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Corina Boar
Denis Gorea
Virgiliu Midrigan

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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 can extract home equity by refinancing their mortgages. The model implies that four-fifths of homeowners are liquidity constrained and willing to pay an average of 13 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. The model reproduces well the observed response of consumption to tax rebates and mortgage relief programs and predicts large welfare gains from policies aimed at providing temporary liquidity relief to homeowners.

Corina Boar
Department of Economics
New York University
19 West 4th Street
New York, NY 10003
and NBER
corina.boar@gmail.com

Virgiliu Midrigan
Department of Economics
New York University
19 W. 4th St.
New York, NY 10012
and NBER
virgiliu.midrigan@nyu.edu

Denis Gorea
IDIS Viitorul
Chisinau, Moldova
denis.gorea@viitorul.org

A online appendix is available at http://www.nber.org/data-appendix/w23345

1 Introduction

Housing wealth is the most important savings instrument for most U.S. households, two-thirds of whom own a home. Housing equity is by far the largest component of homeowners' balance sheets and accounts for approximately 80% of their wealth.[1] 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 over time, thus exposing them to the risk of being unable to meet their mortgage obligations in the event of a transitory income loss or a large housing maintenance expense. 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 shocks.

Our goal in this paper is to ask: how liquid is housing wealth in the U.S.? 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, as well as refinancing decisions. Our model predicts that four-fifths 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 13 cents, on average, for every additional dollar of liquidity extracted from their homes. Overall, the frictions that prevent homeowners from tapping home equity are sizable.

This finding has important implications for our understanding of consumption responses to fiscal stimulus transfers. A large empirical literature (Johnson et al., 2006, Parker et al., 2013) has documented large marginal propensities to consume (MPC) out of tax rebates, a feature inconsistent with the prediction of simple one-asset Bewley models. We show that our model explains two-thirds of the consumption response to cash transfers in the data, quantitatively consistent with Kaplan and Violante (2014), who study a simpler model with liquid and illiquid assets, but abstract from the details of the U.S. housing market. By taking a bottom-up approach and explicitly microfounding the illiquid asset, our paper thus complements a large recent literature studying two-asset models.

Motivated by our finding that housing wealth is illiquid, we evaluate the effects of two types of mortgage assistance programs that provide relief to liquidity constrained homeown-

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[1] See Section 2 for a description of the data source underlying these numbers.

ers. We show that a mortgage modification program that reduces short-term payments, but does not entail wealth transfers to homeowners, has a sizable impact on consumption. Its effect is almost as large as that of a program that reduces both short- and long-term debt obligations, thus entailing a wealth transfer to homeowners. This result is consistent with the empirical findings of Ganong and Noel (2019), who study similar interventions that were part of the Home Affordable Mortgage Program (HAMP). We also show that mortgage forbearance programs, which provide automatic relief for homeowners who experience a spell of low income, have substantial welfare gains. We therefore conclude that policies that provide short-term liquidity to homeowners, as opposed to long-term debt relief, are very effective, a result that echoes the point made by Eberly and Krishnamurthy (2014).

Agents in our model face persistent and transitory income shocks and can save in a liquid asset at a relatively low interest rate. They can either rent or purchase housing subject to transaction costs. Homeowners face transitory home maintenance shocks. They 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 30-year, fixed-rate contracts which require payment of interest and principal over time. Homeowners have the option to extract home equity by refinancing their mortgage. We assume that there are both monetary and non-pecuniary costs of obtaining a new mortgage. The non-pecuniary costs are a stand-in for other barriers to obtaining a mortgage such as time costs, information gathering costs and other behavioral factors.

We parameterize the model using data from the 2001 SCF on the poorest 80% of households and the Panel Study of Income Dynamics (PSID).[2] We choose parameter values to match moments that describe household income, the homeownership rate, the distribution of liquid assets, the ratio of home values and mortgage debt to aggregate income, as well as the frequency of home equity extraction. We document using PSID data that approximately 8% of homeowners extract home equity per year, a number very close to that reported by Bhutta and Keys (2016) using a large panel of consumer credit records.

Even though we calibrate the parameters of the model to only reproduce a number of unconditional moments from the data, the model also reproduces a wide range of characteristics of household balance sheets, as well as conditional moments that describe the characteristics of households who refinance and their refinancing behavior. Notably, owing

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[2] 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.

to the non-pecuniary costs of mortgage origination, the model is successful in reproducing the low fraction of households that refinance following a decline in mortgage rates, a pervasive finding in the literature.

We evaluate the severity of liquidity constraints by conducting an experiment in which we increase homeowners' liquid assets and mortgage debt by the same amount, leaving their overall wealth unchanged. This experiment effectively offers homeowners a one-time opportunity to extract home equity for free. We find that 82% of homeowners are better off, with the average homeowner willing to pay 13 cents for every dollar of home equity extracted. We thus conclude that liquidity constraints are severe and bind for most homeowners, even though much fewer of them are hand-to-mouth in the sense of hitting the borrowing constraint on liquid assets.

This result suggests that there is a critical distinction between whether a household is hand-to-mouth and whether a household is liquidity constrained. Intuitively, a household may have a positive amount of liquid savings, and therefore not be hand-to-mouth, yet it may be better off with an even more liquid portfolio that would allow it to respond to potentially bad income realizations in the future. Such a household would value the option to convert home equity into liquid assets, yet is unable to do so because of the costs of mortgage origination.

Though we focus most of our analysis on studying the steady-state implications of liquidity constraints, we also consider the effect of a decline in house prices and changes in mortgage interest rates. An increase in mortgage rates exacerbates the severity of liquidity constraints because refinancing becomes more costly, as it entails an increase in mortgage payments. Similarly, a fall in house prices, which leaves many borrowers underwater, also makes liquidity constraints more severe and makes mortgage modification programs that increase homeowners' liquidity more valuable.

Related Work Our paper is related to several strands of the literature on housing and macroeconomics.

First, it contributes to research that studies the role of housing in allowing households to smooth consumption. Hurst and Stafford (2004) provide empirical evidence that households use home equity to insure against bad income shocks. On the theory side, two closely related papers are Chen et al. (2020) and Kaplan et al. (2019). Both of these papers study models in which houses are illiquid, mortgages have long durations and there are costs of home equity extraction but, unlike us, focus on the response of consumption to aggregate business cycle shocks. In contrast to these papers, our work measures the importance of housing equity in smoothing idiosyncratic shocks.

Second, our paper is related to the literature studying models of household refinancing behavior in the aftermath of aggregate shocks such as interest rate or house price changes. Consistent with the findings of this literature, in our model refinancing activity also drops after a decline in house prices (Berger et al., 2018, Beraja et al., 2018) and an increase in interest rates (Berger et al., 2020, Eichenbaum et al., 2019).

Third, on the technical side, ours is a model in which households have three assets in their portfolios, owing to frictions on mortgage refinancing. In that sense, we build on the work of Chambers et al. (2009a,b), Chen et al. (2020), Campbell and Cocco (2003), Chatterjee and Eyigungor (2015), Corbae and Quintin (2015), who also consider economies with three assets but focus on answering different questions. Owing to numerous non-convexities in the households' budget sets, solving such models is challenging. In contrast, a much larger literature on housing abstracts from frictions in mortgage refinancing, which reduces the number of assets in households' portfolio (Davis and Heathcote, 2005, Ríos-Rull and Sánchez-Marcos, 2008, Kiyotaki et al., 2011, Iacoviello and Pavan, 2013, Landvoigt et al., 2015, Favilukis et al., 2017).

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 our calibration strategy. Section 5 performs several tests of the model. Section 6 studies the severity of liquidity constraints and the consumption response to cash transfers. Section 7 studies the impact of different mortgage assistance programs. Section 8 presents several robustness checks we have conducted. Lastly, Section 9 concludes.

2 Motivating Evidence

We document 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,[3] 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.

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[3] See Kaplan and Violante (2014).

2.1 Data

We use data from the 2001 Survey of Consumer Finances (SCF) to compute measures of the various components of household wealth. We focus on this time period in order to isolate salient features of household portfolios from adjustments in balance sheets induced by the large house price fluctuations over the subsequent decade. Here we briefly discuss the variables we use.[4] 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 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.[5] 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 excluding these from our definition of wealth does not change our statistics much.

We also use data from the 1999-2001 waves of the Panel Study of Income Dynamics (PSID) to compute several statistics that describe patterns of home equity extraction. We restrict the sample to homeowners who do not report a change in their main residence between 1999 and 2001 and follow Bhutta and Keys (2016) in defining home equity extractors as those who report an increase in their mortgage balance of more than 5% between these two surveys.

2.2 Stylized Facts

Panel A of 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

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

[5] See our Appendix for evidence on this.

distribution.

The aggregate stock of liquid assets is quite high: its per-capita average is equal to \$154,000, or about two-thirds of overall wealth and more than three times annual income.[6] 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 \$670,000, seven times their annual income. The poorest 80% of households, in contrast, have an average stock of liquid assets of only \$17,000, 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 10^{th} percentile is equal to \$32,000. In contrast, the poorest 80% of households have very few liquid assets. Among households in this group, the 10^{th} percentile of liquid assets is equal to $-\$1{,}600$, the 25^{th} percentile is equal to zero, while the 50% percentile is equal to only \$2,700, 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 Panel A of Table 1 indicates, 71% of all households own a home. Among those in the bottom 80% of the wealth distribution, 64% of households own a home. The 25^{th} percentile of liquid assets is equal to \$400 for homeowners in this latter group, thus about 1% of their average income. The median liquid assets of these homeowners is also small, approximately \$5,700.

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 equal to 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.

To summarize, a large fraction of households in the US, and especially those in the bottom 80% of the wealth distribution, hold most of their wealth in the form of housing equity, and have very little additional liquid wealth. This group of households will be the focus of our quantitative analysis.

Frequency of Home Equity Extraction. Whether housing wealth is liquid or not depends on the availability of opportunities to extract home equity. We use the 1999-2001

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[6] We have adjusted all variables for household size using the OECD equivalent scales. All numbers are expressed in 2016 USD.

waves of the PSID to calculate that 15% of mortgage borrowers who do not move increase their mortgage balance by more than 5% over this two–year period, corresponding to an annualized refinancing rate of 7.5%. As Panel B of Table 1 shows, the median homeowner who extracts equity increases their mortgage balance by 24% and the loan-to-value ratio by 11%. These numbers are similar to those reported by Bhutta and Keys (2016) who study a large, nationally representative panel of consumer credit records. They report that 8.5% of mortgage borrowers who did not move extracted home equity in 1999 and 7.3% 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.

Homeowners may refinance for two reasons: to extract home equity and to take advantage of lower interest rates after a period of mortgage rate declines. We argue next that home equity extraction was an important driver of refinancing activity in the 1999-2000 period. First, as Bhutta and Keys (2016) show, the median increase in monthly mortgage payments in those years was larger than the median increase in mortgage balances, suggesting that the majority of those who refinanced did not secure lower interest rates. For example, in 1999 the median increase in monthly payments was 27%, larger than the 23% median increase in the mortgage balance. Second, we document using the PSID data that homeowners who extracted equity between 1999 and 2001 had much lower liquid assets at the beginning of this period. For example, the median liquid assets of those who extracted equity was $800, much lower than the $6,000 median liquid assets of the remaining homeowners, and their median liquid asset to wealth ratio was only 4%, compared to 16% for the other homeowners. These findings corroborate those of Hurst and Stafford (2004), who document a similar pattern using older data.

3 Model

Motivated by these observations we next develop a model that we use to measure how liquid housing wealth is and the implications of refinancing frictions for households' ability to smooth consumption. This is an overlapping generations economy. Agents live for a finite number of periods, are subject to idiosyncratic income and housing maintenance shocks, derive utility from consumption and housing, disutility from home production, and can save using a one-period liquid asset or by purchasing a home. We study a partial equilibrium model, so interest rates and house prices are exogenously given.[7] 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 monetary mortgage origination cost as well as a random utility cost that captures non-pecuniary barriers to borrowing.

3.1 The Economy

We start by describing preferences, the income process, and the assets available for trade.

Preferences. Agents live for T periods. The utility function is time-separable and the life-time utility of an agent is

$$\mathbb{E}\sum_{t=1}^{T}\beta^{t-1}\left(\frac{c_t^{1-\sigma}}{1-\sigma}+\alpha\frac{h_t^{1-\sigma}}{1-\sigma}-\frac{n_t^{1+\gamma}}{1+\gamma}-\xi_t\right)+\beta^T B\frac{(1+w_{T+1})^{1-\sigma}}{1-\sigma},$$

where c denotes consumption, h denotes housing services, n is the amount of time spent on home (non-market) production, ξ is the utility cost of obtaining a new mortgage and w_{T+1} is terminal wealth, which includes liquid assets and the equity in the home in the last period of life. The utility function is characterized by the discount factor β, the relative risk aversion σ, the elasticity of home production hours $1/\gamma$, the weight of housing in preferences α and the strength of the bequest motive B. Notice that the elasticity of intertemporal substitution and between housing and consumption is equal to $1/\sigma$.

Income. An agent i of age t receives income

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

where λ_t is the deterministic life-cycle component of income, $z_{i,t}$ is the persistent component and $e_{i,t}$ is the transitory component. The persistent component evolves over time according to an AR(1) process

$$\log(z_{i,t+1})=\rho_z\log(z_{i,t})+\sigma_z\varepsilon_{i,t+1},$$

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[7] See Gorea and Midrigan (2015, 2018) for versions of the model with endogenous house prices that are consistent with the comovement of house prices, refinancing activity and consumption over the 2002-2008 boom-bust cycle, as well as the evidence in Zevelev (2019) on how the option to refinance affects house prices.

where σ_z is the volatility of innovations and ρ_z is the persistence. The transitory component e is iid and is drawn from a distribution with volatility σ_e. Both the transitory and persistent innovations are drawn from a standard normal distribution.[8]

Home Production. An agent who supplies n hours of home production produces ϕn units of output at a utility cost $\frac{n^{1+\gamma}}{1+\gamma}$. We think of this home production technology as capturing other means through which households can actively smooth their consumption, such as providing various non-market services to neighbors and family members (Morduch and Schneider, 2019).

Liquid Assets. Agents can save using a one-period risk-free liquid asset a at an interest rate $r_l(a)$, which is allowed to increase with the amount the agent saves to capture heterogeneity in rates of return across the wealth distribution (Benhabib et al., 2019). We impose a borrowing limit $\underline{a} < 0$.

Housing. We let h denote the amount of housing the agent owns and p the price of housing. Housing is subject to transaction costs that are proportional to the value of the home and equal to $f_s ph$. These costs are incurred whenever one sells their home. Thus an agent who would like to change their housing stock from h to h' pays $f_s ph + p(h' - h)$ units of output. Agents derive utility from the end-of-the-period housing stock. 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 impact the agents' decision rules.

We assume that homeowners are exposed to depreciation or maintenance shocks that constitute an additional source of risk in disposable resources. We model these costs as a two-point iid process which takes a value $\delta_t = \bar{\delta}$ with probability π_δ and zero otherwise.

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 rate 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

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[8] See Gorea and Midrigan (2018) for an extension with fat tailed shocks, which does not substantively change our findings.

hazard problems that exacerbate maintenance costs of rental property.[9]

Mortgages. Agents can borrow against the value of their homes using mortgages. Since most mortgages in the US are fixed-rate, 30-year contracts, we assume that a mortgage in the model has a maturity of 30 years. An agent who borrows an amount b promises to make a minimum payment $\bar{m}$ in every period of the contract. No arbitrage implies that

$$\bar{m} = \frac{r_m}{1 - (1 + r_m)^{-D}} \times b,$$

where r_m is the interest rate on mortgages and D is the maturity of the contract. We assume no prepayment penalty, so the borrower can repay more than the minimum required amount, $m \geq \bar{m}$. The mortgage balance thus evolves over time according to

$$b' = (1 + r_m)\, b - m.$$

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.* Homeowners in the U.S. have a number of options 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. 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. Gorea and Midrigan (2015) explicitly model the distinction between home equity loans and cash-out refinances and find results similar to those here.

We assume that the monetary cost of mortgage origination has two components, a fixed component, $f_{0,m}$, independent of how much one borrows, as well as a proportional component, $f_{1,m} b'$, that depends on the size of the mortgage b'. These two components capture closing costs, a portion of which is independent of the amount borrowed, as well as fees that are proportional to the amount borrowed. We assume that these costs are the same regardless of whether the agent finances the purchase of a new home, or refinances a mortgage on an existing home.

In addition to monetary costs of obtaining a mortgage, we assume that agents incur non-pecuniary utility costs, meant to capture other barriers to refinancing that homeowners may face, including information gathering costs, time costs and other behavioral factors, which

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

have been shown to be important in the literature (Keys et al., 2016, Andersen et al., 2020). We assume that these costs are iid random draws from an exponential distribution with mean ν. As we show below, these utility costs imply that the probability of refinancing is a smooth, rather than a discontinuous step function of the gains from refinancing, with the parameter ν determining the rate at which the probability of refinancing increases in the gains from doing so.[10]

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

$$b' \leq \theta_m ph, \tag{1}$$

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:

$$\frac{r_m}{1-(1+r_m)^{-D}} b' \leq \theta_y y. \tag{2}$$

These constraints only apply at mortgage origination. We allow agents to roll over the cost of refinancing the mortgage into their debt. An agent who refinances faces no upfront out-of-pocket costs, but has a mortgage balance equal to

$$\hat{b}' = f_{0,m} + (1+f_{1,m})\, b'. \tag{3}$$

Budget Constraints. Consider an agent who enters the period with a house of size h, outstanding mortgage debt b, liquid assets a and income $y+\phi n$. 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.

Agents who *rent* face the budget constraint

$$c + a' + Rh' = y + \phi n + (1 + r_l(a))\, a - (1+r_m) b + (1-f_s) ph - \delta h. \tag{4}$$

The right-hand side represents the agent's liquid wealth after she sells the original house, incurs the selling cost $f_s ph$ and the maintenance cost δh, repays the principal and interest on the outstanding mortgage debt, $(1+r_m)\, b$, and receives income $y+\phi n$ and interest and

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[10] The approach of assuming random costs of taking a discrete action mirrors a long tradition in the *(S,s)* literature. See Dotsey et al. (1999) and Khan and Thomas (2008), as well as Beraja et al. (2018) in a model with refinancing activity.

principal on the liquid account, $(1 + r_l(a))\,a$. The left-hand side sums consumption, c, liquid savings, a', and rental spending, Rh'.

Agents who *purchase* a new home have a budget constraint

$$c + a' + ph' - b' = y + \phi n + (1 + r_l(a))\,a - (1 + r_m)b + (1 - f_s)ph - \delta h. \tag{5}$$

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 $f_{0,m}$, a cost proportional to the amount borrowed, $f_{1,m}b'$, and faces the LTV and PTI constraints (1) and (2). Recall that we subsume the mortgage cost into the mortgage balance, which is given by equation (3).

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

$$c + a' = y + \phi n + (1 + r_l(a))\,a - m - \delta h, \tag{6}$$

where $m \geq \bar{m}$ is the mortgage payment, required to be above the minimum amount $\bar{m}$ determined at origination.

Finally, agents who *refinance* their mortgage face the budget constraint

$$c + a' - b' = y + \phi n + (1 + r_l(a))\,a - (1 + r_m)b - \delta h. \tag{7}$$

These agents repay 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 (1) and (2).

3.2 Recursive Formulation and Decision Rules

We next characterize the problem of renters and homeowners recursively and describe their decision rules.

Recursive Formulation. An agent's state variables are the age t, the liquid assets a, the remaining mortgage balance b, the minimum mortgage payment $\bar{m}$, the house size h, the realization of the persistent and transitory income components z and e, and the maintenance shock δ. Let $s = (t, a, b, \bar{m}, h, z, e, \delta)$ be a vector that collects all of these state variables.

Each period agents have five options: 1. rent, 2. purchase a new home without a mortgage, 3. purchase a new home with a mortgage, 4. refinance an existing mortgage, 5. remain inactive. Let $V^i(s)$ denote the value of option $i = 1, \ldots, 5$, absent the utility cost ξ of obtaining a new mortgage. Let

$$\bar{V}(s) = \int \max\left(V^1(s), V^2(s), V^3(s) - \xi, V^4(s) - \xi, V^5(s)\right) \mathrm{d}F(\xi),$$

be the envelope over these options, integrating over the iid utility cost ξ, drawn from an exponential distribution with mean ν:

$$F(\xi) = 1 - \exp\left(-\frac{\xi}{\nu}\right).$$

We next describe each of these options in detail. The value of renting is

$$V^1(s) = \max_{c,a',h'} \frac{c^{1-\sigma}}{1-\sigma} + \alpha\frac{(h')^{1-\sigma}}{1-\sigma} - \frac{n^{1+\gamma}}{1+\gamma} + \beta\mathbb{E}\bar{V}(t+1, a', 0, 0, 0, z', e', 0)$$

subject to the budget constraint in (4) and the borrowing constraint on liquid assets $a' \geq \underline{a}$. The expectation operator integrates over the possible realizations of income shocks.

The value of purchasing a new home without a mortgage is

$$V^2(s) = \max_{c,a',h'} \frac{c^{1-\sigma}}{1-\sigma} + \alpha\frac{(h')^{1-\sigma}}{1-\sigma} - \frac{n^{1+\gamma}}{1+\gamma} + \beta\mathbb{E}\bar{V}(t+1, a', 0, 0, h', z', e', \delta'),$$

subject to the budget constraint

$$c + a' + ph' = y + \phi n + (1 + r_l(a))\, a - (1 + r_m)b + (1 - f_s)ph - \delta h, \tag{8}$$

and the borrowing constraint on liquid assets. The expectation operator now integrates both the income shocks, as well as the housing maintenance shocks.

The value of purchasing a new home with a mortgage is

$$V^3(s) = \max_{c,a',h',b'} \frac{c^{1-\sigma}}{1-\sigma} + \alpha\frac{(h')^{1-\sigma}}{1-\sigma} - \frac{n^{1+\gamma}}{1+\gamma} + \beta\mathbb{E}\bar{V}(t+1, a', \hat{b}', \bar{m}', h', z', e', \delta'),$$

subject to the budget constraint in (5), the borrowing constraint on liquid assets, and the LTV and PTI constraints in (1) and (2). Since mortgage origination costs are rolled over into the mortgage loan, the balance on the mortgage is

$$\hat{b}' = f_{0,m} + (1 + f_{1,m})b',$$

and the minimum mortgage payment is

$$\bar{m}' = \frac{r_m}{1 - (1 + r_m)^{-D}}\hat{b}'.$$

The value of refinancing a mortgage on the current home is

$$V^4(s) = \max_{c,a',b'} \frac{c^{1-\sigma}}{1-\sigma} + \alpha \frac{h^{1-\sigma}}{1-\sigma} - \frac{n^{1+\gamma}}{1+\gamma} + \beta \mathbb{E} \bar{V}(t+1, a', \hat{b}', \bar{m}', h, z', e', \delta'),$$

subject to the budget constraint in (7), the borrowing constraint on liquid assets, and the LTV and PTI constraints in (1) and (2). The balance on the new loan and the minimum mortgage payment are determined as above.

Lastly, the value of remaining inactive is

$$V^5(s) = \max_{c,a',b'} \frac{c^{1-\sigma}}{1-\sigma} + \alpha \frac{h^{1-\sigma}}{1-\sigma} - \frac{n^{1+\gamma}}{1+\gamma} + \beta \mathbb{E} \bar{V}(t+1, a', \hat{b}', \bar{m}, h, z', e', \delta'),$$

subject to the budget constraint in (6), the borrowing constraint on liquid assets, and the constraint that the agent makes the minimum mortgage payment $\bar{m}$, which implies a limit on the agents' mortgage debt,

$$b' \leq (1 + r_m) b - \bar{m}. \tag{9}$$

Decision Rules. We briefly discuss the first-order conditions characterizing households' optimal choices. Conditional on renting, the optimal choice of rental housing is

$$h' = \left(\frac{R}{\alpha} \right)^{-\frac{1}{\sigma}} c.$$

Consider next the discrete choice of whether to rent or own. This choice is determined by a comparison of the implicit user cost of owning a home and the rental rate R. The user cost of owning a home depends on the households' implicit rate of time preference, the maintenance cost and the fixed cost of selling the home. Liquidity constraints distort the implicit rate of time preference so poorer households are more likely to rent.

The optimal choice of home production is

$$n = \phi^{\frac{1}{\gamma}} c^{-\frac{\sigma}{\gamma}}.$$

Poorer households who have lower consumption engage in more home production. The parameter ϕ determines the effectiveness of home production in smoothing household consumption.

The Euler equation for liquid savings is

$$c^{-\sigma} \geq \beta \mathbb{E} \left(1 + r_l \left(a' \right) + r_l' \left(a' \right) a' \right) c'^{-\sigma},$$

and that for mortgage debt is given by

$$c^{-\sigma} \geq \beta \mathbb{E} \left(1 + r_m\right) c'^{-\sigma} - \beta \mathbb{E} \left(1 + r_m\right) \mu',$$

where μ is the homeowners' marginal valuation of liquidity, that is, the multiplier on the liquidity constraint (9) for inactive homeowners. Combining these two expressions shows that agents borrow up to the point at which their marginal valuation of liquidity is equal to the spread between the mortgage and liquid interest rates:

$$\beta \mathbb{E} \left(1 + r_m\right) \mu' \geq \beta \mathbb{E} \left(r_m - r_l \left(a'\right) - r_l' \left(a'\right) a'\right) c'^{-\sigma}.$$

Intuitively, borrowing more against one's home has both a cost and a benefit. The cost is the interest cost of servicing a mortgage, which is greater than the rate of return on the liquid asset. The benefit is that borrowing more against one's home increases liquid assets and allows households to smooth consumption. At an interior solution the agent equates the cost and the benefit.

Note that there is a critical distinction between whether a household is hand-to-mouth in the sense of hitting the borrowing constraint on liquid assets $a' \geq \bar{a}$ and whether a household is liquidity constrained in the sense of the mortgage borrowing constraint (9) binding. As we show below, the latter constraint binds for a much larger fraction of homeowners. Intuitively, a household may have some liquid savings, yet they may choose to only make the minimum required mortgage payment in anticipation of potentially bad income realizations in the future. Such homeowners would value the option to convert home equity into liquid assets, yet are unable to do so because of the costs of mortgage origination.

Figure 1 illustrates the decision to refinance as a function of an agent's cash-on-hand, $y + \left(1 + r_l \left(a\right)\right) a$, for a simplified version of the model in which homeowners cannot sell their home. Panel A of Figure 1 shows that the welfare gain from refinancing is decreasing in cash-on-hand. A household that refinances can use the equity extracted to finance a higher level of consumption, as shown in Panel B, and a higher level of liquid savings, as shown in Panel C. Given the exponentially distributed utility cost of refinancing, the probability of refinancing, shown in Panel D of Figure 1, is given by

$$\pi^R = 1 - \exp\left(-\frac{\max\left\{V^R - V^N, 0\right\}}{\nu}\right).$$

To understand the role of the random utility costs of refinancing, Figure 2 shows how the probability of refinancing increases in the welfare gains from doing so. To make the numbers interpretable, we convert the welfare gains from refinancing, $V^4 - \max_{i \neq 4} V^i$, into monetary equivalents by scaling these by the marginal utility of consumption of the median household and translating them into 2016 US dollars.[11] The numbers in Figure 2 are based on the calibration of the model discussed in the next section. Notice that in our baseline model with $\nu = 1/3$ the probability of refinancing is equal to 35% for an agent with welfare gains from refinancing of \$5,000. Since the random utility draws are iid, such a homeowner is likely to refinance over the course of three quarters. As ν decreases, the probability of refinancing increases and reaches 75% when $\nu = 1/10$. In the limit, as $\nu \to 0$, the decision to refinance is of the (S, s) form and the refinancing probability jumps discontinuously at 0. The parameter ν thus determines how rapidly a household refinances when the welfare gains from doing so increase.

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. We describe 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. In the robustness section below we show that our results are robust to targeting moments from 2016.

4.1 Parameterization

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 B of Table 2.

4.1.1 Assigned Parameters

We first describe the assigned parameters.

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[11] To convert units in the model to dollars in the data, we note that the average income of the bottom 80% of households was 70,000 2016 US dollars in 2001 and scale units in the model appropriately. We use a similar conversion every time we report monetary amounts.

Demographics and Preferences. A period in the model is 1 quarter. Agents enter at age 25 and live for $T = 244$ quarters, that is, up to age 85. We set the coefficient of relative risk aversion $\sigma = 2$ and the elasticity of home production hours $\gamma = 1$, both common choices in the literature. This value of σ implies an elasticity of substitution between consumption and housing services of 0.5.

Mortgage Debt. The mortgage contract is characterized by four parameters, the maturity of the contract D, the interest rate r_m, the maximum loan-to-value ratio, θ_m, as well as the maximum payment-to-income ratio, θ_y. We set the maturity of the contract to 120 quarters, or 30 years.

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 and subtract the 2.8% inflation rate in 2001, which implies a real after-tax interest rate of $r_m = 2.5\%$.[12]

We set the maximum LTV equal to 0.85 to match the upper tail of the LTV distribution in the data. Finally, we set the maximum payment-to-income ratio at origination equal to 0.35, consistent with the evidence in Greenwald (2018). 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 maximum PTI ratio at origination of 0.21.

Fixed Costs. Consistent with the post-2000 Freddie Mac PMMS data, we set the proportional mortgage origination cost $f_{1,m} = 0.005$, in line with average fees and points on 30-year mortgages. 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. Without loss of generality, we normalize the price of one unit of housing to $p = 1$ in the initial steady-state.

Non-Pecuniary Mortgage Origination Costs. We set $\nu = \frac{1}{3}$ in our baseline parameterization. As we show below, this choice of ν allows the model to match the evidence on how

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

mortgage refinancing responds to changes in interest rates. However, we also report results for lower values of ν, including $\nu = 0$.

Maintenance Costs. We use data from the PSID to measure the magnitude of housing maintenance costs. Most homeowners report negligible such expenses. However, a small fraction of homeowners experience quite large maintenance expenses, with the 95^{th} percentile spending 6.3% of the value of their home in a given year on home repairs. Based on this evidence, we set the annual probability of a maintenance shock $\pi_\delta = 10\%$ and the size of the shock $\bar{\delta} = 0.063$.

4.1.2 Calibrated Parameters

We next discuss how we calibrate 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. We choose the latter to jointly match a number of moments in the data.

Income Process. We use data from the 1999-2007 waves of the 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 assume that the deterministic component of income λ_t is a cubic age polynomial and estimate its coefficients using the PSID data. We choose the persistence ρ_z and the standard deviations σ_z and σ_e to match the variance of log income, the autocovariance of log income at 2- and 4-year horizons and the standard deviation of log income growth over a two year period. These moments allow us to separately identify the volatility of the transitory and persistent income components. As suggested by Krueger and Perri (2012), we scale down the volatility of the transitory shock by 55% to account for measurement error. 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 B of Table 2. The model matches the income moments very well.

Additional Parameters. We choose the remaining parameters listed in Panel B of Table 2 to jointly match a number of moments in the data listed in Panel A of the table. 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 additional sources of heterogeneity (say in the discount rates or income processes), which would complicate the model, without substantially changing any of our conclusions given our partial equilibrium assumption. See Gorea and Midrigan (2015) for an extension along these lines.

Even though all these parameters are jointly identified, below we discuss which moments are most helpful in pinning down each parameter. We set the discount factor $\beta = 0.944$ (annualized) to match an aggregate wealth to income ratio of 1.45, the preference weight for housing in the utility function $\alpha = 0.687$ to match the aggregate housing to income ratio of 1.82, the strength of the bequest motive $B = 10.27$ to match that households older than 65 have twice more wealth than younger households, and the efficiency of home production $\phi = 0.939$ to match the 0.23 ratio of home production to consumption reported by the Bureau of Economic Analysis.[13] We choose a rental rate of housing $R = 0.045$ to ensure that the homeownership rate is equal to 0.64. Intuitively, the higher the rental rate R is, the larger the spread between the user cost of owning vs. renting and the more attractive owning a home is.

We choose the fixed cost of refinancing a mortgage $f_{0,m}$, to match the fraction of borrowers who extract equity. Recall from our discussion in Section 2 that in the PSID 15% of mortgage borrowers increased their mortgage balance between the survey waves of 1999 and 2001, so we target an annual rate of home equity extraction of 7.5%. The implied value of the fixed cost is $1,330, in line with existing estimates (Agarwal et al., 2013).[14] As Panel A of Table 2 shows, the model matches all these targets very well.

Lastly, we assume the following functional form for the return on the liquid asset

$$r_l\left(a\right) = \frac{r_h - r_l}{1 + \exp\left(-\tau_0\left(a - \tau_1\right)\right)} + r_l,$$

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[13] See https://apps.bea.gov/scb/2019/06-june/0619-household-production.htm for a detailed description.

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

where r_l is the lowest possible interest rate, r_h is the highest possible interest rate, τ_0 governs how rapidly the interest rate increases with liquid assets and τ_1 determines the level of assets at which the interest rate starts increasing.[15] We normalize the lower bound $r_l = -2.8\%$, corresponding to a nominal interest rate of 0 and an inflation rate of 2.8%, and choose the remaining parameters to match moments of the distribution of liquid assets and mortgage debt in the data.

We target the mean mortgage debt to income, the mean and median liquid assets of all households as well as of homeowners, the fraction of all households and of homeowners who are hand-to-mouth,[16] and the 90^{th} percentile of the liquid asset distribution of homeowners. As Panel A of Table 2 shows, the model reproduces all the targeted moments well. For example, the average mortgage debt to income ratio is 0.83 in the data and 0.82 in the model, while the mean liquid assets to income ratio is 0.46 in the data and 0.44 in the model. The median liquid assets relative to mean annual income is 0.07 in the data and 0.08 in the model. A large fraction of households are hand-to-mouth (41% in the model and 37% in the data). Though homeowners are richer on average, a substantial fraction of them is hand-to-mouth as well: 32% in the data and 26% in the model.

5 Testing the Model

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 unconditional moments that describe household's portfolio composition, as well as conditional moments that describe who is more likely to refinance, as well how refinancing activity responds to changes in interest rates. We next discuss how the model does along these dimensions, as well as report a number of life-cycle statistics.

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[15] Here we apply the same interest rate schedule irrespective of whether the household is saving or borrowing. Gorea and Midrigan (2015) show that the results are robust to allowing agents access to unsecured credit at credit card borrowing rates, as long as the model matches the low fraction of homeowners with negative liquid asset holdings observed in the data.

[16] In the spirit of Kaplan and Violante (2014), we define hand-to-mouth households as those with liquid wealth that is less than two weeks of income.

5.1 Households' Portfolio Composition

We first report various quantiles of the distribution of individual household balance sheets in both the model and the data.

Panels A and B of Table 3 report the distribution of liquid assets for all households and for homeowners. The model reproduces well the distribution of liquid assets of homeowners as well as the bottom 75% of the overall liquid asset distribution. The model under-predicts the concentration of liquid assets at the top, owing to the fact that in the model there are no rich households who rent. In the robustness section, we introduce additional frictions to homeownership that allow the model to reproduce the liquid asset distribution of renters much better. Since these frictions do not affect our substantive conclusions, we opted to relegate this extension to the robustness section for expositional clarity.

Panels C and D of Table 3 show that the model reproduces very well the distribution of household wealth and the distribution of the share of home equity in household wealth. For example, the poorest 25% of households have almost no wealth both in the model and in the data, while households at the 90^{th} percentile have wealth that is four times greater than average annual income. Similarly, the median homeowner has 87% of all their wealth in housing in both the model and the data, while 25% of homeowners have effectively no wealth other than their home.

Panels E and F of Table 3 show that the model is also able to capture the distribution of the loan-to-value and payment-to-income ratios in the data. As discussed in the Appendix, we scale down the payment-to-income ratio in the data to reflect that, unlike in the model, payments include inflation and taxes. For example the median LTV ratio is 0.62 in the data and 0.70 in the model, and the median PTI ratio is 0.11 in the data and 0.10 in the model.

Panel G of Table 3 shows that the model reproduces well the dispersion in the housing to income ratio in the data, which ranges from 1 at the 10^{th} percentile to 6 at the 90^{th} percentile in both the model and the data. Lastly, Panel H of Table 3 shows that the model also reproduces the distribution of the age of mortgage contracts well, reinforcing the ability of the model to capture the frequency with which homeowners reset their mortgages in the data.

5.2 Role of the LTV and PTI Constraints

We have shown above that the model reproduces well the distribution of LTV and PTI ratios in the data. We next ask: what is the relative importance of these two constraints in hindering homeowners' ability to tap equity from their homes? To do so, we calculate the fraction of all new mortgages for which the LTV or PTI constraints are binding. We find that 60% of all new mortgages are at the 85% LTV limit, 12% of new mortgages are against the PTI limit, while only 28% of mortgages are unconstrained. This suggests that both constraints play an important role, but the LTV constraint more so, quantitatively consistent with the evidence in Greenwald (2018).

Even though the PTI constraint seems to bind for relatively fewer households, we next argue that it nevertheless plays an important role. To do so, we permanently remove this constraint and find substantial welfare gains, averaging $1,100 for all households and $1,300 for homeowners, numbers similar to the magnitude of the fixed cost of mortgage refinancing. As before, we compute these welfare gains by comparing the value of the agents in the new and old regime and scaling the difference by the marginal utility of consumption to convert it into monetary units. The frequency of refinancing increases by 30% immediately following the elimination of the PTI constraint, suggesting that the payment-to-income constraint is indeed an important barrier to accessing home equity.

5.3 Characteristics of Borrowers who Refinance

We next evaluate the ability of the model to reproduce conditional evidence on the characteristics and behavior of households who extract home equity.

Panel A of Table 4 shows that 23% of mortgage borrowers are ahead on their payments in the model, a number very close to the corresponding 21% that we document in the SCF data, and also in line with the evidence in Adelman et al. (2010), who report that 22% of homeowners curtailed their mortgage.[17] Since a household in the model is liquidity constrained if the minimum mortgage payment constraint (9) binds, that we match this fraction suggests that the model reproduces well the share of liquidity constrained homeowners in the data.

Consider next the amount of home equity extracted conditional on refinancing. In the PSID data the median borrower who extracts home equity increases their mortgage balance

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[17] Note that both in the data and in the model the statistic refers to the fraction of mortgage borrowers that have curtailed at least once in the lifetime of a mortgage contract. The fraction who curtail in any given period is, of course, much smaller.

by 24%, a number close to that reported by Bhutta and Keys (2016). In the model the corresponding statistic is 19%. Similarly, the median borrower who extracts increases their LTV by 11 percentage points in the data and 12 percentage points in the model. The model thus reproduces well the amount of equity that homeowners extract.

Panel B of Table 4 evaluates the model's ability to reproduce the characteristics of home equity extractors. Recall from our discussion in Section 2 that homeowners who extract have much lower liquid assets. The model reproduces this pattern: the median liquid asset to wealth ratio of those who extract is 0.04 in both the model and the data, while the median liquid asset to wealth ratio of non-extractors is 0.16 in the data and 0.15 in the model. We therefore conclude that the model replicates well the characteristics of borrowers who refinance, as well as of those who do not.

5.4 Refinancing in Response to Mortgage Interest Rate Declines

A pervasive puzzle documented in the literature on household finance is that a substantial fraction of mortgage borrowers fail to refinance after large declines in mortgage interest rates, even though there are large apparent financial gains from doing so (Johnson et al., 2019, Keys et al., 2016, Andersen et al., 2020). We argue next that our model reproduces this evidence well, owing to the random utility costs of refinancing. Specifically, we focus on the evidence in Johnson et al. (2019), who study a sample of 800,000 borrowers who were given the option to reduce their mortgage rates by a median of 1.75 percentage points under the Home Affordable Refinance Program (HARP) at no upfront cost between 2011 and 2013. These homeowners were approved for a mortgage refinance and stood to experience substantial savings, in excess of $15,000 on average, from locking in a lower interest rate. Johnson et al. (2019) find that only 16% of those who received such offers chose to refinance, a number close to that reported by Keys et al. (2016) based on a smaller sample of households in Chicago.[18]

We gauge the model's ability to reproduce these patterns by conducting the following experiment: we engineer a permanent fall in the pre-tax interest rate on mortgages r_m of 1.75 percentage points and solve for the household's decision rules. We consider three versions of the model: our baseline with the mean random utility cost $\nu = 1/3$, as well as $\nu = 1/10$ and $\nu = 0$, the latter corresponding to an economy without utility costs. Each of these economies has been recalibrated to match the set of moments discussed in the previous section. We

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[18] See also Caplin et al. (1997), who document a similar pattern using older data.

report the full set of parameter values and moments in the Appendix. We note here that models with lower utility costs require a larger fixed monetary cost $f_{0,m}$ of obtaining a new mortgage. As Panel A of Table 5 shows, this fixed cost increases from \$1,330 in our baseline to \$3,580 in the absence of utility costs.

We first describe how these utility costs shape refinancing activity in steady-state, when mortgage interest rates are constant at 2.5%. Panel A of Table 5 shows that 22% of homeowners with a mortgage would refinance in the absence of utility costs. That is, 22% of homeowners have a value of refinancing, V^4, that exceeds the value of all other options. For this subset of households, the welfare gains from refinancing, scaled by the marginal utility of consumption,

$$\frac{V^4 - \max_{i \neq 4} V^i}{u'(c)},$$

are equal to \$1,020. The utility costs prevent most of these homeowners from refinancing: only 1/10 of them actually do so in a given quarter. Thus, the overall frequency of refinancing is 2% per quarter, or 8% per year.

Consider next the models with lower utility costs of obtaining a new mortgage. As these utility costs decrease and the monetary costs increase, the fraction of those who would benefit from refinancing falls, but the probability of refinancing conditional on benefiting from doing so increases, so that the fraction of households who refinance remains unchanged at 2% per quarter.

We next study the effect of a decline in the mortgage interest rate r_m. As Panel B of Table 5 shows, now a much larger fraction of households has positive welfare gains from refinancing absent utility costs, in that $V^4 > \max_{i \neq 4} V^i$. This fraction ranges from 79% in our baseline model with $\nu = 1/3$ to 44% when $\nu = 0$. The average welfare gains from refinancing range from \$2,730 with $\nu = 1/3$ to \$480 when $\nu = 0$.

To see why these gains are so much larger, we calculate the difference between the present value of the mortgage payments under the original mortgage contract and that under the new mortgage contract, net of the mortgage origination costs. We refer to this difference as the savings from refinancing. These savings are very large, on the order of \$15,000, much larger than the actual welfare gains from refinancing. The reason the actual welfare gains are lower is that the interest rate drop we consider is a permanent one, so some households exercise the option value of waiting to refinance at a later date.

The last row in Panel B of Table 5 reports the fraction of households who actually refinance in the first quarter following the interest rate drop. Even though most households would be better of refinancing absent utility costs, only 16% of them actually do so in our baseline model, a number identical to that reported by Johnson et al. (2019) and Keys et al. (2016). As the utility cost decreases, the fraction of homeowners who refinance increases to 24% when $\nu = 1/10$ and 44% when $\nu = 0$. We thus conclude that a value of $\nu = 1/3$ is required to match this evidence, but show below that our main results on the importance of liquidity constraints are largely unaffected by the choice of ν.

5.5 Life-Cycle Statistics

Figure 3 reports how average income, the wealth to income ratio, the home value 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. Panel A of the figure shows how income evolves over the life-cycle. The model matches the hump-shaped income profile in the data by construction. As shown in Panels B–D, the model also reproduces well the life-cycle evolution of overall wealth, home values and housing wealth.

To summarize, we calibrate the parameters of the model to reproduce a number of *unconditional* moments from the data, but the model succeeds in also reproducing salient features of the *distribution* of households' liquid assets, mortgage debt and housing, as well as *conditional* moments that describe the characteristics of households who refinance and their refinancing behavior in normal times as well as in response to changes in mortgage interest rates. The model also matches reasonably well the life-cycle profiles of income, wealth and housing equity in the data. We thus view it as a useful laboratory to study the importance of liquidity constraints faced by homeowners and evaluate the effect of policies aimed at alleviating them.

6 Importance of Liquidity Constraints

We next 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. Four-fifths of homeowners are liquidity constrained. 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 show that, owing to the severity of these liquidity constraints, the model is able to reproduce the large marginal propensity to consume (MPC) out of an unaticipated one-time cash transfer, akin to the tax rebates provided under various fiscal stabilization programs.

6.1 Severity of Liquidity Constraints

We evaluate the severity of liquidity constraints by asking: 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, thus leaving their overall wealth unchanged. We set Δb equal to 1% of the value of one's home, thus effectively offering homeowners a one-time opportunity to extract home equity up to 1% of the value of their home for free.

Panel A of Table 6 shows that 82% of all homeowners benefit from such an opportunity. Thus, approximately four-fifths 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 constrained homeowners' average valuation of liquidity, which we compute as the change in the households' value upon the liquidity injection, scaled by their marginal utility of consumption and the amount of the transfer, $\frac{\Delta V}{\Delta b}\frac{1}{u'(c)}$.

In effect, this valuation tells us the amount that the household is willing to pay for every dollar they can extract from their housing wealth. The table shows that the average household is willing to pay 13 cents for every dollar of housing wealth extracted, with substantial heterogeneity across households. The value of liquidity ranges from 1 cent on the dollar at the 10^{th} percentile to 27 cents on the dollar at the 90^{th} percentile. Notice that the implied value of liquidity is relatively insensitive to the size of the random utility costs of mortgage origination. Even in the absence of such costs ($\nu = 0$), 80% of homeowners are liquidity constrained and the mean valuation of liquidity is 12 cents on the dollar. We conclude that even though random utility costs are important in determining the decision to refinance after changes in interest rates, they do not substantively alter our model's implications regarding the severity of liquidity constraints. Of course, in drawing this conclusion we recalibrated each alternative model to match the same set of facts as the benchmark model.

We also note that the fraction of liquidity-constrained homeowners is much larger than the fraction of hand-to-mouth homeowners. Recall that one quarter of homeowners in our model have liquid wealth that is less than two weeks of their income, yet nearly 80% of homeowners value liquidity. To see why this is the case, Panel B of Table 6 reports the fraction of the transfer that homeowners consume in the period in which they receive it, $\Delta c/\Delta b$. Notice that, on average, homeowners only consume 13 cents of every dollar received in the same quarter. This fraction ranges from 0.02 at the 10^{th} percentile to 0.27 at the 90^{th} percentile. This suggests that homeowners choose to save most of the additional liquidity for precautionary reasons, in anticipation of future negative income and home maintenance shocks. The next two columns of the table show that the random utility costs do not substantively change this calculation.

Figure 4 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, in excess of 20% compared to zero for homeowners without a mortgage. This result reflects selection, as high LTV homeowners are poor on average and thus have higher payment-to-income ratios. This pattern is confirmed in Panels B–D, which show that the value of liquidity is increasing in the payment-to-income ratio and decreasing in the amount of liquid assets and income. Intuitively, homeowners with low required payments, high liquidity and high income have sufficient resources to finance their mortgage payments and smooth consumption, and therefore value an additional dollar of liquidity less.

6.2 Value of Liquidity After Increase in Mortgage Interest Rates

So far we have conducted our analysis in a stationary environment with constant interest rates. The value of liquidity is, however, also influenced by the time path of interest rates. If interest rates are higher (lower) relative to historical levels, the implicit cost of refinancing may be higher (lower) since refinancing would lock in a higher (lower) interest rate. Given that most mortgages in the US are fixed rate mortgages, we next investigate the extent to which the value of liquidity responds to changes in interest rates.

Specifically, we consider a one-time permanent 1 percentage point increase in mortgage interest rates above their initial level and calculate homeowners' valuation of liquidity in the first period after this shock. The last column of Table 6 shows that the value of liquidity increases considerably. Though the fraction of homeowners who value liquidity changes little, from 0.82 in steady state to 0.83, the average value of liquidity increases from 0.13 to 0.20. Intuitively, the fraction of homeowners who refinance falls, as refinancing implies paying a higher interest rate for the remainder of the mortgage contract.

6.3 Marginal Propensity to Consume Out of a Cash Transfer

Motivated by the evidence of large consumption responses to cash transfers such as tax rebates provided in fiscal stimulus packages (Johnson et al., 2006, Parker et al., 2013), we ask whether liquidity frictions in the housing market can account for the large MPC observed in the data.

As is well known, standard one-asset models with idiosyncratic risk and incomplete markets are not able to reproduce the evidence that household consume, on average, 20-25 cents of a every dollar of cash transfer. Kaplan and Violante (2014) augment this model by assuming that households have access to a second illiquid asset that has a higher rate of return and requires a fixed cost to adjust its balance. They find that such a model can generate two-thirds of the consumption response to a $500 dollar cash transfer, akin to the tax rebate studied by Johnson et al. (2006). Since in the data the vast majority of illiquid wealth is in the form of housing, here we study whether a model that is consistent with the institutional details of the US housing market and the frequency of home equity extraction, thus microfounding the two-asset model of Kaplan and Violante (2014), can reproduce the large consumption responses to cash transfers.

Table 7 shows that the marginal propensity to consume out of an unanticipated one-time $500 cash transfer is, on average, 0.17. This number is similar to that predicted by the Kaplan and Violante (2014) model and equal to two-thirds of the magnitude observed in the data. The MPC ranges from 0.03 at the 10^{th} percentile to 0.33 at the 90^{th} percentile. Since homeowners are wealthier on average than renters, their MPC is lower, 0.14 on average, but nevertheless substantially higher than that predicted by a standard one-asset model. Notice, once again, that the magnitude of the utility adjustment costs does not meaningfully impact this calculation, as shown by Panels B and C of Table 7.

Figure 5 shows that the MPCs are highest exactly for those homeowners with the highest valuation of liquidity: those with high LTV, PTI and low levels of liquid assets and income. We therefore conclude that the frictions that make home equity illiquid go a long way towards explaining the large MPCs documented in the data and that there is a tight connection between the value of liquidity and households' inability to smooth consumption, as proxied by a high MPC. The conclusion that the US housing market is relatively illiquid suggests that providing relief to homeowners in distress requires interventions that directly improve their liquidity position. We next study two such interventions.

7 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 liquidity relief for homeowners. We consider two types of programs: a mortgage modification program akin to the Home Affordable Modification Program (HAMP), and a mortgage forbearance policy that reduces mortgage payments for homeowners experiencing a transitory spell of low income. We show that both of these policies have a substantial impact on household welfare.

7.1 Mortgage Modification Program

We first consider two modifications of mortgage contracts that change homeowners' debt obligations and allow us to disentangle the effect of short- and long-term debt reductions. These interventions attempt to replicate the essence of the loan modification programs that were part of HAMP, studied by Ganong and Noel (2019). These researchers exploit two natural experiments. The first one is a mortgage modification that resulted in a payment reduction, but no change in the mortgage principal. The second one resulted in both a payment and a principal reduction. By exploiting quasi-experimental assignment of borrowers to each of these modifications, they find that the policies had a similar impact on borrowers' consumption expenditure. The authors therefore conclude that it is liquidity, and not wealth, that determines consumption decisions.

To capture the economic background against which these policies were implemented, we simulate an unanticipated 25% fall in house prices, which leaves a substantial fraction of homeowners underwater and no longer able to refinance. Consistent with the evidence of Beraja et al. (2018), who find that declines in house prices greatly reduce refinancing activity, in our model only 2% of homeowners refinance in the first year after the shock, compared to 8% in the steady-state. We then conduct two experiments. The first one, which we label "Only Payment Reduction", consists of a one-time reduction in borrowers' mortgage payments of $8,000, as in the data, but leaves their mortgage balance unaffected. This intervention thus backloads payments by extending the maturity of the mortgage contract. The second one, which we label "Payment and Principal Reduction", consists of the same one-time reduction in mortgage payments of $8,000, but also reduces the mortgage principal by the same amount, thus forgiving a fraction of the mortgage debt.

Table 8 reports the welfare implications of these two policies. Since HAMP was targeted at underwater borrowers, in the table we report both the effect of the interventions on all borrowers, as well as on underwater borrowers, those with an LTV in excess of 95%. We find that the majority of borrowers (87%), and an even larger fraction of those who are underwater (97%) benefit from the payment reduction. These households experience a welfare gain equal to 16 cents, on average, for every dollar of payment reduction. The welfare gains are even larger, 22 cents on the dollar, for underwater borrowers. We also calculate the consumption response to these payment reductions and find that, on average, households increase their consumption in the first year by 36 cents for every dollar of payment reduction. This consumption response is even larger, 46 cents on the dollar, for underwater borrowers. Thus, a policy that backloads mortgage payments leads to a substantial increase in welfare and consumption, especially for underwater homeowners, even though it does not change the mortgage debt of households.

Consider next the effect of simultaneously reducing the mortgage payment and forgiving a fraction of the mortgage principal. Not surprisingly, all borrowers benefit from this policy. Interestingly, the consumption response to this alternative program is quantitatively similar to that resulting from the payment reduction only: 39 cents on the dollar overall and 46 cents on the dollar for underwater borrowers. This result is in line with the evidence in Ganong and Noel (2019) who find similar consumption responses across the two programs. Hence, payment reduction policies go a long way towards increasing household consumption and welfare even if they are not associated with principal reduction.

7.2 Mortgage Forbearance Program

Mortgage forbearance programs provide temporary relief to borrowers by reducing their mortgage payment in the event of a job loss, natural disaster or major illness. Although most lenders in the U.S. have such programs, these are limited in scope.[19] We next consider the impact such a policy has in our model. The policy we consider reduces the required quarterly payment on one's mortgage to at most 15% of income. The required payment is therefore

$$\bar{m}_t = \min\left[\frac{r_m}{1-(1+r_m)^{-D}} \times b,\ 0.15 \times y_t\right],$$

where b is the initial loan. Since in the steady-state of our model 25% of borrowers have a PTI that exceeds 15%, such a policy provides automatic temporary relief to a quarter of

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

mortgage borrowers. For inactive households who are liquidity constrained and therefore make the minimum mortgage payment, the budget constraint reads

$$c_t + a_{t+1} = y_t + \phi n_t + \left(1 + r_l\left(a_t\right)\right) a_t - \bar{m}_t - \delta h_t,$$

so the policy effectively provides additional liquidity to these households, but does not change their mortgage balance.

Panel A of Table 9 shows the impact of such a policy on the model's steady state implications. Notice that the homeownership rate increases substantially, from 65 to 72%, as does the mortgage debt to income ratio, from 0.82 to 1. Intuitively, owning a home is now more attractive, inducing marginal households to enter the housing market. The frequency with which households extract home equity is unchanged, at 8% a year, a result that reflects two opposing forces. On one hand, mortgage forbearance reduces the need to extract equity, since the policy acts as an automatic stabilizer that provides liquidity in bad times to homeowners in need. On the other hand, the marginal households who enter the housing market are poorer and more constrained and thus have a higher propensity to refinance. Overall, 26% of homeowners receive these payment reductions in any given quarter. For these households, the reduction in the mortgage payment is \$520, on average.

Panel B of Table 9 reports the welfare consequences of such an intervention. As usual, we convert the welfare gains into monetary equivalents by scaling them by the marginal utility of consumption. The average welfare gains are large, on the order of \$1,800. To interpret this magnitude, recall that the fixed cost of mortgage refinancing is equal to \$1,300. Not surprisingly, homeowners benefit relatively more from mortgage forbearance, but renters benefit too, with welfare gains equal to \$1,600 on average, owing to the anticipation of a more attractive housing market. Clearly, poorer households benefit more, with the poorest 25% gaining \$2,600.

We thus conclude that policies aimed at providing relief for homeowners have a substantial impact, a result that reflects the tightness of liquidity constraints in our model.

8 Robustness

We next discuss the robustness of our results. We consider an alternative calibration to more recent data from 2016, a version of the model without heterogeneity in the rate of return on liquid assets, an extension with moving shocks and additional barriers to homeownership, as well as a version of the model without home production. We recalibrate all these models and we show that our conclusion that liquidity constraints in the U.S. housing market are sizable is robust to these perturbations.

8.1 Calibration to 2016

We calibrate our benchmark model to data from 2001 in order to ensure that the moments we target are not driven by the large boom and bust in the U.S. housing market during the subsequent period. Here we show that calibrating the model to data from 2016, the latest available period in our data, reinforces our conclusions that the U.S. housing market is illiquid.

Our calibration strategy is identical to that in our benchmark model. We report the key set of moments and parameters for this variation of the model in Table 10.[20] A comparison of this table and Table 2 reveals that households have less liquid assets in 2016 compared to 2001: the average (median) liquid asset to average income ratio is 0.33 (0.03) in 2016 compared to 0.46 (0.07) in 2001. A second notable change is that the fraction of homeowners who extracted equity in the preceding two-year period in PSID declined, from 15% to 9%.

As Panel B of Table 10 shows, liquidity constraints are much more severe for this calibration of the model, owing to the lower frequency of refinancing and lower liquid asset holdings. The mean willingness to pay for one dollar of home equity extracted is equal to 20 cents, compared to 13 cents in our benchmark model. Agents spend an average of 16 cents for every dollar extracted, compared to 12 cents in the benchmark model. Therefore, our conclusion that the U.S. housing market is illiquid is reinforced if we target moments from 2016 instead.

8.2 Constant r_l

We assume in our benchmark model that the return on the liquid asset increases with liquid asset holdings in order to capture heterogeneity in rates of return across the wealth distribution. Here we illustrate the consequences of assuming that the interest rate on the liquid asset is constant. We report the key moments we target and implied parameter values in Panels A and B of Table 11. As the table shows, the model does a poorer job at reproducing the low liquid asset holdings at the bottom of the distribution. For example, median liquid assets relative to annual per-capita income is 0.07 in the data, compared to 0.14 in the model.

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[20] See the Appendix for the full list of moments and parameters for this and all other robustness checks.

Recall that our benchmark model predicts a ratio of median liquid assets to income of 0.08, much closer to the data. Owing to the counterfactually larger holdings of liquid assets at the bottom of the distribution, the model now predicts that liquidity constraints are slightly less severe. Only 76% of homeowners are constrained, with an average willingness to pay equal to 0.11. In contrast, in our benchmark model 82% of homeowners are liquidity constrained, with an average willingness to pay of 0.13.

8.3 Moving Shocks

Our benchmark model assumes no non-pecuniary barriers to homeownership. Agents in the model therefore only rent if they are relatively poor and cannot take advantage of the lower user cost of owner-occupied housing due to the LTV and PTI constraints on borrowing. Owing to this feature, the model fails to match the upper tail of the liquid asset distribution for renters. For example, the 90^{th} percentile of liquid assets to income of renters is equal to 1 in the data and only 0.29 in the model. Since renters account for almost one-third of all households, the model is also unable to match the upper tail of the overall distribution of liquid assets to income. For example, the 90^{th} percentile of this distribution is 1.50 in the data and 0.66 in the model.

To ensure that we have some rich households who rent, here we introduce an iid moving shock. Specifically, with probability $\pi_{h,r}$ a homeowner receives a moving shock and sells the home to become a renter. In addition, not all renters can enter the housing market: we assume a constant hazard $\pi_{r,r}$ with which a renter continues to rent. We choose these two additional parameters to match the 8% frequency of housing turnover in the 2001 Mortgage Bankers Association data, as well as moments of the distribution of liquid assets for renters.

Table 11 shows that this extension reproduces the distribution of liquid assets of all households much better. For example, the 90^{th} percentile of liquid assets to income is equal to 1.28, much closer to the 1.5 in the data. However, our conclusions regarding the severity of liquidity constraints are largely unchanged. We now find that 84% of homeowners are liquidity constrained, and willing to pay 12 cents for every dollar of home equity extracted, numbers very similar to those in our benchmark.

8.4 No Home Production

We finally illustrate the role home production plays in our benchmark model by setting ϕ, the parameter that governs the productivity of the home production sector, to zero. Table 11 shows that the model has a harder time rationalizing the very low liquid asset holdings of the bottom 50% of households: the median liquid assets to income is equal to 0.14, compared to 0.07 in the data and 0.08 in our benchmark calibration. Because agents cannot use home production to insure against bad income realizations, they compensate by accumulating more precautionary savings. Consequently, the model predicts that liquidity constraints are less severe: the mean willingness to pay for an additional dollar of home equity is now equal to 9 cents, compared to 13 cents in the benchmark model.

9 Conclusions

This paper is motivated by the observation that most U.S. households hold a disproportionately large share of their wealth in the form of housing equity. If home equity is illiquid, households are potentially exposed to large fluctuations in consumption stemming from idiosyncratic shocks. Whether this is indeed the case has important implications for the design of stabilization policies. We quantify how illiquid housing equity is by studying a life-cycle economy that explicitly models the key institutional details of the U.S. housing and mortgage market and that is parameterized to match salient features of household balance sheets and the frequency of home equity extraction.

We find that the U.S. housing market is very illiquid. Specifically, four-fifths of U.S. homeowners are liquidity constrained, in that they would benefit from a more liquid portfolio composition. On average, these homeowners would pay 13 cents for every dollar of home equity extracted, a sizable liquidity premium. The majority of liquidity constrained households have positive holdings of liquid assets and are therefore not hand-to-mouth. Rather, these homeowners value additional liquidity for precautionary reasons, in anticipation of the possibility of negative income shocks that might make it harder to finance mortgage payments and smooth consumption.

Our findings have implications for understanding consumption responses to various stabilization policies. First, the model can account for two-thirds of the consumption response to cash transfers of the type studied by Johnson et al. (2006), a number similar to that of the two-asset model by Kaplan and Violante (2014). In that sense, our paper complements a large recent literature studying two-asset models by taking a bottom-to-top approach and explicitly microfounding the illiquid asset. Second, we show that the model can also reproduce the evidence in Ganong and Noel (2019) that the consumption of homeowners responds much more to payment rather than debt reductions. Owing to the severity of liquidity constraints, the model predicts sizable welfare gains from mortgage assistance policies aimed at providing temporary liquidity relief to homeowners.

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Table 1: Motivating Evidence

A. Liquid Assets of US Households. 2001 SCF

	All HHs	Richest 20%	Poorest 80%
mean income	49,000	92,200	37,300
mean wealth	241,000	947,000	54,000
mean liquid assets	154,300	670,000	17,100
fraction homeowners	0.71	0.97	0.64
Lower tail of distribution of liquid assets. All households			
10th percentile	-900	32,100	-1,600
25th percentile	200	96,700	0
50th percentile	7,000	232,100	2,700
Lower tail of distribution of liquid assets. Homeowners			
10th percentile	-500	30,600	-1,400
25th percentile	1,600	94,600	400
50th percentile	15,600	225,000	5,700
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

B. Home Equity Extraction. 1999-2001 PSID

	Extract	Do Not Extract
fraction per year	0.08	0.92
median % increase in balance	0.24	
median change in LTV	0.11	
mean liquid assets	15,600	52,900
median liquid assets	800	6,000
mean liquid assets to wealth ratio	0.09	0.21
median liquid assets to wealth ratio	0.04	0.16

Note: All statistics adjusted for HH size using OECD equivalence scales and reported in 2016 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
variance log income	0.44	0.43	mean liquid assets	0.46	0.44
autocov log income 2 years	0.33	0.34	median liquid assets	0.07	0.08
autocov log income 4 years	0.31	0.31	mean liquid assets homeowners	0.53	0.64
std dev log income growth 2 years	0.41	0.41	median liquid assets homeowners	0.15	0.15
fraction homeowners	0.64	0.65	fraction hand-to-mouth	0.41	0.37
mean wealth	1.45	1.38	fraction hand-to-mouth homeowners	0.32	0.26
mean housing to income	1.82	1.77	90^{th} pct liquid assets homeowners	1.69	1.69
mean mortgage debt to income	0.83	0.82	mean wealth retirees to workers	2.00	2.04
fraction borrowers who extract	0.08	0.08	home production to consumption	0.23	0.25

B. Parameter Values

Assigned			*Calibrated*		
T	61	number of adult years	β	0.944	discount factor
σ	2	relative risk aversion	α	0.687	preference weight on housing
γ	1	home production elasticity	ϕ	0.939	efficiency home production
D	30	mortgage maturity	B	10.27	bequest motive
r_m	0.025	mortgage interest rate	R	0.045	rental rate of housing
θ_m	0.85	maximum LTV	$f_{0,m}$	1,330	fixed cost mortgage, 2016 USD
θ_y	0.21	maximum PTI	τ_0	0.358	slope liquid i-rate schedule
$f_{1,m}$	0.005	proportional cost mortgage	τ_1	10.33	location liquid i-rate schedule
ν	1/3	mean utility cost mortgage	r_h	0.016	upper bound liquid i-rate
f_s	0.06	cost of selling home	ρ_z	0.964	AR(1) persistent income comp.
π_δ	0.10	prob. maintenance shock	σ_z	0.150	volatility persistent income comp.
$\bar{\delta}$	0.063	size maintenance shock	σ_e	0.327	volatility transitory income comp.
r_l	-0.028	lower bound liquid i-rate			

Note: We scale the moments of the distribution of liquid assets, mortgage debt, wealth and housing by average annual income. A period in the model is equal to one quarter. All parameter values reported in Panel B are appropriately annualized.

Table 3: Households' Portfolio Composition

	Data	Model		Data	Model
A. Liquid Assets, All			**B. Liquid Assets, Homeowners**		
10th percentile	-0.04	-0.05	10th percentile	-0.04	-0.04
25th percentile	0	-0.01	25th percentile	0.01	0.02
50th percentile	0.07	0.08	50th percentile	0.15	0.15
75th percentile	0.48	0.27	75th percentile	0.68	0.36
90th percentile	1.50	0.66	90th percentile	1.69	1.69
C. Wealth			**D. Share Home Equity, Homeowners**		
10th percentile	0	-0.03	10th percentile	0.36	0.54
25th percentile	0.04	0.07	25th percentile	0.64	0.72
50th percentile	0.73	0.60	50th percentile	0.87	0.87
75th percentile	2.34	1.46	75th percentile	0.99	0.97
90th percentile	3.94	3.60	90th percentile	1.04	1.05
E. LTV, Borrowers			**F. PTI, Borrowers**		
10th percentile	0.18	0.33	10th percentile	0.05	0.05
25th percentile	0.39	0.54	25th percentile	0.08	0.07
50th percentile	0.62	0.70	50th percentile	0.11	0.10
75th percentile	0.77	0.79	75th percentile	0.17	0.15
90th percentile	0.88	0.83	90th percentile	0.24	0.23
G. Housing Value to Income Ratio			**H. Mortgage Age, Years**		
10th percentile	1.02	1.45	10th percentile	0	0
25th percentile	1.62	1.89	25th percentile	1	1
50th percentile	2.48	2.70	50th percentile	3	3
75th percentile	3.78	4.08	75th percentile	6	6
90th percentile	6.43	6.07	90th percentile	10	9

Note: We scale the distribution of liquid assets and wealth (Panels A to C) by average annual income.

Table 4: Additional Model Implications

	Data	Model
A. Mortgage Debt Management		
fraction ahead on payments	0.21	0.23
median growth in balance when extract	0.24	0.19
median change in LTV when extract	0.11	0.12
B. Characteristics of Borrowers who Refinance		
mean liquid assets to wealth: extractors	0.09	0.05
mean liquid assets to wealth: non-extractors	0.21	0.17
median liquid assets to wealth: extractors	0.04	0.04
median liquid assets to wealth: non-extractors	0.16	0.15

Table 5: Refinancing After A Decline in Mortgage Rate

	Data	$\nu = 1/3$	$\nu = 1/10$	$\nu = 0$
A. Refinancing in Steady State				
monetary cost of refinancing, $f_{0,m}$, 2016 USD		1,330	2,590	3,580
fraction who would refinance absent utility cost		0.22	0.08	0.02
average welfare gains from refinancing, 2016 USD		1,020	920	1,520
fraction who refinance		0.02	0.02	0.02
B. Refinancing After Decline in Mortgage Rate				
decline in pre-tax mortgage rate	1.75	1.75	1.75	1.75
fraction who would refinance absent utility cost		0.79	0.75	0.44
average welfare gains from refinancing, 2016 USD		2,730	1,500	480
fraction with positive savings from refinancing		1.00	0.99	0.98
average savings from refinancing, 2016 USD		15,970	14,600	13,610
fraction who refinance	0.16	0.16	0.24	0.44

Notes: The statistics in the data are from Johnson et al. (2019). The welfare gains from refinancing are computed as the difference between the value of refinancing and the best alternative option, scaled by the marginal utility of consumption. The average savings from refinancing are calculated as the difference between the PV of the mortgage payments under the original mortgage contract, net of the mortgage payments upon refinancing to the lower interest rate and the mortgage origination costs.

Table 6: Importance of Liquidity Constraints

A. Value of Liquidity

	$\nu = 1/3$	$\nu = 1/10$	$\nu = 0$	$\nu = 1/3$ and r_m increase
Fraction better off	0.82	0.81	0.80	0.83
Willingness to pay				
mean	0.13	0.13	0.12	0.20
10th percentile	0.01	0.01	0.01	0.02
25th percentile	0.05	0.05	0.04	0.07
50th percentile	0.12	0.12	0.10	0.19
75th percentile	0.20	0.19	0.18	0.30
90th percentile	0.27	0.26	0.25	0.38

B. Fraction Consumed

	$\nu = 1/3$	$\nu = 1/10$	$\nu = 0$	$\nu = 1/3$ and r_m increase
mean	0.12	0.11	0.10	0.14
10th percentile	0.01	0.01	0.01	0.02
25th percentile	0.05	0.05	0.04	0.06
50th percentile	0.10	0.09	0.08	0.11
75th percentile	0.17	0.16	0.15	0.18
90th percentile	0.27	0.26	0.27	0.27

Note: The table reports results from a one-time liquidity injection that increases homeowners' liquid assets and mortgage debt by 1% of the value of their homes, leaving their wealth unchanged.

Table 7: Marginal Propensity to Consume out of a \$500 Cash Transfer

A. Economy with $\nu = 1/3$

	all	homeowners	renters
mean	0.17	0.14	0.22
10^{th} percentile	0.03	0.02	0.06
25^{th} percentile	0.07	0.06	0.12
50^{th} percentile	0.14	0.11	0.20
75^{th} percentile	0.22	0.18	0.25
90^{th} percentile	0.33	0.27	0.43

B. Economy with $\nu = 1/10$

	all	homeowners	renters
mean	0.16	0.13	0.22
10^{th} percentile	0.03	0.02	0.06
25^{th} percentile	0.07	0.05	0.13
50^{th} percentile	0.13	0.10	0.20
75^{th} percentile	0.22	0.18	0.25
90^{th} percentile	0.33	0.27	0.43

C. Economy with $\nu = 0$

	all	homeowners	renters
mean	0.15	0.11	0.21
10^{th} percentile	0.02	0.02	0.06
25^{th} percentile	0.06	0.05	0.13
50^{th} percentile	0.13	0.10	0.19
75^{th} percentile	0.21	0.17	0.24
90^{th} percentile	0.33	0.29	0.39

Note: The table reports the marginal propensity to consume out of a one-time \$500 cash transfer.

Table 8: Mortgage Modification Program

	Only Payment Reduction		Payment and Principal Reduction	
	All	Underwater	All	Underwater
fraction better off	0.87	0.97	1	1
Δ welfare/transfer	0.16	0.22	1	1
Δ consumption/transfer	0.36	0.46	0.39	0.47

Table 9: Mortgage Forbearance Program

	Before	After
A. Steady State Comparisons		
fraction homeowners	0.65	0.72
mortgage debt to income	0.82	1
fraction borrowers who extract	0.08	0.08
fraction homeowners with reduced payments		0.26
mean payment reduction, 2016 USD		520
B. Average Welfare Gains, 2016 USD		
all households		1,770
homeowners		1,880
renters		1,580
poorest 25%		2,630

Table 10: Robustness: 2016 Calibration

A. Moments

	2016 Data	Model
I. Aggregate Moments		
fraction homeonwers	0.59	0.60
wealth to income	1.27	1.24
housing to income	1.86	1.80
mortgage debt to income	0.92	0.89
mean liquid assets to income	0.34	0.33
fraction borrowers who extract	0.05	0.05
II. Distribution of Liquid Assets		
10th percentile	-0.05	-0.05
25th percentile	0.00	-0.03
50th percentile	0.03	0.05
75th percentile	0.30	0.25
90th percentile	1.12	0.73

B. Parameter Values

discount factor, β	0.944
preference housing, α	0.700
fixed refi cost, $f_{0,m}$, 2016 USD	5,400
upper bound liquid rate, r_h	0.012
rental rate housing, R	0.049

C. Severity of Liquidity Constraints

	2001 calibration	2016 calibration
fraction liquidity constrained	0.82	0.83
mean valuation liquidity	0.13	0.20
mean fraction consumed	0.12	0.16

Table 11: Additional Robustness Checks

A. Moments

	Data	Constant r_l	Moving shocks	No home prod.
I. Aggregate Moments				
fraction homeowners	0.64	0.64	0.65	0.67
wealth to income	1.45	1.40	1.37	1.32
housing to income	1.82	1.70	1.76	1.71
mortgage debt to income	0.83	0.73	0.87	0.84
mean liquid assets to income	0.46	0.43	0.48	0.45
fraction borrowers who extract	0.08	0.07	0.08	0.08
II. Distribution of Liquid Assets				
10th percentile	-0.04	-0.03	-0.05	-0.04
25th percentile	0.00	0.02	0	0.03
50th percentile	0.07	0.14	0.10	0.14
75th percentile	0.48	0.39	0.30	0.29
90th percentile	1.50	0.87	1.28	0.62

B. Parameter Values

	Constant r_l	Moving shocks	No home prod.
discount factor, β	0.952	0.945	0.914
preference housing, α	0.475	0.793	0.976
fixed refi cost, $f_{0,m}$, 2016 USD	1,030	160	990
upper bound liquid rate, r_h	0.007	0.014	0.021
rental rate housing, R	0.042	0.054	0.048

C. Severity of Liquidity Constraints

	Constant r_l	Moving shocks	No home prod.
fraction liquidity constrained	0.76	0.84	0.82
mean valuation of liquidity	0.11	0.12	0.09
mean fraction consumed	0.09	0.14	0.05

Figure 1: Decision to Refinance

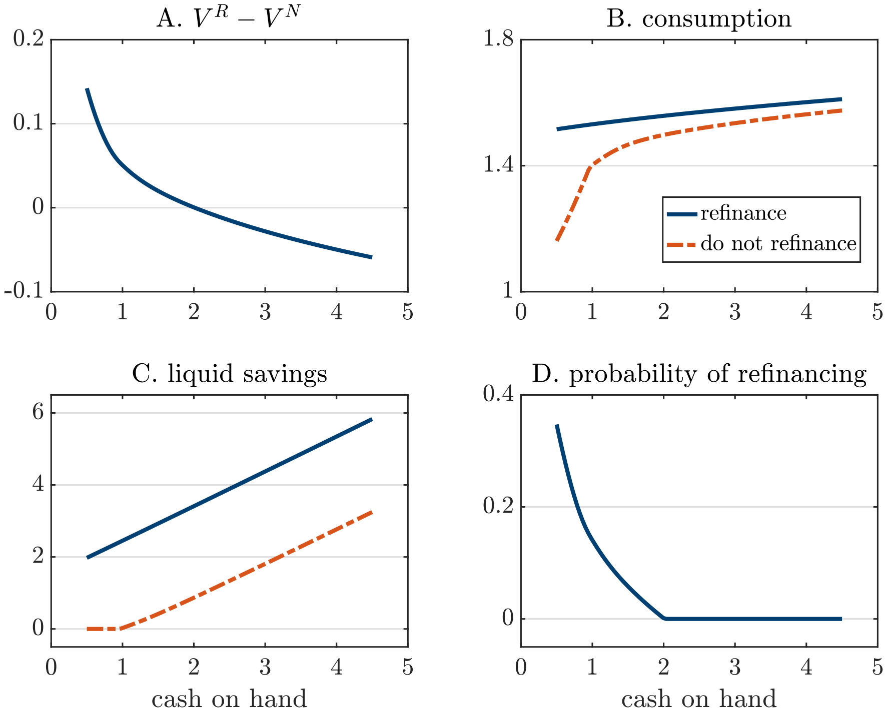

Figure 2: Probability of Refinancing

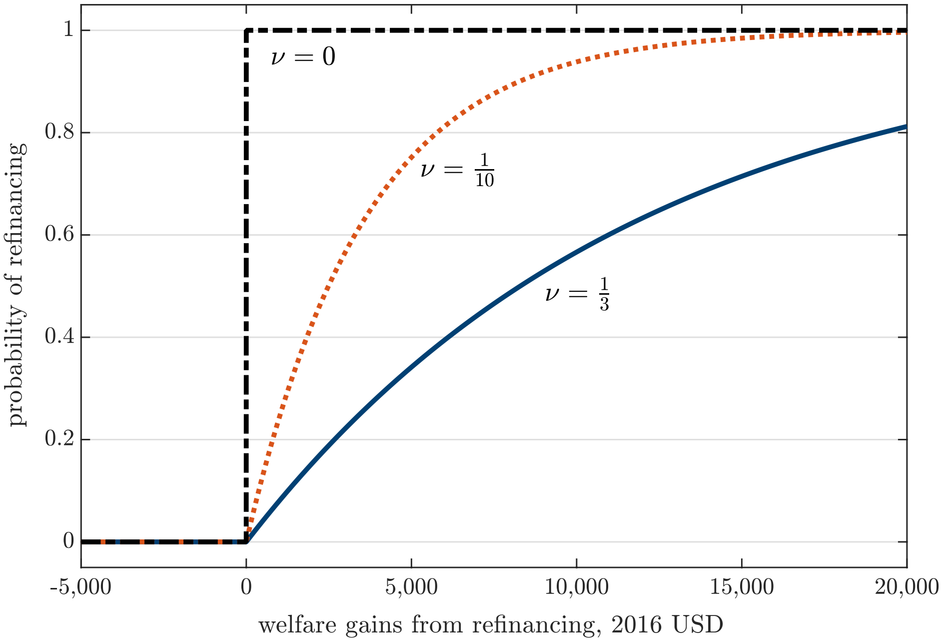

Figure 3: Life-Cycle Statistics

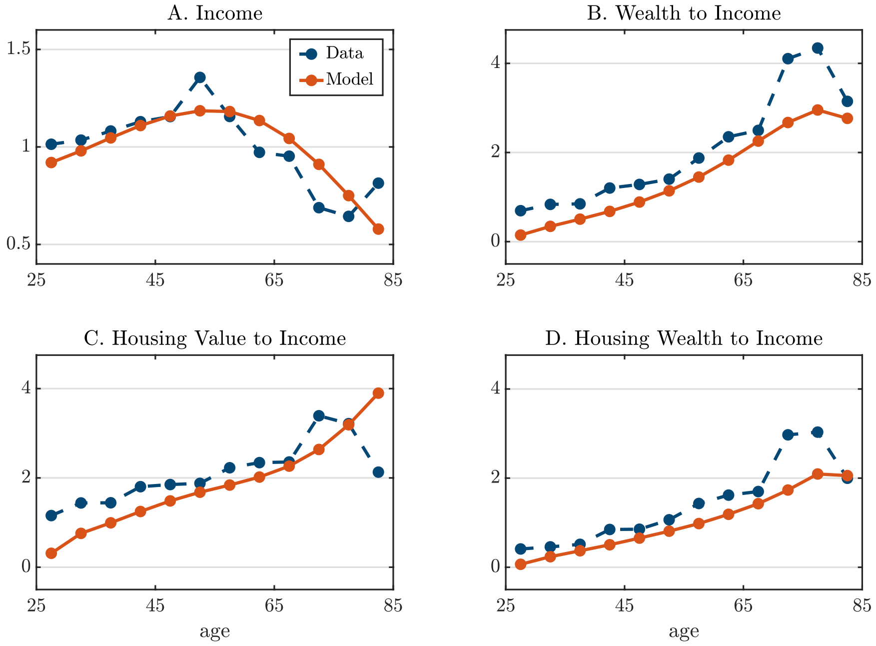

Figure 4: Value of Liquidity

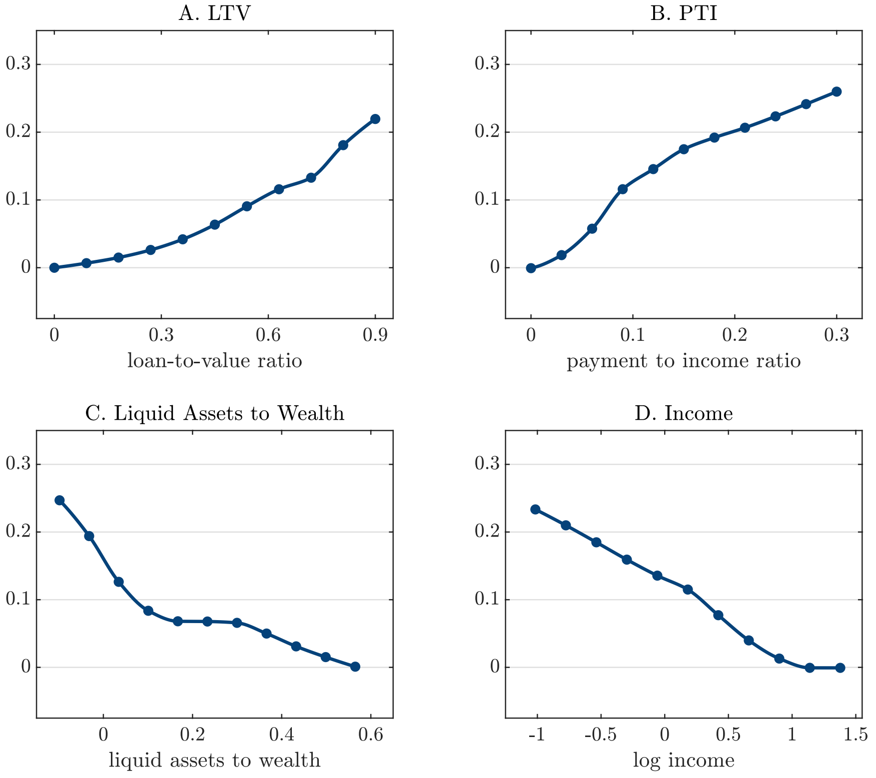

Figure 5: Marginal Propensity to Consume out of a Cash Transfer