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Homeownership and Housing Transitions: Explaining the Demographic Composition*

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Abstract

The homeownership rate was relatively stable for the few decades preceding 1995, followed by a large increase between 1995-2005 and a subsequent decline over the next ten years. We document the evolution of homeownership rate across various age groups for the period 1995-2015. Two interesting empirical findings emerge. First, there are uneven variations in the homeownership rates across age: it is large for the young but small for the old. Second, the total variation is mostly driven by renter-to-owner transitions of the young. We next consider a life-cycle model featuring housing tenure decisions to explain these empirical facts. Housing is modeled as an indivisible and lumpy investment subject to both loan-to-value (LTV) and debt-to-income (DTI) credit constraints and transaction fees. Our quantitative model reasonably replicates the key distributions and transitions between housing tenures over the life cycle. Our analysis suggests that variations in the DTI limit play a crucial role in accounting for the overall rise in homeownership and the uneven behavior across age groups.

JEL Classification: E21, J11, R21

Keywords: Homeownership rate, Debt-to-income constraint, Life-cycle model

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1 Introduction

The homeownership rate in the United States was relatively stable around 64 percent from 1970s to 1995. However, since then it rose close to 70 percent, peaking in around 2005. Following 2015, and during the Great Recession the homeownership rate fell gradually and was back close to its long-run average of 64 percent in 2015. During this same time period of 1995-2015, there were major changes in credit constraints and transaction costs for buying and selling houses. Notably, the loosening of the credit access in the run-up to the housing boom, and tightening during the following decade during the housing bust and in the aftermath of the global financial crisis has been well-documented. In this paper we consider the role of borrowing constraints and transactions costs in explaining the evolution of aggregate homeownership and its composition across different age groups.

We first empirically document the evolution of homeownership across age for the period 1995-2015, and how different age cohorts contribute to the aggregate variation in the homeownership rate. We show that there are uneven movements in the homeownership rates across age groups: it is large for the young cohorts but small for the old cohorts.[1] In addition, we provide new evidence on the transitions across housing tenure status during this time period, and find that the total variation in homeownership for the entire time period considered is primarily driven by renter-to-owner transitions. Thus, variations in the overall inflows into the ownership pool are more important than outflows, i.e. owner-to-renter transitions, in explaining the homeownership rate, even during the Great Recession. Once we decompose these transitions by age, we find, as expected, that most of the renter-to-owner transition is also concentrated among the younger cohorts. To the best of our knowledge, flows across housing tenure status have not been explored in detail in the literature earlier, and specifically not for this time period.[2]

In order to consider the role of borrowing constraints and transaction costs in explaining the aggregate and distributional effects on homeownership and housing transitions, we consider a dynamic general equilibrium life-cycle model. This model features idiosyncratic productivity

[1] Adelino, Schoar and Severino (2017) consider homeownership rates by income quintiles over this sample period, and conclude that rates increased for the middle and upper income households, but not for the lowest income groups in the housing boom period. The subsequent drop in homeownership is driven broadly by all income groups but the lowest income households experience the sharpest reduction.

[2] The only study that we are familiar with is Bachmann and Cooper (2014) which focuses on gross flows within and between renter-occupied properties and owner-occupied properties between 1970 and 2000. They focus on 15 percent of U.S. households that tend to move in a given year and show that housing turnover exhibits a hump-shaped pattern between 1970 and 2000, attributing it to changes in the age composition of the population.

shocks and lumpy and indivisible housing choice. We also introduce two types of credit constraints, loan-to-value (LTV) and debt-to-income (DTI) constraints, and transaction fees for buying and selling. Greenwald (2016) highlights the importance of considering the limits on ratio of mortgage payments to income rather than loan-to-value credit constraints, as they fundamentally alter the dynamics of credit in the economy.[3] While LTV constraints have been explored in the housing life-cycle literature earlier, debt-to-income type constraints have not been explored to a great extent in the literature at-large, and particularly not in the context of life-cycle models.[4]

We find that the model can reproduce the distribution of the homeownership by age groups well. Once we introduce changes in transaction costs of buying and selling and loosening of credit constraints, the model can also match the changes in homeownership rates across different age groups, and can qualitatively match the transitions across housing tenure status. In principle, LTV type credit constraints are relevant for young cohorts who have limited assets for downpayments and DTI credit constraints affect lower income households. Since younger housholds are also on the lower end of the income distribution, loosening borrowing constraints of both types should have the largest impact on young households. On the other hand, transaction costs for selling are most likely to have larger effects on older households who might sell their house to upgrade to a larger house or to consume after retirement as they get closer to end of life. Transaction costs for buying, should in principle be relevant for both younger and older cohorts.

We find that overall the debt-to-income constraint plays a crucial role in explaining different homeownership rates across age groups over time, but loan-to-value constraints and transaction costs do not. For almost all households, except the retired households, the debt-to-income constraint is more likely to be binding than the loan-to-value constraint. Accordingly, relaxation of the debt-to-income constraint leads to relatively large effects on the homeownership rate, particularly for the young, since this credit constraint is more likely to be binding for the young households. However, changes in loan to value ratio alone have limited effects on the homeownership rate. This is consistent with the findings of others (see Ortalo-Magne and Rady (2006) and Chambers, Garriga and Schlagenhauf (2009)). Variations in the two transaction fees cannot account for the increase in the total homeownership rate and uneven behaviors across age cohorts at the same time. While the decrease in the cost for buyers can account for the rise in the aggregate home-

[3]In the context of his model, he shows that limits on payment to income ratio can amplify the transmission of interest rates to debt, house prices and economic activity. In addition, a relaxation of this constraint plays an important role in explaining the boom in house prices and household debt.

[4]One notable exception is Kaplan, Mitman and Violante (2017), who consider the role of belief shocks on the housing boom and bust around the Great Recession.

ownership rate, it fails to match the uneven changes across age groups, yielding similar effects on the young and old cohorts. A decrease in transaction fees for sellers reduces the aggregate homeownership rate but increases the size of housing stock for homeowners, which leads to a rise in the price-to-rent ratio since the significant rise in the intensive margins (the size of housing stock) dominates the decrease in the extensive margins (the homeownership rate).

Overall, while changes in the DTI constraints help explain the changes in the homeownership behavior across various age groups, the changes in transaction costs for sellers affect the intensive margin and generate a rise in the house price relative to the rental price. Note that in the analysis we impose exogenous variations in the credits constraints and transaction costs, and abstract from introducing any interest rate and house price shocks during this period.[5] Thus, our model economy with all the factors incorporated endogenously generates a modest fraction, over 25%, of the rise in price-to-rent ratio seen in the data accompanying the rise in homeownership rates.

The next section discusses empirical facts on changes in the distribution of homeownership rate across age groups. In Section 3, we build a life-cycle model featuring housing tenure decisions. Section 4 summarizes the baseline results of the model economy. Section 5 shows how changes in the credit constraints and transaction costs produce uneven variations in the homeownership rates across age groups. Section 6 concludes.

1.1 Related Literature

Our paper is related to two main strands of literature. Firstly, various explanations for the evolution in the homeownership rates have been explored in the literature. Chambers, Garriga and Schlagenhauf (2009) have perhaps the most detailed analysis where they focus on the rise in the homeownership rate from 1994 to 2005, and examine the role of demographic changes and mortgage innovations. In the context of a quantitative general equilibrium overlapping generation model with housing, they conclude that mortgage innovations, such as conventional fixed rate mortgages, account for the majority of the observed increase in homeownership during that period. Fisher and Gervais (2011) explore the role of marrying later in life, and idiosyncratic earnings risk on the fall

[5] Abstracting from these factors is driven by the desire to keep the model tractable, and partially justified by the fact that our focus is on homeownership rates and not housing price dynamics. Piazzesi and Schneider (2009) use survey evidence to show that among other factors, future house price expectations do not play a major role in the decision to buy a house. In addition, Bailey et al. (2019) provide evidence that house price expectations might play an important role in the decisions for the intensive margin, i.e. the size of the house or the size of down payment that a household decides to put down, but it is not clear whether it affects the extensive margin, and thus the homeownership rate.

in homeownership rates among younger households during 1980-2000, and only a partial recovery during 2001-2005 period. Anagnostopoulos, Atesagaoglu and Carceles-Poveda (2013) argue that the skill-biased technological change that began during the 1970s has been an important factor behind the observed change in the distribution of homeownership rates by age going into the late 1990s. Garriga and Hedlund (2017) have a model with housing search, tighter credit constraints, and higher left tail labor income risk and find that the model can produce the drop in housing prices and homeownership rates during the Great Recession. In departure from most of these studies, we also focus on the evolution of homeownership and its composition from 2005 onwards until 2015, and more importantly, also consider the transition matrix of the various housing tenure states by age groups.

The second related strand of literature has considered the role of borrowing constraints and transaction costs in driving housing tenure status or housing decisions. Examples include Chambers, Garriga and Schlagenhauf (2009) who explore the role of these frictions in explaining the evolution of homeownership rates. Yang (2009) shows how downpayment requirements and transaction costs can explain the life-cycle patterns in consumption and housing.[6] Halket and Vasudev (2014) explore their role for jointly explaining evidence on homeownership and household mobility. Iacoviello and Pavan (2013) use reductions in downpayments to explain the cyclicality and volatility of housing investment, and the procyclicality of debt. Relative to these studies, one of our contributions is to consider a DTI type constraint in addition to the commonly employed LTV credit constraint, and additionally we explore the role of these credit constraints and costs in explicitly driving housing transitions.

2 Empirical Facts

In this section, we summarize some empirical facts about the changes in the distribution of homeownership rate across age groups.

[6] Our model is perhaps closest to Yang (2009), but we have a different focus of explaining homeownership rates and housing transitions across age groups. In addition, in our model we also allow for indivisible decision of housing stock and thus consider both the extensive and intensive margin of housing.

2.1 Data

We mainly use the Annual Social and Economic (ASEC) supplement of the Current Population Survey (CPS), which contains detailed questions covering economic characteristics surveyed in every March.[7] The basic unit of observations for the CPS is a household, and the sample size is around 60,000 on average.[8]

We consider households whose head's age is between 26 and 85 to be consistent with the model. We then classify households into two categories by housing tenures: owners and renters. We also divide households into five groups according to heads' age: we construct five age quintiles, which implies that we do not fix the range of ages for each age group for each year. This method allows us to control the effects of variations in the life expectancy over time.[9]

As a robustness check, we compare the findings in the CPS with those found in the American Housing Survey (AHS).[10] Since the CPS and the AHS are not panel data, it is hard to keep track of disaggregate movements between housing tenures over time using the two data sets. Hence, we use the Panel Study of Income Dynamics (PSID) when computing transitions between housing tenures across age groups.[11] Sample selection strategy used for the AHS and the PSID is similar to that for the CPS.

2.2 Trends of Homeownership and Tenure Transitions

2.2.1 Trends of Aggregate Homeownership

Figure 1 shows the trends of the share of U.S. housing that is owner-occupied for the last forty years from three different data sources: the CPS, the AHS[12], and the CPS/HVS (the Housing Vacancy Survey).[13] The three different data sources show the similar trends over the sample periods.[14]

[7] The CPS data are downloaded from Integrated Public Use Microdata Series (IPUMS).

[8] See Appendix for more details on the sample selection.

[9] We find that the mean age of each group shows little variation for the period 1995-2015. See Figure A2 in Appendix.

[10] The AHS is a survey about housing units while the CPS is a survey for households.

[11] Bachmann and Cooper (2014) also mainly use the PSID to compute housing turnover rates.

[12] Since the AHS are available biennially from 1983 to 2013, we convert biennial samples into annual ones using a linear interpolation.

[13] For the CPS and the AHS, we use whole samples to compare aggregate homeownership rates of the two data sets with that of the CPS/HVS. The CPS (ASEC) is weighted to the population to describe characteristics of people living in households. The CPS/HVS is weighted to housing units, rather than the population, in order to more accurately estimate the number of occupied and vacant housing units. Because of the differences in weighting, estimates of the number of households in the ASEC and HVS do not match.

[14] For the years of 1979-1982, there seem to be problems with the ownership data in the CPS: the homeownership rate jumps up in 1979 and down in 1982. To address this issue, we computed the growth rate between 1978 and

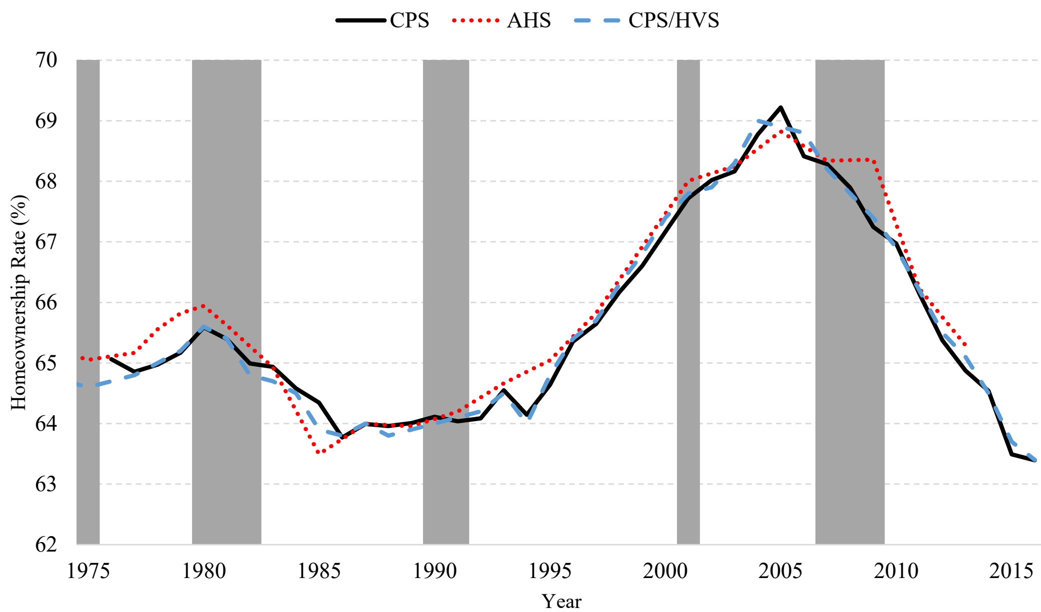


Figure 1: Aggregate Homeownership Trends in the U.S.
Note: Trend of the homeownership rate in the U.S. for the last forty years from the CPS, the AHS, and the CPS/HVS (the Housing Vacancy Survey). The rates in the CPS and AHS are computed by the authors, while the rate in the CPS/HVS from FRED with ID of RHORUSQ156N.

As found in Figure 1, the rate has been relatively constant at around 64-65 percent until 1995. However, in 1995, the rate began to trend upward and reached a record high of around 70 percent in around 2005.[15] Afterward, it decreased to the long-run average over the period 2005-2015.[16]

2.2.2 Distributions over Life Cycle

There is considerable heterogeneity between the young and the old with respect to various characteristics including tenure decisions. Table 1 summarizes the long-run averages of the homeownership rates over the life cycle using the CPS, the AHS, and the PSID.[17] As can be seen, the rate across age is hump-shaped: the homeownership rate increases until the fourth quinitile and decreases in the fifth quintile.[18] Figure 2 presents the distributions of the total assets, housing assets,

1979 in the CPS/HVS and recomputed the homeownership rate for 1979 using the growth rate. Then we updated the periods of 1980-1982 using the growth rates in the CPS given the homeownership rate in the previous year.

[15] Chambers, Garriga and Schlagenhauf (2009) also document changes in homeownership from 1994 to 2005 and find similar empirical results.

[16] The trend of the homeownership rate in the PSID, which is reported in Figure A1 in Appendix, is broadly similar to that in the CPS or the AHS.

[17] When computing the aggregate homeownership rate for Table 1, the restricted sample is used to be consistent with the model. The restricted sample is defined as the data where households whose head's age is less than 26 or greater than 85 are dropped.

[18] We also compute the average homeownership rate and the mean age across age quintiles using the sample period 1995-2015. We find similar numbers but the rate is not hump-shaped but increasing over age in the sample.

Table 1: AVERAGE HOMEOWNERSHIP RATE ACROSS AGE QUINTILES

	Quintiles					Total
	1st	2nd	3rd	4th	5th	
CPS	48.86	67.35	75.38	79.77	77.73	69.53
AHS	49.83	68.88	75.80	78.93	75.23	68.95
PSID	47.65	68.34	77.35	80.97	78.16	69.87
Mean Age	30.6	39.7	49.1	60.1	74.7	50.85

Note: The sample period of the CPS, the AHS, and PSID are 1976-2016, 1973-2013, and 1970-2015. Mean age for each age quintile is computed using the CPS. When constructing the age groups, we drop households whose head's age is less than 26 or greater than 85.

income, and consumption over the life cycle.[19] Key findings from Figure 2 can be summarized as follows. First, the old are income-poorest while mid-aged households are income-richest. Second, young cohorts own relatively small amount of assets while old households own a large amount.[20] In particular, young households barely own housing stock. Lastly, there is smaller heterogeneity in the consumption distribution across age groups.

2.2.3 Trends of Disaggregate Homeownership over 1995-2015

The empirical findings shown above regarding the large heterogeneity between the homeownership rates of the young and old lead to a question of whether there are uneven changes in the homeownership rates by age cohorts over the period 1995-2015. Figure 3 shows the homeownership trends across age quintiles between 1995 and 2015 using the CPS, and shows that the young and old cohorts behave significantly differently. Over the period 1995-2005, the homeownership rates for young households (the first and second quintiles) increased. Particularly, the youngest show a dramatic rise in the homeownership rate: the slope of the homeownership rate curve for them is steepest among all the curves. For the same period, the curves for old households (the fourth and fifth age quintiles) are almost flat: there was no evident direction of change in the homeownership rate for the old, and variations in the rate for them were relatively small. Interestingly, almost opposite patterns are found for the period 2005-2015: the homeownership rate for youngest households fell significantly, while the rate has been relatively constant for the oldest. This suggests a symmetric behavior for each age quintile, both on the up- and down-swing of the homeownership

[19] All statistics are normalized by each mean. Information on income and asset is from the PSID 1994. Consumption is nondurable consumption which is computed from the Consumer Expenditure Survey (CEX) for the period 1980-2006. The CEX data are from Heathcote, Perri and Violante (2010).

[20] Total assets are the sum of housing stock and non-housing assets.

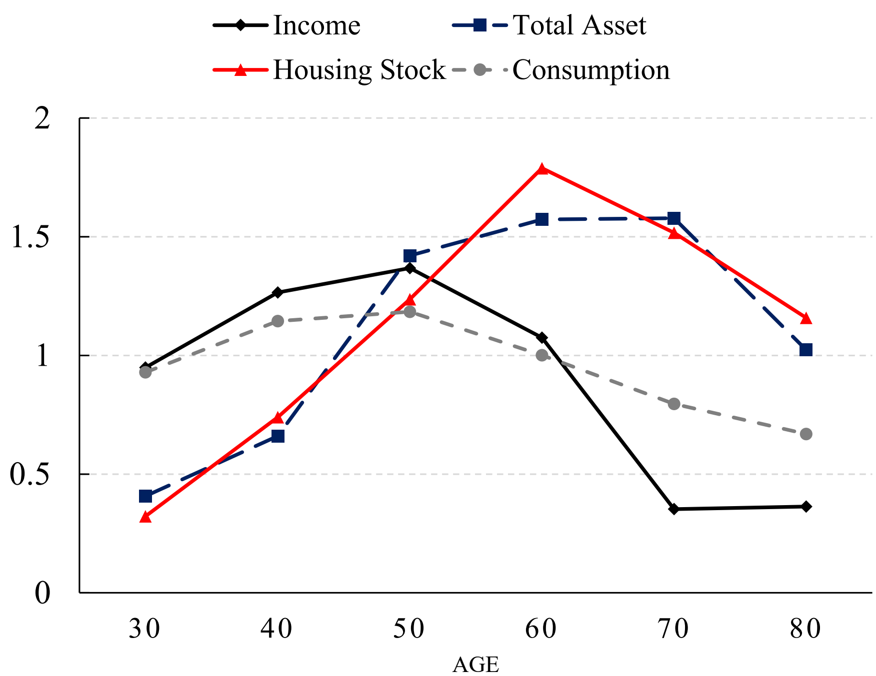


Figure 2: Income, Assets, Consumption Distributions over the Life cycle
Note: Information on income and assets is from the PSID 1994, and information on consumption is from the CEX 1980-2006. Total assets are the sum of housing stock and non-housing assets. All statistics are normalized by each mean.

rate over 1995-2015.

Figure 4 shows the homeownership rate across the various age quintiles for 1995, 2005 and 2015. It is apparent that for the most part the increase in the homeownership rates across various age groups from 1995-2005 was essentially almost reversed from 2005-2015.

In Table 2, we compute changes in the homeownership rates and contribution rates to the total variation for each age quintile between the periods 1995-2005 and 2005-2015. The contribution rate for quintile i is defined as:

$$contribution\_rate_i = 100 \times \Delta_i / \sum_i \Delta_i \tag{1}$$

where Δ_i is a change in the homeownership rate for quintile i. Over the period 1995-2005, the aggregate homeownership rate increased by around 4.08pp (percentage point).[21] Importantly, this change is largely driven by young households. The rate for the youngest rose by 6.34pp whereas the

[21] We define the total change in the rate in Table 2 as a simple average of five age groups, which is different from the true total variation. However, the difference between the two statistics is small. For example, the true value of total variation in the homeownership rate for period 1995-2005 in the CPS is 4.36pp while the simple average is 4.08pp.

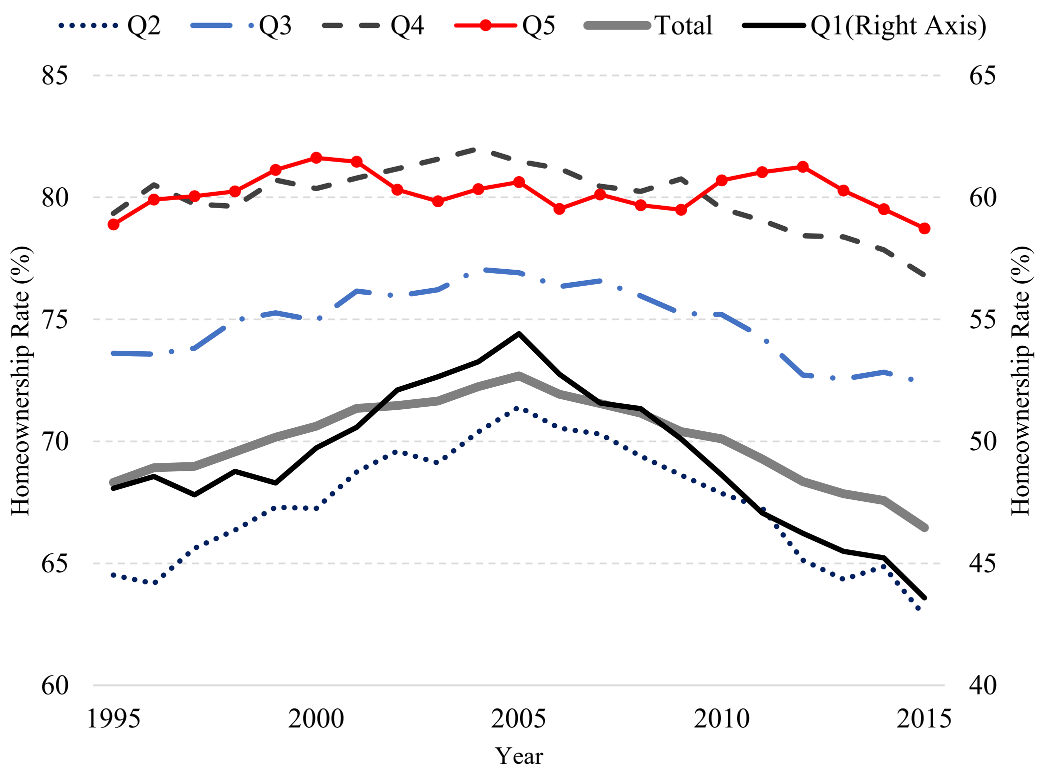


Figure 3: Homeownership Trends across Age Quintiles for 1995-2015
Note: The unit of measure for the first age quintile is on the right axis, while for the others on the left axis. When constructing the age groups and the total homeownership rates, we drop households whose head's age is less than 26 or greater than 85.

rate for the oldest went up by only 1.74pp. Hence, a contribution rate for young households (the first and second quintiles) to the total variation is around 60 percent while the old (the fourth and fifth quintiles) contribute less than 20 percent to the aggregate change. We can find similar evidence over the period 2005-2015, in which the homeownership rate decreased. On the downswing, the homeownership rate for the bottom quintile fell by 10.83pp, which is relatively large compared to the average variation, 6.09pp, in an absolute sense. On the other hand, households in the top age quintile show the smallest change in the homeownership rate: the rate for them decreased only by around 2pp. Not surprisingly, young households have a big contribution to the total variation on the downswing as well. The sum of contribution rates for the first two age quintiles is about 65 percent whereas that for the last two age quintiles is around 20 percent. As a robustness check, we also use the AHS and PSID to compute the contribution rates to the total variation for each age quintile and find consistent results.[22] Therefore, we conclude that there are uneven changes in the

[22]The contribution rates in the AHS are computed for period 1995-2005 and 2005-2013 due to data availability, and those for the PSID are computed using 1995-2003 and 2003-2015 since the homeownership rate has a peak value in 2003 in the PSID.

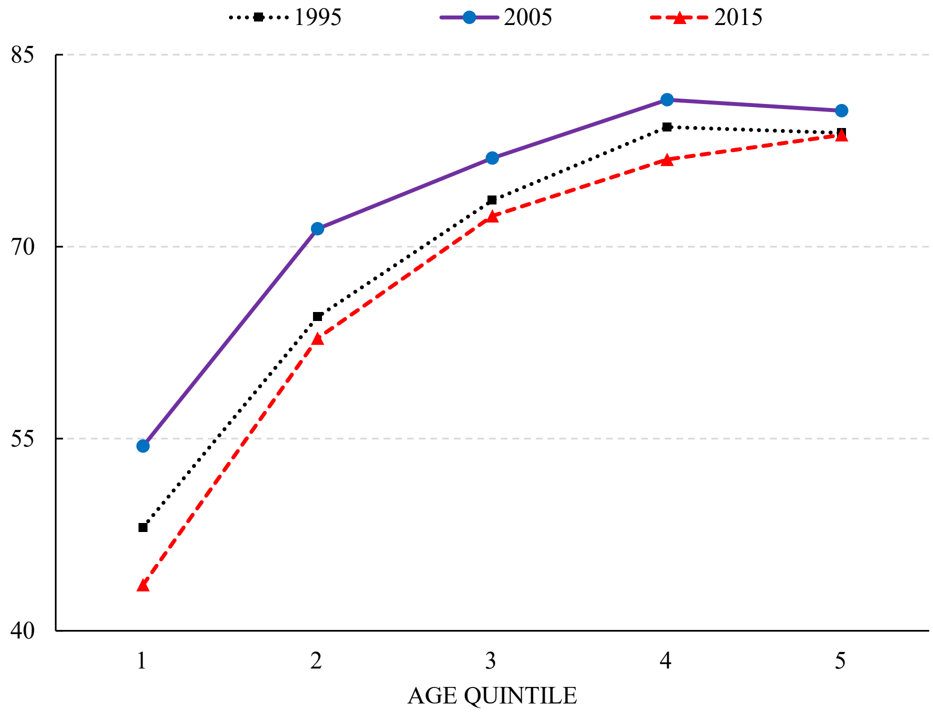


Figure 4: Homeownership Rate by Age for 1995, 2005 and 2015

Note: Y-axis is a homeownership rate.

homeownership rates across age groups for the periods 1995-2015: it is large for young cohorts but small for the old. We also compute the contribution rates across the income distribution, in order to establish if this finding is an age or income story. Notably, we find that the total variation is not driven by households in the bottom of the income distribution.[23]

2.2.4 Housing Tenure Transitions over 1995-2015

The next question that arises is whether the changes in the homeownership rates are driven primarily by inflows or outflows into the homeownership pool. Therefore, we next compute transitions of housing tenure across age quintiles to investigate who primarily drives the change in homeownership rate. This is one of the novel contributions of this paper. Figure 5 and Table 3 report two-year transition probabilities between the housing tenures from the PSID. Two interesting findings emerge. First, as shown in Figure 5, the total variation over the period 1995-2015 is mostly driven by renter-to-owner (R2O) transitions: the total R2O transition is inverted V-shaped while total owner-to-renter (O2R) transition is relatively flat. According to Table 3, before the homeownership rate started to increase (1993-1995), the transition probability for R2O is 0.152. This

[23]See Table A1 in Appendix for more details.

Table 2: Growth Accounting of the Homewonership Rate for 1995-2005 and 2005-2015

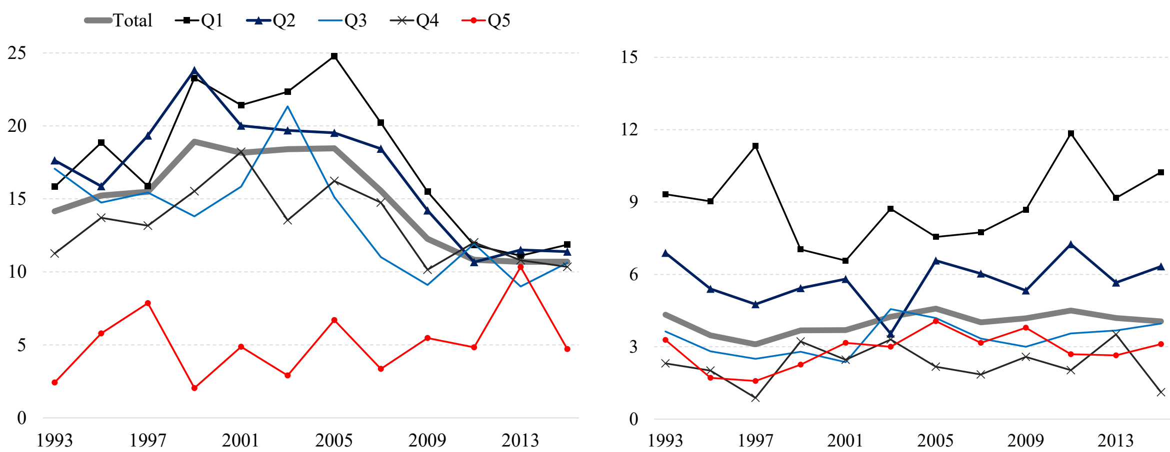
	Quintiles					Total
	1st	2nd	3rd	4th	5th	
	(A) 1995-2005					
Change (pp)	6.34	6.89	3.30	2.13	1.74	4.08
Contribution rate (%)	31.06	33.79	16.20	10.44	8.51	100
Contribution rate (AHS)	32.24	32.50	12.45	7.20	15.62	100
Contribution rate (PSID)	50.05	20.27	6.61	6.99	16.11	100
	(B) 2005-2015					
Change (pp)	-10.83	-8.56	-4.51	-4.67	-1.89	-6.09
Contribution rate (%)	35.54	28.10	14.82	15.33	6.21	100
Contribution rate (AHS)	37.24	26.69	22.50	13.25	0.32	100
Contribution rate (PSID)	49.74	18.28	22.38	9.05	0.54	100

Note: The baseline statistics are from the CPS. The total change in the homeownership rate is a simple average of five age quintiles. The contribution rates for the AHS are computed using 1995-2005 and 2005-2013, and those for the PSID are computed using 1995-2003 and 2003-2015.

means that 15.2 percent of renters became owners over the periods 1993-1995. The transition probability for R2O increased to 0.185 (a 21.7 percent increase) for the period 2003-2005, and it fell to 0.107 (a 42.2 percent decrease) during 2013-2015, which makes the simple average percent change around 32 percent. However, the transition probability for O2R increased (decreased) on the upswing (downswing), which implies that the O2R transitions negatively affected the change in the aggregate homeownership rate. Thus, we argue that R2O transitions play an essential role in accounting for the huge change in the homeownership rate between 1995 and 2005.[24]

Second, young cohorts contribute most significantly to the variation in renter to owner transitions: R2O transition probability for the first two age quintiles increased significantly while the rest of age quintiles showed smaller changes on the up- and down-swing. For example, R2O transition probability for the youngest increased by around 6pp (around 32 percent) on the upswing and decreased by around 12.9pp (around 52 percent) on the downswing, while the corresponding probability for the oldest rose by only 1pp (around 18 percent) on the upside and fell by only 2pp (around 30 percent) in the later part of the sample.

[24]Note that the change in R2O is not perfectly symmetric. The R2O transition probabilities dip lower much more significantly for the downswing period of 2005-2015 than they rise over the upswing period of 1995-2005.



R2O Transition (%) O2R Transition (%)

Figure 5: Transition Probabilities between Tenures for 1993-2015
Note: These are two-year transition probabilities between tenures from the PSID. R2O (O2R) denotes the transition probability from renters (owners) to owners (renters).

Even if the aggregate transition probability for O2R is relatively stable over the period 1995-2015, there are heterogeneous behaviors across age quintiles. The O2R transition probability for the youngest looks different from most other cohorts: the trend of the O2R transition probability for the youngest is U-shaped, which means that young people transitioned at a declining rate from owners to renters, contributing to the rise in the homeownership rate in the first part of the sample and the reverse was true when the homeownership rate was falling in the second part of the sample. On the other hand, most of the older age groups showed slightly inverted-V shaped trend or a flat profile for the O2R transitions. Additionally, the level of O2R transitions is largest for the youngest cohort and seems to go down with age.[25]

The main empirical findings are summarized as follows. First, the homeownership rate has been relatively stable for the last few decades preceding 1995, but it shows large changes over the period 1995-2015. Second, the uneven variations in the homeownership rates across age groups are found: it is large for the young but small for the old. Lastly, the total variation is mostly driven by renter-to-owner (R2O) transitions and not owner-to-renter transitions (O2R) for the full sample.

[25] We do not find a particularly large O2R probability for the oldest cohort in our sample. The tenure transition decision for the elderly has, however, received earlier attention in the literature (see for example Jones (1997) and the references within). Overall, there is only weak support that the elderly are driven by life-cycle motives and transition out of homeownership. Another reason why we might not capture large O2R transitions is that our sample ends at age 85 for the head of household. Banerjee (2012) concludes based on data from University of Michigan's Health and Retirement Study that the transition rates from homeownership to renting increase for the elderly after age 85, driven primarily by the death of a spouse or a drop in household income.

Table 3: Transition Probabilities between Tenures

	Quintiles					Total
	1st	2nd	3rd	4th	5th	
			(A) 1993-1995			
R2O	0.188	0.158	0.147	0.137	0.057	0.152
O2R	0.090	0.054	0.028	0.020	0.017	0.035
			(B) 2003-2005			
R2O	0.248	0.195	0.151	0.162	0.067	0.185
O2R	0.075	0.066	0.042	0.022	0.040	0.046
			(C) 2013-2015			
R2O	0.119	0.114	0.106	0.103	0.047	0.107
O2R	0.102	0.063	0.040	0.011	0.031	0.040

Note: These are two-year transition probabilities between tenures from the PSID. R2O (O2R) denotes the transition probability from renters (owners) to owners (renters).

The renter-to-owner (R2O) transitions are also the largest among the young.

2.3 Driving Forces for Homeownership Changes

We next empirically document possible driving forces which may account for the observed variations in the homeownership rate and the uneven changes across age quintiles between 1995 and 2015. We consider changes in the DTI and LTV constraints, and the two transaction costs as the key driving factors since, as we show below, their trends are closely related to the homeownership trends.

2.3.1 DTI Constraint

The first candidate considered as a driving force for the changes in homeownership rates are changes in the DTI limit. Figure 6 shows the trend of the aggregate DTI and payment-to-income (PTI) ratios, which are defined as outstanding mortgage debt and mortgage debt service payments divided by disposable personal income, respectively.[26] Broadly similar to the trend of homeownership, the DTI or PTI ratio also increased over 1995-2007 and decreased afterwards.[27] In particular,

[26]The data are from FRED: mortgage debt outstanding by type of holder: individuals and other holders (FRED ID: MDOTHIOH), total disposable personal income (FRED ID: DSPI), and mortgage debt service payments as a percent of disposable personal income (FRED ID: MDSP).

[27]The PTI ratio, which captures changes in flows is closely related to the DTI ratio, which captures changes in the stock, under reasonable assumptions. We will discuss this issue in more detail later. Note, however that the trend of PTI is amplified by the effects coming from changes in the interest rates over time.

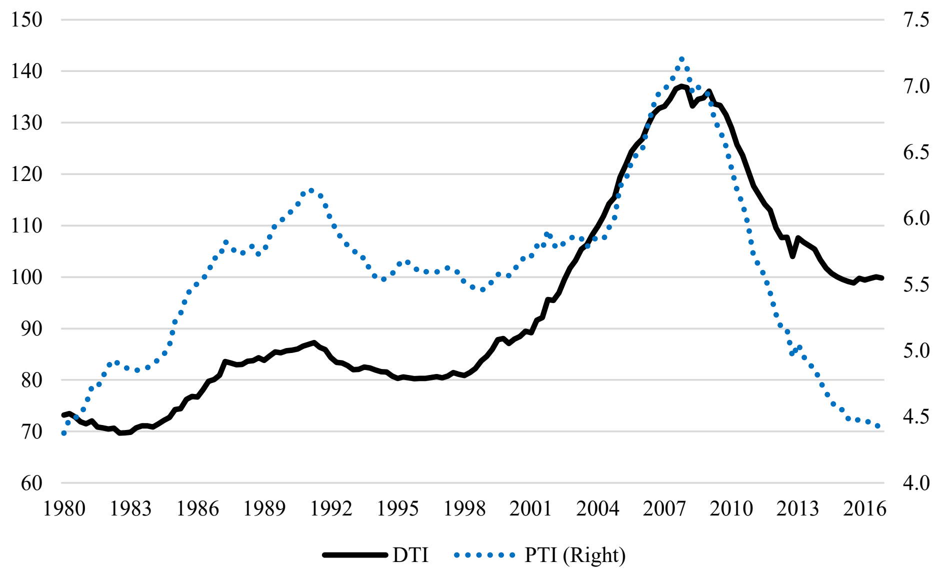


Figure 6: Trend of Aggregate DTI and PTI Ratio

Note: The DTI (PTI) ratio is defined as the ratio of mortgage debt outstanding (mortgage debt service payments) divided by disposable personal income. The unit of measure for the DTI ratio is on the left axis, while that for the PTI ratio is on the right axis. Data are from FRED.

the DTI rose sharply in early 2000 and fell significantly during the recent financial crisis. This, however, represents aggregate equilibrium movement in these variables, not necessarily dictated by regulatory measures alone. Therefore, in order to dig further, we consider loan-level data to shed light on the institutional changes in the PTI limits during this sample period.

The upper panel of Figure 7 shows the distribution of PTI based on Freddie Mac's Single Family Loan-Level Dataset in three periods: 2000, 2005, and 2015. This figure provides clear evidence that considerable changes occurred in PTI constraints over period 2000-2015.[28] PTI constraints were loosened during the boom period with many mortgagors taking on PTI ratios higher than 50 percent.[29] In contrast, PTI ratios were limited by institutional constraints in 2000 and 2015. In particular, Greenwald (2016) has also documented the sharp 45% limit in 2015.

2.3.2 LTV Constraint

The trend of the LTV ratio, particularly for certain mortgage loans, is also consistent with that of the aggregate homeownership rate. Bachmann and Ruth (2017) report that the LTV ratio,

[28]In the data, the PTI ratio is based on (1) the sum of the borrower's monthly debt payments, including monthly housing expenses that incorporate the mortgage payment the borrower is making at the time of the delivery of the mortgage loan to Freddie Mac, divided by (2) the total monthly income used to underwrite the loan as of the date of the origination of the such loan.

[29]PTI ratios are top-coded at 65 percent in the data.

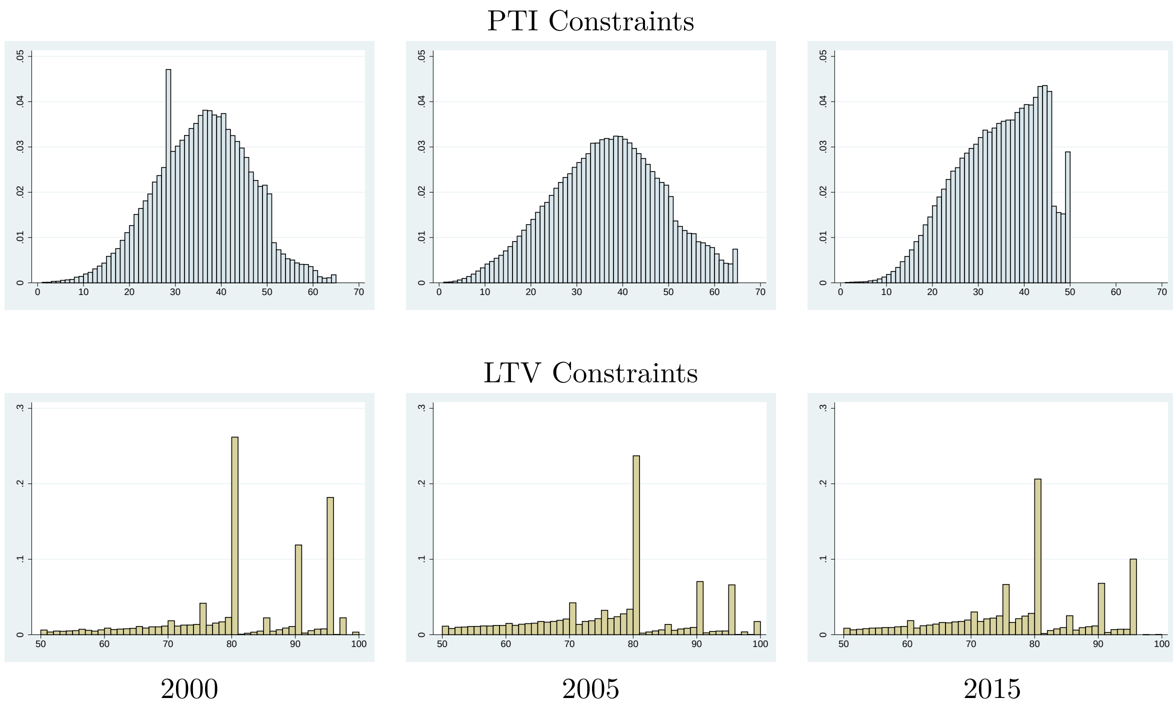


Figure 7: Distributions of PTI and LTV Constraints

Note: Histograms are weighted by loan balance. Data are from Freddie Mac's Single Family Loan-Level Dataset. X-axis is PTI or LTV ratio, while y-axis is density.

which can be interpreted as the inverse of downpayment ratio for first-time home-buyers, was around 90 percent in 1995, had a peak value of near 100 percent in 2005, and started to decrease afterwards.[30] Favilukis, Ludvigson and Van Nieuwerburgh (2017) also document extensive industry analysis suggesting that LTV ratio went up for both sub-prime and prime mortgages between 2002 and 2006, and have since returned to normal levels.[31] Jurgilas and Lansing (2013) use Federal Reserve Flow of Funds Account data to show that average LTV of mortgaged homeowners grew significantly between 1995 and 2007.

Another supportive piece of empirical evidence is from the distribution of the LTV ratio. The bottom panel of Figure 7 shows the distribution of combined LTV based on Freddie Mac loans.[32]

[30] See Figure 17 of Bachmann and Ruth (2017), which presents the LTV ratio for first-time home buyer mortgage loans, based on the AHS. The data are provided by Duca, Muellbauer and Murphy (2011).

[31] Their industry analysis suggests that LTV ratios for sub-prime mortgages went up by close to 10% between 2001 and 2005, while there was a much larger increase for prime mortgages with LTV ratio for conforming first and second mortgages rising by around 24% between 2002 and 2006. They also document that while households routinely bought homes with 100 percent financing using a piggyback second mortgage or home equity loan by the end of 2006, the maximum loan-to-value (LTV) ratios for combined (first and second) mortgages have since returned to previously normal levels of no greater than 75-80 percent of the appraised value of the home.

[32] In the case of a purchase-mortgage loan, the LTV ratio is obtained by dividing the original mortgage loan amount on the note date plus any secondary mortgage loan amount disclosed by the seller by the lesser of the mortgaged property's appraised value on the note date or its purchase price. In the case of a refinance-mortgage loan, the ratio is obtained by dividing the original mortgage loan amount on the note date plus any secondary mortgage loan

This figure provides some evidence of loosening credit constraints in 2005 with larger number of loans with higher LTV, closer to 100, in comparison with 2000 and 2015. Importantly, as also pointed out by Greenwald (2016), the distributions of LTV ratios do not show any remarkable difference across the three years, implying that the impact of the LTV changes on tenure decisions may be limited.

2.3.3 Transaction Fees

We next consider changes in transaction costs. Based on the information in the CEX, we compute transaction costs for buyers and sellers for the period 1995-2015.[33] The left panel of Figure 8 shows the data for transaction fees. Buying costs declined during 1995-2005 from 3.5 percent to 2.5 percent of the house price and rose again close to 3.5 percent between 2005-2015. In contrast, selling cost is rather noisy, fluctuating between $6-7$ percent and has no clear trend. This is a result of the fact that the sample size for the fee for sellers in the CEX is small since only households who sold a house in the reference year report.[34]

Another piece of evidence regarding changes in transaction costs are documented by the Federal Housing Finance Agency (FHFA). The agency provides mortgage-related initial fees and charges, which cover only a subset of transaction costs involved in a sale of a house.[35] Figure 8 shows the series of the initial fees and charges from the FHFA has a U-shaped pattern during 1995-2015. In 1995, the fees and charges were around 0.9 percent of the value of the house, they decreased by 50 percent and to the lowest value of 0.4 percent in 2005, and the fees have risen since then.[36]

In what follows, we first develop a life-cycle model to match the data moments from the economy. Next, we explore the role of the changes in credit constraints and transaction costs discussed above in driving homeownership trends across age over time.

amount disclosed by the seller by the mortgaged property's appraised value on the note date.

[33] Appendix provides information about what the buying and selling costs capture in the CEX in more detail. Notably, in the CEX there is information about closing costs and price paid for the property when buying, total expenses in the sale of the property, and the selling price of the property.

[34] The sample for buying costs is larger since buyers can answer questions about the house they live in independent of the reference year of purchase.

[35] The fees and charges are defined as all fees, commissions, discounts, and points paid by the borrower, or seller, in order to obtain a loan, including any general charge for making the loan and specific charges made to offset specific lending expenses, but charges for mortgage, credit, life, or property insurance, property transfer costs, title search, and title insurance are excluded.

[36] This observation is broadly consistent with the literature. For example, Chambers, Garriga and Schlagenhauf (2009) argue that a number of private programs have developed since the early 1990s, leading to a reduction in closing costs.

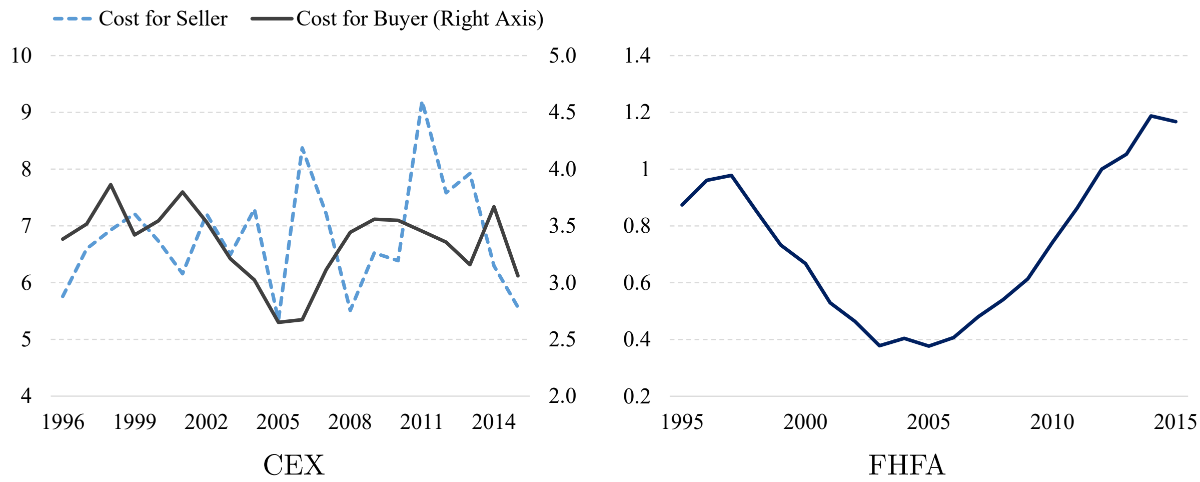


Figure 8: Trend of Transaction Costs

Note: The transaction cost for buyers is on the right axis. Data are from the CEX and Federal Housing Finance Agency (FHFA). The transaction costs are shown as the percentage of the value of the house.

3 Life Cycle Model

We construct a simple dynamic stochastic general equilibrium (DSGE) life-cycle model with a large population of heterogeneous households under an incomplete capital market, featuring housing tenure decision to explain the dynamics of homeownership rate and housing transitions shown in the previous section. The model economy consists of three building blocks: households, firms, and a government.

3.1 Housing Characteristics

As in Chambers, Garriga and Schlagenhauf (2009), housing investment is assumed to be lumpy and indivisible: the size of housing stock $h \in \{0\} \cup \mathcal{H}$ where $\mathcal{H} \equiv \{\underline{h}, ..., \overline{h}\}$, and $\underline{h}$ and $\overline{h}$ represent the minimum and maximum sizes, respectively. When a household decides to be a renter ($h' = 0$), she is able to access rental houses, d, in a rental market, and the same sizes are also available for rental houses, i.e., $d \in \mathcal{H}$.[37] Owner-occupied and rental houses yield a flow of housing services, s, via a linear technology, $s = g(z) = z$, where $z \in \{h, d\}$. Following Chambers, Garriga and Schlagenhauf (2009) and Anagnostopoulos, Atesagaoglu and Carceles-Poveda (2013), owned and rental housing capital are assumed to depreciate at different rates, where the depreciation rate for rental housing, δ_r, is larger than that for owner-occupied houses, δ_o, i.e., $\delta_r > \delta_o$.[38] This feature

[37] Homeowners are not allowed to rent a rental house, i.e., $d = 0$ if $h' > 0$.
[38] Depreciation for housing capital can be interpreted as the proportional maintenance cost.

helps motivate why households want to be homeowners. We also assume that houses owned by retirees depreciate at a higher rate than those owned by working households, implying that retired house owners pay higher maintenance costs:

$$\delta_o = \begin{cases} \delta_{ow} & if\ j < J_r \\ \delta_{or} & if\ j \geq J_r \end{cases}, \tag{2}$$

where $\delta_{or} > \delta_{ow}$. This feature helps match the homeownership distribution over the life cycle and especially the homeownership rate for the older cohort. When households buy or sell their houses, they are required to pay transaction fees, which are proportional to the size of the house. The transaction fees for selling and buying are denoted by ϕ and ϕ, respectively.

3.2 Production

Following Favilukis, Ludvigson and Van Nieuwerburgh (2017), we assume that there are two production sectors in the model economy: a nondurable goods sector (denoted by f) and a construction sector (denoted by h). Firms in the nondurable goods sector and the construction sector produce nondurable goods and housing structures, respectively. Let K_i, L_i, and Z_i denote aggregate nonhousing capital stock, aggregate effective labor, and total factor productivity in sector i, where $i \in \{f, h\}$. The production technology for nondurable goods is represented by a constant-returns-to-scale Cobb-Douglas production function:

$$F(K_f, L_f, Z_f) = Z_f K_f L_f^{1-},$$

and the production function of the construction sector is similarly given by:

$$G(K_h, L_h, Z_h) = Z_h K_h^{\eta} L_h^{1-\eta},$$

where we assume that producing nondurable goods is more capital intensive than housing structures $> \eta$.[39] Firms in both sectors determine demand for labor and capital to maximize current profits such that:

$$\max_{K_f, L_f} \{F(K_f, L_f, Z_f) - wL_f - (r + \delta_k)K_f\},$$

[39] This assumption is standard in the two-sector housing model literature such as Favilukis, Ludvigson and Van Nieuwerburgh (2017) and Seok and You (2019) among others.

$$\max_{K_h,L_h}\{qG(K_h,L_h,Z_h)-wL_h-(r+\delta_k)K_h\},$$

where δ_k is the depreciation rate for non-housing capital, w is the wage rate, r is the rental rate for capital, and q is house price. In addition, it is assumed that rental housing firms operate in competitive markets and use capital borrowed from the households (Anagnostopoulos, Atesagaoglu and Carceles-Poveda, 2013). This implies that the rental price, denoted by p, should be equal to the financial and depreciation costs:

$$p = r + q\delta_r.$$ [40]

3.3 Households

3.3.1 Preference

Households have a finite horizon. In each period, the economy is populated by J overlapping generations. Age of a household is indexed by $j \in \{1, 2, ..., J\}$, where each household is born at age 1 and lives to a maximum of J. Survival probability from age j to age $j + 1$ is denoted by $_j \in [0, 1]$, where $_J = 0$. Households make decisions on consumption, housing services, and saving. Each household maximizes expected lifetime utility over consumption c_j and housing services s_j given by:

$$E\left[\sum_{j=1}^{J}\left(^{j-1}\prod_{k=0}^{j-1} {}_k \quad \frac{c_j^{1-\sigma_c}}{1-\sigma_c} + (1- \quad)\frac{s_j^{1-\sigma_s}}{1-\sigma_s}\right)\right] \tag{3}$$

where is the time-discount factor, is a weight for consumption, σ_c is the constant relative risk aversion (CRRA) for consumption, and σ_s is the CRRA for housing service.[41] Each household is endowed with a unit of time in each period, and they supply it to the labor market inelastically until they retire at age, J_r.

[40] Suppose that firms in the real estate sector borrow an amount of assets A_R, which will be linearly transformed into housing capital. They should pay interest rA_R for the principal. They rent houses to renters at a price p and are in charge of the depreciation of the house with price of q where the depreciation rate is δ_r. Thus, the equilibrium condition in competitive markets, where the marginal revenue, p, equals to the marginal cost, $r + q\delta_r$, gives us $p = r + q\delta_r$.

[41] We assume that $_0 = 1$.

3.3.2 Earnings

When a household works, she earns wxv as labor income, where w is the wage rate for the efficiency unit of labor, x denotes stochastic labor productivity, and v is a deterministic age-efficiency profile. The idiosyncratic risks to productivity, x, follows an AR(1) process in logs:

$$\ln x' = \rho_x \ln x + \varepsilon, \quad \varepsilon \sim N(0, {\sigma_x}^2). \tag{4}$$

The capital market is incomplete following Huggett (1993) and Aiyagari (1994): households cannot fully insure against their idiosyncratic productivity shocks. For deterministic age-efficiency profile, v, we assume that it is given by:

$$v = \begin{cases} 1 + \kappa - \frac{|j - J_p|}{J_p - 1}\kappa & if\ j < J_r \\ 0 & if\ j \geq J_r \end{cases}, \tag{5}$$

where κ captures the size of difference in labor productivity between the mid-age group and others. Notice that v has a peak value at the age of $J_p\,(< J_r)$ in the model.[42] A household can save or borrow by trading assets a, which provides the real rate of return, r.

In the model economy, a household can earn income from various sources: labor income or social security benefits, interest earnings, and inherited bequests. Households have to pay labor income taxes during their working age, while after retirement they receive a lump-sum social security benefit. Due to the assumption of exogenous probability of death, the lump-sum transfer from accidental bequests is introduced in the model economy. The bequest system in this paper follows a standard assumption in the literature. We follow Anagnostopoulos, Atesagaoglu and Carceles-Poveda (2013) and assume that when a household dies accidentally, a new household starts life with wealth coming from accidental bequests and the remaining assets are equally distributed to the surviving households. The share of wealth going to a new household is determined by matching the distribution of assets among the young households in the data. This implies that the total amount of accidental bequests is equal to the sum of the total initial asset holdings for the entering

[42] See Figure A3 in Appendix for a graphical representation of the deterministic age-efficiency profile.

cohort and the total amount of transfers. Therefore, we can define the non-housing gross income for a household, y, as:

$$y = (1-\tau)\, wxv + (1+r)a + tr + b\mathbb{I}_{j \geq J_r},$$

where τ is the labor income tax rate, tr is the lump-sum transfer from accidental bequests, b is a social security benefit, and $\mathbb{I}_{j \geq J_r}$ is an indicator function indicating if a household is retired.

3.3.3 Borrowing Constraints

Most studies in the literature document the effects of loan-to-value (LTV) limits on housing-related decisions. However, the role of debt-to-income (DTI) constraints remains relatively unstudied in spite of their importance in housing investment decisions.[43] In this sense, one of contributions in this paper is that we consider both LTV and DTI constraints in the context of a life-cycle model. A LTV borrowing constraint implies that a household can use housing stock as collateral for mortgage loans and borrow $(1-\chi)$ percent of the value of the house, at most, from the asset market. In other words, when buying a house, she is required to hold a minimum downpayment which amounts to a fraction χ of the value of housing stock. Formally,

$$a' \geq -q(1-\chi)h'.$$

A household also faces the DTI constraint.[44] She can borrow λ percent of her labor income at most:

$$a' \geq -\lambda wxv.$$[45]

Finally, a household must satisfy both LTV and DTI constraints,

$$a' \geq -\Phi(a, h, x, v),$$

where

$$\Phi(a, h, x, v) = \begin{cases} \min\{q(1-\chi)h', \lambda wxv\} & if\ j < J_r \\ q(1-\chi)h' & if\ j \geq J_r \end{cases}. \tag{6}$$

[43]For instance, Greenwald (2016) and Kaplan, Mitman and Violante (2017) introduce both LTV and payment-to-income(PTI) limits to study the macroeconomic implications of mortgage credit growth, and housing boom and busts respectively.

[44]Under the constant payment assumption, we can easily recover the PTI ratio from the DTI ratio as follows. Suppose that a household, who earns income y, holds the level of housing debt, D. Then, the DTI ratio is nothing but $DTI = \frac{D}{y}$. The constant payment schedule, P satisfies, $P = mD$ where $m = \frac{r}{1-(1+r)^N}$, r is the interest rate, and N is the length of mortgage. The PTI ratio is defined as $PTI = \frac{P}{y} = mDTI$.

[45]The idiosyncratic income shocks in the DTI constraint may play a limited role in variations in housing tenure decisions when the DTI limit is relaxed since the shocks are persistent.

Eq. 6 implies that working households should satisfy both constraints while only LTV constraints are relevant for retirees.[46] The large heterogeneity between the young and old in terms of income and assets in the economy may endogenously generate the different effects of each constraint on housing-related decisions across age cohorts.

3.3.4 Household's Problem

There are four types of households in the model economy: renter-to-renter (R2R), renter-to-owner (R2O), owner-to-renter (O2R), and owner-to-owner (O2O). Individual state variables are the vector (a, h, x, j). The value function for a household of $R2R$ type is:

$$V_R(a, 0, x, j) = \max_{c,a',d} \left\{ \frac{c^{1-\sigma_c}}{1-\sigma_c} + (1 - \quad) \frac{s^{1-\sigma_s}}{1-\sigma_s} + \quad {}_j E[V(a', 0, x', j + 1))] \right\}$$

subject to

$$c + a' + pd = y,$$

and

$$c > 0, \;\; a' \geq -\Phi(a, h, x, j), \;\; \mu' = \mathbb{T}(\mu), \tag{7}$$

where p is rental price, μ is a joint distribution of the individual state variables, and $\mathbb{T}$ denotes a transition operator for μ.

Similarly, the value function for a household of $R2O$ type is:

$$V_O(a, 0, x, j) = \max_{c,a',h'} \left\{ \frac{c^{1-\sigma_c}}{1-\sigma_c} + (1 - \quad) \frac{s^{1-\sigma_s}}{1-\sigma_s} + \quad {}_j E[V(a', h', x', j + 1))] \right\}$$

subject to

$$c + a' + q(1 + \phi_b)h' = y, \text{ and Eq. 7.}$$

Next, the value function for a household of $O2R$ type is defined as:

[46]Notice that Eq. 6 holds not just at origination but at all times, and can be interpreted as refinancing being possible and costless, and as house prices move up, home equity loans are possible. This timing assumption is standard in the literature such as Yang (2009) and Iacoviello and Pavan (2013). This simplification is partially justified also since we are interested in comparing steady state to steady state equilibrium in our analysis. Others in the literature, such as Garriga, Kydland and Sustek (2017), have studied the role of long-term debt instead of one-period debt which is important for transitional dynamics and the propagation of aggregate shocks such as monetary policy shocks.

$$V_R(a, h, x, j) = \max_{c,a',d} \left\{ \frac{c^{1-\sigma_c}}{1-\sigma_c} + (1 - \;) \frac{s^{1-\sigma_s}}{1-\sigma_s} + \quad {}_j E[V(a', 0, x', j + 1))] \right\}$$

subject to

$$c + a' + pd = y + (1 - \phi_s - \delta_o)qh, \text{ and Eq. 7.}$$

Lastly, the value function for a household of $O2O$ type is:

$$V_O(a, h, x, j) = \max_{c,a',h'} \left\{ \frac{c^{1-\sigma_c}}{1-\sigma_c} + (1 - \;) \frac{s^{1-\sigma_s}}{1-\sigma_s} + \quad {}_j E[V(a', h', x', j + 1))] \right\}$$

subject to

$$c + a' + \mathbb{I}_{h' \neq h}(1 + \phi_b)qh' = y + \mathbb{I}_{h' \neq h}(1 - \phi_s)qh - \delta_o qh, \text{ and Eq. 7.}$$

Given the state variables, a household's housing tenure decision will be made by:

$$V(a, h, x, j) = \max \left\{ V_O(a, h, x, j), V_R(a, h, x, j) \right\}.$$

3.4 Government

The government plays two roles in this economy. First, the government employs a pay-as-you-go social security system to provide retirement benefits: it collects taxes from working households and distributes transfers to retirees as a lump-sum payment, b. It is assumed that the government is required to have a balanced budget:

$$\tau \int wxv d\mu = \int b d\mu_r,$$

where μ_r is the measure of retirees in the economy.[47] The other role of the government in the economy is distributing the transfers from accidental bequests discussed above.

3.5 Definition of Equilibrium

Let the state variables for households be the vector $\omega \equiv (a, h, x, j)$. A recursive competitive equilibrium consists of a set of optimal decision rules $\{c(\omega; \mu), a'(\omega; \mu), d(\omega; \mu), h'(\omega; \mu)\}$, a set of pricing functions $\{q(\mu), p(\mu), r(\mu), w(\mu)\}$, a set of inputs $\{K_f(\mu), K_h(\mu), L_f(\mu), L_h(\mu)\}$, a forecasting function for μ, $\mathbb{T}(\mu)$, and a set of value functions $\{V_O(a, h, x, j), V_R(a, h, x, j), V(a, h, x, j)\}$ such that:

[47] More precisely, $\mu_r(a, h, x, j) = \begin{cases} 0 & if \; j < J_r \\ \mu(a, h, x, j) & if \; j \geq J_r \end{cases}.$

1. Household optimization problem: The optimal decision rules $c(\omega;\mu)$, $a'(\omega;\mu)$, $d(\omega;\mu)$, and $h'(\omega;\mu)$ solve the value functions given $q(\mu), p(\mu)$, $r(\mu)$, $w(\mu)$ and $\mathbb{T}(\mu)$.

2. Firm's optimization problem: firms maximize profits such that:

$$r(\mu) + \delta_k = F_1(K_f, L_f, Z_f) = qG_1(K_h, L_h, Z_h)$$

$$w(\mu) = F_2(K_f, L_f, Z_f) = qG_2(K_h, L_h, Z_h)$$

3. Accidental bequest:

$$tr + A_1 = A_d,$$

   where A_1 is total amount of asset holdings for the entering cohort, and A_d is total assets (housing and non-housing assets) for non-surviving households.

4. Market clearing: For all μ,

$$L_f(\mu) + L_h(\mu) = \int xv d\mu,$$

$$K_f(\mu) + K_h(\mu) = \int a(\omega;\mu) d\mu - D(\mu),$$

$$D(\mu) = \int d(\omega;\mu) d\mu,$$

$$C + I_K + \delta_r D + \Gamma = F(K_f, L_f, Z_f),$$

$$I_H = G(K_h, L_h, Z_h),$$

   where $C = \int c(\omega;\mu)d\mu$, $I_K = \int a'(\omega;\mu)d\mu - (1-\delta_k)\int a d\mu_s$, $I_H = \int h'(\omega;\mu)d\mu - \int(1-\delta_o)h d\mu_s$, Γ is aggregate transaction costs, and μ_s is a measure for surviving households.

5. Balanced budget of the government:

$$\tau \int wxv d\mu = \int b d\mu_r,$$

   where μ_r is a measure for retirees.

6. Consistency of individual and aggregate behaviors.

3.6 Parameterization

In Table 4, we summarize the parameter values. As is standard in literature, we use the conventional parameter values adopted in many previous studies. The period in the model economy is a year.

Housing Characteristics The number of housing sizes, $N_h \equiv |\mathcal{H}|$, is chosen to be 5. We assume that the maximum house size is three times as large as the smallest one ($\bar{h} = 3\underline{h}$), where the housing sizes are equally spaced. We set the minimum size of housing stock, $\underline{h}$, and housing depreciation rates for renters, δ_r, to jointly target the aggregate homeownership rate of around 70 percent in the restricted sample and the housing stock to output ratio of 1.2.[48] For depreciation rates for housing stock owned by working households, we set $\delta_{ow} = 0.035$ following Chambers, Garriga and Schlagenhauf (2009), and we choose depreciation rates for houses owned by retirees, δ_{or}, to match the homeownership rate of around 77 percent in the oldest age quintile. For transaction costs for buyers and sellers, we calibrate them using the CEX for the period 1995-2015, as documented in Section 2.3.3. Based on the averages over the sample period, we set $\phi_b = 0.035$ and $\phi_s = 0.07$. This is consistent with other estimates in the literature: Gruber and Martin (2003) find using a shorter sample that the median household in the CEX pays costs on the order of 7 percent to sell houses and 2.5 percent to buy. Fisher and Gervais (2011) also find that the estimates of U.S. housing transactions costs in the Global Property Guide are in the range $1.05 - 2.2$ percent for buyers and $6.51 - 9$ percent for sellers.[49]

Demographics and Preferences We assume that an individual household starts her life and enters the labor market at age of 26 (model age 1) and retires at age of 65 (model age 40), lives until age of 86 (model age 61). We choose to match non-housing assets to output ratio of 2.5 following Chambers, Garriga and Schlagenhauf (2009). Survival probabilities come from 1995 U.S. Life Tables of the National Center for Health Statistics. Initial assets for the new entrants, a_1, are assumed to follow a log-normal distribution, i.e., $\log a_1 \sim N(\mu_1, \sigma_1^2)$. We choose μ_1 and σ_1 to match the wealth share and the wealth Gini coefficient of the cohort at age 26 in the PSID 1994.

[48] This measure is based on the literature: housing stock to output ratio is 1.2 in Yang (2009), 1.08 in Anagnostopoulos, Atesagaoglu and Carceles-Poveda (2013), and 1.3 in Alpanda and Zubairy (2016).

[49] According to Fisher and Gervais (2011), the costs include real estate agent fees, fees and taxes associated with recording an official record of the transaction, attorney fees, real estate transfer taxes, title search, and title insurance but exclude other costs such as appraisal fees, home insurance, mortgage and bank-related fees, and inspection fees.

Table 4: Parameters of the Model Economy

Parameter	Value	Description
		Demographics
J_r	65	Retirement Age (model: 40)
$J\psi$	86	Terminal age (model: 61)
μ_1	0.17	Mean of initial asset distribution
σ_1	3.1	Standard deviation of initial asset distribution
j		1995 U.S. Life Tables of the National Center
		Preference
	0.9384	Time discount factor
σ_c	3.0	CRRA for consumption
σ_s	1.0	CRRA for housing service
	0.92	Weight on consumption good
		Housing
$\underline{h}\psi$	1.51	Lower bound for housing stock
N_h	5	Number of housing sizes
$\chi\psi$	0.2	Downpayment ratio (1-LTV ratio)
$\lambda\psi$	0.9	DTI ratio
$\phi\psi_b$	0.035	Transaction fee for buying
$\phi\psi_s$	0.070	Transaction fee for selling
δ_{ow}	0.035	Depreciation rate for working households' housing
δ_{or}	0.042	Depreciation rate for retirees' housing
δ_r	0.048	Depreciation rate for rental housing
		Skills
ρ_x	0.977	Persistence of productivity shocks
σ_x	0.12	Standard deviation of productivity shocks
J_p	51	Peak age for labor productivity (model: 25)
$\kappa\psi$	0.5	Parameter for deterministic age-efficiency profile
		Technology
	0.32	Capital income share in non-durable goods sector
$\eta\psi$	0.13	Capital income share in housing sector
δ_k	0.1	Depreciation rate for non-housing capital
		Government
$\tau\psi$	0.0652	Tax rate for labor income
$b\psi$	0.52	Social Security benefit
$tr\psi$	0.072	Lump-sum transfer from accidental bequests

Following Chambers, Garriga and Schlagenhauf (2009), we assume that the CRRA coefficients for consumption, σ_c, and housing services, σ_h are 3 and 1, respectively.[50] The parameter   is set to match the ratio of housing services to consumption, which is around 0.20 in the data based on authors' calculation.[51]

Productivity and Borrowing Constraints It is well-known that individual labor productivity shocks have a large variance and high persistence (Floden and Linde, 2001; French, 2005; Chang and Kim, 2006; Chang, Kim and Schorfheide, 2013). We use $\rho_x = 0.977$ and $\sigma_x = 0.12$ following French (2005). For the deterministic age-efficiency profile, we assume that an individual household has a peak value of deterministic labor productivity at age 51 (model age 25), and the labor efficiency of a household at age 51 is 50 percent larger than that of a household at start age.[52] In other words, we choose $J_p = 51$ (model age 25) and $\kappa = 0.5$. Downpayment ratio, χ, is set to 0.2 following the literature on housing such as Chambers, Garriga and Schlagenhauf (2009) and Yang (2009). The DTI ratio, λ, is chosen to be 0.9, based on the average aggregate mortgage debt-to-income in the economy in 1995 and 2005 (see Figure 6).[53]

Production and Government Aggregate productivity in both sectors, Z_f and Z_h, are assumed to be constant at one. We use very standard values for the production-related parameters: we choose $= 0.32$ and $\delta_k = 0.1$, and we set $\eta = 0.13$ following Seok and You (2019). The social security tax, τ, is set to match a replacement ratio of 33 percent over average labor income following Nakajima (2010), and social security benefits, b, are chosen in order for the government to run a balanced budget. Lump-sum transfer, tr, is set based on the accidental bequest assumption that is described above.

[50]As discussed in Chambers, Garriga and Schlagenhauf (2009), the growth rate of the housing services to consumption ratio over the life cycle is determined by the relative size between σ_c and σ_s.

[51]When computing the ratio of housing services to consumption, we use (a) the sum of imputed rental of owner-occupied nonfarm housing (FRED ID: DOWNRC1A027NBEA) and rental of tenant-occupied nonfarm housing (FRED ID: DTENRC1A027NBEA) and divide it by (b) the sum total services (FRED ID: PCESV) and nondurable goods (FRED ID: PCND) less (a), i.e., the ratio of housing services to consumption = (a)/[(b)-(a)]. This definition is consistent with that in the model economy.

[52]This is typical in the literature such as Anagnostopoulos, Atesagaoglu and Carceles-Poveda (2013), and well supported by empirical papers including Hansen (1993) and Diaz-Gimnez, Glover and Rios-Rull (2011).

[53]It should be noted that under the constant payment the implied PTI limit in our model for a household who earns average labor income is around 0.3, which is a reasonable number compared to other studies in literature. For instance, Greenwald (2016) chooses 0.36 for the PTI limit, and Kaplan, Mitman and Violante (2017) use 0.25 and 0.5 depending on the states in the model economy.

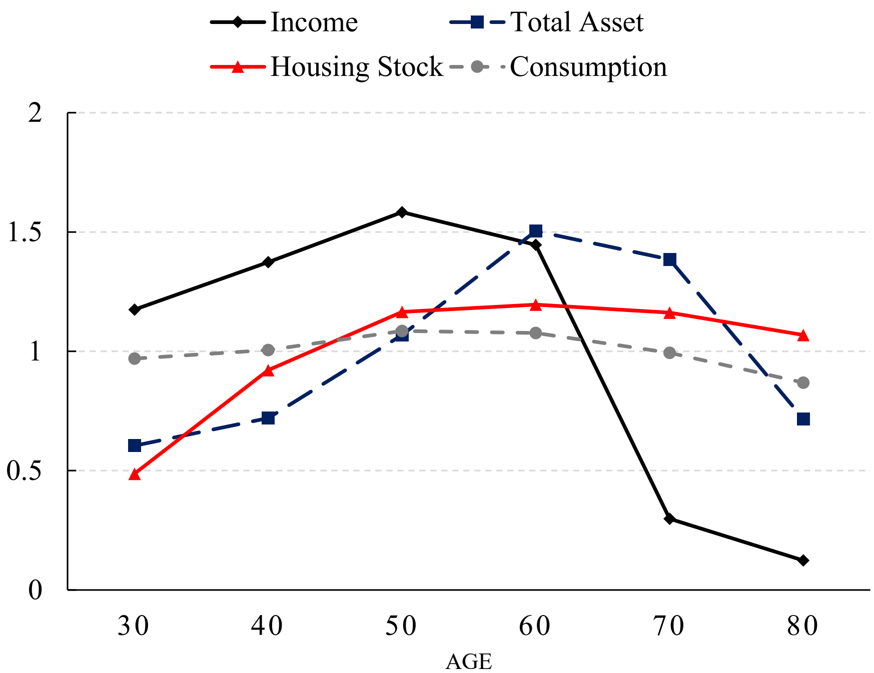


Figure 9: Income, Asset, Consumption Distributions over the Life Cycle: Model
Note: All statistics are are normalized by each mean.

4 Benchmark Findings

In this section, we summarize the baseline findings for the model economy. We first examine the model's fit of total wealth, housing stock, income and consumption distributions over the life cycle, presented in Figure 9. In the model economy, i) the income profile is hump-shaped where it has the peak at age of 50 and decreases significantly after retirement, ii) distributions of total asset and housing stock are also inverted U-shaped curves over age, and iii) consumption distribution over the life cycle is relatively smooth. These are all patterns roughly observed in the U.S. data (See Figure 2), and thus we conclude that the model economy overall performs well in terms of the life-cycle distributions.

We next evaluate the performance of the model economy with respect to the distribution of income and assets over the life cycle, since these distributions across cohorts are very important in predicting the impact of credit constraints. Table 5 reports the Gini coefficients of income and wealth across age distribution in the data and the model. Our quantitative model economy performs well in terms of the Gini coefficients of income and wealth over the life cycle even if wealth and income are less concentrated in the model compared to the data. Overall, the Gini coefficient

Table 5: Gini Coefficient of Income and Wealth by Age Quintiles

	Quintiles					Total
	1st	2nd	3rd	4th	5th	
			(A) Data			
Income	0.45	0.48	0.46	0.60	0.83	0.57
Wealth	0.86	0.76	0.73	0.66	0.68	0.75
			(B) Model			
Income	0.39	0.38	0.38	0.38	0.65	0.45
Wealth	0.84	0.71	0.61	0.57	0.56	0.67

Note: Data for income and wealth Gini coefficients are from the PSID 1994.

of income over age shows an increasing pattern in the data, and this pattern also emerges in the model economy. The wealth Gini in the data shows a decreasing pattern with age, which is also well replicated by the model economy.

The performance of the model economy can be further evaluated in matching certain housing features over the life cycle, both from a static and dynamic perspective. From a static view, we analyze the mean values of homeownership rate over the life cycle, shown in the upper panel of Table 6. The model economy successfully replicates the shares across the age quintiles, and is hump-shaped with the peak value occurring in the fourth age quintile, as is true in the data. Additionally, we also examine housing size. The middle panel of Table 6 reports housing sizes in terms of the number of rooms and square feet by age cohorts in the data (the AHS) and the model economy.[54] The distribution of housing size over the life cycle is hump-shaped in the data, and the model successfully captures the magnitude and the shape by age cohorts.

Next, we move on to the dynamic perspective: transitions between housing tenure across age quintile. Table 7 reports transition probabilities between the housing tenures in the data and the model.[55] Statistics for the data are the averages of four transition matrices over 1993-2013. It should be noted that due to data availability, both the data and the model show the two-year transition probabilities. Our quantitative model economy performs well in terms of the aggregate transitions of housing tenures. In the data, the O2O transition is very persistent while the R2R is less so: the O2O transition rate is 0.958, but the R2R is 0.862. These findings resemble the corresponding facts in the model economy: transition probability for O2O is 0.972 while the one

[54] The average number of rooms and the square feet in the model are normalized by the data.

[55] In the steady state equilibrium, the agent type distribution and aggregate statistics are constant over time. At the individual level, however, there is a lot of movement going on: individual households are hit by idiosyncratic shocks every period and adjusting their financial asset holdings and housing stock accordingly. This individual level dynamics allows us to compute transitions between the housing tenures in the model.

Table 6: Homeownership Rate, Housing Size, and Fraction of Movers by Age Quintiles

	Quintiles					Total
	1st	2nd	3rd	4th	5th	
			(A) Homeownership Rate			
Data						
CPS	48.86	67.35	75.38	79.77	77.73	69.53
AHS	49.83	68.88	75.80	78.93	75.23	68.95
Model	44.49	67.60	76.53	78.49	77.60	69.35
			(B) Housing Size			
Data						
Number of rooms	5.48	6.13	6.35	6.17	5.61	5.94
Square feet	1866	2065	2165	2120	1970	2035
Model						
Number of rooms	5.44	6.03	6.23	6.10	5.85	5.94
Square feet	1864	2066	2135	2090	2003	2035
			(C) Fraction of Movers			
Data						
R2R	32.6	23.5	17.3	18.3	8.2	100
O2O	40.9	21.0	19.5	9.1	9.5	100
All	45.4	22.5	15.5	9.5	7.0	100
Model						
R2R	35.6	14.7	15.5	22.9	11.3	100
O2O	40.0	17.5	15.0	17.5	10.0	100
All	44.1	21.4	14.7	14.4	5.4	100

Note: For the ownership rates, the sample period of the CPS (AHS) is 1976-2016 (1973-2013). When constructing the age groups in the data, we drop households whose head's age is less than 26 or greater than 85 to be consistent with the model economy. For the housing size, the data are from the AHS 1995. The information for the distribution of movers is from the PSID 2013-2015.

Table 7: TRANSITION PROBABILITIES ACROSS TENURES: DATA AND MODEL

	Quintiles					Total
	1st	2nd	3rd	4th	5th	
			(A) Data			
R2R	0.833	0.856	0.873	0.868	0.931	0.862
R2O	0.166	0.144	0.127	0.132	0.069	0.138
O2R	0.094	0.062	0.036	0.024	0.038	0.042
O2O	0.906	0.938	0.964	0.975	0.957	0.958
			(B) Model			
R2R	0.850	0.830	0.865	0.897	0.994	0.874
R2O	0.150	0.170	0.135	0.103	0.006	0.126
O2R	0.049	0.042	0.032	0.024	0.008	0.028
O2O	0.951	0.958	0.968	0.976	0.992	0.972

Note: Transition probabilities between tenures in the PSID and the model economy. Transition probabilities are two-year transitions for both data and model.

for R2R is 0.874 in the model economy. Not surprisingly, the fact that R2O transition is larger than that of O2R is also generated in the model economy. We next evaluate the performance of the model economy with respect to disaggregate transitions between housing tenures over the life cycle. In the data, R2O transitions are decreasing with age. The model economy can match this profile for R2R or R2O transitions over age reasonably well. Overall, the transition probability of R2O shows the observed decreasing pattern with age: the probability for the first quintile is 0.15, but it is close to zero for the fifth quintile. Additionally, the model economy broadly replicates the decreasing pattern of O2R transition over the life cycle.

Interestingly, our model economy also replicates the observed patterns of the fraction of movers across age reasonably well. The bottom panel of Table 6 shows the distribution of movers across age quintile for O2O, R2R, and all the households in the PSID and the model. The baseline model reproduces the decreasing patterns of the fraction of movers over age for O2O, R2R, and at the aggregate level. For example, around 45 percent of moving households belong to the youngest group and 7 percent of movers are the oldest in the data while 44.1 percent and 5.4 percent of movers belong to the first and fifth age groups in the model economy, respectively.

5 Uncovering Uneven Variation in Homeownership

We now employ our quantitative model economy to investigate the observed variations in the homeownership rate and the uneven changes across age quintiles between 1995 and 2015. We consider changes in the DTI and LTV constraints, and the two transaction costs as the key driving factors since their trends are closely related to the homeownership trends, as shown in Section 2.3.[56]

5.1 Modifying Credit Constraints and Transaction Costs

Motivated by the empirical evidence presented in Section 2.3, we investigate if variation in each factor (DTI and LTV constraints and the two transaction costs) can account for the uneven behaviors across age quintiles using our quantitative model. In order to do this, we compute the steady-state equilibrium in the model economy by allowing one factor to change at a time, keeping others unchanged. Following that, we also consider the model with all the factors included.

We showed in the empirical section that the movement in the homeownership rate at the aggregate and disaggregate level is rather symmetric from 1995-2005 and 2005-2015 (see Figures 1 and 4). Also as shown Section 2.3, the two credit constraints and transaction costs have also roughly exhibited a symmetric behavior over these two subsamples, thus we only consider the effects of the loosening of the credit constraints and reduction in transaction costs over 1995-2005. Our results for the reversal of these policies and related parameters would lead us to our initial steady state.

5.1.1 Loosening DTI Constraint

We first analyse the effects of loosening of the DTI constraint, and consider an increase in the DTI ratio from 0.9 to 1.3. As reported in Figure 6, the aggregate DTI or PTI ratio related to mortgage debt rose by 40-50 percent over the period 1995-2007. Based on this, we assume that the DTI ratio rises to 1.3 on the upswing, which is an increase of 44%.[57]

The impact of an increase in the DTI ratio is reported in Panel (A) of Table 8. Loosening the DTI limits plays an essential role in accounting for both aggregate and disaggregate variations in the homeownership rates. A rise in DTI ratio increases the aggregate homeownership rate by 8.73pp, which is slightly larger than the data. In particular, the uneven variations in the homeownership rates across age groups are successfully replicated when relaxing the DTI constraint (See

[56] Note that we assume exogenous movements in the credit constraint and transaction costs in our experiments, and that can be thought of as a reduced form way of partially capturing the changes in house prices during this period.

[57] Between 2005 and 2015, Figure 7 shows that the PTI limit went from 65% to 50%, so an overall decline of about 30%. We also conduct sensitivity analysis with a variation in the DTI limit of close to 30%.

also Figure 12). The rate for the youngest households rises by 23.05pp whereas the homeownership rate for the fifth quintile goes up by 2.59pp. Consequently, the contribution rate for young cohorts (the first and second quintiles) in the total variation is close to 75 percent while the old (the fourth and fifth quintile) contribute around 13 percent to the aggregate change, which is consistent with the empirical findings discussed earlier.

Table 8: Changes in Homeownership Rate and Housing Size

	Quintiles					Total
	1st	2nd	3rd	4th	5th	
Data (1995-2005)						
Change in Rate (pp)	6.34	6.89	3.30	2.13	1.74	4.08
	(31.06)	(33.79)	(16.20)	(10.44)	(8.51)	(100)
Change in Sizes (%)	-13.24	-4.07	-3.74	-1.89	-2.03	-5.01
(A) Loosening DTI Constraint						
Change in Rate (pp)	23.05	9.87	5.14	3.01	2.59	8.73
	(52.79)	(22.61)	(11.77)	(6.89)	(5.93)	(100)
Change in Sizes (%)	-33.03	-12.55	-6.03	-3.50	-3.10	-10.51
(B) Loosening LTV Constraint						
Change in Rate (pp)	0.00	0.03	0.01	0.03	0.25	0.06
	(0.00)	(9.38)	(3.13)	(9.38)	(78.12)	(100)
Change in Sizes (%)	0.03	0.01	0.04	0.01	-0.28	-0.05
(C) Reducing Transaction Fee for Buyer						
Change in Rate (pp)	4.21	1.37	1.49	2.07	4.35	2.70
	(31.21)	(10.16)	(11.05)	(15.34)	(32.25)	(100)
Change in Sizes (%)	-8.94	-1.89	-1.53	-2.72	-4.97	-3.61
(D) Reducing Transaction Fee for Seller						
Change in Rate (pp)	-7.88	-4.12	-1.11	-0.99	-2.38	-3.30
	(47.82)	(25.00)	(6.74)	(6.01)	(14.44)	(100)
Change in Sizes (%)	19.75	8.11	2.51	1.52	2.11	5.05
(E) All Factors						
Change in Rate (pp)	4.56	1.99	1.76	1.37	1.86	2.31
	(39.51)	(17.24)	(15.25)	(11.87)	(16.12)	(100)
Change in Sizes (%)	-8.25	-0.53	-1.05	-1.65	-2.81	-2.31

Note: The total change in the homeownership rate is a simple average of five age quintiles. Values in ( ) are contribution rates, which are computed based on the changes in the homeownership rates. The unit of housing sizes in the data is square feet of housing stock.

Interestingly, loosening the DTI limits has a negative effect on the intensive margin: the average housing size for homeowners decreases by 10.51 percent, and this is mainly due to a significant decrease from the young cohorts. This result implies that relaxing the DTI limits allows renters to buy smaller houses than those of existing homeowners, and particularly young renters buy much smaller ones. The loosened DTI constraint increases the extensive margin of housing demand (homeownership rates) but decreases the intensive margin of housing stock demanded (housing sizes). This off-setting effect of the intensive margin on housing demand leads to a rather small rise in house price and a decrease in rent.[58] According to Table 9, the house price increases by 0.27 percent and the rent decreases by 1.4 percent in the model with relaxed DTI limits, which increases the price-to-rent ratio by 1.69 percent.

Table 9: Changes in Prices

	DTI	LTV	Buying Cost	Selling Cost	All
House Price (%)	0.27	0.01	-0.21	1.20	1.22
Rent (%)	-1.40	-0.08	1.10	-6.21	-6.31
Price/Rent (%)	1.69	0.09	-1.30	7.90	8.03

Note: "DTI", "LTV", "Buying Cost", "Selling Cost", and "All" denote the cases of loosening DTI constraints, loosening LTV constraints, reducing transaction fees for buyers, reducing transaction fees for sellers, applying all the factors, respectively.

In order to understand the importance of DTI limits in explaining the tenure decisions for young households relative to the old, let us first consider the effects of relaxing the DTI limits on old cohorts. Since retirees do not earn labor income after retirement by construction, they are not directly affected by changes in the DTI ratio according to Eq. 6. Hence, the impact of the loosened DTI constraint is relatively small for the old since their tenure decisions are only indirectly influenced by the general equilibrium effects. In contrast, a variation in the DTI ratio has large effects on working households, but the effects are different across age cohorts. Since the deterministic age-efficiency profile is hump-shaped as assumed in Eq. 5, young households earn a small amount of earnings relative to mid-aged workers, suggesting that the number of households for whom DTI constraints are likely to be the dominant credit constraints may be relatively large in the younger cohorts. The left panel in Figure 10 shows the fraction of households for whom the DTI limit is the dominant constraint (i.e., DTI limits are less than the LTV limits) among *marginal households* in the baseline model and the model with the loosened DTI constraint. We define a *marginal household* as a renter whose value function is close enough to the value function when she would become a house owner given the state variables. Formally, a household is a *marginal household* if

[58]The price-to-rent ratio in the model is $q/p\psi$ where $p\psi = r\psi + q\delta_r.\psi$

$$V_R(a,h,x,j) > V_O(a,h,x,j) \text{ and } \frac{V_R(a,h,x,j) - V_O(a,h,x,j)}{V_O(a,h,x,j)} \leq \xi, \tag{8}$$

where $\xi(<1)$ is a small number. We also define a *DTI-dominant marginal household* if a marginal household's DTI limits are less than the LTV limits:

$$\lambda w x v < q(1-\chi)\widetilde{h}, \tag{9}$$

where $\widetilde{h}$ is the average size of housing stock in the economy.[59] As shown in the left panel of Figure 10, households for whom the DTI limits are dominant constraints are concentrated among the young cohorts in the baseline model economy. As found in the left panel of Figure 10, when the DTI ratio increases, all working cohorts experience a loosening of their credit constraint. Importantly, many more young households experience a loosening of their borrowing constraints than the mid-aged cohorts. For example, the DTI limits are dominant credit constraints for around 92 percent of marginal households at 30 in the baseline model, but this fraction decreases to around 32 percent when DTI limits are relaxed, while the share of the DTI-dominant marginal households at 60 shows a relatively small change with a rise in the DTI ratio. Therefore, young renters who face a more relaxed DTI ratio are less limited by the DTI constraints and are able to buy houses.[60] This suggests that DTI constraints are important in decisions of house purchase as also supported by the empirical facts found in Figure 7.

We also provide suggestive empirical evidence that DTI limits for young households were largely loosened during 1995-2007 and tightened over 2007-2016 when compared to older households. The left panel of Figure 11 exhibits the distribution of the DTI ratio across age quintiles for three years (1995, 2007, and 2016) using the Survey of Consumer Finances (SCF).[61] This figure clearly shows that young cohorts are largely affected by loosening the DTI limits on the upswing and downswing. For example, during the housing boom (1995-2007), the DTI ratio for the youngest increased by around 61 percent, but it rises only by 6 percent for the oldest.

[59] We simply choose $\xi = 0.01$ and use average housing stock for $\widetilde{h}$, but other reasonable numbers for ξ and $\widetilde{h}$ make no difference in a qualitative sense.

[60] This result is also robust when we use the share of the DTI-dominant marginal households in each age bin. See Figure A4 in Appendix.

[61] The DTI ratio is defined as "Total value of debt held by household" divided by "Total amount of income of household." We also use an alternative definition of the DTI ratio using "Total value of mortgages and home equity loans secured by the primary residence held by household"and find very similar results.

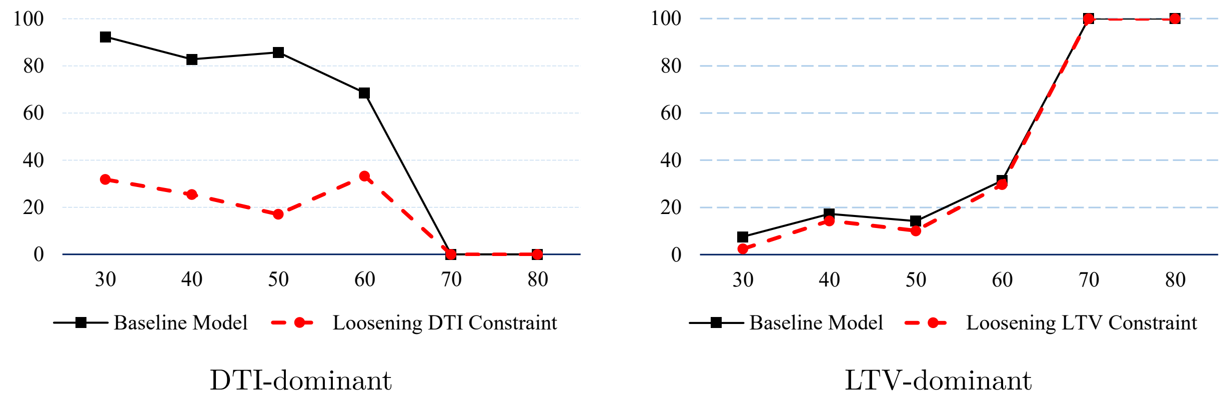


Figure 10: Fraction of DTI- and LTV-Dominant Households in Model

Note: The figure shows the fraction of DTI-dominant and LTV-dominant households among marginal households. Marginal households are defined as in Eq. 8. Y-axis is density, and x-axis represents mean age of each bin.

5.1.2 Loosening LTV Constraint

Next, we consider a decrease in the downpayment ratio by 20 percent.[62] As noted by Chambers, Garriga and Schlagenhauf (2009), the downpayment ratio for the first-time buyers decreases from 21.6 percent (29.8 percent) in 1995 to 16.3 percent (24.1 percent) in 2003 for the Federal Housing Administration (FHA) loans (other loans), which leads us to assume a 20 percent decrease in downpayment for the period 1995-2005.[63]

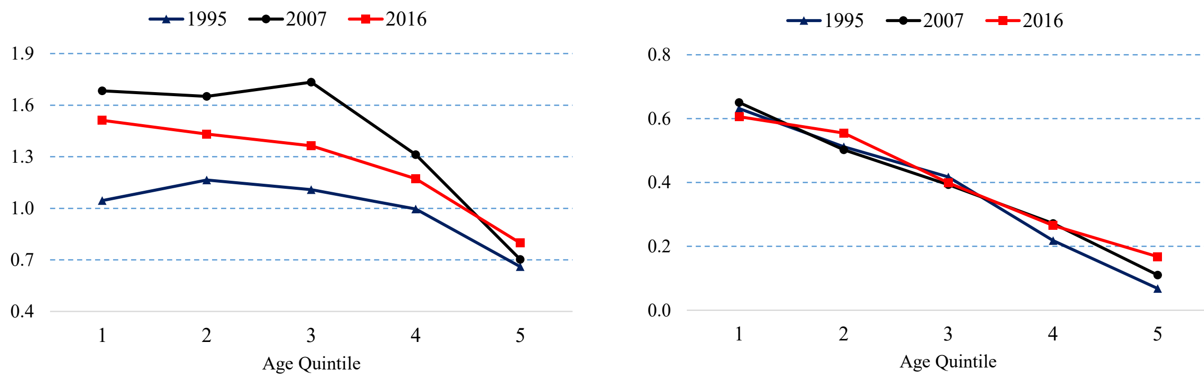
Panel (B) in Table 8 summarizes the impact of a decrease in downpayment (or an increase in the LTV ratio) in the model economy. The effect of a reduction in the downpayment on the aggregate homeownership rate is small. With the loosened LTV constraint, the long-run aggregate homeownership rate is almost constant: it increases by only 0.06pp. In addition, the intensive margin (housing sizes of homeowners) is not affected: the average home size decreases by 0.05 percent. This finding is consistent with Chambers, Garriga and Schlagenhauf (2009) who also find that the downpayment reduction does not affect the aggregate homeownership rate much.[64] In this case, general equilibrium effects play an limited role since the price-to-rent ratio almost does not change (See Table 9). The limited impact of the LTV changes is already conjectured by the

[62] With this assumption, the LTV ratio changes from 0.8 to 0.84.

[63] Some additional evidence referenced earlier suggest larger LTV ratio changes for some sub-populations. Bachmann and Ruth (2017) report a 10 percent increase in the LTV ratio of first-time home buyers. Favilukis, Ludvigson and Van Nieuwerburgh (2017) document that LTV ratios for sub-prime mortgages went up by close to 10% between 2001 and 2005, while the LTV ratio for prime mortgages for conforming first and second mortgages rose by around 24% between 2002 and 2006. Given the limitations of our analysis, we can not distinguish between the LTV ratio for different types of households in the economy based on income or credit history. However, we conduct sensitivity analysis for larger changes in the LTV ratio in Section 5.2

[64] In Chambers, Garriga and Schlagenhauf (2009), a 50 percent reduction in downpayment reduces the aggregate homeownership rate from 63.7 to 63.5 percent.

empirical fact shown in the upper panel of Figure 7: the distributions of LTV ratios in the boom and bust periods are almost identical.



DTI Distribution LTV Distribution

Figure 11: DTI and LTV Distributions across Age Quintiles over 1995-2016
Note: Y-axis is DTI or LTV ratio, and x-axis represents age quintiles. The DTI ratio is defined as "Total value of debt held by household" divided by "Total amount of income of household," and the LTV ratio is defined as "Total value of mortgages and home equity loans secured by the primary residence held by household" divided by "Total value of primary residence of household." Data are from SCF.

We also similarly define *LTV-dominant marginal households* and report the share of these in the right panel of Figure 10. It follows that households for whom the LTV limits are dominant credit limits are concentrated among the old cohorts in the baseline model economy. According to Eq. 6, unlike the DTI limits which include only exogenous variables (w, x, and v), the LTV constraints are affected by a household's endogenous decision: choice of house size, h'. Especially for the young households, the LTV constraints are relatively easy to avoid by purchasing small-sized houses, so the DTI limits are the dominant credit constraints for them. Of course, the LTV limits are not binding for most of the mid-aged households since they accumulate enough financial assets. However, poor older cohorts want to use their housing stock as collateral for mortgage loans to smooth consumption, and they repay their remaining debt by selling their houses at the end of the life cycle (i.e., reverse mortgage loan). Accordingly, the share of LTV-dominant marginal households is relatively large in the old cohort, while the fraction is very small for the young in the baseline economy.

As shown in the right panel of Figure 10, with the smaller downpayment ratio, the share of the LTV-dominant households falls for the young marginal households, but the change in the numbers for the young is not as dramatic as in the case of the DTI limit being loosened. For example, the fraction of the LTV-dominant marginal households at 30 is close to 8 percent in the baseline model, and it decreases to 2.5 percent when the LTV limits are relaxed. This implies that the impact of loosening the LTV constraint on the share of these marginal households is too small for them to change their tenure decisions, even if there are heterogeneous effects of the loosened LTV constraint on households over age. This model finding is also supported by the empirical evidence shown in the right panel of Figure 11, which exhibits the distribution of the LTV ratio across age quintiles.[65] Notably, the distributions of the LTV ratio across the age groups were very similar across the three periods.

5.1.3 Reducing Transaction Fees

We next change transaction costs. We assume that transaction costs for buying and selling decrease by 20 percent. According to the left panel of Figure 8, transaction fees for buyers decreased (increased) from 3.4 (2.7) percent to 2.7 percent (3.1) over the period 1995-2005 (2005-2015). Based on these numbers from the CEX, we assume a 20 percent reduction in the transaction costs for buyers. As mentioned earlier, the selling cost information coming from the CEX is very noisy, fluctuating between 6 to 7 percent and has no clear trend, likely due to small sample size. Thus, we choose the same size experiment for selling costs as transaction costs for buyers. Note, however, that we consider additional sensitivity analysis for larger changes in the size of these transaction costs, including considering changes as high as 50%.[66]

We first investigate the impact of a reduction in the transaction fee for buying. The variations in the transaction costs for buyers mainly affects the size of housing stock and the homeownership rate both. A decrease in transaction costs for buying increases the aggregate homeownership rate by 2.7pp, but decreases housing sizes of homeowners by 3.61 percent. This implies that with the lowered transaction fees for buyers, homeowners want to buy smaller houses than those of existing house owners. The decrease in transaction costs for buying has a limited effect on price-to-rent ratio: as Table 9 shows, houses price relative to rent shows a very small change. Now consider reducing selling costs. As shown in Panel (E) of Table 8, a decrease in transaction costs for sellers decreases the homeownership rate by 3.3pp. However, the change in the transaction fees for sellers positively affects the average house size: the housing size of homeowners increases by 5.05

[65]The LTV ratio is defined as "Total value of mortgages and home equity loans secured by the primary residence held by household" divided by "Total value of primary residence of household."

[66]This high value is motivated by the right panel of Figure 8, which shows that mortgage-related initial fees in the FHFA decreased by 50 percent over the period 1995-2005. Favilukis, Ludvigson and Van Nieuwerburgh (2017) provide further evidence of larger changes in transaction fees, where total broker compensation decreased close to 40% between 1997 and 2006 for some sub-prime mortgage loans, and data on FDIC-insured real estate loans suggest fees per real estate dollar lent rose by 30% between 2000 to 2006. Notably, these measures do not distinguish between the share of transaction costs for sellers versus buyers.

percent. Since the significant rise in the intensive margin (house sizes) dominates the decrease in the extensive margin (homeownership rates), the aggregate housing demand increases, and the price-to-rent ratio also rises by 7.9 percent, as found in Table 9. This result implies that some homeowners decide to be renters due to the decrease in the selling costs, and other existing house owners sell their houses with lower costs and buy bigger houses.

While the decrease in the cost for buyer can account for the rise in the aggregate homeownership rate, it fails to match the uneven changes across age groups, generating similar effects across the young and old cohorts. For example, the homeownership rate increases by 4.21pp for the youngest age group, which is comparable to the change in the homeownership rate for the oldest (4.35pp). The change in transaction costs for selling also cannot account for the increase in the aggregate homeownership rate. Therefore, we can conclude that the variations in the two transaction fees cannot account for the increase in the total homeownership rate and uneven behaviors across age cohorts at the same time.

5.1.4 All Factors

Finally, we consider changing all the factors at the same time. In this experiment, we assume that the DTI ratio rises to 1.3, downpayment ratio decreases by 20 percent, and transaction costs for buying and selling decrease by 20 percent. The model economy with all the driving forces successfully reproduces the changes in aggregate homeownership rates and the uneven changes across age groups. According to Panel (E) of Table 8, the total homeownership rate increases by 2.31pp which is about 60 percent of the rise in the aggregate homeownership rate in data between 1995 and 2005.[67] The model economy can also replicate the observed variation in the housing size in terms of square feet, also reported in Table 8.

Importantly, the total change in the aggregate homeownership rate is mostly driven by the young. As can been seen in Panel (E) of Table 8 and Figure 12, the homeownership rate for the youngest increases by 4.56pp with a contribution rate of around 40 percent, while the oldest contribute only around 16 percent to the total variation. These results suggest that the DTI constraint is the main driving force for both aggregate and disaggregate homeownership since the

[67] Other factors that we abstract from, such as changes in interest rates, house price expectations and mortgage structure may help additionally account for the remaining increase in the aggregate homeownership rate. As mentioned earlier, Chambers, Garriga and Schlagenhauf (2009) attribute a large role to mortgage innovations and changes in institutional details in driving up the homeownership rates leading up to 2005. Li and Yao (2007), on the other hand, explicitly considers the role of house prices in a life cycle model, and find differential welfare effects across various age groups.

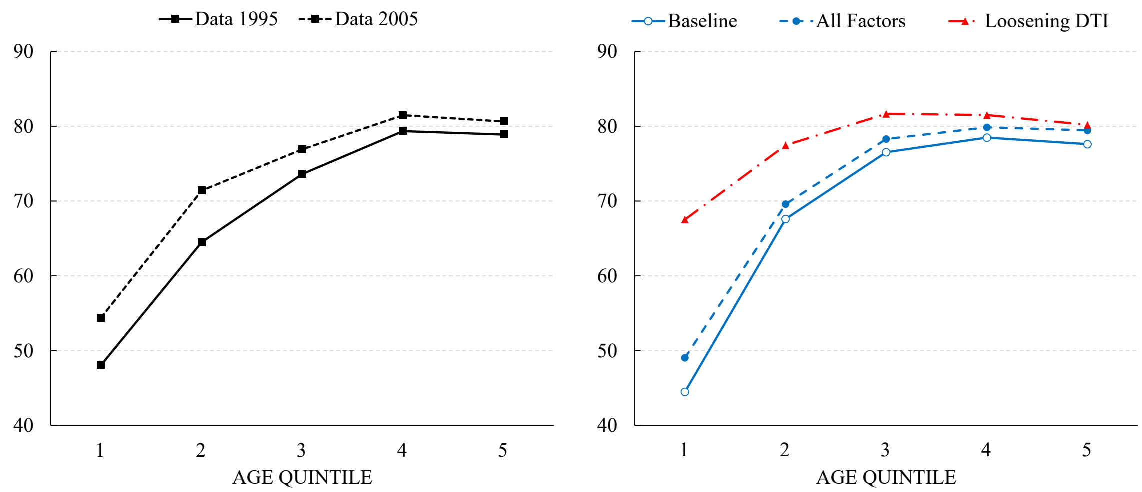


Figure 12: Transitions of Homeownership Rate by Age: Data vs Model

Note: Y-axis is a homeownership rate. "All Factors" represent the model in which the parameters of all the driving forces are recalibrated.

combined impact of all the factors is similar to that of the model with a rise in the DTI ratio from a qualitative perspective.[68] Finally, the model with all factors endogenously increases house price relative to rental price: as found in Table 9, the price-to-rent ratio increases by 8 percent, which accounts for up to around 27 percent of the observed increase in the price-to-rent ratio.[69]

5.1.5 Transition between Tenures

Now we examine the role of each driving force for transitions across tenure states. Our empirical analysis showed that the aggregate change is mostly explained by renter-to-owner (R2O) transitions during both the rise and fall of the homeownership rate between 1995-2015. More precisely, the young largely contribute to the variation in R2O transitions. The empirical findings are well replicated by the model when we change all the factors. First, consistent with empirical findings, R2O transitions play an important role in accounting for the total variation but the contribution of O2R transition is small in the model economy. According to Panel (B) of Table 10, the transition probability for R2O increases from 0.126 to 0.143 with the variations in all the factors but O2R transition shows a much smaller change.

[68]We also compute the model-implied contribution rates across the income distribution and find that this finding is not an income story in that the total variation is not driven by the income-poor.

[69]According to Duca, Muellbauer and Murphy (2011) and Sommer, Sullivan and Verbrugge (2013), the price-to-rent ratio increased by around 30-40 percent for the period 1995-2005. In particular, the model of Sommer, Sullivan and Verbrugge (2013) also endogenously generates the ratio of house price to rent, and their model can account for up to 60 percent of the increase in the price-to-rent ratio over the 1995-2006.

Table 10: TRANSITION PROBABILITIES BETWEEN TENURES

	Quintiles					Total
	1st	2nd	3rd	4th	5th	
Data: 1993-1995						
R2O	0.188	0.158	0.147	0.137	0.057	0.152
O2R	0.090	0.054	0.028	0.020	0.017	0.035
Data: 2003-2005						
R2O	0.248	0.195	0.151	0.162	0.067	0.185
O2R	0.075	0.066	0.042	0.022	0.040	0.046
(A) Baseline Model						
R2O	0.150	0.170	0.135	0.103	0.006	0.126
O2R	0.049	0.042	0.032	0.024	0.008	0.028
(B) All Factors						
R2O	0.177	0.177	0.154	0.118	0.008	0.143
O2R	0.059	0.042	0.034	0.026	0.008	0.032

Note: These are two-year transition probabilities between tenures. R2O (O2R) denotes the transition probability from renters (owners) to owners (renters).

Second, in the model economy the contribution of young households to the variation in R2O transitions is relatively large as in the data. R2O transition probability for the first age group shows a considerable increase while the variation for the oldest is relatively small: the probability of R2O transition for the youngest increases from 0.150 in the baseline model to 0.177 in the model with all the factors but that for the oldest is unchanged at zero.

Third, the model fails to account for the fact that O2R transition declined for the youngest during the housing boom. However, the model can generate the heterogeneous movements of the O2R transitions across age groups to some extent. O2R transition increased for mid-aged and older households on the upswing. This empirical finding is broadly reproduced by the model as the O2R transitions of 3th and 4th quintiles rise.

We find that the DTI constraint is an essential factor in accounting for the variation in the R2O transition among all the various factors considered. In the model with a rise in the DTI ratio (see Panel (B) of Table A3 in Appendix), the total R2O transition increases to 0.168, which is a relatively large change compared to the effects of other driving forces. Not only that, the relaxed DTI constraint also helps to explain the uneven variation in transition between tenures. When relaxing the DTI limit, the contribution of young households to the variation in R2O transition is also large as is in the data and in the model with all the factors. Notably, the R2O probability for young households significantly increases to 0.288. Thus, we argue that the change in DTI limits is the main driving force in explaining the aggregate and disaggregate transitions between tenures over the period 1995-2005.

5.2 Sensitivity Analysis for Size of Experiments

In this section, we check to see if the results are robust to different values of changes in the driving forces for homeownership changes. As reported in Figure 6, the DTI or PTI ratio rose by 40-50 percent over period 1995-2007. Based on this empirical finding, as an upper bound of the DTI limit on the upswing, we consider a case where the DTI ratio is 1.4 (an overall increase of around 56 percent relative to the benchmark value). Since the variations in DTI ratio reflect both endogenous changes in households' debt and disposable income and exogenous institutional changes, we also consider a smaller variation in DTI than that in the data to control for the endogenous variations: we assume that the DTI ratio rises from 0.9 to 1.2. Panel (A) of Table 11 shows the impact of an increase in the DTI ratio with different values of λ. Regardless of the size of changes in the DTI ratio, loosening the DTI limits still plays an essential role in accounting for the aggregate variation in the homeownership rate. When the DTI ratio is 1.2, the aggregate homeownership rate increases by 3.65pp while it rises by around 10pp when the DTI limit is set to 1.4. In particular, the two different DTI limits also successfully replicate the uneven variations in the homeownership rates across age groups. In both cases, the contribution rate for young cohorts (the first and second quintiles) in the total variation is around 70 percent while the old (the fourth and fifth quintile) contribute less than 20 percent to the aggregate change.

Since the downpayment ratio and the transaction fees turn out not to be the main driving factors for both aggregate and disaggregate variations in the homeownership rates, it is more instructive to see whether this is related to the small changes introduced in both these factors. For the LTV constraint, we consider two cases where the downpayment ratio decreases by larger amounts than our baseline case: by 30 percent and 40 percent, which imply that the LTV limit increases by 7.5 percent and 10 percent, respectively.[70] According to Panel (B) of Table 11, in spite of larger changes, the effect of a reduction in the downpayment on the aggregate homeownership rate is still small. In all cases, the total homeownership rate does not change much. For the two transaction fees, we first consider a case where transaction costs decrease by 30 percent. According

[70]This value is consistent with some empirical findings in the literature. For example, Bachmann and Ruth (2017) find that the LTV ratio increased by around 10 percent between 1995 and 2005 for first-time home-buyers.

Table 11: Changes in Homeownership Rate: Sensitivity Analysis

	Quintiles					Total
	1st	2nd	3rd	4th	5th	
(A) Loosening DTI Constraint						
$\lambda\psi = 1.2$	8.48	4.42	2.33	1.56	1.48	3.65
	(46.41)	(24.19)	(21.75)	(8.54)	(8.10)	(100)
$\lambda\psi = 1.4$	24.81	11.23	5.59	4.04	3.54	9.84
	(50.42)	(22.82)	(11.36)	(8.21)	(7.19)	(100)
(B) Loosening LTV Constraint						
$\chi\psi = 0.14$	0.05	0.02	0.00	0.03	0.35	0.09
	(4.07)	(1.63)	(0.00)	(2.44)	(28.46)	(100)
$\chi\psi = 0.12$	-0.31	-0.20	-0.17	0.39	1.52	0.25
	(-25.20)	(-16.26)	(-13.82)	(31.71)	(123.58)	(100)
(C) Reducing Transaction Fee for Buyer						
$\phi_b\psi = 0.0245$	4.35	1.78	1.22	2.95	9.96	4.05
	(14.98)	(6.13)	(4.20)	(10.16)	(34.31)	(100)
$\phi_b\psi = 0.0175$	6.56	3.38	2.08	4.11	12.90	5.81
	(22.60)	(11.64)	(7.17)	(14.16)	(44.44)	(100)
(D) Reducing Transaction Fee for Seller						
$\phi_s\psi = 0.049$	-8.22	-4.54	-1.36	-1.34	-2.12	-3.52
	(46.76)	(25.82)	(7.74)	(7.62)	(12.06)	(100)
$\phi_s\psi = 0.035$	-5.65	-2.84	0.66	2.37	3.22	-0.45
	(252.23)	(126.79)	(-29.46)	(-105.80)	(-143.75)	(100)

Note: Consistent with data, the total change in the homeownership rate is a simple average of five age quintiles. Values in ( ) are contribution rates, which are computed based on the changes in the homeownership rates.

to the right panel of Figure 8, the mortgage-related initial fees in the FHFA decreased by 50 percent over the period 1995-2005, so we also consider a case where the two transaction fees fall by 50 percent as a lower bound case. Regardless of the size of changes in the two transaction fees, the reduction in the buying cost fails to match the aggregate and disaggregate variations in the homeownership rates at the same time as the effects of the change in transaction fees for buyers on the old cohorts is relatively large. On the other hand, the change in transaction costs for selling cannot account for the increase in the aggregate homeownership rate.

From this sensitivity analysis, we can conclude that the main results are robust to different parameter values of the driving factors.

5.3 Role of General Equilibrium Effects

Next we consider the role of general equilibrium effects in accounting for changes in aggregate and disaggregate homeownership rates in our various experiments. In order to do this, we compare the effects of partial and general equilibria for the four driving forces discussed above. We define the partial equilibrium effect as the extent to which an economy changes while keeping prices constant, while prices endogenously evolve in general equilibrium.[71] Therefore, by comparing the two effects, we can see how endogenous price changes play a role in housing tenure variations. Table 12 shows how the four driving forces affect homeownership rates at aggregate and disaggregate levels in both the partial and general equilibria cases.

When loosening both the credit constraints and reducing transaction fees for buyers, there is a relatively small difference in homeownership rates between the partial and general equilibria. For example, as found in Panels (A) in Table 12, in the partial equilibrium, the reduction in the DTI ratio increases the average homeownership rate by 8.73pp, which is similar to the change in the general equilibrium. Importantly, the observed uneven variations in homeownership between the young and the old are also well replicated by the partial equilibrium effect of a change in the DTI ratio: the variation in young cohorts is relatively larger than that in old cohorts. The general equilibrium effect is crucial when reducing transaction fees for sellers. According to Panel (D) of Table 12, in the partial equilibrium, the reduction in the selling cost show little variation in the aggregate homeownership rate significantly: it rises by 0.03pp. In the general equilibrium, however, the increased price-to-rent ratio induced by the rise in the size of owner-occupied houses (price-to-rent ratio increases by 7.41 percent as found in Table 9) dominates the partial equilibrium effect: a change in the aggregate homeownership rate is negative and very large in the general equilibrium.

When all the factors are taken into account, as shown in Panel (E) in Table 12, the general equilibrium effect is still important: i) an endogeneous change in the prices reduces the change in the aggregate homeownership rate in the partial equilibrium, and ii) the observed variation in homeownership rates by the middle three age cohorts are not found in the partial equilibrium.

[71] It should be noted that the distribution of income, wealth, and so forth can change in the partial equilibrium even if the prices are constant. In addition to constant house prices and rent, this also imposes fixed interest rates and thus implicitly captures the effects of the various experiments under long term mortgages with fixed rates.

Table 12: Partial vs. General Equilibrium Effects on Homeownership rates

	Quintiles					Total
	1st	2nd	3rd	4th	5th	
(A) Loosening DTI Constraint						
Partial Equilibrium	23.10	9.91	5.17	3.04	2.61	8.52
General Equilibrium	23.05	9.87	5.14	3.01	2.59	8.73
(B) Loosening LTV Constraint						
Partial Equilibrium	0.00	0.03	0.01	0.03	0.25	0.06
General Equilibrium	0.00	0.03	0.01	0.03	0.25	0.06
(C) Reducing Transaction Fees for Buyer						
Partial Equilibrium	3.17	1.30	1.55	2.12	4.22	2.55
General Equilibrium	4.21	1.37	1.49	2.07	4.35	2.70
(D) Reducing Transaction Fees for Seller						
Partial Equilibrium	-1.05	-1.11	-0.08	0.83	1.52	0.03
General Equilibrium	-7.88	-4.12	-1.11	-0.99	-2.38	-3.30
(E) All Factors						
Partial Equilibrium	10.05	4.59	3.10	4.56	9.85	6.30
General Equilibrium	4.56	1.99	1.76	1.37	1.86	2.31

Note: Values in the table are percentage point (pp) changes from the baseline model.

6 Conclusion

In this paper, we document the evolution of homeownership rates across age for the period 1995-2015. The main empirical findings are summarized as follows. First, the homeownership rate had been relatively stable before 1995, but it shows large changes over the period 1995-2015, with a rise from 1995-2005 and a subsequent decline after. Second, we find that there are uneven variations in the homeownership rates across age groups for the period 1995-2015: it is large for the young but small for the old. Third, the total variation in the participation rate is largely driven by renter-to-owner (R2O) transitions by young households.

To account for these stylized facts, we build a dynamic stochastic general equilibrium (DSGE) life-cycle model which incorporates indivisible and lumpy housing investment, both LTV and DTI constraints, and transaction costs for selling and buying. We find that the model economy successfully reproduces the key distributions over the life cycle including the homeownership profile by age cohorts, and it performs well in terms of transitions between housing tenures across age quintiles.

Then we consider different candidates as potential driving forces to explain homeownership and housing tenure trends in our quantitative model economy. Our analysis indicates that variations in DTI limits play a crucial role in accounting for the variation in the aggregate homeownership rate and the uneven behaviors across age groups including the variations in movements between housing tenures. On the other hand, variations in transaction costs for sellers generate changes in housing on the intensive margin and generate an endogenous rise in the house price-to-rent ratio.

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Appendix

A Data Description

This paper mainly relies on the five data sets: the CPS, the AHS, the PSID, the CEX, and the Freddie Mac Loan-Level data.

A.1 The CPS

The main data set used for the aggregate and disaggregate trend of homeownership rate is the Annual Social and Economic (ASEC) supplement of the Current Population Survey (CPS). The ASEC/CPS is surveyed in every March and contains detailed questions covering economic characteristics such as income, age, and tenure status. The sample size is around 60,000 on average but varies over time, and the basic unit of observations for the CPS is a household. In this paper, we use the CPS sample from 1976 to 2016, and the data are downloaded from Integrated Public Use Microdata Series (IPUMS).[72]

We summarize the sample selection for the CPS. Sample A is used for the trend of the aggregate homeownership rate, while we use Sample B for variations in homeownership rates across age groups. When computing aggregate statistics, we use household weights in the CPS.

Sample A We first define a head of a household using "RELATE" in IPUMS which reports an individual's relationship to the head of household or householder. We drop households who do not have a head of household or householder. We then drop households who whose head's age or tenure information in not reported. We next exclude samples whose head has zero weights.

Sample B Additionally, for age groups, we drop households whose head's age is less than 26 or greater than 85 to be consistent with the model.

A.2 The AHS

We also use the American Housing Survey (AHS) for the trend of homeownership rates as a robustness check. The AHS is a survey about housing units. The AHS contains information on

[72] https://cps.ipums.org/cps/

the number and characteristics of housing units as well as the households that occupy those units. Particularly, this data set is used for computation of the size of a unit in terms of the number of rooms and in the unit and square feet of the unit. Data are available annually from 1973 to 1981, but only biennially from 1983 to 2013. Hence, for the trend of the aggregate homeownership rate, we convert biennial data into annual ones with a linear interpolation. The sample size is around 72,900 per year but has varied over the years. Key variables used in this paper are age, tenure, and the size of the unit. Sample selection for the AHS is almost identical to that used for the CPS.

A.3 The PSID

Since the CPS and the AHS are not panel data, it is not easy to keep track of disaggregate movements between housing tenures over time with these two data sets. Hence, we use the Panel Study of Income Dynamics (PSID) for computation of transitions between housing tenures across age groups. The PSID is a longitudinal survey of a sample of both individuals and the family units. The sample size has varied 4,800 families in 1968 to more than 9,000 in 2013. Since 1968, families had been interviewed each year until 1997 but the survey has been biennial after 1997. Thus, we compute two-year transition probabilities for the period 1995-2015. Sample selection strategy used for the PSID is similar with that for the CPS.

A.4 The CEX

We also use the Consumer Expenditure Survey (CEX) for computing consumption distribution over the life cycle and estimates for the transaction costs. The CEX is a rotating panel of households. It started in 1960, but continuous data are available starting the first quarter of 1980. Each household is interviewed for a maximum of four consecutive quarters. The average size of sample in the CEX is around 13,320 per year. For the distribution of consumption, we use quarterly data over the period 1980q1 to 2007q1, which is from Heathcote, Perri and Violante (2010). For transaction costs for buyers and sellers, we use the CEX for the period 1995-2015. In the CEX, there is information about closing costs and price paid for the property when buying, total expenses in the sale of the property, and the selling price for the property. The questions used for computing the transaction costs are as follows.

- What was the total price paid for the property, not including closing costs?

- What was the total amount of closing costs, including survey costs, title search, recording fees, taxes, escrow payment, points paid by buyer, deed preparation, etc.?
- What was the selling price (trade-in value)?
- What were the total expenses in the sale of this property, including closing costs, commission to realtor, points for financing, and mortgage balance penalties?

A.5 The Freddie Mac Loan-Level Data

We also use the Freddie Mac's Single Family Loan-Level data in Figure 7. The data set includes around 25.4 million fixed-rate mortgages originated between January 1, 1999 and December 31, 2016. In order to construct Figure 7, we use "Original combined loan-to-value (CLTV)" and "Original debt-to-income (DTI) ratio"[73] in the data set. The LTV ratio is obtained by dividing the original mortgage loan amount on the note date plus any secondary mortgage loan amount disclosed by the seller by the lesser of the mortgaged property's appraised value on the note date or its purchase price in the case of a purchase mortgage loan. In the case of a refinance mortgage loan, the ratio is obtained by dividing the original mortgage loan amount on the note date plus any secondary mortgage loan amount disclosed by the seller by the mortgaged property's appraised value on the note date. The PTI ratio is defined as, (1) the sum of the borrower's monthly debt payments, including monthly housing expenses that incorporate the mortgage payment the borrower is making at the time of the delivery of the mortgage loan to Freddie Mac, divided by (2) the total monthly income used to underwrite the loan as of the date of the origination of the such loan.

B Computational Procedures

We find the stationary measure $\mu(a, h, x, \psi)$ as follows.

Step 1. Have guesses for endogenous parameters: ψ, $\underline{h}$, δ_r, δ_{or}, r, τ, b, μ_1, and σ_1.

Step 2. Construct grids for individual state variables, such as asset holdings, a, housing stock h, and logged individual labor productivity, $\widetilde{x} = \ln x$. The numbers of a and x grids are denoted

[73] Sometimes, the "payment-to-income" or "PTI" ratio is also widely known as the "debt-to-income" (DTI) ratio. However, based on the background computation for this variable, we use the term "PTI" for this variable instead of DTI for clarity even if the data provider calls it DTI.

by n_a, and n_x, respectively. We choose $n_a = 150$ and $n_x = 15$. Asset grids are not equally spaced: more asset grid points are assigned on the lower asset range using a convex fucntion. $\hat{s}$ $(\equiv \ln s)$, is equally spaced in the range of $[-3\sigma_{\tilde{x}}, 3\sigma_{\tilde{x}}]$, where $\sigma_{\tilde{x}} = \sigma_x/\sqrt{1-\rho_x^2}$. The number of housing sizes, $N_h \equiv |\mathcal{H}|$, is chosen to be 5. We assume that the maximum house size is three times as large as the smallest one ($\bar{h} = 3\underline{h}$), and the housing sizes are equally spaced.

Step 3. Approximate the transition probability matrices for individual labor productivity, $\mathbb{P}_x$, using Tauchen (1986).

Step 4. Solve the individual value functions at each grid point backwardly from J to 1. In this step, we obtain the optimal decision rules for saving $a'(a,h,x,j)$ and housing investment $h'(a,h,x,j)$, rental housing $d(a,h,x,j)$, and consumption $c(a,h,x,j)$, a set of value functions $V_O(a,h,x,j)$, $V_R(a,h,x,j)$, and $V(a,h,x,j)$. For example, we can solve a problem of the $O2O$ type household as follows:

$$V_O(a,h,x,j) = \max_{a',\,c,\,h'} \left\{ \frac{c^{1-\sigma_c}}{1-\sigma_c} + (1- \ )\frac{s^{1-\sigma_s}}{1-\sigma_s} + \quad j \sum_{x'=1}^{N_x} \mathbb{P}_x(x'|x) V(a', h', x', j+1) \right\},$$

subject to

$$c + a' + \mathbb{I}_{h' \neq h}(1+\phi_b)qh' = y + \mathbb{I}_{h' \neq h}(1-\phi_s)qh - \delta_o qh, \text{ and Eq. } 7.$$

Step 5. Obtain the time-invariant measure, $\mu(a,h,x,j)$ using the optimal decision rules and $\mathbb{P}_x$.

Step 6. Compute aggregate variables using $\mu(a,h,x,j)$. If targeted moments such as are sufficiently close to the assumed ones,[74] then the steady-state economy is found. Otherwise, reset the endogenous parameters, and go back to Step 4.

C Additional Tables and Figures

[74]Targeted moments are the non-housing assets to output ratio of 2.5, the aggregate homeownership rate of around 70 percent, the housing stock to output ratio of 1.2, the homeownership rate in the oldest age quintile of 77 percent, the ratio of housing services to consumption of 20 percent, the replacement ratio of 33 percent, the wealth share and the wealth Gini coefficient of the cohort at age 26, the total accidental bequest, and the balanced budget of the government.

Table A1: Growth Accounting of the Homewonership Rate over Income Distribution

	Quintiles					Total
	1st	2nd	3rd	4th	5th	
	(A) 1995-2005					
Change (pp)	6.68	3.48	3.96	4.20	3.46	4.36
Contribution rate (%)	32.74	17.05	19.40	20.61	16.98	100
	(B) 2005-2015					
Change (pp)	-7.68	-5.04	-6.35	-5.83	-6.24	-6.23
Contribution rate (%)	25.21	16.53	20.84	19.13	20.47	100

Note: The baseline statistics are from the CPS. The total change in the homeownership rate is a simple average of five income quintiles.

Table A2: Transition in Housing Sizes

	Quintiles					Total
	1st	2nd	3rd	4th	5th	
	(A) Levels					
1995						
Number of rooms	5.48	6.13	6.35	6.17	5.61	5.94
Square feet	1866	2065	2165	2120	1970	2035
2005						
Number of rooms	5.63	6.25	6.38	6.29	5.94	6.09
Square feet	1619	1981	2084	2080	1930	1933
2013						
Number of rooms	5.40	6.18	6.19	6.14	5.99	5.98
Square feet	1573	1955	2013	2018	2048	1919
	(B) Changes (%)					
1995-2005						
Number of rooms	2.74	1.96	0.47	1.94	5.88	2.53
Square feet	-13.24	-4.07	-3.74	-1.89	-2.03	-5.01
2005-2013						
Number of rooms	-4.09	-1.12	-2.98	-2.38	0.84	-1.81
Square feet	-2.84	-1.31	-3.41	-2.98	6.11	-0.72

Table A3: TRANSITION PROBABILITIES BETWEEN TENURES

	Quintiles					Total
	1st	2nd	3rd	4th	5th	
Data: 1993-1995						
R2O	0.188	0.158	0.147	0.137	0.057	0.152
O2R	0.090	0.054	0.028	0.020	0.017	0.035
Data: 2003-2005						
R2O	0.248	0.195	0.151	0.162	0.067	0.185
O2R	0.075	0.066	0.042	0.022	0.040	0.046
(A) Baseline Model						
R2O	0.150	0.170	0.135	0.103	0.006	0.126
O2R	0.049	0.042	0.032	0.024	0.008	0.028
(B) Loosening DTI Constraint						
R2O	0.288	0.183	0.143	0.109	0.006	0.168
O2R	0.051	0.038	0.030	0.026	0.008	0.030
(C) Loosening LTV Constraint						
R2O	0.152	0.170	0.135	0.103	0.008	0.128
O2R	0.051	0.042	0.032	0.024	0.008	0.028
(D) Reducing Transaction Fee for Buyer						
R2O	0.176	0.174	0.143	0.139	0.020	0.146
O2R	0.059	0.042	0.032	0.026	0.006	0.030
(E) Reducing Transaction Fee for Seller						
R2O	0.122	0.170	0.150	0.096	0.000	0.146
O2R	0.057	0.044	0.034	0.026	0.012	0.030
(F) All Factors						
R2O	0.177	0.177	0.154	0.118	0.008	0.143
O2R	0.059	0.042	0.034	0.026	0.008	0.032

Note: These are two-year transition probabilities between tenures. R2O (O2R) denotes the transition probability from renters (owners) to owners (renters).

Table A4: Key Aggregate Moments

	Data	Model
Targeted Moments		
$K/Y\psi$	2.50	2.50
$H/Y\psi$	1.20	1.24
$S/C\psi$	0.20	0.19
Homeownership ratio (Restricted sample)	69.53	69.34
Untargeted Moments		
Wealth Gini	0.79	0.67
Income Gini	0.57	0.45

Note: When computing the aggregate homeownership rate, the restricted sample is used to be consistent with the model. The restricted sample is the data where households whose head's age is less than 26 or greater than 85 are dropped. Gini coefficients for wealth and income are computed using the PSID 1994.

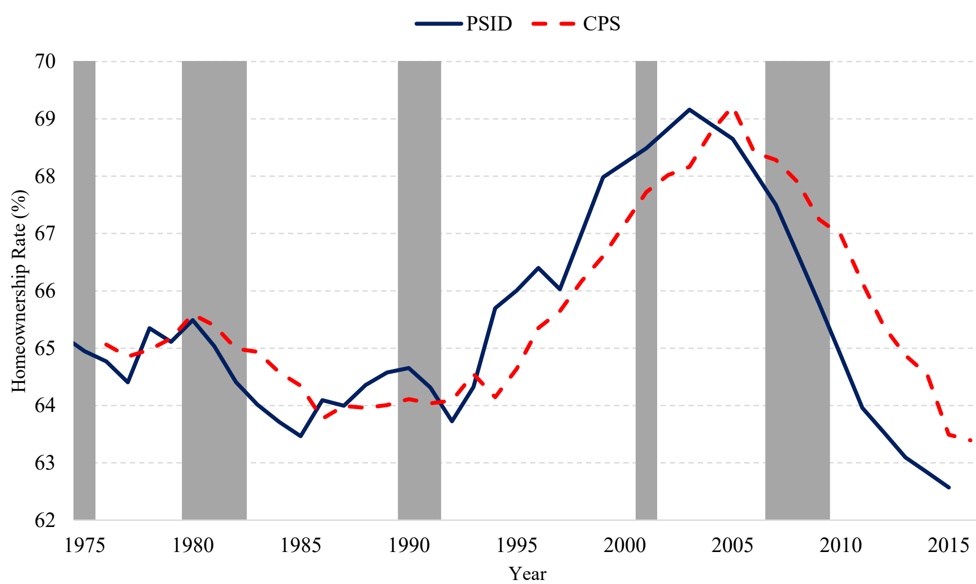


Figure A1: Homeownership Trends (PSID)

Note: Trend of the homeownership rate in the U.S. for the last forty years from the PSID.

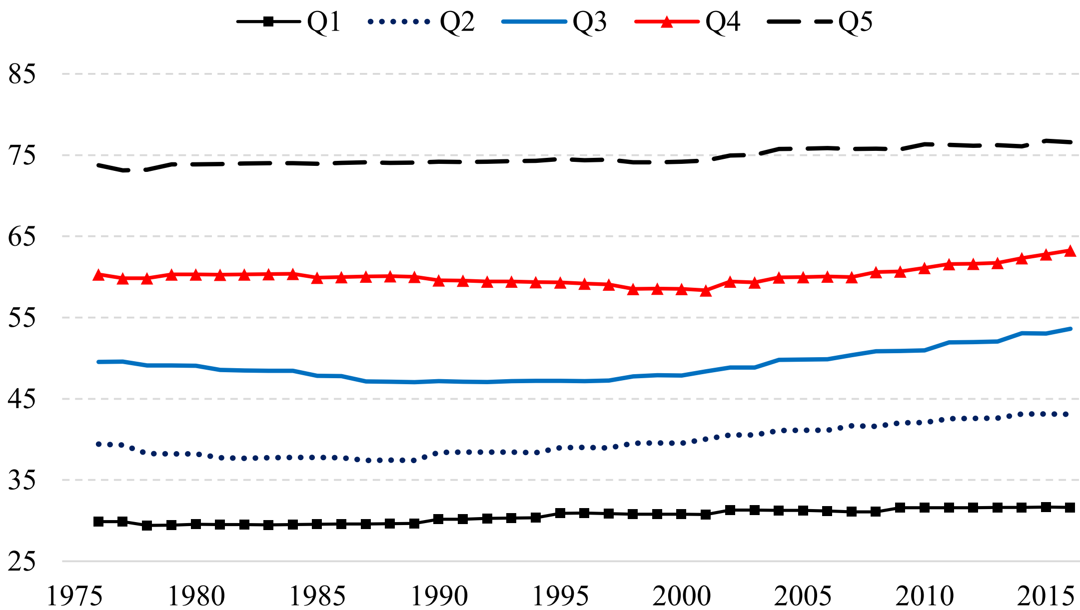


Figure A2: Trend of Mean Age in Each Quintile

Note: Y-axis is age. The data are taken from the CPS.

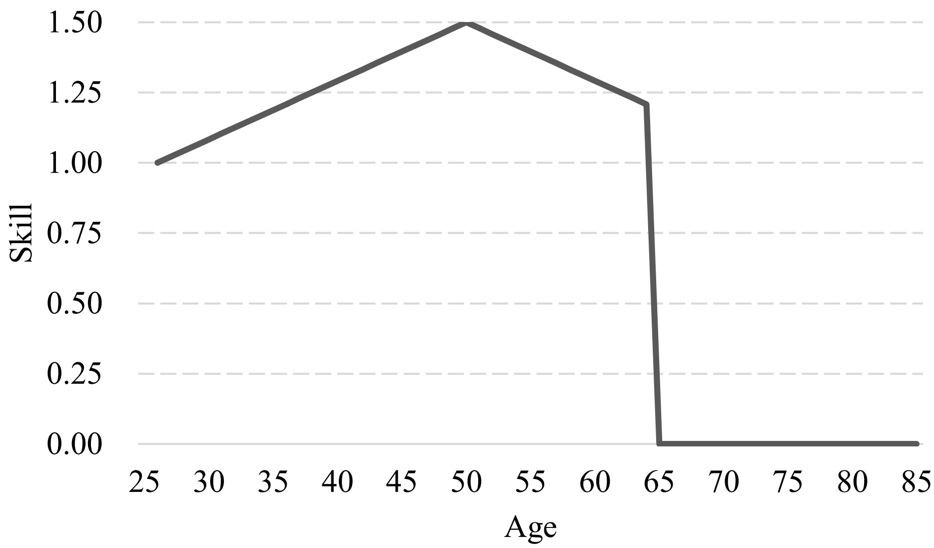
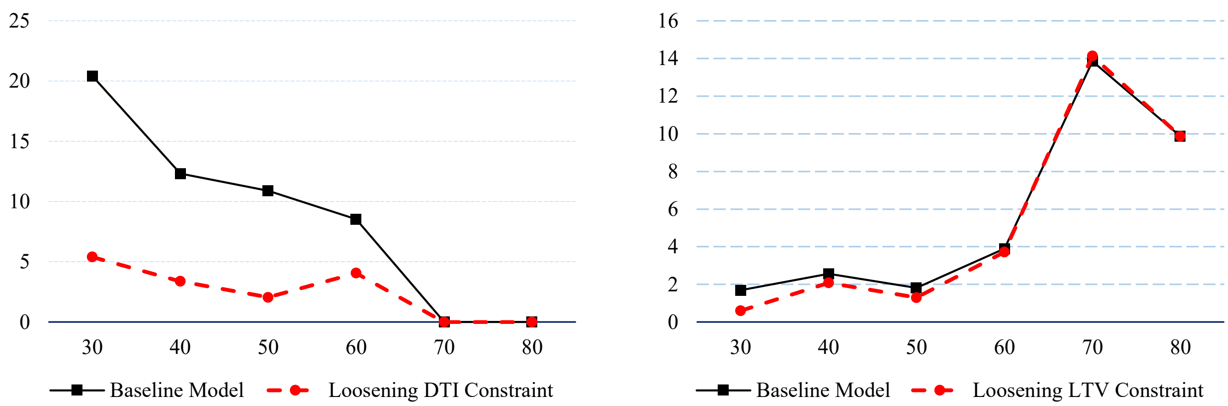


Figure A3: Deterministic Skill Profile over Age



DTI-dominant LTV-dominant

Figure A4: Fraction of DTI- and LTV-Dominant Households

Note: The figure shows the fraction of DTI- and LTV-dominant marginal households in each age bin. Marginal households are defined as in Eq. 8. Y-axis is density, and x-axis represents mean age of each bin.