Do Changes in Mortgage Credit Constraints Explain the Housing Boom and Bust?

Andra C. Ghent

University of Wisconsin-Madison

ghent@wisc.edu

Preliminary and Incomplete

October 1, 2018

Abstract

This paper documents patterns in US mortgage debt and home ownership in recent decades and explores how well changes in mortgage credit constraints can explain these changes. The age-adjusted home ownership rate declined slightly between 2000 and 2007, but the real stock of residential mortgage debt doubled. Since 2007, age-adjusted home ownership rates have trended down significantly as has the real stock of residential mortgage debt. The paper builds an equilibrium life-cycle model of tenure and mortgage choice that shows that a relaxation of the Loan-to-Value (LTV) constraint increases the homeownership rate for young, high-income households.

1 Introduction

The last two decades have featured dramatic changes in the availability and use of mortgage credit. The first part of this paper summarizes data and literature on the mortgage credit landscape in the last two decades. I use this data to generate facts that a theory of the boom and bust in the housing market needs to explain. Most strikingly, any theory of the boom period of 2000-2007 needs to reconcile 1) no increase in the age-adjusted home ownership rate, and 2) a dramatic increase in the real stock of mortgage debt relative to real home prices. The bust period, in contrast, features significant declines in age-adjusted home ownership rates for all ages but especially those under the age of 55.

I then build an equilibrium life cycle model based on Ghent (2015) to study how well changes in credit constraints can explain the boom and bust. In particular, I look at how changes in the maximum loan-to-value (LTV) on a low down payment (LDP) mortgage affect the stock of mortgage debt and home ownership rates by age. I show that the main effect of such a relaxation of the LTV constraint is an increase in the age-adjusted home ownership rate, particularly the home ownership rate of high-income young households.

The findings in this paper indicate that we need to look to other changes in the mortgage landscape to explain increasing levels of mortgage debt with no change in the home ownership rate during the boom. While optimism in home price expectations is likely a necessary ingredient, a promising further candidate is a decrease in the cost of extracting equity. Our findings also suggest that the tightening of mortgage credit constraints during the bust period, in part due to more regulation, is decreasing home ownership consistent with the empirical evidence in Gete and Reher (forthcoming).

2 Trends in Housing Finance

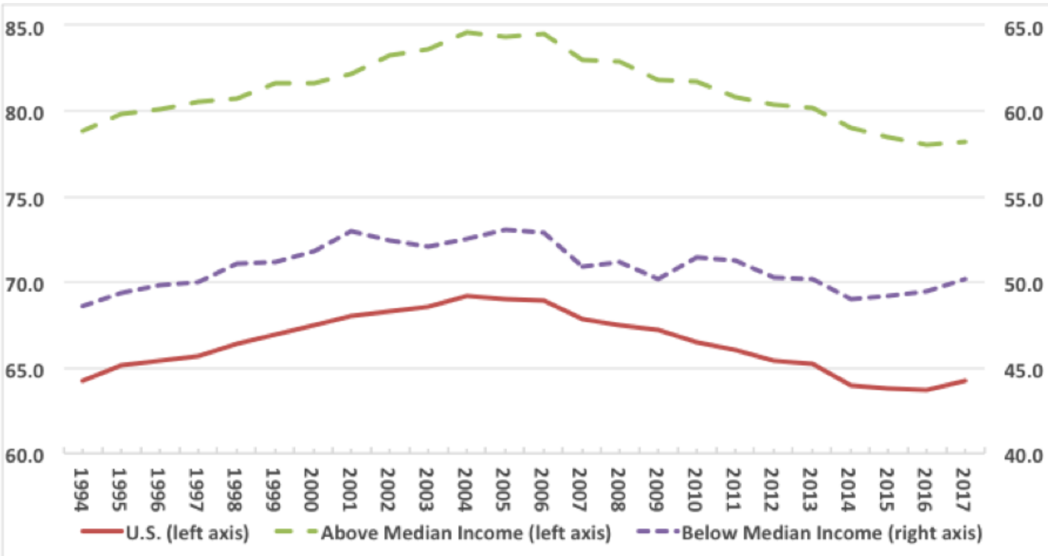
2.1 Homeownership

The top panel of Figure 1 plots the aggregate US home ownership rate as well as the home ownership rate for those above and below the median income. The overall rate rises by 5% (3.3 percentage points) between 1994 and 2000, from 64.2% to 67.5%. Home ownership rises for both low- and high-income American households but the rise is sharper for low-income Americans. The home ownership rate for those below the median income rose by 6.6% while the rise for households above the median income level was only 3.6%.

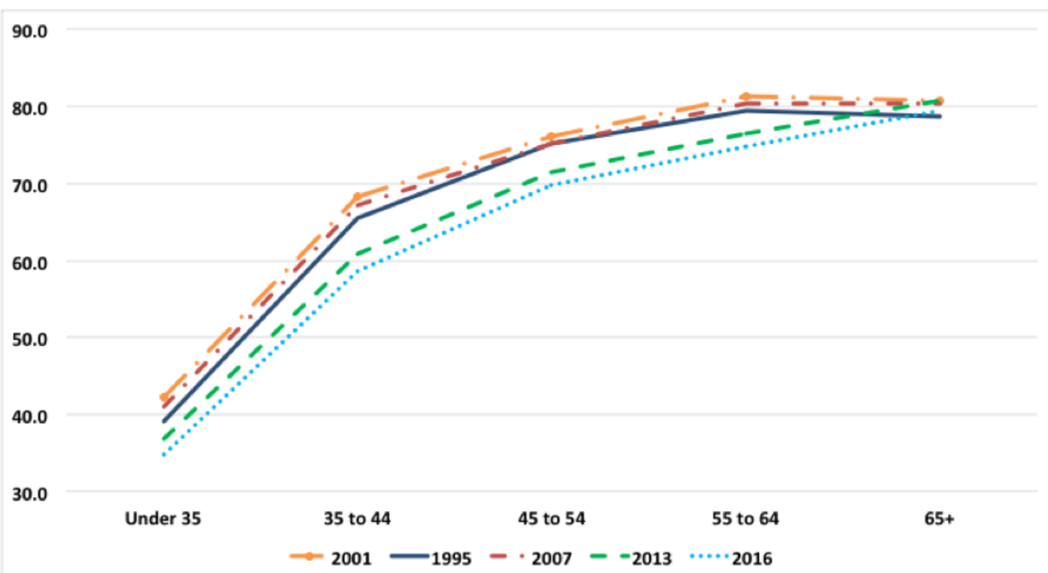
The aggregate home ownership rate peaks at 69.2% in 2004. It stays close to that level until 2007 when it begins a steady decline that levels out at about 64% in 2014. Looking specifically at the 2000 to 2007 period, which is commonly considered to be the boom period for housing prices and nonprime mortgage originations, the increase is just 0.3 percentage points or 0.4%. The home ownership rate for low-income Americans actually declines slightly over this period from 51.8% to 50.9%.

The small increase in the aggregate home ownership rate over the 2000-2007 housing boom is, however, partly due to the aging of the US population. The bottom panel of Figure 1 shows the home ownership rate by broad age category for 1995, 2001, 2007, 2013, and 2016. The home ownership rate in 2001 is higher for every age category than in 1995. However, the home ownership rates within an age category actually *decline* slightly between 2001 and 2017. Home ownership rates by age category fall significantly between 2007 and 2013 for all ages except senior citizens with a slight further decline between 2013

Figure 1: US Homeownership, 1994-2017



(a) By Income Group



(b) By Age Category

Source: U.S. Census Bureau, Current Population Survey / Housing Vacancy Survey, July 26, 2018.

and 2016.

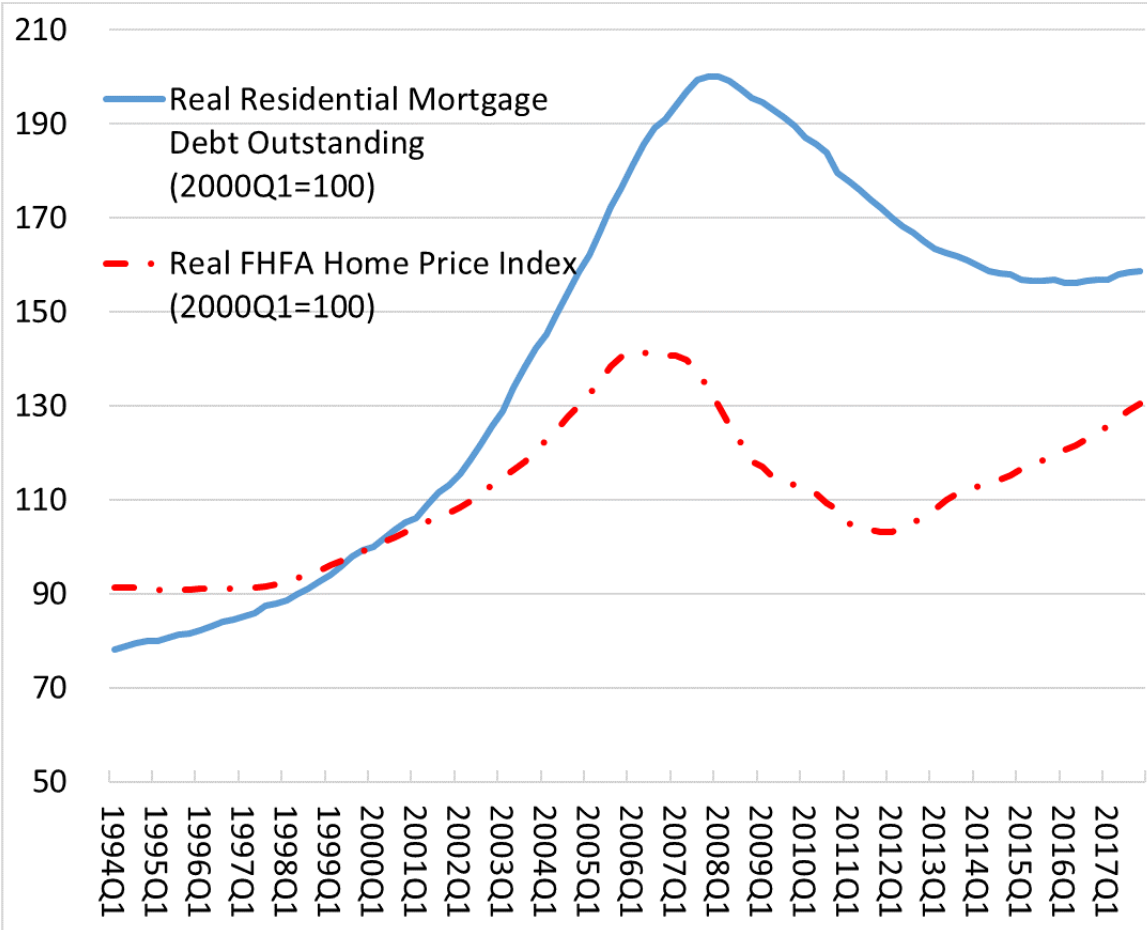
The decline in home ownership in the bust period is of a similar magnitude for low and high income Americans. For households above the median income, home ownership peaks at 84.6% in 2004 and reaches a trough of 78% in 2016, a total decline of 6.6 percentage points or almost 7.8%. Home ownership for households below the median income declines from 53.1% to 49% or about 7.7%.

2.2 Mortgage Credit

Although the age-adjusted home ownership rate did not increase during the boom, the real stock of residential mortgage debt almost doubled over this period as Figure 2 shows. Some of the increase in mortgage debt was likely to finance more expensive homes rather than a deliberate decision by borrowers and lenders to increase leverage. Indeed Adelino et al. (2018) find that the increase in mortgage credit was most pronounced in areas with the fastest increase in home prices. Nevertheless, the increase in the FHFA home price index was only 40% during the boom period.

While very high by historical standards, such growth can account for less than half of the growth in the stock of mortgage debt as Table 1 illustrates. Table 1 shows how a growth rate in home prices of 40% would affect a typical US household's mortgage debt with no change in the household's ability to generate a down payment. For a household that could initially come up with a 20% down payment, the growth in mortgage debt from the increase in home prices would be 50%. For a household that could initially come up with only a 10% down payment, the growth is 44% while the growth is 40% for

Figure 2: US Real Residential Mortgage Debt and Home Prices



Sources: Federal Reserve Financial Accounts of the United States, FHFA, and BLS.

households with no initial down payment.

Thus, most of the growth in mortgage debt between 2000 and 2007 came along the intensive margin with home owners taking on higher relative mortgage burdens. However, Adelino et al. (2018) find no discernible trend in combined LTVs (CLTVs) at origination. Thus, it seems more likely that much of the increase in mortgage debt during the boom is due to home equity extraction, a channel emphasized by Greenspan and Kennedy (2008). Lee et al. (2013) find that the majority of second liens are taken out subsequent to origination, a finding that can reconcile significant growth in mortgage debt along the intensive

Table 1: Hypothetical Change in Mortgage Debt for Home Price Growth of 40%

	2000	**2006**	**Growth**
Home Price	$ 300,000	$ 420,000	40%
LTV	80%	86%	
Mortgage Debt	$ 240,000	$ 360,000	50%
Down Payment	$ 60,000	$ 60,000	
LTV	90%		
Mortgage Debt	$ 270,000	$ 390,000	44%
Down Payment	$ 30,000	$ 30,000	
LTV	100%		
Mortgage Debt	$ 300,000	$ 420,000	40%
Down Payment	$ -	$ -	

Notes: 1) Table shows hypothetical increase in mortgage debt generated by a 40% increase in real home prices between 2000 and 2007. 2) Table assumes no growth in household wealth between the two years such that any increase in home purchase price must be financed. 3) Table shows an initial home price of $300,000 for exposition purposes but growth rates are the same regardless of the initial home price.

margin with no change in CLTVs at origination.

Several recent papers explore how the growth of residential mortgage debt differed across different income groups during the boom. These papers show that the growth in mortgage credit was broad-based and occurred among all income groups rather than being concentrated among low-income borrowers. Figure 3, taken from Foote et al. (2016), illustrates that the growth in mortgage debt during the boom was evenly distributed across household income and neighborhood income quintiles. Foote et al. (2016) argue that, although the growth rate was roughly evenly distributed across income groups, the larger total amounts of debt held by high-income mortgage borrowers generate disproportionate shares of the increase. Adelino et al. (2018) similarly emphasize that both the flow and stock of debt rose across all income groups.

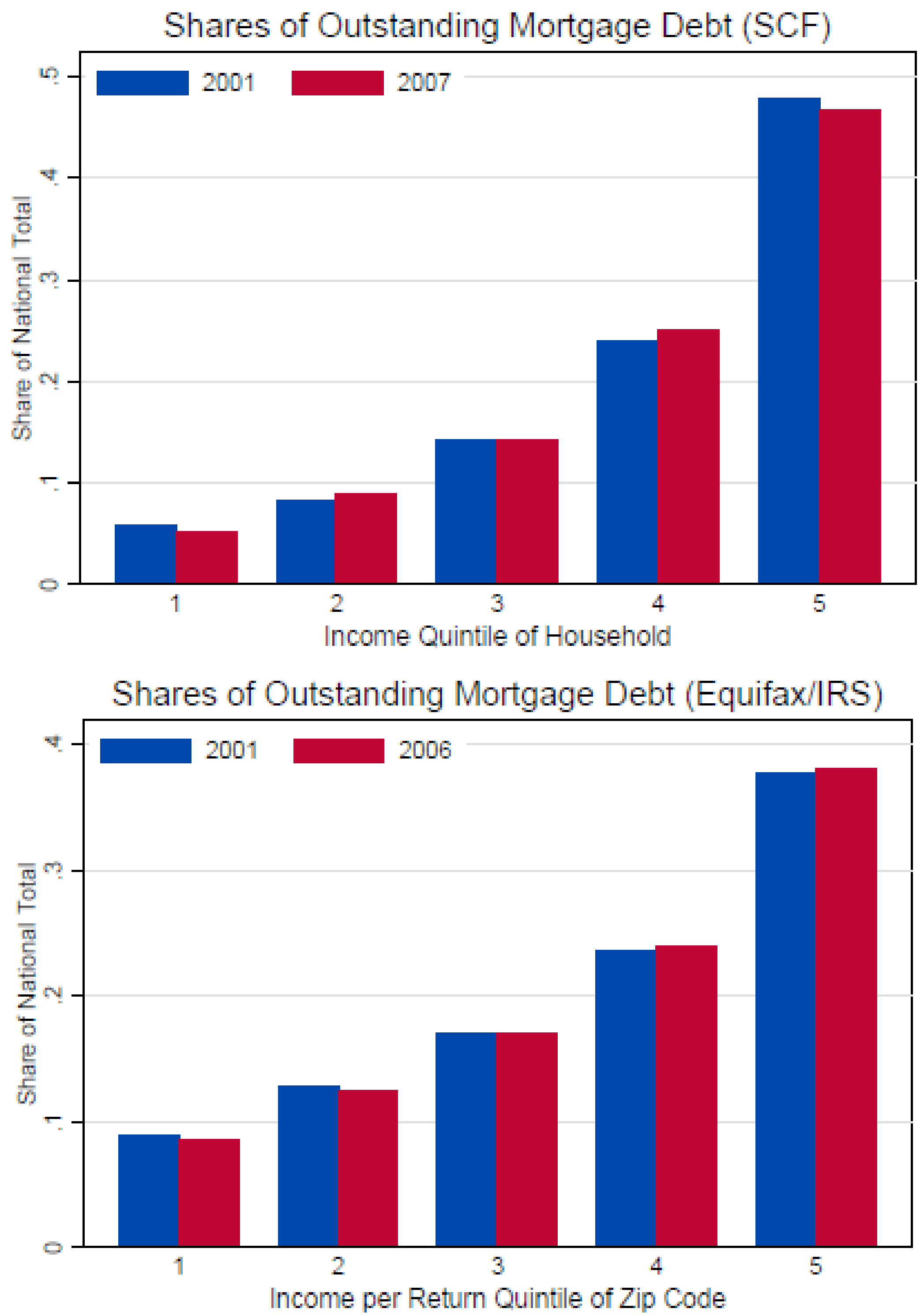
The broad-based growth in mortgage credit was also not confined to borrowers with low credit scores. Indeed, Albanesi et al. (2017) show that mortgage debt growth during the boom was concentrated on borrowers in the upper half of the FICO score distribution. As such, they argue that subprime, at least using a definition of subprime based on borrower credit scores, which are highly correlated with household income, is not a first order factor in the boom.

None of these papers dispute the growth in the PLMBS market during this period. Figure 4 illustrates the explosion in the issuance of PLMBS during the boom. It is worth noting that many of the mortgages securitized in PLMBS were not made to low-income borrowers, however. In their analysis of mortgages on property in California and Florida, Ghent et al. (2015) show that the average borrower in a PLMBS pool had a stated household income of over $100,000. Rather than being a niche product originated to a set of households historically excluded from the mortgage market, subprime was very much a middle-class product.

3 The Model

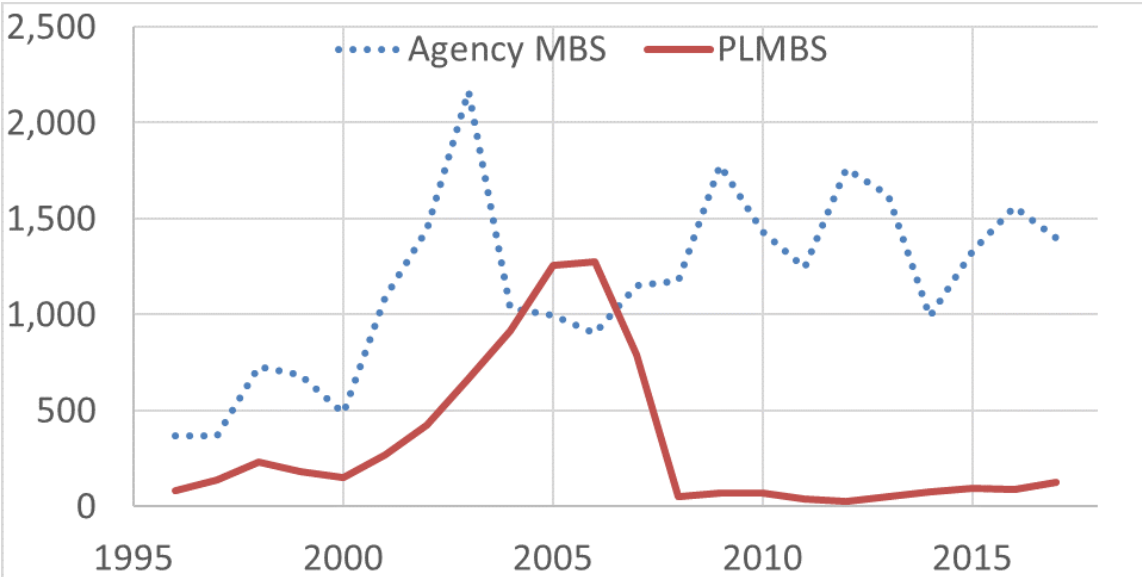
I study an overlapping generations endowment economy similar to that in citetGhent2015. Households live for at most J periods of which $J_{RET} < J$ are spent "working". Each period, the household makes decisions regarding its tenure, assets, and mortgage choice. If the household chooses to rent, it must rent a home of quality h_1. If a household chooses to own its home, it chooses what quality of home to buy, and selects a mortgage (when given a choice). The mortgage rate for each mortgage type is computed as the rate that makes the expected present value of the mortgage equal to the mortgage balance at orig-

Figure 3: Cross-Sectional Distribution of Mortgage Debt



Source: Foote et al. (2016).

Figure 4: US MBS Issuance by Year, USD Billions



Source: SIFMA.

ination. There are a small number of home qualities; a small number of home qualities reduces the computation required to solve the model.

The price of a unit of housing (in terms of the non-housing consumption good) is exogenous. Households face idiosyncratic income and home quality risk.[1] I represent stochastic home values by assuming the home will decrease or increase in quality with exogenously given probability; the home quality follows a Markov chain. As in other models with mortgage choice and foreclosure, I model home prices as exogenous to focus on modeling mortgage contracts and mortgage default in more detail. If a financial intermediary is forced to foreclose on a borrower, it incurs a cost χ (a percentage of the home value at the time of foreclosure) to rehabilitate the home to the quality it was at the time of foreclosure.

[1]See, among others, Case and Shiller (1989), Goetzmann (1993), Quigley and Van Order (1995), Deng et al. (2000), and Flavin and Yamashita (2002) for evidence that a substantial portion of the variation in home values is idiosyncratic.

Similar to Campbell and Cocco (2015) and Corbae and Quintin (2015), there is no option to refinance to keep the model computationally tractable. Prepayment in the model thus corresponds to a sale of the home. When the household wishes to sell its home, it must pay a fixed cost that is a percent of the value of the home. The sale of the home may be viewed as a particular kind of refinancing: the household may refinance into the same value of home with a new mortgage if it pays the fixed moving cost. Viewed this way, the moving cost is akin to a prepayment penalty. The moving cost is what makes the home a commitment device for saving. Because the household cannot easily change its housing investment decision, taking on a mortgage commits the household to a particular savings path.

To fit the home ownership rate patterns of older households in the data, I assume a bequest motive on the part of the household. I model the bequest motive similarly to Campbell and Cocco (2003), Cocco (2005), and Cocco et al. (2005). When a household dies, a newly born household that begins life with no assets immediately replaces it.

At the beginning of each period, the household learns its income for that period and, if it is an owner, whether its home has appreciated or depreciated in value. The household then makes its tenure, housing, mortgage termination, mortgage product, and consumption decisions. If the household chooses to enter into a new mortgage contract, it makes the down payment at the start of the period. At the end of the period, the household receives its income, consumes, and makes rent or mortgage payments. Mortgages are non-recourse in the sense that the lender cannot seize assets other than the house if the borrower defaults on the mortgage.

3.1 Households

Households that choose to own a home take on a T period mortgage. The household's state vector is $\{j, a, H, h, n, h_O, \kappa, y\}$ where $j \in \{0, ..., J-1\}$ represents the household's age, a represents the household's assets, $H \in \{0, 1\}$ is the household's tenure, $h \in \{h_1, h_2, h_3\}$ is the home quality, $n \in \{0, ..., T\}$ is the number of periods the household has remaining on in its current mortgage, and $h_O \in \{h_2, h_3\}$ denotes the home quality that the household chose at origination. As in Gervais (2002) and Corbae and Quintin (2015), the poorest quality home a household can buy is h_2 rather than h_1. Income, y, is exogenous and follows a Markov process. $\kappa \in \{TRAD, LDP\}$ represents the household's mortgage type. A TRAD mortgage is a traditional mortgage that requires a down payment of ν_{TRAD} percent, full amortization over the term of T periods, and carries a constant interest rate of r_{TRAD}. A LDP mortgage is a mortgage that requires a down payment of ν_{LDP}, is fully amortizing over T periods, and carries a constant interest rate of r_{LDP}.

The household aged j that enters the period with assets a, tenure H, home quality h, n periods remaining on its mortgage, mortgage type κ, and income y thus chooses its tenure, housing, mortgage, and assets to maximize

$$u\left(c, h', H'\right) + \beta \pi_j E V\left(j+1, a', H', h', n', h'_O, \kappa', y'\right) + \beta\left(1 - \pi_j\right) E \ln W \tag{1}$$

where

$$n' = \left\{ \begin{array}{c} \left(1 - \mathbf{1}_S - \mathbf{1}_D\right) \max\left(0, n-1\right) + \mathbf{1}_B (T-1) \; if \; H' = 1 \\ 0 \; if \; H' = 0 \end{array} \right\},$$

The indicator function $\mathbf{1}_B$ takes on a value of one if the household buys a new home in that period, and hence takes on a new mortgage, and 0 otherwise. The indicator $\mathbf{1}_D$ takes on a value of 1 if the household chooses to default in that period, 0 otherwise. The indicator $\mathbf{1}_S$ takes a value of 1 if the household chooses to sell its home, 0 otherwise. π_j is the probability that a household that has survived to age j survives to age $j+1$.

W represents net worth in equation (1) and $V(\cdot)$ is defined by

$$V(j, a, H, h, n, h_O, \kappa, y) = max \left\{ \begin{array}{c} u(c, h', H') + \\ \beta\pi_j EV\left(j+1, a', H', h', n', h'_O, \kappa', y'\right) \\ +\beta\left(1-\pi_j\right) E \ln W \end{array} \right\}.$$

In computing expected net worth, I assume that when a household dies the housing position is liquidated and the financial intermediary is repaid the debt if the house value is adequate or receives the house value.

For a household that starts the period as a renter $(H = 0)$, the constraint on (1) is

$$c + a' = y + (1+r)\left(a - H'v(\kappa) qh'\right) - H'\left(p_T(\kappa) + \delta h'\right) - \left(1 - H'\right) Rh_1 \qquad (2)$$

where q is the price per unit of housing, $p_n(\kappa)$ is the payment due on a mortgage of type κ with n periods remaining, δ is the depreciation rate, and R is the rental rate.

If the household starts the period as an owner $(H = 1)$, it decides whether to default on its mortgage and whether to sell its home. If the household decides to default, $H' = 0$.

The constraints on (1) if $H = 1$ are thus

$$\begin{aligned}
c + a' &= y + (1+r)\left(a + \mathbf{1}_S\left[q\left(1-\sigma\right)h - b_n\left(\kappa\right)\right] - H'\mathbf{1}_B\nu\left(\kappa\right)qh'\right) \\
&\quad - H'\left[\left(1-\mathbf{1}_B\right)p_n\left(\kappa\right) + \mathbf{1}_B p_T\left(\kappa'\right) + \delta h'\right] - \left(1-H'\right)Rh_1, \\
H' &\equiv 0 \; if \; \mathbf{1}_D = 1, && (3) \\
& \kappa' \left\{ \begin{array}{c} \in \{TRAD, LDP\} \;\; if \; \mathbf{1}_B = 1 \\ = \kappa \; if \; \mathbf{1}_S \cup \mathbf{1}_D = 0 \\ = \emptyset \; if \; H' = 0 \end{array} \right\}, \; and && (4) \\
h'_O &\equiv h_O \; if \; \mathbf{1}_B = 0. && (5)
\end{aligned}$$

where σ represents the transactions cost of selling a home and $b_n(\kappa)$ is the outstanding balance on a mortgage of type κ with n periods remaining on its term.

The interpretation of (3) is that if the household chooses to default on its mortgage, it must rent for that period. Equations (4) and (5) represent the fact that the household cannot refinance. Equation (4) says that the household can only enter into a new mortgage contract when it buys a new home and κ is null if the household chooses to rent. Households in the model choose between TRAD and LDP. Equation (5) is mechanical: it says merely that the household's state variable for the home quality at origination does not change if the household does not buy a new home.

The Benefits of Home Ownership

In this framework, there are two potential benefits of owning a home relative to renting. First a premium for owning relative to renting is built into the felicity function through its dependence on tenure chosen in that period, H'. In this respect, I follow Hu (2005), Chu (2014), and Corbae and Quintin (2015). Arguably, the owner-occupied utility premium captures the benefit from a household being able to customize an owner-occupied home (e.g., paint the kitchen purple or install carpeting instead of wood floors) and any psychic benefit from owning relative to renting.

Second, households can only rent a home of quality h_1; if a household wants to consume housing services associated with a home of quality h_2 or h_3, it must be a home owner. I follow Corbae and Quintin (2015) in this respect. These assumptions are important to generate home ownership rates similar to what we observe in the data. The assumption that all rental homes are of quality h_1 also implies that the housing share of expenditure is declining in income. The assumptions are also important for understanding the results regarding welfare.

3.2 Financial Intermediary

As in Corbae and Quintin (2015), the financial intermediary is an infinitely lived company that accepts household savings and makes mortgage loans. It earns the exogenously given rate r on savings. Each period, it pays a servicing cost ϕ, a percent of the value of the mortgage, on each mortgage it holds. It also holds a stock of housing capital which it can rent out at rate R per unit or sell to households as owner-occupied housing. It incurs the maintenance cost δ on its housing stock and a cost χqh of rehabilitating housing units it acquires through foreclosure. In equilibrium, it must make zero profits. Since the value of a home must be equal to the present value of future rents, in equilibrium each unit of housing rents at rate $R = rq + \delta$ where q is the price per unit of housing.

3.3 Home Values

As in Corbae and Quintin (2015), stochastic house prices are captured by households facing an exogenously given probability that their house changes in quality and, hence, value. In particular, a home owner that currently owns a home of quality h_2 faces a probability λ that the home will increase to quality h_3 and a probability λ that the home will decrease to quality h_1. A home owner that currently owns a home of quality h_3 faces a probability λ that the home will depreciate to quality h_2. A home owner that owns a home of quality h_1 faces a probability λ that the home will increase to a home of quality h_2. Rental units, all of which are of quality h_1, do not change in quality.

3.4 Steady State Equilibrium and Computation

In equilibrium, lenders make zero profits. This implies that the contract rates, r_{TRAD} and r_{LDP} are the rates that equate the expected present value of the mortgage to the loan balance at origination. The equilibrium concept in this paper is the same as that Athreya (2002): the equilibrium is a pooling equilibrium where the financial intermediary offers the same interest rate to all borrowers in a particular product category. In Corbae and Quintin (2015), the mortgage interest rate is specific to a single household's asset, income, and housing combination such that it represents financial intermediaries assessing the risk of individual households. Introducing interest rates specific to each individual is unlikely to qualitatively change the predictions of the model regarding how credit constraints affect different age groups and substantially increases the computational cost of solving the model. The opportunity cost of the lender's funds is the riskless interest rate, r; it costs lenders ϕ to service the mortgage rate. Lenders thus compute the present value of the mortgage rate by discounting the expected cash flows by $r + \phi$. An equilibrium is thus a set of interest rates, $\{r_{TRAD}, r_{LDP}\}$, such that the average present value of a mortgage contract κ is equal to the size of the mortgage at origination.

The solution algorithm consists of two loops. In an inner loop, I solve the household's problem using grid search over each of the choice variables for a given pair of interest rates, r_{TRAD} and r_{LDP}. I simulate the model over 20,000 households for 1,000 periods for each mortgage rate or rates. I drop the first 100 periods as burn-in iterations.

The outer loop solves for the mortgage rate or rates. After solving the household's problem and simulating the model based on the solution to the household's problem, I compute the average present value of a mortgage contract of type κ. With a large enough number of households and periods, the average present value of the mortgage contract will also be the expected present value of the mortgage contract. Thus, if the difference between the average present value of a mortgage contract and the loan balance at origination is sufficiently small, the mortgage rates constitute an equilibrium.

4 Benchmark Parameterization

Table 2 summarizes the benchmark parameterization. Several of the parameters are fixed based on empirical estimates. The remaining parameters are chosen to ensure that the model matches certain moments in the data.

Table 2: Benchmark Parameterization

Parameter	Description	Value	Fixed or Calibrated
β	3-Yr Discount Factor	0.857	Fixed
ν_{TRAD}	Down Payment Share for TRADs	20%	Fixed
r	3-Yr Real Risk-Free Rate	0.12	Fixed
ψ	Non-housing Consumption Share	0.76	Fixed based on Davis and Ortalo-Magné (2011)
θ	Owner-occupied Premium	0.0	Calibrated
h_1	Small House Size	29,390	Calibrated
h_2	Mid-Size House Size	45,421	Calibrated
h_3	Large House Size	66,795	Calibrated
q	Relative Price of Housing	1.0	Calibrated
λ	House Price Shock Probability	0.15	Calibrated
ϕ	Servicing Cost	0.02	Calibrated
χ	Foreclosure Discount	0.25	Fixed based on Campbell et al. (2011)
δ	Housing Depreciation	0.04	Calibrated
ρ	Selling Costs	0.08	Fixed
T	Mortgage Contract Term	10	Fixed (30 years)
J	Maximum Life Span	20	Fixed
J^{ret}	Retirement Age	13	Fixed

4.1 Preferences

The felicity function is

$$u\left(c, h, H\right) = \psi \ln c + \left(1 - \psi\right) \ln h + \theta \mathbf{1}_{h > h_1}.$$

I set ψ to 0.76 implying that renters spend 24% of their consumption expenditure on housing based on the estimates in Davis and Ortalo-Magné (2011). There are no good estimates for θ such that I use θ to calibrate the model to match certain characteristics of the data.

4.2 Demographics

A period in the model corresponds to 3 years. The household is born at age 25, such that $j = 0$ corresponds to a chronological age of 25. The household lives until at most 85 years of age corresponding to $J = 20$. The age at which the household retires, J^{RET}, is 13 such that the household retires at a chronological age of 64. I take the survival probabilities, $\{\pi_j\}_{j=0}^{J-1}$, from Arias et al. (2008).

4.3 Income

I assume that the income process during working years follows an AR(1) process with a quadratic polynomial in age. That is, the process for income is

$$y_t = \rho y_{t-1} + \gamma_1 age_t + \gamma_2 age_t^2 + \varepsilon_t \tag{6}$$

where ε_t has variance σ_ε^2. I estimate the parameters of (6) using triennial PSID data on earnings from 1967 to 1992. I estimate the model using all heads of households between the ages of 25 and 64 that have positive labor income in the year prior to the survey, that have only high school degrees, and that are not part of the Survey of Economic Opportunities sample. The measure of income is all labor income. I convert income for all years into 1983$ prior to estimation using the CPI (all items). This estimation procedure yields $\hat{\rho} = 0.76$, and $\hat{\sigma}_\varepsilon^2 = 8817$. After removing the age-specific mean of income, I then approximate (6) with a three state Markov chain using the approach of Tauchen and Hussey (1991). After retirement, labor income is set to 60% of income in the last working year following Cocco et al. (2005) and Yao and Zhang (2005).

The transition probability matrix that governs the transitions between states is

$$\begin{bmatrix} 0.7049 & 0.2877 & 0.0073 \\ 0.1667 & 0.6667 & 0.1667 \\ 0.0073 & 0.2877 & 0.7049 \end{bmatrix}.$$

For example, a household that is a low income earner in period t has a 70.5% chance of being a low income earner in period $t+1$, a 28.8% of being a medium income earner in period $t+1$, and a 0.007% chance of being a high-income earner in period $t+1$. The ergodic distribution associated with this Markov chain is such that, in the steady state, 26.85% of households have low income, 46.3% of households have medium income, and 26.85% of households have high income. In the simulations, income at birth is randomly allocated to match the ergodic distribution.

4.4 Housing Costs

Based on the estimates of Campbell et al. (2011), I set χ, the foreclosure discount, to 0.25. I choose λ, the probability of an idiosyncratic home value shock, the home qualities, h_1, h_2, and h_3, the relative price of housing, q, and the mortgage servicing cost, ϕ, to calibrate the model to match the key moments in the data. The calibration implies that the price of the homes in 1983\$ (the same units as income) are $\$29,390$, $\$45,421$, and $\$66,795$. By comparison, the median home price in the 1980 US census was $\$54,022$ in 1983\$. I set T, the mortgage term, to 10 such that mortgages have 30 year terms. For TRADs, households must make a 20% down payment such that $\nu = 0.2$. The three-year risk-free rate, r, is 12%. Selling costs, ρ, are 8% of the value of the home as in Cocco (2005). I use δ, the per period depreciation rate on housing, to calibrate the model to match particular moments in the data.

5 Results

Table 3 presents equilibrium statistics regarding the model when there is no LDP option, when $\nu_{LDP} = 10\%$, and when $\nu_{LDP} = 0\%$. There is a unique equilibrium with positive home ownership in all three cases. I present moments from the data for comparison. For all three parameterizations, the home ownership rate is increasing in household income consistent with the data. Going from no LDP option to an option with $\nu_{LDP} = 10\%$ increase the home ownership rate slightly, from 71.3% to 71.5%. The increase in home ownership in this case is quite slight because only a small fraction (2%) of home owners choose the LDP mortgage because of its higher rate. For the parameterization chosen, it just does not help many individuals become home owners.

Table 3: Steady State Equilibria

	Data					Model		
Moment	1995	2001	2007	2013	2016	no LDP	$\nu_{LDP} = 0.1$	$\nu_{LDP} = 0.0$
Home Ownership Rate	65.1%	68.0%	67.8%	65.2%	63.7%	71.3%	71.5%	72.5%
Low Income						30%	30%	30%
Mid Income						83%	83%	83%
High Income						92%	92%	98%
Under 35	39%	42%	41%	37%	35%	31%	31%	37%
35-44	66%	68%	67%	61%	59%	70%	71%	70%
45-54	75%	76%	75%	71%	70%	81%	81%	81%
55-65	80%	81%	80%	77%	75%	86%	86%	86%
65+	79%	81%	80%	81%	80%	76%	76%	76%
Loan-to-Income	171%	182%	241%	246%	230%	208%	207%	199%
Rent-to-Income	36.3%	35.2%	34.6%	38.4%	37.0%	32.3%	32.9%	34.2%
Share of Home Owners Using LDPs						-	2.2%	12.0%
Ann. TRAD Mtg Rate						5.27%	5.27%	5.27%
Ann. NDP Mtg Rate						-	5.93%	7.08%
Average Real 30-year Mtg Rate	5.93%	4.97%	4.34%	1.98%	1.65%	5.27%	5.28%	5.33%
Foreclosure Rate						1.29%	1.31%	1.41%

Notes: 1) Data sources are US Census CPS / Housing Vacancy Survey, Federal Reserve Consumer Finance Survey, and Federal Reserve Bank of St. Louis. 2) In columns (2)-(6) I subtract 2% from the nominal mortgage rate for expected inflation to make the mortgage rates comparable to the model.

Introducing the option of $\nu_{LDP} = 0\%$ increases the home ownership rate more substantially as 12% of home owners finance home ownership with no down payment mortgages when that option is available. This raises the aggregate home ownership rate to 72.5%. The increase in home ownership from no down payment mortgages is almost exclusively because young households can become home owners earlier. The home ownership rate for those under age 35 is 37% when $\nu_{LDP} = 0\%$ while it is only 31% in the other two versions of the model. In contrast, the home ownership rates for other age categories are unaffected. In fact, virtually the *only* households that take out an LDP when $\nu_{LD} = 0\%$ are those below age 35; the share of originations using LDPs are all under 0.5% for households above the age of 34.

Looking at differences across income, the home ownership rate rises only for high income households when I introduce no down payment mortgages into the economy. The reason is that only young households that expect to have high future income, but do not currently have the assets for a down payment, avail themselves of the option to become home owners while young. Because income has a strong persistent component, young high income earners smooth their consumption over the life cycle by becoming home owners earlier.

The finding that tightening credit constraints decreases the home ownership rate and especially that of younger households is consistent with the empirical evidence in Duca and Rosenthal (1994) from prior to 1995. The predictions of the model are also consistent with the empirical evidence of Gete and Reher (forthcoming) using US data from the bust. However, the change in the home ownership rate from relaxing the LTV constraint is inconsistent with the 2001 to 2007 data. Not only does the overall age-adjusted home ownership rate fall between 2001 and 2007, it falls for the youngest age group.

Perhaps surprisingly, overall debt-to-income ratios actually fall slightly in this economy. The main reason for the slight decline is that relaxing the LTV constraint introduces high income young households into the home ownership pool. Because they still have low assets, having yet to have worked long enough to accumulate substantial net worth, they buy small houses relative to their incomes and thus have lower loan to income ratios than most home owners. This lowers the aggregate debt to income ratio. This fact, too, is inconsistent with the sharp rise in the debt-to-income ratio over the boom period.

6 Conclusions

This paper has explored how well a model of tenure and mortgage choice with binding LTV constraints can fit US home ownership and mortgage debt patterns over the last two decades. The main finding is that a relaxation of the LTV constraint raises the home ownership rate primarily for high income, young households. This is inconsistent with static to declining age-adjusted US home ownership but increasing debt levels over the 2000 to 2007 housing boom. The effects of the LTV constraint in the model are, however, consistent with tightening LTV constraints since 2007 having reduced home ownership, particularly for high income Americans.

The empirical facts regarding home ownership and debt levels appear consistent with a significant decline in the costs of equity extraction, particularly for home owners staying in their current home, during the housing boom of the 2000s. A fruitful direction for future research is explicitly modeling the effect of declines in the costs of home equity extraction in a life cycle model with housing decisions.

An important limitation of the model is its assumption of exogenous home prices. Previous research has shown that collateral constraints can meaningfully affect home prices in life cycle models.[2] A useful further direction of research would thus be to endogenize home prices in a life-cycle model with mortgage and tenure choice.

REFERENCES

ADELINO, M., A. SCHOAR, AND F. SEVERINO (2018): "Dynamics of Housing Debt in the Recent Boom and Great Recession," in *NBER Macroeconomics Annual 2017, volume 32*, ed. by M. Eichenbaum and J. A. Parker, University of Chicago Press, 265–311.

ALBANESI, S., G. DEGIORGI, AND J. NOSAL (2017): "Credit Growth and the Financial Crisis: A New Narrative," Working Paper, University of Pittsburgh.

ARIAS, E., L. CURTIN, R. WEI, AND R. ANDERSON (2008): "US decennial life tables for 1999-2001, United States life tables," *National Vital Statistics Reports*, 67, 1–36.

ATHREYA, K. B. (2002): "Welfare implications of the Bankruptcy Reform Act of 1999," *Journal of Monetary Economics*, 49, 1567 – 1595.

CAMPBELL, J. Y. AND J. F. COCCO (2003): "Household Risk Management and Optimal Mortgage Choice*," *The Quarterly Journal of Economics*, 118, 1449–1494.

——— (2015): "A Model of Mortgage Default," *The Journal of Finance*, 70, 1495–1554.

[2]See, for example, Ortalo-Magné and Rady (2006), Chu (2014), Landvoigt et al. (2015), and Favilukis et al. (2017).

CAMPBELL, J. Y., S. GIGLIO, AND P. PATHAK (2011): "Forced Sales and House Prices," *American Economic Review*, 101, 2108–31.

CASE, K. E. AND R. J. SHILLER (1989): "The Efficiency of the Market for Single-Family Homes," *American Economic Review*, 79, 125–137.

CHU, Y. (2014): "Credit constraints, inelastic supply, and the housing boom," *Review of Economic Dynamics*, 17, 52 – 69.

COCCO, J. F. (2005): "Portfolio Choice in the Presence of Housing," *The Review of Financial Studies*, 18, 535–567.

COCCO, J. F., F. J. GOMES, AND P. J. MAENHOUT (2005): "Consumption and Portfolio Choice over the Life Cycle," *The Review of Financial Studies*, 18, 491–533.

CORBAE, D. AND E. QUINTIN (2015): "Leverage and the Foreclosure Crisis," *Journal of Political Economy*, 123, 1–65.

DAVIS, M. A. AND F. ORTALO-MAGNÉ (2011): "Household expenditures, wages, rents," *Review of Economic Dynamics*, 14, 248 – 261.

DENG, Y., J. M. QUIGLEY, AND R. VAN ORDER (2000): "Mortgage Terminations, Heterogeneity and the Exercise of Mortgage Options," *Econometrica*, 68, 275–307.

DUCA, J. V. AND S. S. ROSENTHAL (1994): "Borrowing constraints and access to owner-occupied housing," *Regional Science and Urban Economics*, 24, 301 – 322.

FAVILUKIS, J., S. C. LUDVIGSON, AND S. VAN NIEUWERBURGH (2017): "The Macroeconomic Effects of Housing Wealth, Housing Finance, and Limited Risk Sharing in General Equilibrium," *Journal of Political Economy*, 125, 140–223.

FLAVIN, M. AND T. YAMASHITA (2002): "Owner-Occupied Housing and the Composition of the Household Portfolio," *American Economic Review*, 92, 345–362.

FOOTE, C. L., L. LOEWENSTEIN, AND P. S. WILLEN (2016): "Cross-Sectional Patterns of Mortgage Debt during the Housing Boom: Evidence and Implications," Working Paper 16-12, Federal Reserve Bank of Boston.

GERVAIS, M. (2002): "Housing taxation and capital accumulation," *Journal of Monetary Economics*, 49, 1461 – 1489.

GETE, P. AND M. REHER (forthcoming): "Mortgage Supply and Housing Rents," *The Review of Financial Studies*.

GHENT, A. C. (2015): "Home Ownership, Household Leverage and Hyperbolic Discounting," *Real Estate Economics*, 43, 750–781.

GHENT, A. C., R. HERNÁNDEZ-MURILLO, AND M. T. OWYANG (2015): "Did Affordable Housing Legislation Contribute to the Subprime Securities Boom?" *Real Estate Economics*, 43, 820–854.

GOETZMANN, W. N. (1993): "The single family home in the investment portfolio," *The Journal of Real Estate Finance and Economics*, 6, 201–222.

GREENSPAN, A. AND J. KENNEDY (2008): "Sources and uses of equity extracted from homes," *Oxford Review of Economic Policy*, 24, 120–144.

HU, X. (2005): "Portfolio choices for homeowners," *Journal of Urban Economics*, 58, 114 – 136.

LANDVOIGT, T., M. PIAZZESI, AND M. SCHNEIDER (2015): "The Housing Market(s) of San Diego," *American Economic Review*, 105, 1371–1407.

LEE, D., C. MAYER, AND J. TRACY (2013): "A new look at second liens," in *Housing and the Financial Crisis*, ed. by E. L. Glaeser and T. Sinai, University of Chicago Press, chap. 5, 205–234.

ORTALO-MAGNÉ, F. AND S. RADY (2006): "Housing Market Dynamics: On the Contribution of Income Shocks and Credit Constraints," *The Review of Economic Studies*, 73, 459–485.

QUIGLEY, J. M. AND R. VAN ORDER (1995): "Explicit tests of contingent claims models of mortgage default," *The Journal of Real Estate Finance and Economics*, 11, 99–117.

TAUCHEN, G. AND R. HUSSEY (1991): "Quadrature-Based Methods for Obtaining Approximate Solutions to Nonlinear Asset Pricing Models," *Econometrica*, 59, 371–396.

YAO, R. AND H. H. ZHANG (2005): "Optimal Consumption and Portfolio Choices with Risky Housing and Borrowing Constraints," *The Review of Financial Studies*, 18, 197–239.