage debt:

$$m = (1 + r_l)a + (1 - f_s)Ph - (1 + r_m)b. \tag{8}$$

The other state variables are the household's age, t, the permanent and transitory income components, z and e, the size of one's home, h, as well as the mortgage debt, b. The value function satisfies

$$V_t(m, b, h, z, e) = \max_{a', b', h'} u(c, h') + \beta \mathbb{E}_{z', e'} V_{t+1}(m', b', h', z', e'), \tag{9}$$

where the maximization operator includes the choice of two continuous variables, a' and b', as well as the discrete choices of what house size to purchase, whether to rent, and whether to refinance or obtain a new mortgage.

Value of Liquidity. For any given level of wealth m and housing stock h, the state variable b summarizes how liquid a household's portfolio is. A greater level of mortgage debt b, holding wealth and housing constant, implies a greater stock of liquid assets, a, and less home equity. A homeowner is said to *value liquidity* if the value function increases in b, that is, if $\partial V_t(\cdot)/\partial b > 0$. We therefore let

$$\nu_t = \frac{\partial V_t(\cdot)}{\partial b} / u_{c,t} \tag{10}$$

denote a household's marginal valuation of liquidity, expressed in units of marginal utility of consumption, $u_{c,t}$. This object gives the household's willingness to pay to exchange one unit of housing equity for one unit of liquid assets. We refer to agents for whom $\nu_t > 0$ as *liquidity constrained,* since these are homeowners who would benefit from a more liquid portfolio.

Two groups of homeowners value liquidity. The first are the *marginal* homeowners near the thresholds for refinancing or selling their home. Since both of these options entail a fixed cost, marginal homeowners benefit from additional liquidity by exercising the option value of waiting.

The second group of homeowners are the inactive ones. Their budget constraint can be written as

$$c = m + y - (1 - f_s)Ph + b' - a', \tag{11}$$

and their borrowing constraint is given by (1). Since the outstanding mortgage debt b only appears in the borrowing constraint of these agents' problem, their marginal valuation of liquidity, $\partial V/\partial b$, is simply equal to γ times the multiplier on that constraint. Inactive agents are therefore liquidity constrained whenever the minimum mortgage payment constraint binds.

Decision Rules. The Euler equation for liquid savings is

$$u_{c,t}(m, b, h, z, e) = \beta(1 + \tilde{r}_t(m, b, h, z, e))\mathbb{E}_{z',e'} u_{c,t+1}(m', b', h', z', e'), \tag{12}$$

where $\tilde{r}$ is the shadow interest rate faced by the agent and is equal to the interest rate on the liquid asset, r_l, plus the multiplier on the $a' \geq 0$ constraint. We follow Kaplan and Violante (2014) in referring to households for whom this constraint binds as *hand-to-mouth*.

The Euler equation for mortgage debt is

$$\mathbb{E}_{z',e'} \frac{\partial V_{t+1}(m', b', h', z', e')}{\partial b'} \geq (r_m - \tilde{r}_t(m, b, h, z, e))\mathbb{E}_{z',e'} u_{c,t+1}(m', b', h', z', e'), \tag{13}$$

with equality if the borrowing constraint does not bind. The left-hand side of this expression is the expected marginal valuation of liquidity next period. The right-hand side is the cost of borrowing, given by the difference between the mortgage rate r_m and the effective return on the liquid asset, $\tilde{r}$. In deciding how much to borrow the agent thus trades off the interest cost of mortgage debt against the value of liquidity.

Figure 1 illustrates the mortgage debt choice by showing how the two sides of (13) vary with the amount borrowed. As b' increases, the agent has more liquidity and faces a lower shadow rate on the liquid asset, $\tilde{r}$. The intersection of the two curves pins down the optimal amount the agent would like to borrow. Also notice that the expected marginal valuation of liquidity, $\partial V_{t+1}/\partial b'$ is non-monotone in b', owing to non-convexities in the agent's choice set. When b' is low, the marginal valuation of liquidity is increasing in b'. In this region additional liquidity raises the probability that the agent will be able to exercise the option to postpone a costly equity withdrawal. In contrast, when b' is sufficiently high, the marginal value of liquidity falls owing to a drop in the likelihood of a binding liquidity constraint. Since homeowners have multiple options of home equity extraction (selling the house vs. refinancing), there are potentially multiple local solutions to the Euler equation in (13), which require use of global optimization methods.

We used spline interpolation to approximate the value functions, Gaussian quadrature to compute integrals, and successive application of Brent's method to calculate optimal decision rules. Owing to the non-convexities in the agents' choice set, obtaining sufficiently accurate decision rules requires that we solve the problem at about 300 million nodes in the state space.

4 Quantification

We parameterize the model to match salient features of households' portfolio composition and frequency of home equity extraction described in Section 2, as well as moments of their income process. We next describe the income measure we use, our calibration strategy and evaluate the model along a number of dimensions not explicitly targeted in calibration. Given our focus on the steady-state implications of liquidity constraints, the statistics we target are those for 2001, the year prior to the boom-bust episode in the U.S. housing market.

4.1 Income Measure

We use data from the 1999-2007 waves of the Panel Study of Income Dynamics (PSID) to parameterize the idiosyncratic income process. We compute taxable income for each household by adding wages (net of pension contributions), social security income, pension income, unemployment compensation and other transfers. We then subtract federal and state income taxes and deflate the resulting data using the CPI and the OECD equivalence scales. The Appendix contains a more detailed description of our computations.

Our notion of income captures disposable income net of contributions or withdrawals from retirement accounts. This allows us to focus our analysis on a household's choice between housing and liquid wealth, and abstract from the choice of how much to save using retirement accounts. We conjecture that this choice is fairly innocuous. As Kaplan and Violante (2014) show, the median household's holdings of retirement assets are small, around $950.

4.2 Parameterization

A period in the model is 1 year. Agents enter at age 25 and live for $T = 61$ periods, that is, up to age 85. They work for $J = 40$ years, up to age 65, at which point they retire and experience a gradual reduction in income.

We divide the parameters of the model into two groups. The first includes parameters that we assigned based on external evidence. The second includes parameters that are chosen in order to minimize the distance between a number of moments in the model and in the data. We next describe each set of parameters and report them in Panel C of Table 2.

4.2.1 Assigned Parameters

Mortgage Debt. The mortgage contract is characterized by four parameters, the interest rate r_m, the fraction of principal to be repaid each period, γ, the maximum loan-to-value ratio, θ_m, as well as the maximum payment-to-income ratio, θ_y.

The average 30-year fixed mortgage rate in 2001 was equal to 6.97%. We multiply this number by $1-0.239$, the average marginal subsidy on mortgage interest. We finally subtract the 2.8% inflation rate in 2001, which gives us a real after-tax interest rate of $r_m = 2.5\%$.[12]

We choose the parameter governing the duration of mortgages, γ, to match the *mortgage half-life*: the number of periods required for homeowners to repay half of the present value of their mortgage obligations. In the U.S., the typical mortgage is a 30-year fixed-rate mortgage in which the borrower repays a constant amount each period. The half-life of such a mortgage is the scalar τ which solves

$$\frac{1-(1+r_m)^{-\tau}}{1-(1+r_m)^{-30}} = \frac{1}{2},$$

implying a mortgage half-life of $\tau = 12.28$ years. In contrast, in our model mortgages are geometrically decaying perpetuities and the half-life satisfies

$$\left(\frac{\gamma}{1+r_m}\right)^{\tau} = \frac{1}{2}.$$

Matching the half-lives in the model and the data thus requires that we set

$$\gamma = (1+r_m)\left(\frac{1}{2}\right)^{\frac{1}{12.28}} = 0.969.$$

[12] See our Appendix for the data sources underlying these numbers.

We set the maximum LTV equal to 0.9, somewhat higher than the 0.8 value typically used in the literature, in order to match the upper tail of the LTV distribution in the data. For example, the 90th percentile of the LTV distribution in the data is equal to 0.92. Finally, we set the maximum payment-to-income ratio at origination equal to 0.35, consistent with the evidence in Greenwald (2015). Since mortgage payments in our model are, in contrast to the data, net of the tax deduction and inflation, we must adjust the PTI ratio in the model accordingly. In addition, we adjust the PTI to reflect the share of mortgage payments in overall household debt payments, since it is the latter that matters for the PTI constraint. Overall, our calculations, described in detail in the Appendix, imply a PTI ratio of 0.20.

Liquid Asset. We use the evidence in Davis et al. (2006) to set the return on the liquid asset, r_l. They report an after-tax return on 3-year Treasuries of 2.9% for 2001, from which we subtract the 2.8% CPI inflation to arrive at $r_l = 0.1\%$.

Fixed Costs. We set the proportional mortgage origination cost, $f_{1,m} = 0.01$, in line with average of discount points paid on new mortgages.[13] As we discuss below, we choose $f_{0,m}$, the fixed cost of mortgage origination, to match the frequency of home equity extraction in the data. We set $f_s = 0.06$, a typical estimate of the cost of transacting a house.

4.2.2 Calibrated Parameters

We next discuss how we have calibrated the rest of the parameters of the model. We divide these into two groups: those that characterize the income process, and the remaining parameters that determine the households' savings and refinancing decisions.

Income Process. A total of 7 parameters describe the income process. We target 8 statistics from the bi-annual PSID data to pin these down. We report the statistics we target in Panel A of Table 2 and the parameter values that minimize the distance between the moments in the data and in the model in Panel C of Table 2.

We set the mean of the initial permanent income draw, $\mu_{0,z} = -0.386$, to match a 0.21 log-point difference between the average income of households whose head is aged 45 to 55 years and those with a household head aged 25 to 35 years. We set the standard deviation of the initial income draw, $\sigma_{0,z} = 0.539$, to match the 1.03 ratio of the standard deviation of log

[13] See Agarwal et al. (2013), and the references therein.

income of those aged 45 to 55 years to those aged 25 to 35 years. We choose the parameter determining the drift of income in retirement, $\mu_{R,z} = -1.04$, to match the 0.29 log-point difference between the average income of workers and retirees.

We set $\kappa = 0.327$ in the Tukey distribution to match the 6.39 kurtosis of the distribution of bi-annual income growth in the PSID. We note that this degree of kurtosis is lower than the estimates in Guvenen et al. (2016) for two reasons. First, income in our household-level data may come from multiple earners. Second, our measure of income changes is over a two-year period and time aggregation further reduces kurtosis. Overall, the value of κ required to match the kurtosis of income changes in the PSID data implies a kurtosis of (annual) transitory and persistent income shocks of 18.5. In our Robustness section we report how our results change when we assume Gaussian income shocks.

We choose the volatility of persistent income shocks, $\sigma_z = 0.093$, that of transitory income shocks, $\sigma_e = 0.109$, as well as the persistence parameter, $\rho_z = 0.944$, to match the cross-sectional variance of log income (0.42 in the model, 0.44 in the data), its 2-year autocovariance (0.35 and 0.33), its 4-year autocovariance (0.32 and 0.31) and the standard deviation of bi-annual income growth (0.42 and 0.41). Intuitively, the rate at which the autocovariance decays with the horizon, together with the other moments, allows us to disentangle the relative variability of transitory and persistent income shocks. These parameter values imply a standard deviation of persistent income shocks of about 0.19 and that of transitory shocks of about 0.22, in line with existing estimates.[14]

Additional Parameters. We have a total of 4 remaining parameters that we choose by minimizing the distance between a number of moments in the model and in the data. We report the parameter values in the right column of Panel C of Table 2. These are the discount factor, β, the fixed cost of refinancing a mortgage, $f_{0,m}$, the preference weight on housing, α, and the rental rate of housing, R.

We choose these parameters to minimize the distance between 7 moments in the model and in the data. Panel A of Table 2 reports the values of the moments we target. These moments describe the composition of aggregate wealth into liquid and illiquid assets, the fraction of homeowners, as well as the frequency with which homeowners extract home equity by refinancing their existing mortgages. Recall from our discussion in Section 2 that, motivated by the evidence in Bhutta and Keys (2016), we target an 8% overall rate of home equity

[14] See for example, Floden and Lindé (2001) and Storesletten et al. (2004).

extraction. We construct this statistic using the same approach as in Bhutta and Keys (2016), by focusing on the sample of individuals with positive mortgage debt who *do not transact* their home in a given year and by defining extractors as those whose mortgage debt increases from one year to another.

The wealth moments we target are those for the poorest 80% of the households in the SCF sample. It is clear from Table 1 that the wealthier group of households have very large holdings of liquid assets and are thus unlikely to be liquidity constrained. Accounting for the large liquid holdings of the richer households would require adding additional sources of heterogeneity (say in the discount rates, or returns on liquid assets or income processes), which would complicate the model, without substantially changing any of our conclusions given our small open economy assumption.[15]

The first four rows of the right-hand side of Panel A in Table 2 report several aggregate per-capita wealth moments, all scaled by aggregate per-capita annual income. We reproduce well the aggregate wealth (1.45 in the data vs. 1.44 in the model) and the value of the aggregate housing stock (1.82 vs. 1.80), but understate the average holdings of mortgage debt (0.83 vs. 0.57) and mean liquid assets (0.46 vs. 0.21). We are unable to match these last two moments because of the large wedge between the mortgage and liquid interest rates (2.5% vs. 0.1%) we have assumed. This leaves us with two parameter, the preference for housing and the discount factor, to match a combination of these four statistics, but not each in isolation. As the next row of the table shows, however, the model matches exactly the median liquid assets of households (0.07 times mean per-capita annual income in both the model and the data), so its failure to reproduce the aggregate stems from its failure to match the distribution of liquid assets at the upper tail, a feature which is less consequential for the model's implications for the severity of liquidity constraints. We report in our Robustness section results from an extension of the model with heterogeneity in the rate of return on liquid assets that is capable of reproducing the upper tail of the liquid asset distribution and show that our results are robust to this modification.

The model also reproduces well the two other statistics we have targeted: the homeownership rate of 64%, as well as the 8% Bhutta-Keys frequency of home equity extractions. Intuitively, the rental rate R pins down the homeownership rate, while the fixed cost of home equity extraction $f_{0,m}$ pins down the fraction of homeowners who extract home equity.

[15] See the earlier draft of this paper, Gorea and Midrigan (2015, 2017), for an extension along these lines.

We also note, in Panel B of Table 2, that the model reproduces well additional features of the data that we have not explicitly targeted in our calibration. The fraction of homeowners who transact their home is equal to 3.6% in our model (4.4% in the data), the fraction of homeowners with a positive balance on their mortgage is equal to 73% in the model (71% in the data), and retirees have about 2 times more wealth than workers both in the model and in the data.

Panel C of Table 2 reports the values of these remaining 4 parameters. The discount factor necessary to match the aggregate wealth in the data is equal to $\beta = 0.95$. The preference weight on housing needed to match the aggregate housing stock is equal to $\alpha = 0.064$. The fixed cost of obtaining a new home equity loan is equal to 2.32% of the annual per-capita average income, or about \$650.[16] Although there is quite a bit of variation in how much homeowners pay in closing costs and other fees when borrowing against their home, our estimates are in line with those reported elsewhere.[17] Finally, the model requires a rental rate of housing of $R = 0.033$, thus quite a bit higher than the 2.5% interest rate on mortgages. This wedge compensates homeowners for the liquidity constraints they face and is necessary to match the homeownership rates in the data.[18]

4.3 Additional Moments Not Targeted in Calibration

We next evaluate the model's ability to account for a number of additional features of the data not targeted in our calibration. Since our focus is on measuring the severity of liquidity constraints faced by individual homeowners, it is imperative that the model reproduces well the distribution of liquid assets among homeowners, as well as the share of housing in their wealth. We next discuss how the model does along these dimensions, as well as report a number of life-cycle statistics.

Households' Portfolio Composition. We next report various quantiles of the distribution of individual household balance sheets in both the model and the data. Table 3 reports these additional statistics.

Panels A and B of Table 3 report the distribution of liquid assets for renters and homeowners. The model reproduces the 10th, 25th and 50th percentiles of these distributions well.

[16] The average per-capita income of the 80% poorest households in the data is \$27,500.

[17] See www.federalreserve.gov/pubs/refinancings/, as well as our Appendix.

[18] See our Appendix for evidence on the relative cost of renting vs. owning a home.

For example, the median renter has liquid assets of about 1% of per-capita aggregate income in the data and 3% in the model, while the median homeowner has liquid assets of about 15% of per-capita annual income in the data and 10% in the model. Importantly, the model matches well the fraction of hand-to-mouth households in the data. About 26% of households have no liquid assets, consistent with the findings of Kaplan and Violante (2014). The fraction of hand-to-mouth households is slightly higher among renters (29%) than homeowners (25%).

The model fails to match the upper percentiles of the distribution of liquid assets, which are substantially greater in the data. For example, the 90th percentile of liquid assets of homeowners is equal to 0.65 in the model and 1.69 in the data. Since we focus on measuring liquidity constraints, which bind at the bottom of the liquid asset distribution, we conjecture that this discrepancy does not greatly affect our conclusions. As we show in the Robustness section (Section 7), our model can replicate the upper tail of the distribution of liquid assets if we add heterogeneity in the rate at which households can save in the liquid asset. That model's predictions regarding the valuation of liquidity are very similar to our Benchmark's.

Panel C of Table 3 reports the distribution of housing values across agents in our model. The model reproduces this distribution reasonably well, though it somewhat understates the dispersion in house sizes. The model also matches well the distribution of loan-to-value ratios (Panel D) for those who borrow: the 25th percentile of 0.40 (0.32 in the model), the median of 0.64 (0.56), and the 75th percentile of 0.79 (0.78). Given that the model reproduces well the distribution of liquid assets, housing values and LTVs, it also matches well statistics derived from these. Panel E and F of Table 3 show that the model reproduces well the housing share of homeowners' wealth and the overall wealth distribution. For example, the median share of housing equity in total wealth is equal to 87% in the data and 92% in the model.

Life-Cycle Statistics. Figure 2 reports how average income, the wealth to income ratio, housing to income ratio and the housing wealth to income ratio evolve over the life-cycle. We used the SCF to calculate the data counterpart of these statistics. In Panel A of Figure 2, we report how income evolves over the life-cycle. The model fails to capture the decline in income observed at about age 55 in the data, but otherwise matches the income profile in the data reasonably well. The model slightly understates the wealth holdings of households across all age groups, primarily due to our inability to match the average holdings of liquid assets. The model also understates the housing stock of young households but reproduces well the rate at which housing increases over the life-cycle. Finally, as Panel D shows, the model does a good job at reproducing the evolution of housing equity over the life-cycle.

To summarize, we calibrate the four key parameters of the model to reproduce a number of *aggregate* statistics, but the model succeeds in also reproducing salient features of the *distribution* of households' liquid assets, mortgage debt and housing. It also matches reasonably well the life-cycle profiles of income, wealth and housing equity observed in the SCF data. Given its parsimony, the model fails to reproduce the high liquid asset holdings at the top of the distribution, but as we show below, this failure is inconsequential for the model's implications for the severity of liquidity constraints which bind at the bottom of the distribution.

5 Importance of Liquidity Constraints

We first report a number of statistics that describe homeowners' propensity to extract home equity. We then study the model's implications for the severity of liquidity constraints. We find that these constraints play a substantial role in distorting homeowners' consumption choices. Three quarters of homeowners value liquidity, a number that greatly exceeds the fraction of hand-to-mouth homeowners. As we show below, most agents value liquidity for precautionary reasons, anticipating the possibility of ending up hand-to-mouth in future periods. We then ask: what institutional features of the housing market in the U.S. are responsible for the severity of these constraints?

5.1 Decision to Extract Home Equity

We relate homeowners' decision of whether to extract home equity to i) the loan-to-value ratio on their current mortgage, ii) the minimum payment required on the mortgage, scaled by the household's income, iii) the liquid assets to wealth ratio, and iv) their income. We define home equity extraction broadly, as both the act of refinancing one's mortgage, as well as the sale of one's home. We divide homeowners into bins according to each of the four characteristics above and calculate the fraction of homeowners who extract equity for homeowners in each bin.

To aid in interpreting these statistics, we start by reporting, in Figure 3, the distribution of the loan-to-value ratio, minimum payment-to-income ratio, liquid assets to wealth ratio and income across homeowners. The LTV distribution has a mass of about 25% at 0 and is approximately uniformly distributed otherwise. The minimum payment-to-income ratio has a mean of about 10% and reaches 40% at its peak. The liquid asset to wealth ratio is concentrated in the neighborhood of 0 – 0.20 while the distribution of income is well-approximated by a log-normal.

Figure 4 reports how the proportion of homeowners who extract home equity varies with each of these characteristics. Those with the lowest LTV are most likely to extract home equity: the proportion that do so is about 15% for those without a mortgage and falls to 5% for those with an LTV of 85%. The propensity to extract increases in the minimum payment-to-income ratio: those at the bottom of this distribution have a probability of extracting of about 10%, whereas those with a minimum payment of 40% of their income have a probability of extracting of about 60%. The ability to repay one's mortgage obligations is thus a critical determinant of one's probability of home equity extraction.

Also notice that the probability of extraction is the highest for those with low holdings of the liquid assets (about 20%) and falls to zero for those whose liquid assets exceed about 40% of their overall wealth. Finally, the probability of extraction is U-shaped in one's income: those at both the lower and upper tails of the income distribution are more likely to extract home equity.

5.2 Severity of Liquidity Constraints

We next ask: how much do homeowners in our model value liquidity? We answer this question by conducting an experiment which we refer to as *liquidity injection.* We increase all homeowners' liquid assets and mortgage debt by the same amount, Δb, leaving their overall wealth unchanged. We set Δb equal to 10% of the value of one's home, thus effectively offering homeowners a one-time opportunity to extract home equity up to 10% of the value of their home for free.

Panel A of Table 4 shows that 74% of all homeowners benefit from such an opportunity. Thus, about three quarters of homeowners are liquidity constrained in our Benchmark economy, in that they would be better off with a more liquid portfolio allocation. The remaining rows of the panel report the constrained homeowners' average valuation of liquidity, which we compute using the discrete counterpart of (10). The average valuation of liquidity among all those who benefit from it is equal to 5.1%. Liquidity constrained homeowners are therefore willing to pay 5.1 cents for every dollar they can extract from their housing wealth. This number varies considerably across homeowners, with a 25th percentile equal to 2.1% and a 90th percentile equal to 10.4%.

We also report how the willingness to pay for additional liquidity varies between hand-to-mouth homeowners and everyone else. Recall that we defined hand-to-mouth homeowners as those who would be at their liquid asset limit, $a' = 0$, absent the liquidity injection. About one-third of all homeowners who value liquidity are hand-to-mouth and their average valuation of liquidity is equal to 6.2%, slightly higher than the unconditional average. Non-hand-to-mouth homeowners have a somewhat smaller valuation of liquidity, 4.5% on average.

Panel B of Table 4 reports the average fraction of the additional liquidity that constrained homeowners would consume in the period of the injection, $\Delta c/\Delta b$. A small fraction of homeowners choose to *reduce* consumption when they obtain additional liquidity: the 10th percentile of constrained homeowners would cut their consumption by 11.5 cents for every additional dollar extracted. These are the marginal homeowners who are near the adjustment thresholds and are either able to postpone the costly option of extracting home equity in the current period (which would have increased their consumption) or anticipate a reduction in the probability of doing so in the future. Most homeowners, however, choose to increase their consumption when receiving additional liquidity: the median constrained homeowner increases their consumption by 14.8 cents for every dollar of additional home equity they receive.

The last two columns of the panel report how consumption changes in response to additional liquidity for the group of hand-to-mouth and non-hand-to-mouth homeowners. Hand to mouth homeowners consume a relatively large fraction of the additional liquidity they receive, ranging from 9.4% at the 10th percentile to 84.3% at the 90th percentile, with a median of 36.8. Non-hand-to-mouth homeowners have, in contrast, much smaller propensities to consume out of additional liquidity. Of these, about 30% of constrained homeowners cut consumption by postponing the option to sell or refinance, while the rest increase their consumption by modest amounts. In all, the median average propensity to consume out of the additional liquidity is 9.7% for liquidity constrained owners who are not hand-to-mouth. These agents save the remainder of the amount extracted in their liquid account in order to smooth consumption in future periods. We thus conclude that liquidity constraints in our model distort the majority of homeowners' consumption choices.

Figure 5 shows how the average valuation of liquidity varies across different types of homeowners. Panel A of the figure shows that homeowners with the highest LTV ratios have the largest valuation of liquidity, about 6% on average, compared to 3% for homeowners without a mortgage. Low LTV homeowners value additional liquidity less since they are more likely to either sell their home or obtain a new mortgage in the near future. Intuitively, such homeowners effectively have a mortgage with a low expected maturity and thus value the increase in the limit on their current mortgage less.

Panel B of the figure shows that the marginal valuation of liquidity is hump-shaped in homeowners' minimum payment-to-income ratio, ranging from 2% for those with no remaining payment to 10% for those with a 30% payment-to-income ratio. Intuitively, homeowners with low required payments have sufficient resources to finance their mortgage payments and value an additional dollar of liquidity little. In contrast, those with high required payments are very likely to refinance their existing mortgage or sell their home and would also benefit less from additional liquidity. Hence, agents at the mid-point of the payment-to-income distribution are those who value additional liquidity the most. Panel C of the figure shows that the marginal valuation of liquidity is roughly constant in one's liquid asset to wealth ratio. Even though those with low liquid assets are indeed constrained, they are also more likely to extract home equity and thus refinance their current mortgage. Finally, as Panel D of Figure 5 shows, homeowners with relatively low income value liquidity the most.

These results illustrate that our measure of valuation of liquidity is a local one. Since homeowners who extract home equity, either by selling their home or refinancing, do not value a larger line of credit on their existing mortgage, this measure provides a lower bound on how much agents value the option to extract home equity. The experiments we conduct below provide a more global measure, by reporting on how the model's implications change as we eliminate the frictions that prevent homeowners from extracting equity.

5.3 Role of Each Friction

Homeowners in our model face several frictions that prevent them from using housing wealth to smooth consumption fluctuations: a fixed cost of refinancing one's mortgage, a payment-to-income constraint that reduces the amount of equity low-income homeowners can extract, as well as the requirement that mortgage borrowers build equity in their home over time. We next study the relative importance of each of these frictions by eliminating each in isolation.

Cost of Mortgage Refinancing. Table 5 reports how the key implications of the model change as we vary the fixed costs of home equity extraction. We consider two extreme scenarios in which both the fixed and variable cost of refinancing is set to zero and infinity, respectively.[19] Panel A of the table contrasts the steady-state implications of these alternative economies to those of our Benchmark model.

Eliminating the fixed cost of refinancing substantially increases the fraction of homeowners who extract home equity – to 54% compared to 8% in our Benchmark. The homeownership rate increases to 70%. The increase in demand for housing is quite sizable, leading to a 8.6% increase in house prices in the new steady state.

Absent costs of refinancing agents would have much smaller holdings of the liquid asset: the median falls to 1% of aggregate income. Consequently the fraction of hand-to-mouth homeowners increases, from 25% to 45%. Intuitively, if agents can freely extract home equity, there is no need to save in the liquid asset, which is dominated in rate of return. We define, as earlier, a hand-to-mouth homeowner as one for whom the $a' \geq 0$ constraint binds, as opposed to a homeowner with a high marginal propensity to consume out of transitory income shocks. In our economy these concepts are inversely related due to the wedge between the mortgage and liquid interest rates. Absent costs of refinancing, which introduce a precautionary savings motive in the liquid asset, agents prefer to pay down their higher-interest mortgages and hold essentially no liquid assets.

We illustrate this point in the last row of the panel, which reports the median homeowner's marginal propensity to consume out of a transitory income shock. The median MPC is equal to 19.4% in our Benchmark model with refinancing costs and falls to about 14% in an economy without a cost of refinancing. Thus, refinancing costs increase the marginal propensities to consume by about 35%, a sizable amount.

Consider next the alternative extreme of eliminating the option to refinance one's mortgage altogether. This experiment is motivated by the experience of Texas, where prior to 1998 a home could be pledged as collateral only at the time of purchase. In 1998 a new law gave homeowners in Texas access to several means of home equity extraction, including cash-outs and home equity loans. As Zevelev (2017) reports, by comparing the evolution of house prices in Texas and its bordering states, the new law increased house prices in Texas by 3.8% overall and as much as 5.5% in regions with low housing price elasticities.

The last column of Panel A of Table 5 reports what happens in our model when we eliminate the option to refinance, an experiment aimed at reproducing the experience of

[19] We keep the cost of obtaining a mortgage on a newly-purchased home unchanged in these experiments.

homeowners in Texas prior to 1998. We find, consistent with the empirical evidence in Zevelev (2017), that the removal of the option to extract home equity reduces house prices by 5.5% in our economy in which, recall, housing is in fixed supply. The removal of the option to refinance reduces the fraction of hand-to-mouth homeowners, to about 20% compared to 25% in the Benchmark model, and increases the marginal propensity to consume from 19.4% to 21.5%.

Panel A of Table 5 also makes it clear that our Benchmark economy's implications are closer to those of an economy without refinancing opportunities than to an economy without costs of refinancing. For example, the marginal propensity to consume out of transitory shocks is only slightly higher in the economy without opportunities to refinance compared to those in our Benchmark model (21.5% vs. 19.4%), but are much larger in our Benchmark model compared to an economy without refinancing costs (19.4% vs. 14.1%). In this sense, the ability of homeowners to smooth consumption is almost the same in our economy, calibrated to match the frequency of home equity extraction in the data, as in an economy in which home equity extraction is absent altogether.

Payment-to-Income Constraint. Another impediment to households' ability to use their homes to smooth consumption fluctuations is the presence of payment-to-income constraints at mortgage origination. Recall from Figures 4 and 5 that the lowest income households have the largest propensities to extract home equity and also value liquidity the most. The payment-to-income constraint reduces the amount these agents can borrow, potentially exacerbating their liquidity constraints. In Panel B of Table 5 we report the results of experiments in which we eliminate these constraints.

We find that the 20% payment-to-income constraint in our Benchmark model has little impact on its own: in its absence house prices would only increase by about 1.6% in an economy with a fixed supply of housing, while the fraction of hand-to-mouth homeowners and the median marginal propensity to consume out of transitory shocks are unchanged. Intuitively, fixed costs of home equity extraction make it suboptimal for low-income homeowners to borrow too much since doing so increases the possibility that future negative income shocks may make it difficult to honor the minimum required mortgage payments. This precautionary behavior keeps most new mortgages below the 20% payment-to-income limit even absent the constraint.

We illustrate this interaction between refinancing costs and the PTI constraint by studying an economy in which we simultaneously eliminate both the fixed cost of mortgage refinancing, as well as the PTI constraint. We report the results of this experiment in the last column of Panel B of Table 5. Notice that house prices now increase by about 15%, suggesting that the demand for housing is much greater than in the economy with no costs of refinancing in which agents are subject to a PTI constraint. Recall that house prices only increase by 8.6% in the latter compared to our Benchmark model. We thus conclude that the payment-to-income constraint does not bind when costs of refinancing are relatively large, as in our Benchmark economy, but its effect would be sizable absent such costs.

Mortgage Duration. An important ingredient in our model is the parameter γ that determines the minimum amount of principal mortgage borrowers must repay each period. The lower γ is, the more rapidly homeowners must repay their mortgage. We show next that the requirement that homeowners pay down their principal over time substantially exacerbates the severity of liquidity constraints. To see this, we study an economy in which we set γ equal to 1 so that mortgages are interest-only perpetuities. Panel C of Table 5 shows that house prices would be about 9.5% larger in this economy compared to our Benchmark model calibrated to match the half-life of 30-year mortgages in the U.S. data. The requirement that homeowners in our model build up home equity over time is thus quite onerous: it exacerbates the role of liquidity constraints and greatly depresses house prices. Motivated by this observation, we next study the impact of several policies that reduce the required mortgage payments for homeowners in distress.

6 Impact of Mortgage Assistance Programs

Motivated by the observation that a large fraction of homeowners in our model are liquidity constrained, we next evaluate the impact of policies aimed at providing relief for homeowners. We consider two types of programs: *mortgage forbearance* programs that temporarily reduce mortgage payments for homeowners experiencing a transitory spell of low income, as well as programs that allow homeowners in distress to borrow against their homes in order to make up for the temporary fall in income. We show that both of these policies have a substantial impact.

6.1 Mortgage Forbearance Policies

Although most lenders in the U.S. have such programs, these are limited in scope and allow modest relief since they reduce required mortgage payments to at most 30% of a homeowner's income.[20] As Figure 3 shows, most homeowners in our model have minimum mortgage payments far below the 30% fraction of their income so these programs are not sufficiently generous to have much impact. We therefore consider more generous forbearance policies that restrict the required payment on one's mortgage to at most 5% and 15% of a borrower's income. We mimic the mortgage forbearance policies in the data by changing the minimum payment homeowners must make in any given period to

$$\Delta_{i,t} = \min\left[\phi y_{i,t}, (1-\gamma+r_M)b_{i,t}\right],$$

limiting it to a fraction $\phi \in \{5\%, 15\%\}$ of one's income, $y_{i,t}$. The budget constraint of inactive homeowners who do not curtail their mortgage now reads

$$c_{i,t} + a_{i,t+1} = y_{i,t} + (1+r_l)a_{i,t-1} - \Delta_{i,t},$$

as opposed to

$$c_{i,t} + a_{i,t+1} = y_{i,t} + (1+r_l)a_{i,t-1} - (1-\gamma+r_m)b_{i,t}$$

originally.

Panel A of Table 6 shows the impact of such a policy on the model's steady state implications. A 5% forbearance policy would have a substantial impact on the demand for houses, increasing house prices by 8.5%. The frequency of refinancing would fall to 5% per year, compared to 8% in our Benchmark model. The distribution of liquid assets and marginal propensities to consume would change little, however. Mortgage forbearance thus works mostly by reducing the need for homeowners to refinance, but does not strongly reduce the precautionary motive for saving in the liquid asset.

A 15% forbearance policy would, in contrast, have a substantially smaller impact. It would increase house prices by about 2.7% and reduce the frequency of refinancing to only 7%. Too few households would be able to take advantage of such a policy since most homeowners in our model have minimum required payments below the 15% threshold.

The drawback of mortgage forbearance is that it is too blunt of a tool since it only reduces mortgage payments for those who have a relatively large mortgage. Forbearance

[20] See our Appendix for more details on existing forbearance policies.

policies thus do not provide much relief for homeowners who have already repaid a substantial fraction of their mortgages. These homeowners may also experience a spell of low income and would prefer to extract some of the equity in their homes, but do not benefit from mortgage forbearance policies which are primarily aimed at high LTV homeowners. Motivated by this observation, we next consider an alternative policy, one that directly targets those with a transitory income loss and does not condition on one's required mortgage payments.

6.2 Credit Lines for the Unemployed

The policy we consider here allows homeowners with a transitory spell of low income (a negative realization of the transitory income shocks, $e_{i,t}$), to borrow against their homes to make up for the income shortfall. Specifically, we modify inactive homeowners' borrowing limit to

$$b' \leq \gamma b + \max\left[\left(\exp(z) - \exp(z+e)\right), 0\right].$$

Here the term $\exp(z)$ is the amount of income the household would have earned absent the transitory income shock e and $\exp(z)\exp(e)$ is the amount of income actually earned. The policy we consider thus offers homeowners with negative transitory income shocks with $e < 0$, which we think of as temporarily unemployed, a credit line that covers the shortfall in income. Because agents face fat-tailed income shocks in our environment, this policy has a quite modest incidence as very few homeowners experience large transitory income declines. Yet these are precisely the homeowners who value the ability to borrow the most.

Panel B of Table 6 shows that this policy, though much more limited in scope than the mortgage forbearance policies considered above, has a substantial impact. It increases house prices by about 5.7% and reduces the frequency of mortgage refinance from 8% to 5%. Note also that this policy substantially reduces the precautionary savings motive, decreasing the median liquid assets of homeowners to 3% of per-capita annual income and raising the fraction of hand-to-mouth homeowners to 33%.

The effectiveness of this simple policy suggests that a large fraction of homeowners who refinance in our model are indeed those who experience large transitory income declines. We thus conclude that policies aimed at providing relief for homeowners have a substantial impact in our model.

7 Robustness

We next discuss the robustness of our results to changes in the parameters governing the return on liquid assets, as well as the nature of income shocks. We show that our conclusion that liquidity constraints in the U.S. housing market are sizable is robust to perturbations in these parameters.

7.1 Increase Return on Liquid Asset

We report, in Panels A and B of Table 7, how the moments and parameter values change when we increase the interest rate on liquid assets from 0.1% in our Benchmark model to 1% and 2%, respectively. We keep all the assigned parameters unchanged and re-calibrate the four endogenous ones by targeting the same set of moments used earlier. We only report a subset of the moments used in calibration – the remaining ones are very similar to the ones in the Benchmark model.

As the interest rate on liquid assets increases, both mortgage debt and liquid assets increase in the aggregate, to levels much closer to those in the data. For example, when $r_l = 2\%$ the aggregate mortgage debt to income ratio is 0.82 (0.83 in the data) and the aggregate liquid assets to income ratio is 0.40 (0.46 in the data). Total wealth, in contrast, changes little. Reducing the wedge between the mortgage and liquid rates thus allows us to better match the aggregate balance sheets of homeowners.

Increasing the return on liquid assets substantially worsens, however, the model's ability to match the lower tail of the distribution of liquid assets, which our Benchmark model reproduces well. For example, median liquid assets are equal to 0.07 of aggregate per-capita income in the data, a number that our Benchmark model reproduces exactly, but increases to 0.10 and 0.15 when we increase the return on liquid assets to 1% and 2%, respectively. Similarly, the model's ability to match the lower tail of the homeowner's liquid asset distribution, which our Benchmark model matches quite well, worsens. As Panel C of Table 7 shows, the fraction of hand-to-mouth homeowners falls to 10% when the interest rate on liquid assets is 2%, considerably smaller than in the data and our Benchmark model.

Panel B of Table 7 shows that the parameter values that best fit the data are largely unchanged when we increase the return on the liquid asset, with the exception of the fixed cost of refinancing, which falls to 0.62% of per-capita average income (2.32% in our Benchmark). Intuitively, when the interest rate on the liquid asset is high, agents save much more in that asset and rely less on home equity to smooth consumption. The fixed cost required to match the fraction of extractors in the data thus falls considerably.

Panel C of Table 7 reports how the severity of liquidity constraints changes as we increase the interest rate on liquid assets. The median homeowner's marginal propensity to consume out of transitory income shocks falls to 14.1% when $r_l = 2\%$ compared to 19.4% in our Benchmark model with a 0.1% rate of return on the liquid asset. The fraction of homeowners who value liquidity actually increases, to 83% compared to 74% in our Benchmark, owing to the lower wedge between the interest rate on liquid assets and the mortgage rate. The marginal valuation of liquidity falls in half when $r_l = 2\%$, to 2% compared to 4.1% in our Benchmark model, for the median liquidity constrained homeowner.

We thus conclude that raising the return on the liquid assets reduces the severity of liquidity constraints, due to the counterfactually higher liquid asset holdings of homeowners at the lower end of the distribution.

7.2 Heterogeneity in Rate of Return on Liquid Asset

Motivated by our Benchmark model's inability to simultaneously match the high average and low median holdings of liquid assets, here we assume heterogeneity in the rate at which households can save in the liquid asset. We assume that households have access to two liquid savings instrument. The first one pays the rate $r_l = 0.1\%$ as in our Benchmark. The second one pays a relatively high rate of return r_h but requires a fixed fee f. This fee precludes poor agents from taking advantage of the higher return security. We calibrate the return r_h and the fee f (2.6% and 0.0178, respectively), as well as the other parameters of the model, in order to simultaneously match the median and average holdings of the liquid assets observed in the data.

Panel A of Table 8 shows that we now reproduce well the overall amount of mortgage debt in the data (0.88 vs. 0.83), the mean liquid assets (0.48 vs. 0.46), the median liquid assets (0.06 vs. 0.07), and the upper tail of the liquid asset distribution of homeowners. Panel B of Table 8 shows that the calibrated parameters change little, with the exception of the fixed cost of refinancing, which falls to 1.84% of per-capita income, compared to 2.32% in our Benchmark model.

Consider next this model's implications for the severity of liquidity constraints, reported in Panel C of Table 8. As earlier, about one quarter of homeowners are hand-to-mouth.

Intuitively, the higher return liquid asset only affects the decision rules of the richer households and not those at the lower tail of the liquid asset distribution. The median marginal propensity to consume out of transitory income shocks changes little, from 19.4% to 18.6%. More homeowners are liquidity constrained now (80% compared to 74% in the Benchmark model), though the additional homeowners who are now constrained value liquidity less, so the median valuation of liquidity falls from 4.1% to 3%. We conclude that our Benchmark model's predictions are robust to modifications that allow us to match the relatively large holdings of liquid assets at the top of the distribution.

7.3 Gaussian Shocks

We finally study the role played by our assumption that income shocks are leptokurtic in the Benchmark model. We do so by assuming that shocks are now drawn from a Gaussian distribution and by recalibrating all parameters, including those characterizing the income process. The last column of Table 8 shows this model's implications. With Gaussian shocks, agents find it optimal to hold somewhat more liquid assets – the median liquid assets of homeowners is now 15% of per-capita average income compared to 10% in our baseline model. Homeowners also need to refinance more frequently, since negative income shocks are more likely. Consequently, the model now requires a higher fixed cost of refinancing (2.82% compared to 2.32% in the baseline) to match the frequency of home equity extraction in the data. Overall, however, the model's implications for the severity of liquidity constraints are unchanged: 77% of homeowners are liquidity constrained and the median constrained homeowner is willing to pay 4.2 cents for every dollar of home equity extracted, numbers very close to those in our Benchmark model. We thus conclude that our results are robust to the nature of the income process we assume.

8 Conclusions

We have studied the severity of liquidity constraints in the U.S. housing market. We found that frictions that prevent homeowners from tapping into housing wealth are sizable: three quarters of of homeowners are liquidity constrained and are willing to pay an average of 5 cents to extract an additional dollar from their home. The majority of liquidity constrained agents have positive holdings of liquid assets and are therefore not hand-to-mouth. Rather, these homeowners value additional liquidity for precautionary reasons, desiring a buffer of liquidity to make up for the possibility of future transitory income losses and to finance their mortgage payments. Mortgage assistance policies that provide lines of credit for households who experience transitory income losses greatly reduce the severity of liquidity constraints.

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Table 1: Liquid Assets of US Households. 2001 SCF

	All HHs	Richest 20%	Poorest 80%
mean income	36,000	68,000	27,500
mean wealth	177,700	696,900	39,800
mean liquid assets	113,800	494,100	12,600
fraction homeowners	0.71	0.97	0.64
Lower tail of distribution of liquid assets. All households			
10th percentile	-656	23,700	-1,200
25th percentile	154	71,300	0
50th percentile	5,110	171,200	2,000
Lower tail of distribution of liquid assets. Homeowners			
10th percentile	-386	22,600	-1,060
25th percentile	1,170	69,800	278
50th percentile	11,500	165,900	4,230
Share of housing equity in homeowner's wealth			
25th percentile	0.46	0.24	0.64
50th percentile	0.77	0.43	0.87
75th percentile	0.96	0.70	0.99

Note: All statistics adjusted for HH size using OECD equivalence scales and reported in 2001 US Dollars. See Section 2.1 for a description of the variables we use.

Table 2: Parameterization

A. Moments Used in Calibration

	Data	Model		Data	Model
log mean income 45-55 rel. 25-35	0.21	0.21	aggregate wealth to income	1.45	1.44
std log income 45-55 rel. 25-35	1.03	1.03	aggregate housing to income	1.82	1.80
log mean income workers rel. retirees	0.29	0.29	aggregate mortgage debt to income	0.83	0.57
kurtosis log income growth 2 years	6.39	6.39	aggregate liquid assets to income	0.46	0.21
variance log income	0.44	0.42	median liquid assets to income	0.07	0.07
autocov log income 2 years	0.33	0.35	fraction homeowners	0.64	0.64
autocov log income 4 years	0.31	0.32	BK (2017) fraction of extractors	0.08	0.08
std dev log income growth 2 years	0.41	0.42			

B. Additional Moments

	Data	Model
fraction homeowners who sell home	0.044	0.036
fraction homeowners with mortgage	0.71	0.73
mean wealth retirees / workers	2.00	1.97

C. Parameter Values

Assigned			*Calibrated*		
T	61	number of years to live	$\mu_{0,z}$	-0.3861	mean initial log income draw
J	40	period of retirement	$\sigma_{0,z}$	0.5389	std dev initial log income draw
r_m	0.025	mortgage interest rate	$\mu_{R,z}$	-1.0399	drift in income after retirement
γ	0.969	coupon depreciation	κ	0.3269	Tukey kurtosis parameter
θ_m	0.90	maximum LTV	σ_z	0.0926	volatility persistent income comp.
θ_y	0.35	maximum PTI	σ_e	0.1090	volatility transitory income comp.
$f_{1,m}$	0.01	refi cost, fraction of loan	ρ_z	0.9443	AR(1) persistent income comp.
r_l	0.001	liquid interest rate	β	0.9499	discount factor
f_s	0.06	cost of selling home	$f_{0,m}$	0.0232	fixed refi cost
			α	0.0637	preference weight on housing
			R	0.0326	rental rate of housing

Table 3: Households' Portfolio Composition

	Data	Model		Data	Model
	A. Liquid Assets, Renters			**B. Liquid Assets, Owners**	
10th percentile	-0.05	0	10th percentile	-0.04	0
25th percentile	0	0	25th percentile	0.01	0
50th percentile	0.01	0.03	50th percentile	0.15	0.10
75th percentile	0.15	0.10	75th percentile	0.68	0.27
90th percentile	1.00	0.19	90th percentile	1.69	0.65
	C. Housing Value			**D. LTV Ratio, Borrowers**	
10th percentile	0.67	0.71	10th percentile	0.19	0.17
25th percentile	1.30	1.09	25th percentile	0.40	0.32
50th percentile	2.18	1.60	50th percentile	0.64	0.56
75th percentile	3.33	2.31	75th percentile	0.79	0.78
90th percentile	4.93	3.73	90th percentile	0.92	0.89
	E. Share Home Equity in Owner's Wealth			**F. Wealth**	
10th percentile	0.36	0.67	10th percentile	0	0
25th percentile	0.64	0.81	25th percentile	0.04	0.08
50th percentile	0.87	0.92	50th percentile	0.73	0.68
75th percentile	0.99	1.00	75th percentile	2.34	1.92
90th percentile	1.04	1.00	90th percentile	3.94	3.85

Note: We scale the distribution of liquid assets and wealth (Panels A, B, and F) by aggregate income and housing values (Panel C) by the average income of homeowners.

Table 4: Value of Liquidity

A. Value of Liquidity

Fraction homeowners who value 10% liquidity injection		0.74	
Willingness to pay for liquidity, ν	all	HtM (34%)	not HtM (66%)
mean, %	5.1	6.2	4.5
25th percentile, %	2.1	3.8	1.6
50th percentile, %	4.1	5.7	3.2
75th percentile, %	7.1	8.1	6.1
90th percentile, %	10.4	10.6	10.1

B. Average Fraction of Additional Liquidity Consumed

	all	HtM	not HtM
10th percentile, %	-11.5	9.4	-17.7
25th percentile, %	2.4	21.3	-2.4
50th percentile, %	14.8	36.8	9.7
75th percentile, %	27.7	57.6	16.9
90th percentile, %	53.3	84.3	23.2

Table 5: Role of Each Friction

A. Cost of Refinancing

	Benchmark	No Refi Cost	No Refinance
Δ house price, %	–	8.6	-5.5
homeownership rate	0.64	0.70	0.66
fraction refinance	0.08	0.54	0
fraction HtM homeowners	0.25	0.45	0.21
median liquid assets, homeowners	0.10	0.01	0.12
median MPC trans. income, %, homeowners	19.4	14.1	21.5

B. Remove PTI Constraint

	Benchmark	W/ Refi Cost	No Refi Cost
Δ house price, %	–	1.6	15.0
homeownership rate	0.64	0.63	0.69
fraction refinance	0.08	0.09	0.58
fraction HtM homeowners	0.25	0.25	0.48
median liquid assets, homeowners	0.10	0.07	0.01
median MPC trans. income, %, homeowners	19.4	19.4	13.7

C. Mortgages as Perpetuities

	Benchmark	$\gamma = 1$
Δ house price, %	–	9.5
homeownership rate	0.64	0.68
fraction refinance	0.08	0.06
fraction HtM homeowners	0.25	0.23
median liquid assets, homeowners	0.10	0.06
median MPC trans. income, %, homeowners	19.4	20.1

Table 6: Effect of Mortgage Assistance Programs

A. Mortgage Forbearance

	Benchmark	$\phi = 5\%$	$\phi = 15\%$
Δ house price, %	–	8.5	2.7
homeownership rate	0.64	0.66	0.64
fraction refinance	0.08	0.05	0.07
fraction HtM homeowners	0.25	0.24	0.24
median liquid assets, homeowners	0.10	0.08	0.10
median MPC trans. income, %, homeowners	19.4	20.1	19.6

B. Credit Lines for the Unemployed

	Benchmark	Credit Lines
Δ house price, %	–	5.7
homeownership rate	0.64	0.68
fraction refinance	0.08	0.05
fraction HtM homeowners	0.25	0.33
median liquid assets, homeowners	0.10	0.03
median MPC trans. income, %, homeowners	19.4	20.9

Table 7: Robustness: Vary Interest Rate on Liquid Asset

A. Wealth Moments

	Data	$r_l = 0.1\%$	$r_l = 1\%$	$r_l = 2\%$
I. Aggregate Moments				
wealth to income	1.45	1.44	1.43	1.43
housing to income	1.82	1.80	1.80	1.85
mortgage debt to income	0.83	0.57	0.64	0.82
mean liquid assets to income	0.46	0.21	0.28	0.40
median liquid assets to income	0.07	0.07	0.10	0.15
II. Distribution of Liquid Assets Homeowners, rel. aggregate income				
10th percentile	-0.04	0	0	0
25th percentile	0.01	0	0.03	0.09
50th percentile	0.15	0.10	0.15	0.26
75th percentile	0.68	0.27	0.35	0.55
90th percentile	1.69	0.65	0.84	1.21

B. Parameter Values

	$r_l = 0.1\%$	$r_l = 1\%$	$r_l = 2\%$
discount factor, β	0.9499	0.9480	0.9448
fixed refi cost, $f_{0,m}$	0.0232	0.0166	0.0062
preference housing, α	0.0637	0.0659	0.0717
rental rate housing, R	0.0326	0.0327	0.0327

C. Severity of Liquidity Constraints, Homeowners

	$r_l = 0.1\%$	$r_l = 1\%$	$r_l = 2\%$
fraction hand-to-mouth	0.25	0.19	0.10
median MPC, trans. income, %	19.4	17.0	14.1
fraction liquidity constrained	0.74	0.76	0.83
median valuation liquidity, %	4.1	3.3	2.0

Table 8: Additional Robustness Checks

A. Wealth Moments

	Data	Benchmark	Heterogeneity r_l	Gaussian
I. Aggregate Moments				
wealth to income	1.45	1.44	1.44	1.45
housing to income	1.82	1.80	1.84	1.81
mortgage debt to income	0.83	0.57	0.88	0.59
mean liquid assets to income	0.46	0.21	0.48	0.23
median liquid assets to income	0.07	0.07	0.06	0.10
II. Distribution of Liquid Assets Homeowners, rel. aggregate income				
10th percentile	-0.04	0	0	0
25th percentile	0.01	0	0	0.02
50th percentile	0.15	0.10	0.10	0.15
75th percentile	0.68	0.27	0.30	0.32
90th percentile	1.69	0.65	1.81	0.69

B. Parameter Values

	Benchmark	Heterogeneity r_l	Gaussian
discount factor, β	0.9499	0.9442	0.9493
fixed refi cost, $f_{0,m}$	0.0232	0.0184	0.0282
preference housing, α	0.0637	0.0748	0.0658
rental rate housing, R	0.0326	0.0334	0.0338

C. Severity of Liquidity Constraints, Homeowners

	Benchmark	Heterogeneity r_l	Gaussian
fraction hand-to-mouth	0.25	0.24	0.22
median MPC, trans. income,%	19.4	18.6	18.5
fraction liquidity constrained	0.74	0.80	0.77
median valuation of liquidity, %	4.1	3.0	4.2

Figure 1: Optimal Choice of Mortgage Debt

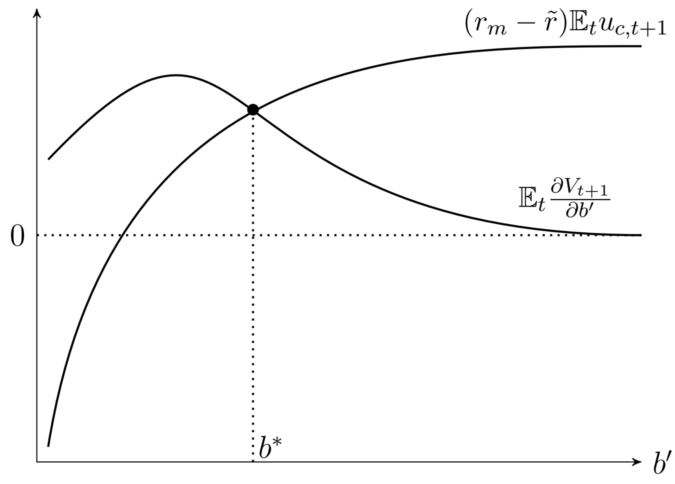

Figure 2: Life-Cycle Statistics

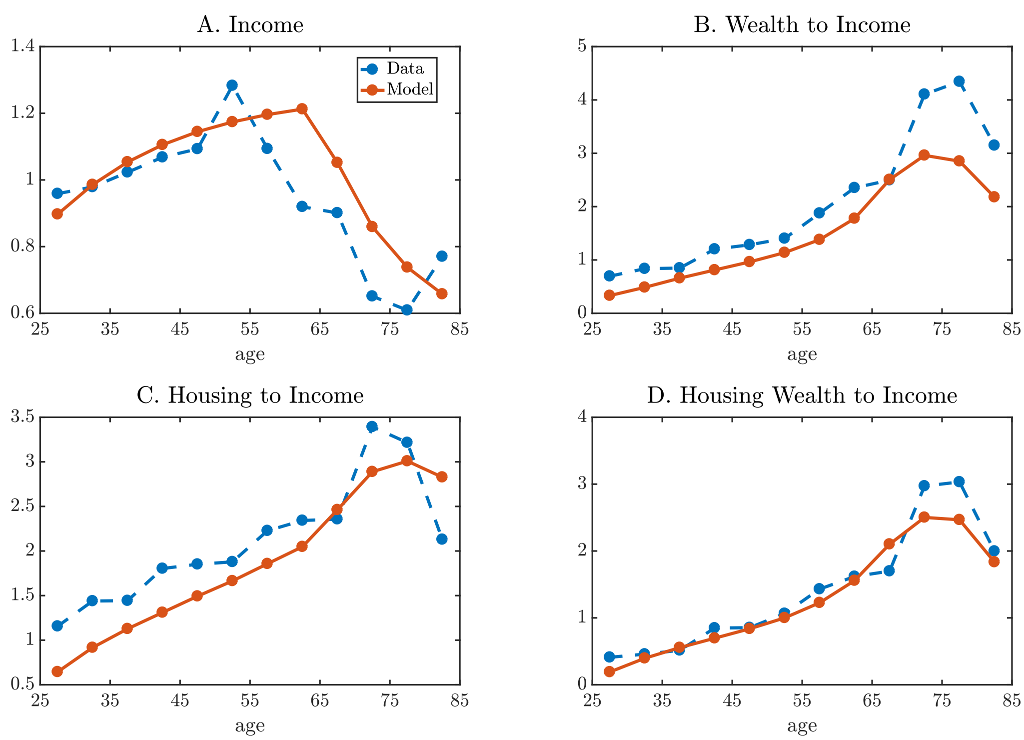

Figure 3: Distribution of Homeowners' Characteristics

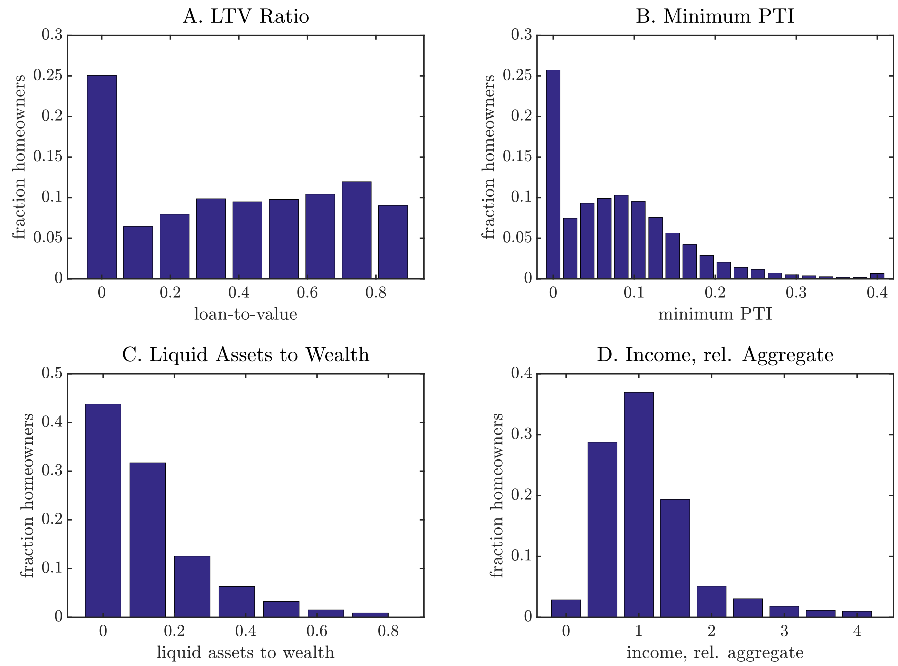

Figure 4: Proportion Who Extract Home Equity

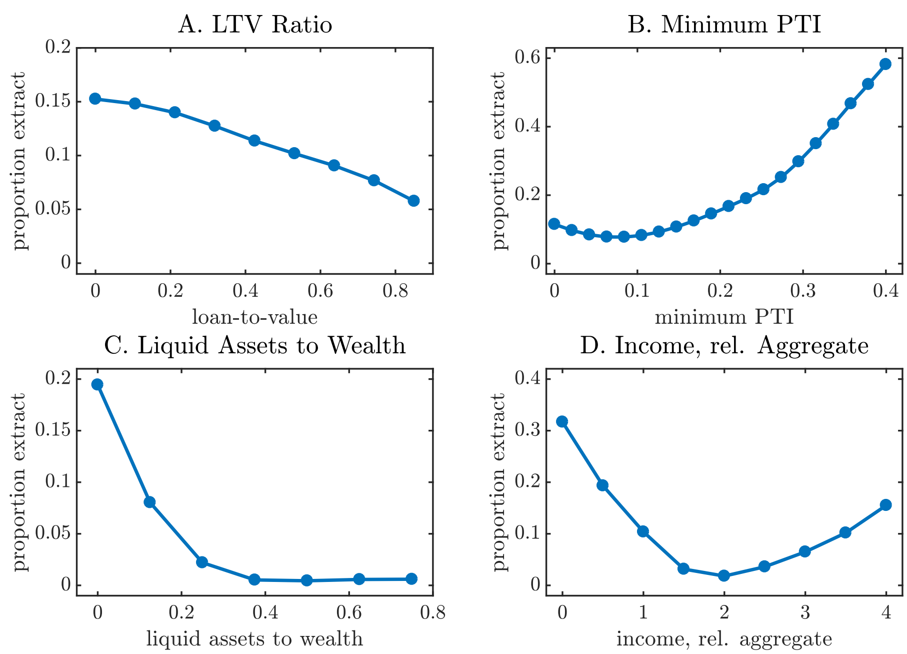

Figure 5: Average Valuation of Liquidity