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) 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 a variation in the DTI limit plays 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 to 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. At the same time, changes in loan to value ratio alone affect the intensive margin, i.e. size of house and relaxation in this credit constraint leads to larger houses. The effects on the homeownership rates are rather limited in general equilibrium. This is consistent with the findings of others (see Ortalo-Magne and Rady (2006) and Chambers, Garriga and Schlagenhauf (2009)). In contrast, since the debt-to-income constraint is more likely to be binding for the young households, relaxation of this credit constraint leads to relatively large effects on the homeownership rate, particularly for the young. Transaction costs play a relatively small role overall for the homeownership rates, since in addition to the pri-

[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 burst around the Great Recession.

mary effects highlighted above, there are additional general equilibrium effects. Low transaction costs provide an ideal opportunity for households to increase the size of their house. Thus, changes in the transaction costs also have a primary effect on the intensive margin. The resulting increased housing demand leads to a rise in price-to-rent ratio which discourages households from buying new houses, or renters to become homeowners.

Overall, while changes in the DTI constraints help explain the changes in the homeownership behavior across various age groups, the changes in LTV constraints and transaction costs for buyers 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. However, our model economy with all the factors incorporated endogenously generates a significant fraction of the rise in price-to-rent ratio seen in the data accompanying the rise in homeownership rates.[5]

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 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

[5] In Section 5.4, we consider an exogenous change in house prices relative to rent in the model economy and find that the exogenous variation in prices is not the main driving force for changes in housing tenure decisions.

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.

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

[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.

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

around 60,000 on average.[8] The range of the CPS sample is 1976-2016.

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.

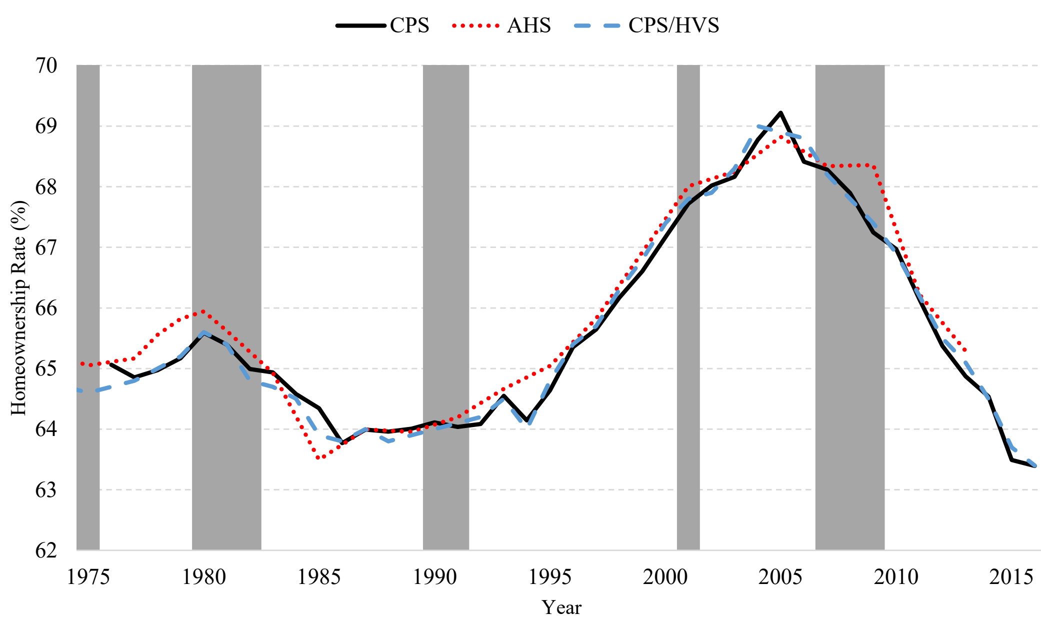


Figure 1: Aggregate Homeownership Trends in the U.S.
Note: Trend of the homeownership rate in the U.S. for the last forty years from the CPS, the AHS, and the CPS/HVS (the Housing Vacancy Survey). The rates in the CPS and AHS are computed by the authors, while the rate in the CPS/HVS from FRED with ID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

[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 A4 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.

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] 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]

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.

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 homeown-

[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 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.

ership 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, 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.

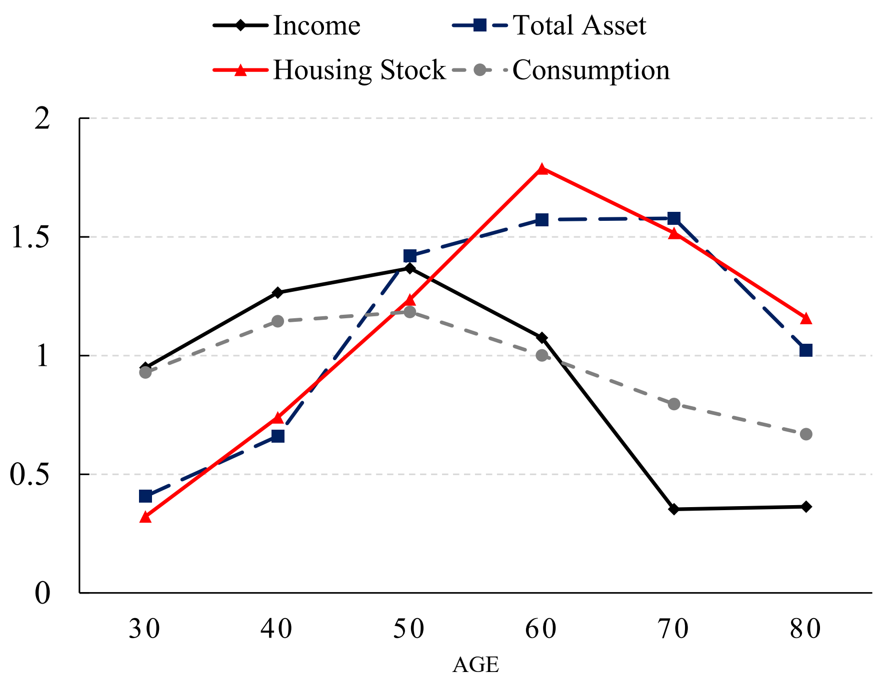


Figure 2: Income, Assets, Consumption Distributions over the Life cycle
Note: Information on income and assets is from the PSID 1994, and information on consumption is from the CEX 1980-2006. Total assets are the sum of housing stock and non-housing assets. All statistics are normalized by each mean.

[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 in Table A1 in Appendix. We find similar numbers but the rate is not hump-shaped but increasing over age in the sample.

[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.

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. According to Figure 3, 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 for changes 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 has fallen 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 rate over 1995-2015.[21]

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).[22] Importantly, this change is largely driven by young households. The rate for the youngest rose by 6.34pp whereas the

[21] Consistent evidence for the uneven changes in the homeownership rate can be found in Figure A2 and A3 in Appendix.

[22] 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.

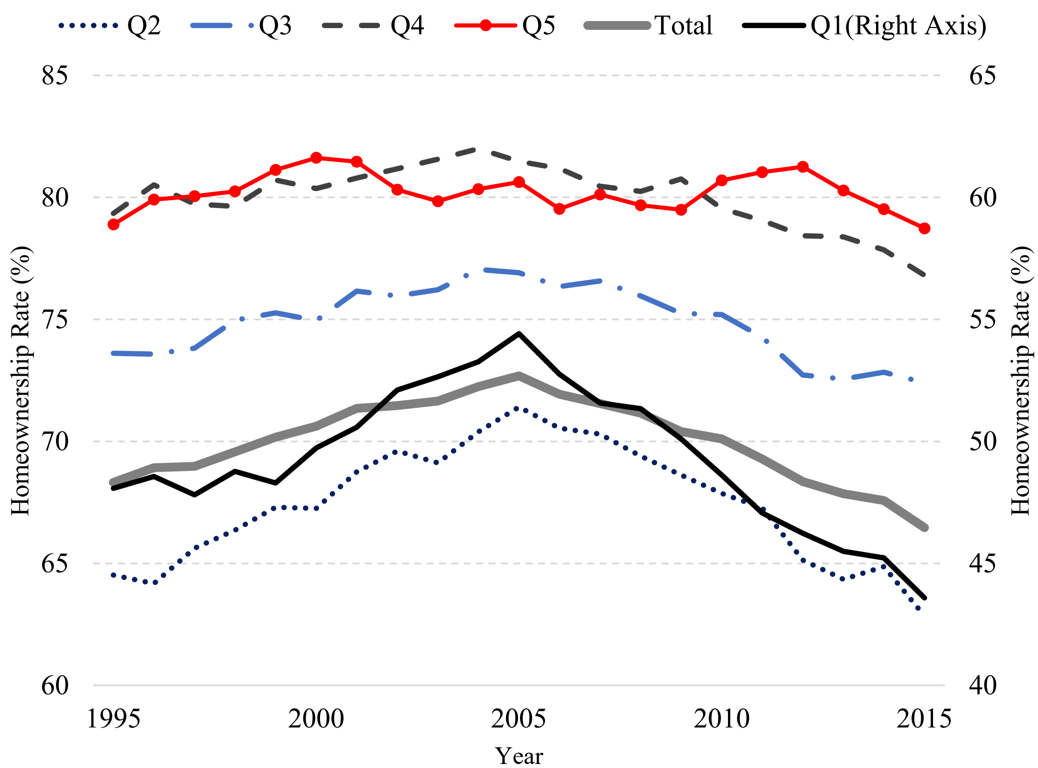


Figure 3: Homeownership Trends across Age Quintiles for 1995-2015
Note: The unit of measure for the first age quintile is on the right axis, while for the others on the left axis. When constructing the age groups and the total homeownership rates, we drop households whose head's age is less than 26 or 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.[23] Therefore, we conclude that there are uneven changes in

[23]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.

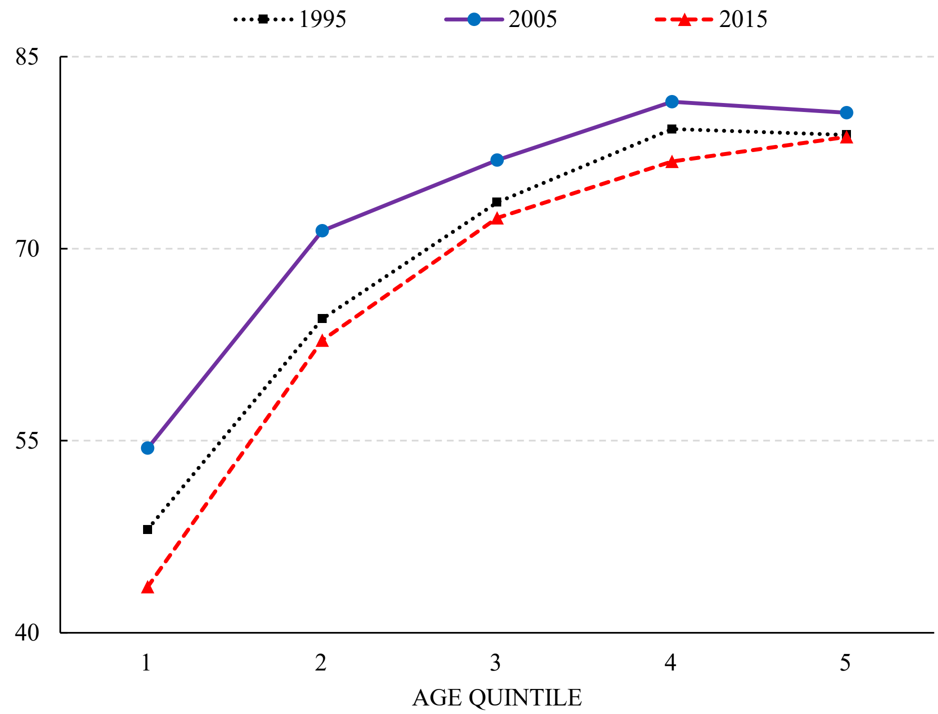


Figure 4: Homeownership Rate by Age for 1995, 2005 and 2015

Note: Y-axis is a homeownership rate.

the homeownership rates across age groups for the periods 1995-2015: it is large for young cohorts but small for the old.

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 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

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.

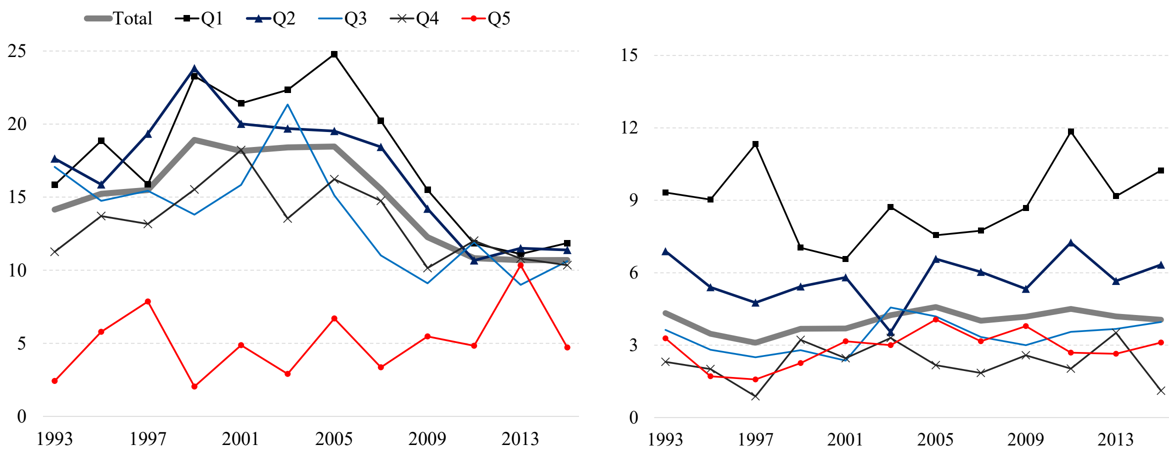
change around 32 percent. However, the percent change for the O2R transitions on average is around 22 percent. Thus, we argue that R2O transitions play an essential role in accounting for the huge change in the homeownership rate between 1995 and 2005.[24]

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 deceased 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) on the down-side.

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

[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.

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]



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).

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

[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).

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., $d \in \mathcal{H}$.[26] Owner-occupied and rental houses yield a flow of housing services, s, via a linear technology, $s = g(h', d)$:

[26] Homeowners are not allowed to rent a rental house, i.e., $d = 0$ if $h' > 0$.

$$s = \begin{cases} h' & if\ h' > 0 \\ \omega d & if\ h' = 0 \end{cases}, \tag{2}$$

where $\omega < 1$. Eq. 2 and $\omega < 1$ imply that renters enjoy less amount of housing services given the same size of housing than homeowners. 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., $\delta_r > \delta_o$.[27] Both these features help motivate why households want to be homeowners. 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_s and ϕ_b, respectively.

3.2 Households

3.2.1 Preference

Households have a finite horizon. In each period, the economy is populated 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 $\psi_j \in [0, 1]$, where $\psi_J = 0$. Households make decisions on consumption, housing services, and saving. Each household maximizes the expected lifetime utility over consumption c_j and housing services s_j given by:

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

where β is the time-discount factor, γ 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.[28] 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.

[27] Depreciation for housing capital can be interpreted as the proportional maintenance cost.

[28] We assume that $\psi_0 = 1$.

3.2.2 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:

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

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.[29] 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 is a bit different from the standard assumptions in the literature in the sense that the distribution of housing and non-housing assets is different from one another.[30] We assume that when a household dies accidentally, her descendant is born and starts life with financial assets she left behind. However, it is assumed that her housing assets are equally distributed to all living households by the government. In this way, an initial endowment of financial assets for a new-born household is

[29]See Figure A5 in Appendix for a graphical representation of the deterministic age-efficiency profile.

[30]Accidental bequests in the literature typically assume that all the remaining assets are equally distributed to the surviving households.

endogenously generated, while the literature typically assumes exogenous initial endowments. In addition, this assumption allows some young households to buy houses as observed in the data. 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.

3.2.3 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. 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.[31] As far as the LTV constraint is concerned, 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,

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

A household also faces the DTI constraint.[32] She can borrow λ percent of her labor income at most:

$$a' \geq -\lambda wxv.$$[33]

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

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

[31] Similarly, Greenwald (2016) introduce both LTV and payment-to-income (PTI) limits to study the macroeconomic implications of mortgage credit growth.

[32] 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 $PTI = \frac{P}{y} = mDTI$

[33] 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.

where

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

Eq. 6 implies that working households should satisfy both constraints while only LTV constraints are limited for retirees.[34] Large heterogeneity between the young and the 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.

3.2.4 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:

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

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:

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

subject to

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

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

[34] Notice that Eq. 6 holds not just at origination but at all times. This timing assumption is standard in the literature such as Chambers, Garriga and Schlagenhauf (2009) and Yang (2009).

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

subject to

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

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

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

subject to

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

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

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

3.3 Production

The production technology for the representative firm is represented by a constant-returns-to-scale Cobb-Douglas production function:

$$Y = F(K,L,Z) = ZK^{\alpha}L^{1-\alpha}$$

where K and L denote aggregate non-housing capital stock and aggregate effective labor, respectively. Z is aggregate productivity. Non-housing capital is assumed to depreciate at δ_k. The representative firm determines demand for labor and capital to maximize current profits such that:

$$\Pi = \max_{K,L}\left\{F(K,L,Z) - wL - (r+\delta_k)K\right\}.$$

We assume perfectly elastic supply of housing services. In other words, demand of housing stock entirely determines the equilibrium level. 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 should be equal to the financial and depreciation costs:

$$p = r + \delta_r.$$ [35]

[35]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 where the depreciation rate is δ_r. Thus, the equilibrium condition in competitive markets, where the marginal revenue, p, equals to the marginal cost, $r+\delta_r$, gives us $p = r + \delta_r$.

3.4 Government

The government plays two roles in this economy. First, the government employs 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:

$$\tau \int wxvd\mu = \int bd\mu_r,$$

where μ_r is a measure for retirees.[36] 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 forecasting function for μ, $\mathbb{T}(\mu)$, a set of inputs $\{K(\mu), L(\mu)\}$, a set of pricing functions $\{p(\mu), r(\mu), w(\mu)\}$, a set of optimal decision rules $\{c(\omega;\mu), a'(\omega;\mu), d(\omega;\mu), h'(\omega;\mu)\}$, 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:

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

2. The firm's optimization: For all μ,

$$r(\mu) = F_K(K(\mu), L(\mu), Z) - \delta_k,$$

$$w(\mu) = F_L(K(\mu), L(\mu), Z).$$

3. Accidental bequest:

$$tr = \int hd\mu_d,$$

where μ_d is a measure for non-surviving households.

4. Market clearing: For all μ,

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

$$L(\mu) = \int xvd\mu,$$

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

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

$$Y = C + I_K + I_H + \delta_r D + \Gamma,$$

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

5. Balanced budget of the government:

$$\tau \int wxvd\mu = \int bd\mu_r,$$

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 ($\bar{h} = 3\underline{h}$), and the housing sizes are equally spaced. We set the minimum size of housing stock, $\underline{h}$, and the parameter in the housing service technology for renters, ω, to jointly target the aggregate homeownership rate of around 70 percent in the restricted sample and the housing stock to output ratio of 1.1.[37] For transaction costs for buyers and sellers, we calibrate them using the CEX for the period 1995-2015. In the CEX, there is information about closing costs and price paid for the property when buying,

[37] This measure is also 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).

Table 4: Parameters of the Model Economy

Parameter	Value	Description
		Demographics
J_r	65	Retirement Age (model: 40)
J	86	Terminal age (model: 61)
ψ_j		1995 U.S. Life Tables of the National Center
		Preference
β	0.949320	Time discount factor
σ_c	3.0	CRRA for consumption
σ_s	1.0	CRRA for housing service
γ	0.915	Weight on consumption good
		Housing
$\underline{h}$	1.15	Lower bound for housing stock
N_h	5	Number of housing sizes
χ	0.2	Downpayment ratio (1-LTV ratio)
λ	0.9	DTI ratio
ω	0.89	Housing service technology parameter
ϕ_b	0.035	Transaction fee for buying
ϕ_s	0.07	Transaction fee for selling
δ_o	0.035	Depreciation rate for owner-occupied housing
δ_r	0.075	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)
κ	0.5	Parameter for deterministic age-efficiency profile
		Technology
α	0.32	Capital income share
δ_k	0.1	Depreciation rate for non-housing capital
		Government
τ	0.1447	Tax rate for labor income
b	0.41	Social Security benefit
tr	0.022	Lump-sum transfer from accidental bequests

total expenses in the sale of the property, and the selling price for the property.[38] Based on the averages of the estimates, we set $\phi_b = 0.035$ and $\phi_s = 0.07$. Similarly, Gruber and Martin (2003) find 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 Global Property Guide are in the range $1.05 - 2.2$ percent for buyers and $6.51 - 9$ percent for sellers.[39] For depreciation rates for owner-occupied and rental housing, we set $\delta_o = 0.075$ and $\delta_r = 0.035$, following Chambers, Garriga and Schlagenhauf (2009).

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 β to match non-housing assets to output ratio of 2 following Yang (2009). Survival probabilities come from 1995 U.S. Life Tables of the National Center for Health Statistics. Following Chambers, Garriga and Schlagenhauf (2009), we assume that the CRRA coefficients for consumption and housing services are 3 and 1, respectively, i.e., $\sigma_c = 3$ and $\sigma_s = 1$.[40] The parameter γ is set to match the ratio of housing services to consumption, which is 0.21 in the data based on authors' calculation.[41]

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.[42] In

[38] 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?

[39] 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.

[40] 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.

[41] 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.

[42] 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).

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 debt-to-income in the economy.[43][44]

Production and Government Aggregate productivity Z is assumed to be constant at one. We use very standard values for the production-related parameters: we choose $\alpha = 0.32$ and $\delta_k = 0.1$. 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 when an individual dies accidentally, her housing assets are equally distributed to all living households.

4 Benchmark Findings

In this section, we summarize baseline findings of the model economy. We first examine the model's fit to the distributions over the life cycle. Figure 6 presents life cycle profiles of total wealth, housing stock, income, consumption. The corresponding profiles in the data are in Figure 2. Overall, the model economy performs well also in terms of the life-cycle distributions. In the model economy, i) income profile is hump-shaped where it has the peak at age of 50 and decreases significantly after retirement, ii) total asset distribution is also an inverted U-shaped curve over age, iii) young cohorts own relatively a small amount of housing stock, and iv) consumption distribution over the life cycle is relatively smooth. These are all patterns roughly observed in the U.S. data (See Figure 2).

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. A static view can be analyzed using mean values of homeownership rate over age. The upper panel of Table 5 exhibits the share of housing that is owner-occupied over the life cycle. The model economy successfully

[43] 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.

[44] When computing the DTI ratio, we use total household credit market debt outstanding (FRED ID: CMDEBT) and total disposable personal income (FRED ID: DPI).

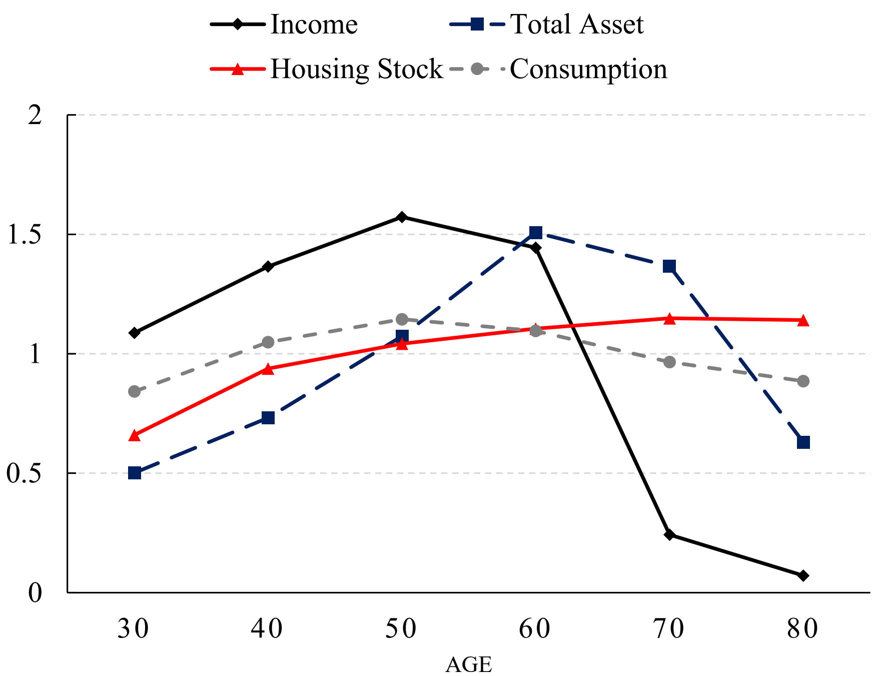


Figure 6: Income, Asset, Consumption Distributions over the Life Cycle: Model
Note: All statistics are are normalized by each mean.

replicates the shares across age quintile. As shown in the upper panel of Table 5, the homeownership ratio across age quintile in the model 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 5 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.[45] The distribution of housing size over the life cycle is hump-shaped in the data, and the model broadly captures the magnitude and the shape by age cohorts.

Next, we move on to the dynamic perspective: transitions between housing tenures. We compute transitions of the tenures across age quintile using the model economy.[46] Table 6 reports transition probabilities between the housing tenures in the data and the model. Statistics for the data are the averages of four transition matrices over 1993-2013. It should be noted that the data show the two-year transition probabilities due to data availability, while the model reports the one-year ones. Our quantitative model economy performs well in terms of the aggregate transitions of

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

[46]In the steady state equilibrium, the type distribution and aggregate statistics are constant over time. At the individual level, however, there are a lot of movements 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 5: 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	50.30	67.68	75.03	80.16	77.02	70.02
			(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	5.96	5.97	6.16	6.15	5.94
Square feet	1865	2042	2046	2110	2106	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	53.7	0.0	46.3	0.0	0.0	100
O2O	58.9	17.8	17.8	2.2	3.3	100
All	54.5	18.8	20.9	4.2	1.6	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.

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 0.978 while one for R2R is 0.935 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 0.128, but it is zero for the fifth quintile. Additionally, the model economy broadly replicates the hook-shaped 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 5 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 and at the aggreagte level even if it fails to match that for R2R households. 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 54.5 percent and 1.6 percent of movers belong to the first and fifth age groups in the model economy, respectively.

Table 6: 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	0.872	0.942	0.955	0.986	1.000	0.935
R2O	0.128	0.058	0.045	0.014	0.000	0.065
O2R	0.025	0.010	0.018	0.006	0.052	0.022
O2O	0.975	0.990	0.982	0.994	0.948	0.978

Note: Transition probabilities between tenures in the PSID and the model economy. Transition probabilities are two-year transitions in the PSID while the model reports the one-year ones.

5 Uncovering Uneven Variation in Homeownership

5.1 Driving Forces for Homeownership Changes

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.

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. However, in Section 5.4, we explicitly consider an exogenous change in house prices alone to assess its role in explaining the trends in homeownership rates and transitions across tenure status seen in the data.

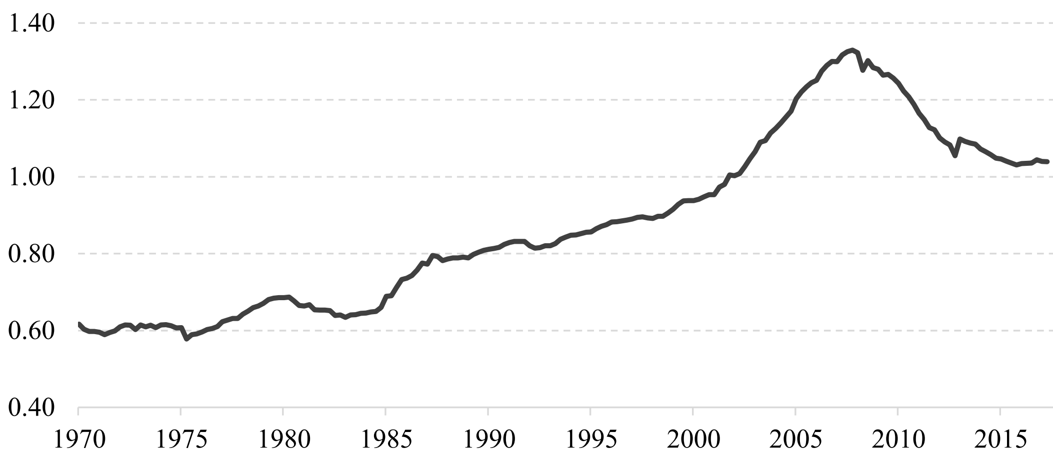


Figure 7: Trend of Aggregate DTI Ratio
Note: The DTI ratio is defined as total household credit market debt outstanding divided by total disposable personal income. Data are from FRED.

5.1.1 DTI Constraint

The first candidate considered as a driving force for the changes in homeownership rates is the DTI limit. Figure 7 shows the trend of the aggregate DTI ratio, which is defined as the ratio of total household debt outstanding divided by total disposable personal income.[47] Broadly similar to the trend of homeownership, the DTI ratio also increased over 1995-2007 and decreased afterwards. In

[47]The data are from FRED: total household credit market debt outstanding (FRED ID: CMDEBT) and total disposable personal income (FRED ID: DPI).

particular, the DTI rose sharply in early 2000 and fell significantly during the recent financial crisis. The upper panel of Figure 8 shows the distribution of PTI based on Freddie Mac's Single Family Loan-Level Dataset in three periods: 2000, 2005, and 2015.[48] This figure provides clear evidence that considerable changes occurred in PTI constraints over period 2000-2015.[49] PTI constraints were loosened during the boom period with many mortgagors taking on PTI ratios higher than 50 percent.[50] In contrast, PTI ratios were limited by institutional constraints in 2000 and 2015. In particular, Greenwald (2016) documents the sharp 45% limit in 2015.

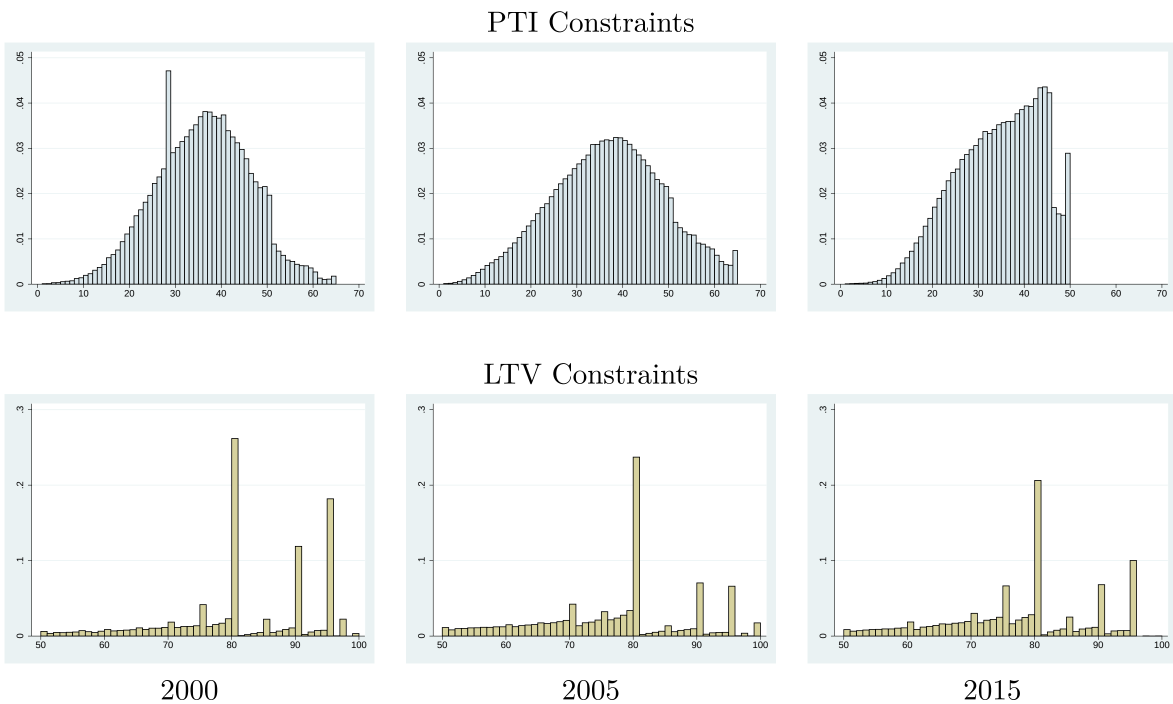


Figure 8: Distributions of PTI and LTV Constraints
Note: Histograms are weighted by loan balance. Data are from Freddie Mac's Single Family Loan-Level Dataset. X-axis is PTI or LTV ratio, while y-axis is density.

5.1.2 LTV Constraint

The trend of the LTV ratio is consistent with that of the aggregate homeownership rate. According to Bachmann and Ruth (2017) among others, the LTV ratio, which can be interpreted as the inverse of downpayment ratio, has increased for the period 1995-2005 and decreased until 2015.

[48] As discussed above, the PTI ratio is closely related to the DTI ratio under reasonable assumptions, so PTI constraints can be a proxy for the DTI limits.

[49] 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.

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

As reported by Bachmann and Ruth (2017), the LTV ratio was around 90 percent in 1995, had a peak value of near 100 percent in 2005, and started to decrease afterwards.[51] Another supportive piece of empirical evidence is from the distribution of the LTV ratio. The bottom panel of Figure 8 shows the distribution of combined LTV based on Freddie Mac loans.[52] 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 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.

5.1.3 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.[53] The left panel of Figure 9 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 very 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.[54] Another possible source of the historical trend for transaction costs is the Federal Housing Finance Agency (FHFA). The agency provides mortgage-related initial fees and charges.[55] Figure 9 exhibits the series of the initial fees and charges from the FHFA. Similar to the trend of buying costs in the CEX, the costs in the FHFA, which capture only a subset of the transaction costs, show 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

[51] 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).

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

[53] The appendix provides information about what the buying and selling costs capture in the CEX. Gruber and Martin (2003) also obtain the estimates of average transactions costs for the median buyer and seller using the CEX.

[54] 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.

[55] 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.

and to the lowest value of 0.4 percent in 2005, and the measures have risen after 2005.[56]

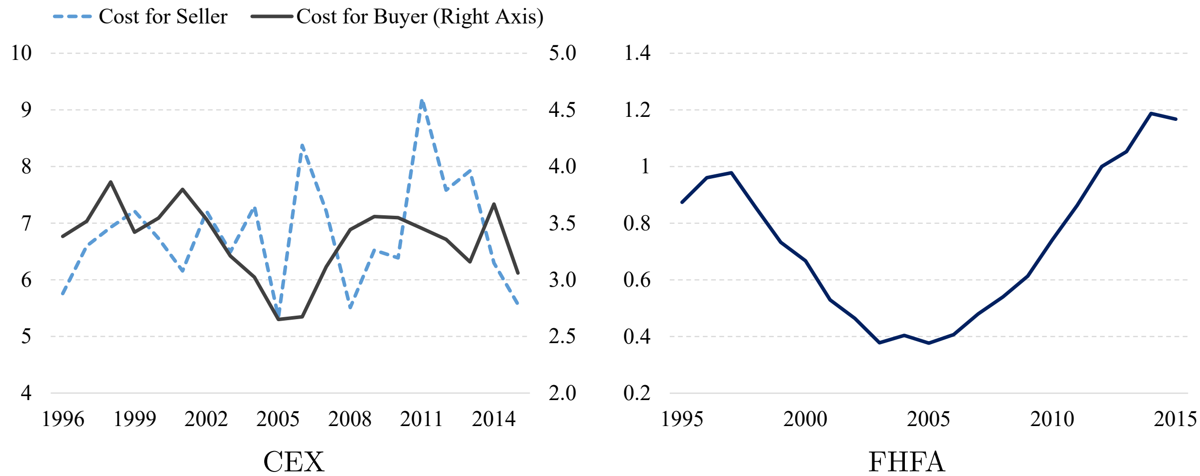


Figure 9: Trend of Transaction Costs

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.

5.2 Modifying Credit Constraints and Transaction Costs

The above empirical findings show that the trends of the two constraints and the two transaction costs are closely related to the homeownership trends. Based on the empirical evidence, we investigate if variation in each factor can account for the uneven behaviors across age quintiles using our quantitative model. To do this, we compute the steady-state equilibrium in the model economy by allowing one factor to change at a time but keeping others unchanged. After 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 in the last section, 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.

For these experiments, we assume that i) the DTI ratio rises to 1.0 from 0.9, ii) the downpay-

[56]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.

ment ratio decreases by 20 percent, and iii) both transaction costs fall by 20 percent. As reported in Figure 7, the DTI ratio rose by 30 percent over period 1995-2005 and fell by 12.5 percent. Since these variations in DTI reflect both endogenous changes in households' debt and disposable income and exogenous institutional changes, we choose a smaller variation in DTI than that in the data to control for the endogenous variations: we assume that the DTI ratio is one on the upswing (it increased by around 11 percent from the benchmark value). As noted by Chambers, Garriga and Schlagenhauf (2009), 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 assuming a 20 percent decrease in downpayment for the period 1995-2005. According to the left panel of Figure 9, 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 the numbers, we have an assumption of a 20 percent reduction in the transactions cost for buyers. We apply the same number to the selling costs.

5.2.1 Loosening DTI Constraint

We first consider loosening of the DTI constraint. For this analysis, we increase the DTI ratio from 0.9 to one. The impact of an increase in the DTI ratio are reported in Table 7. It seems that 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 6.0pp, which is similar to the data. In particular, the uneven variations in the homeownership rates across age groups are successfully replicated when relaxing the DTI constraint. According to Panel (A) of Table 7, the rate for youngest household rises by 8.66pp whereas the rate for the fifth quintile goes up by 4.22pp. Consequently, the contribution rate for young cohorts (the first and second quintiles) in the total variation is close to 45 percent while the old (the fourth and fifth quintile) contribute around 30 percent to the aggregate change, which is consistent with the empirical findings discussed earlier.

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 the 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.[57] In contrast, a variation in a DTI ratio hugely

[57] Of course, their tenure decisions are indirectly influenced by the general equilibrium effect.

Table 7: Loosening DTI Constraint

	Quintiles					Total
	1st	2nd	3rd	4th	5th	
(A) Homeownership Rates						
Change (pp)	8.66	4.48	7.17	4.84	4.22	6.00
Contribution rate (%)	29.49	15.25	24.41	16.48	14.37	100
(B) Housing Sizes						
Change (%)	18.77	16.88	15.97	18.17	14.38	16.86
(C) Price-to-rent Ratio (%)						
Change (%)						20.00

affects working households, but the effects are different across age cohorts. Since 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. This suggests that the number of households whose DTI constraints are likely to be binding may be relatively large in the younger cohorts. The left panel in Figure 10 shows the fraction of households in each age cohort whose DTI constraints may be binding in the baseline model and the model with the loosened DTI constraint. We assume that a DTI constraint for a household is *almost* binding if her future asset is close enough to the limit:

$$a' \leq -(1-\xi)\lambda wxv, \tag{8}$$

where $\xi(< 1)$ is a small number.[58] As shown in the left panel of Figure 10, households for whom the DTI limits are binding are concentrated among the young cohorts in the baseline model economy. When a 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 fraction of households at 40 whose DTI constraint is binding is around 18 percent in the baseline model, but it decreases to 11 percent when DTI limits are relaxed, while the share of households at 60 with binding constraints does not change much with a rise in the DTI ratio. Therefore, young renters who face a more relaxed DTI ratio are less limited by the constraints and are able to buy houses. This suggests that DTI constraints are

[58] We simply choose $\xi = 0.1$ for Figure 10, but other small numbers make no difference in a qualitative sense.

important in decisions of house purchase as also supported by the empirical facts found in Figure 8. We also provide suggestive empirical evidence that DTI limits for young households were largely loosened during 1995-2007 and tightened over 2007-2016 when comparing 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).[59] 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.

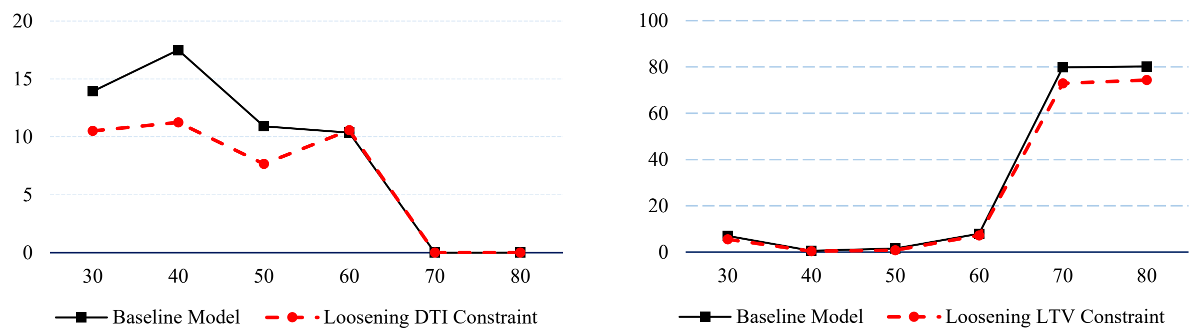


Figure 10: Fraction of Households Whose DTI or LTV Is Almost Binding in the model

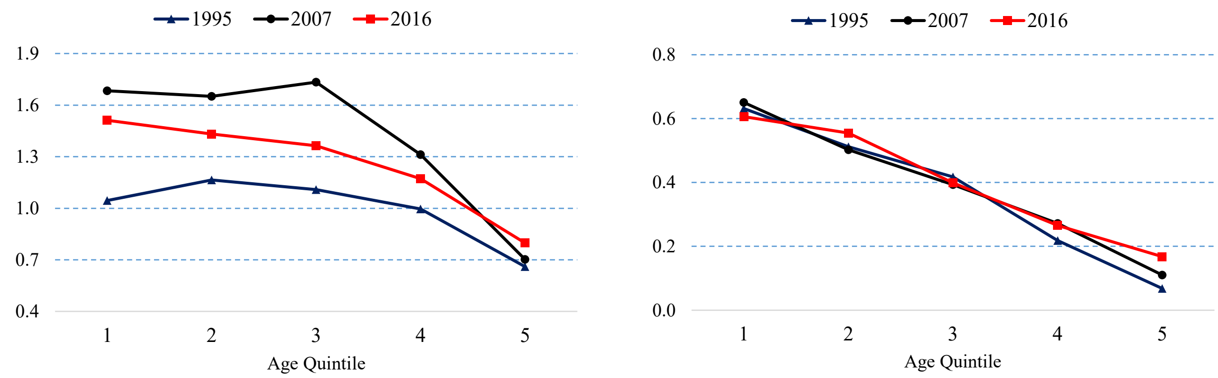
Note: Y-axis is density, and x-axis represents mean age of each bin.

Interestingly, loosening the DTI limits also has a positive effect on the intensive margin: the average housing size increases by 16.86 percent as shown in Panel (B) of Table 7. The rise of the intensive margins along with the increase in the extensive margins leads to a large rise in the price-to-rent ratio.[60] According to Panel (C) of Table 7, the house price relative to the rental price increases by around 20 percent in the model with relaxed DTI limits, which represents the economy in 2005. This is more than the half the increase in price-to-rent ratio observed over the period 1995-2005.[61]

[59]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. See Figure A6 in Appendix.

[60]The price-to-rent ratio in the model is $1/p$ where $p = r + \delta_r$.

[61]The price-to-rent ratio rose by around 30-40 percent in the U.S. data. See Figure 2 in Duca, Muellbauer and Murphy (2011) and Sommer, Sullivan and Verbrugge (2013) for the trend of the house price-to-rent ratio.



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."

5.2.2 Loosening LTV Constraint

Next, we decrease the downpayment ratio by 20 percent.[62] 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 decreases by only 0.52pp. However, the intensive margin (housing sizes) is affected to some extent: the average home size increases by 7.36 percent. In this case, general equilibrium effects play an important role in preventing a rise in homeownerhsip. A significant increase in housing size leads to an increase in the price-to-rent ratio, which affects extensive margins negatively. 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.[63] The limited impact of the LTV changes is already conjectured by the empirical fact shown in the upper panel of Figure 8: the distributions of LTV ratios in the boom and bust periods are almost identical.

We also compute the share of households for whom the LTV limits are almost binding using a equation similar to Eq. 8 and report them in the right panel of Figure 10. As shown in the right panel of Figure 10, with the smaller downpayment ratio, the number of households whose LTV constraints are binding falls for all age cohorts, but the change in the numbers for the young

[62]With this assumption, the LTV ratio changes from 0.8 to 0.84.
[63]In Chambers, Garriga and Schlagenhauf (2009), a 50 percent reduction in downpayment reduces the aggregate homeownership rate from 63.7 to 63.5%.

Table 8: Loosening LTV Constraint

	Quintiles					Total
	1st	2nd	3rd	4th	5th	
(A) Homeownership Rates						
Change (pp)	1.18	-2.64	0.12	-0.50	-0.90	-0.52
Contribution rate (%)	-43.07	96.35	-4.38	18.25	32.85	100
(B) Housing Sizes						
Change (%)	9.24	6.09	7.19	8.07	6.32	7.36
(C) Price-to-rent Ratio (%)						
Change (%)						13.26

is not as dramatic as in the case of the DTI limit being loosened. For example, the fraction of households at 30 whose LTV constraint is around 7 percent in the baseline model, decreases to 5.5 percent when the LTV limits are relaxed. This implies that a change in the LTV ratio is not the main driving force for the relatively large variation in homeownership rates for young cohorts. 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.[64] As shown by the right panel of Figure 11, the distributions of the LTV ratio across the age groups were very similar across the three periods.

5.2.3 Reducing Transaction Fees

We next change transaction costs. We assume that transaction costs for buying and selling decrease by 20 percent. 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 rather than the homeownership rate. With the lowered transaction fees for buyers, home owners want to buy bigger houses that they own. According to Panel (B) of Table 9, the intensive margin for the housing stock increases by 3.56 percent when we lower the transaction costs for buyers. An increase in housing sizes leads to a rise in price-to-rent ratio. Interestingly, the general equilibrium effect induced by a rise in the intensive margins discourage renters to purchase houses, and hence the homeownership increases by only 1.68pp with a decrease in transaction fees for buyers as found

[64] 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."

in Panel (A) of Table 9. This finding is also consistent with Chambers, Garriga and Schlagenhauf (2009).

Table 9: Reducing Transaction Fee for Buyer

	Quintiles					Total
	1st	2nd	3rd	4th	5th	
(A) Homeownership Rates						
Change (pp)	1.84	1.28	1.95	1.37	1.66	1.68
Contribution rate (%)	22.72	15.80	24.07	16.91	20.49	100
(B) Housing Sizes						
Change (%)	3.33	3.03	3.37	3.90	3.69	3.56
(C) Price-to-rent Ratio (%)						
Change (%)						4.65

Now consider reducing selling costs. As shown in Panel (A) of Table 10, a decrease in transaction costs for sellers does not affect the homeownership rate due to the general equilibrium effects. As found in Panel (A) of Table 10, the aggregate homeownership rate changes by only 0.01pp. Similarly, the change in the transaction costs for sellers does not change the average house size. In any case, variations in the two transaction fees cannot account for the change in the aggregate homeownership rate or the uneven behaviors across age cohorts.

Table 10: Reducing Transaction Fee for Seller

	Quintiles					Total
	1st	2nd	3rd	4th	5th	
(A) Homeownership Rates						
Change (pp)	0.54	-0.72	0.11	0.26	0.22	0.01
Contribution rate (%)	131.71	-175.61	26.83	63.41	53.66	100
(B) Housing Sizes						
Change (%)	-1.70	-2.00	0.28	0.40	0.28	-0.49
(C) Price-to-rent Ratio (%)						
Change (%)						-1.39

5.2.4 All Factors

Finally, we consider all the factors at the same time. In this experiment, we assume that down-payment ratio decreases by 20 percent, the DTI ratio rises to one from 0.9, 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 (A) of Table 11, the total homeownership rate increases by 7.04pp which is a bit larger than that in the data.[65] This total change is mostly driven by the young. As can been seen in Panel (A) of Table 11 and Figure 12, the homeownership rate for the youngest increases by 11.59pp with a contribution rate of around 32 percent, while the oldest contribute only around 12 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 combined impact of all the factors is similar to that of the model with a rise in the DTI ratio. We do not explicitly account for the house price boom and bust during the period under consideration of 1995-2015, and the role that house price expectations might have played since our model endogenously generates an increase in the house price-to-rental price ratio.[66] Finally, the model with all factors successfully generates the observed increase in house price relative to rental price: the price-to-rent ratio increases by 30 percent which is comparable to the data.[67]

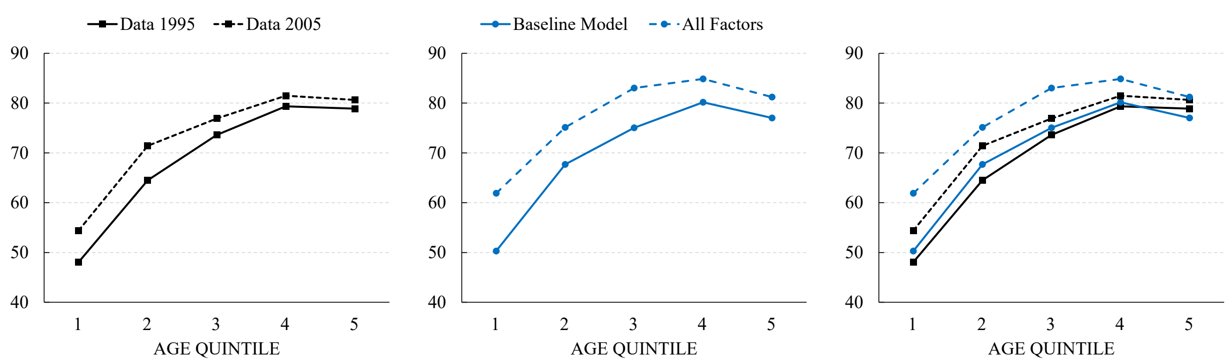


Figure 12: TRANSITIONS OF HOMEOWNERSHIP RATE BY AGE: DATA VS MODEL
Note: Y-axis is a homeownership rate. "All Factors" represent the model in which the parameters of all the driving forces are recalibrated.

[65] The model economy can also replicate the observed variation in the housing size in terms of the number of rooms reported in Table A2 in Appendix.
[66] Li and Yao (2007), for instance, explicitly considers the role of house prices in a life cycle model.
[67] According to Duca, Muellbauer and Murphy (2011), the price-to-rent ratio increased by around 30 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 11: Considering All Factors together: Credit constraints and transaction fees

	Quintiles					Total
	1st	2nd	3rd	4th	5th	
(A) Homeownership Rates						
Change (pp)	11.59	7.45	7.99	4.69	4.19	7.04
Contribution rate (%)	32.28	20.75	22.25	13.06	11.67	100
(B) Housing Sizes						
Change (%)	27.64	26.49	25.87	25.35	18.35	24.68
(C) Price-to-rent Ratio (%)						
Change (%)						29.19

5.2.5 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. Let us first discuss the performance of the full model. The empirical findings are well replicated 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 (F) of Table 12, the transition probability for R2O increases from 0.065 to 0.093 with the variations in all the factors but O2R transition shows a very small change.

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 three age groups shows a considerable increase while variations in other groups are relatively small. For example, the probability of R2O transition for the youngest increases from 0.128 in the baseline model to 0.204 in the model with all the factors but that for the oldest is unchanged at zero.

Third, the model can generate the heterogeneous movements of the O2R transitions across age groups to some extent. In the data, O2R transition declined for the youngest during the housing boom. This empirical finding is broadly reproduced by the model in that O2R transitions of the young cohorts fall. However, the model fails to account for the fact that O2R transition increased for the old on the upswing: O2R transitions decrease for old age cohorts in the model economy

Table 12: Transition Probabilities between Tenures

	Quintiles					Total
	1st	2nd	3rd	4th	5th	
(A) Baseline Model						
R2O	0.128	0.058	0.045	0.014	0.000	0.065
O2R	0.025	0.010	0.018	0.006	0.052	0.022
(B) Loosening DTI Constraint						
R2O	0.197	0.064	0.042	0.010	0.000	0.091
O2R	0.021	0.014	0.016	0.006	0.053	0.023
(C) Loosening LTV Constraint						
R2O	0.143	0.057	0.052	0.013	0.000	0.069
O2R	0.031	0.020	0.018	0.005	0.052	0.025
(D) Reducing Transaction Fee for Buyer						
R2O	0.137	0.056	0.047	0.015	0.000	0.067
O2R	0.017	0.010	0.016	0.006	0.048	0.021
(E) Reducing Transaction Fee for Seller						
R2O	0.132	0.058	0.049	0.014	0.000	0.067
O2R	0.028	0.011	0.020	0.005	0.052	0.023
(F) All Factors						
R2O	0.204	0.059	0.049	0.011	0.000	0.093
O2R	0.012	0.008	0.016	0.008	0.047	0.019

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

with all the factors.

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 (Panel (B) of Table 12), the total R2O transition increases to 0.091, which is a relatively large change compared to the effects of other driving forces. Not only that, an increase in the 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. As shown in Panel (B) of Table 12, the R2O probability for young households (the first two age groups) increases significantly. Thus, we argue that a DTI limit is the main driving force to explain aggregate and disaggregate transitions between tenures over the period 1995-2005.

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,[68] while, as shown in the last part, prices endogenously evolve in general equilibrium. Therefore, by comparing the two effects, we can see how the endogenous price change plays a role in housing tenure variations. Table 13 shows how the four driving forces affect homeownership rates at aggregate and disaggregate levels in both the partial and general equilibrium cases. As noted in Chambers, Garriga and Schlagenhauf (2009), the general equilibrium effect is crucial when loosening the LTV constraint. According to Panel (B) of Table 13, in the partial equilibrium, the reduction in the downpayment ratio increases the aggregate homeownership rate significantly: it rises by 14.40pp. In the general equilibrium, however, the increased price-to-rent ratio induced by the rise in demand for owner-occupied houses (it increases by 13.26 percent as found in Table 8) completely offsets the partial equilibrium effect: a change in the aggregate homeownership rate is very small in the general equilibrium. The same logic can be applied to the case with reducing transaction fees for sellers: the reduction in transaction costs for selling decreases the homeownership rate a bit in the partial equilibrium, but it returns to the baseline level due to the general equilibrium effect (see Panel (D) in Table 13). As shown in Panel (C) in Table 13, the general equilibrium effect is relatively small when reducing transaction fees for buyers: the aggregate homeownership rate increase by 2.11pp in the partial equilibrium, but the endogenous price change decreases it by only 0.43pp. Intuitive explanations are as follows. Renters want to buy houses or homeowners want to increase their house size with the reduction in buying costs given the constant prices (the partial equilibrium effect). This leads to an endogenous increase in the relative house prices to rent, which makes some households sell their houses (the general equilibrium effect). However, relatively high transaction fees for sellers prevent homeowners selling their houses, so the general equilibrium effect may be small in this case.

Interestingly, when loosening the DTI constraint, there is a relatively small difference in homeownership rates between the partial and general equilibria. As found in Panel (A) in Table 13,

[68] 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.

Table 13: Partial vs. General Equilibrium Effects on Homeownership rates

	Quintiles					Total
	1st	2nd	3rd	4th	5th	
(A) Loosening DTI Constraint						
Partial Equilibrium	9.69	7.32	8.50	6.44	6.04	7.69
General Equilibrium	8.66	4.48	7.17	4.84	4.22	6.00
(B) Loosening LTV Constraint						
Partial Equilibrium	17.52	11.91	10.28	13.51	17.64	14.40
General Equilibrium	1.18	-2.64	0.12	-0.50	-0.90	-0.52
(C) Reducing Transaction Fees for Buyer						
Partial Equilibrium	2.77	2.03	2.18	1.88	1.59	2.11
General Equilibrium	1.84	1.28	1.95	1.37	1.66	1.68
(D) Reducing Transaction Fees for Seller						
Partial Equilibrium	-4.04	-3.53	-2.44	-2.26	-2.10	-2.71
General Equilibrium	0.54	-0.72	0.11	0.26	0.22	0.01
(E) All Factors						
Partial Equilibrium	14.17	11.09	10.42	14.80	17.57	14.04
General Equilibrium	11.59	7.45	7.99	4.69	4.19	7.04

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

in the partial equilibrium, the reduction in the DTI ratio increases the average homeownership rate by 7.69pp, which is similar to the change in the general equilibrium. The observed uneven variations in homeownership between the young and the old are also well replicated by the partial equilibrium effect: the variation in young cohorts is relatively larger than that in old cohorts. This result implies that the increased price-to-rent ratio in the case of the loosened DTI constraint plays a limited role in accounting for changes in aggregate and disaggregate homeownership rates, even if the variation in price-to-rent ratio is relatively large (it rises by 20 percent according to Table 7). Then why is the role of general equilibrium effects smaller when loosening the DTI constraint? According to Eq. 6, the DTI constraint consists of only exogenous variables while the LTV limit contains the housing stock decision, which is a choice variable. Hence, households' endogenous decisions induced by the general equilibrium effect do not affect the DTI limit but do impact the LTV constraint.

When all the factors are taken into account, as shown in Panel (E) in Table 13, 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 by 50 percent, and ii) the observed different variations in homeownership rates by age cohorts are not found in the partial equilibrium.

5.4 Exogenous Change in House Price

The sample period we consider, with the dramatic rise and fall in the homeownership rates, is also characterized by a rise and fall in house prices. This rise in house prices between 1995-2005 is considered to be beyond what would be suggested by fundamentals, and so we consider an exogenous change in house prices relative to rent in the model. In particular, in this experiment, we assume that the price-to-rent ratio increases by 30 percent as observed in the data. Since we change the price exogenously, this counterfactual analysis only captures the partial equilibrium effect. Table 14 summarizes the results of the exogenous price change. From this experiment, two interesting results emerge. First, as found in the upper panel of Table 14, the rise in the exogenous price decreases the aggregate homeownership rate: households tend to sell their houses in response to a rise in the relative house price to rental rate. This is because households in our model economy do not buy real estate for investment purposes but only for residential purpose. Second and more importantly, in terms of the magnitude of the change in the homeownership rate, the exogenous change in a house price relative to rent is not the main driving force for the variation in housing tenure decisions, as the exogenous price variation changes the aggregate homeownership rate by less than 2 percent in absolute terms.

Table 14: Considering Exogenous Change in House Price in the model

	Quintiles					Total
	1st	2nd	3rd	4th	5th	
(A) Homeownership Rates						
Change (pp)	-2.04	-3.86	0.53	-1.19	-1.70	-1.72
Contribution rate (%)	24.70	46.73	-6.42	14.41	20.58	100
(B) Housing Sizes						
Change (%)	7.49	4.15	1.5	2.45	-1.24	2.68
(C) Transition Probabilities						
R2O	0.131	0.040	0.060	0.012	0.000	0.064
O2R	0.025	0.012	0.019	0.007	0.052	0.024

Additionally, according to the middle panel of Table 14, the exogenous rise in the price-to-rent ratio enables most of the households to increase their house sizes. This result suggests that households who sell their houses tend to have larger rental houses due to a reduction in the relative rental price. Also, as found in the bottom panel of Table 14, the exogenous price rise is not the main factor for the observed variation in transitions between tenures.

6 Conclusion

In this paper, we document the evolution of homeownership 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 LTV limits and transaction costs generate changes in housing on the intensive margin and generate an endogenous rise in 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).[69]

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

[69] 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 to draw Figure 8. The data set includes around 25.4 million fixed-rate mortgages originated between January 1, 1999 and December 31, 2016. To draw Figure 8, we use "Original combined loan-to-value (CLTV)" and "Original debt-to-income (DTI) ratio"[70] 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, μ_{ss} as follows.

Step 1. Have guesses for endogenous parameters.

Step 2. Construct grids for individual state variables, such as asset holdings, a, and logged individual labor productivity, $\widetilde{x} = \ln x$. More asset grid points are assigned on the lower as-

[70] 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.

set range using a convex function. $\widetilde{x}$ is equally spaced in the range of $[-3\sigma_{\widetilde{x}}, 3\sigma_{\widetilde{x}}]$, where $\sigma_{\widetilde{x}} = \sigma_x/\sqrt{1-\rho_x^2}$.

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 $h'(a,h,x,j)$, housing services $s(a,h,x,j)$, 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 $V(a,h,x,j)$.

Step 5. Obtain the time-invariant measure, μ_{ss} using the optimal decision rules and $\mathbb{P}_x$.

Step 6. Compute aggregate variables using μ_{ss}. If targeted values are sufficiently close to the assumed ones, then the steady-state economy is found. Otherwise, reset the endogenous parameters, and go back to Step 4.

C Additional Tables and Figures

Table A1: Homeownership Rate Across Age Quintiles

	Quintiles					Total
	1st	2nd	3rd	4th	5th	
CPS 1995-2015	49.34	67.41	74.89	80.00	80.23	69.86
Mean Age	31.2	41.0	49.8	60.1	75.4	51.5

Note: When constructing the age groups, we drop households whose head's age is less than 26 or greater than 85.

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: Key Aggregate Moments

	Data	Model
Targeted Moments		
K/Y	2.00	2.00
H/Y	1.10	1.13
S/C	0.21	0.22
Homeownership ratio (Restricted sample)	69.53	70.00
Untargeted Moments		
Wealth Gini	0.79	0.88
Income Gini	0.57	0.61

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.

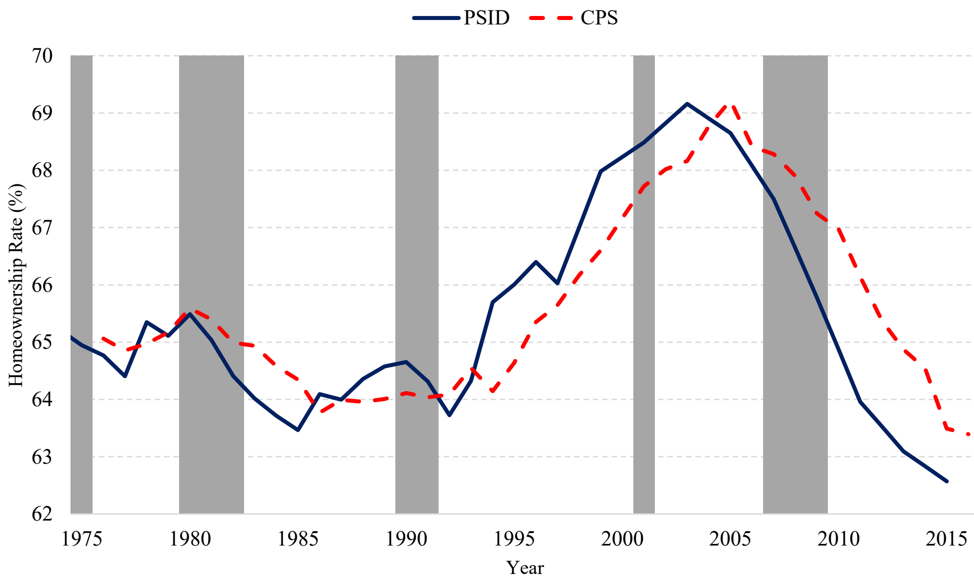

Figure A1: Homeownership Trends (PSID)

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

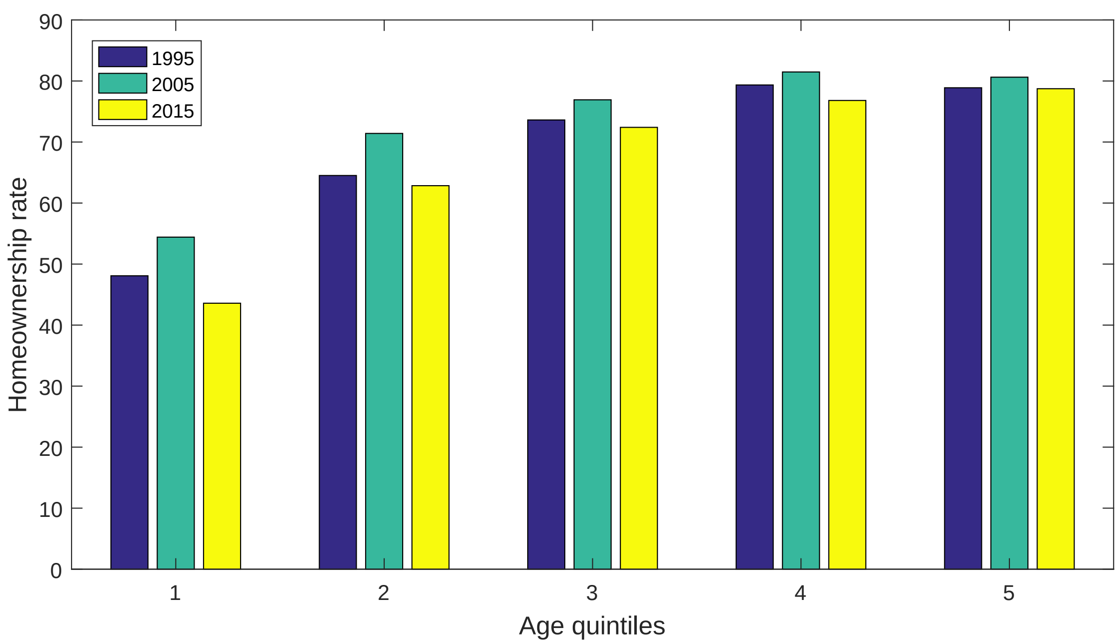

Figure A2: Trend of Homeownership by Age Quintile over 1995-2015

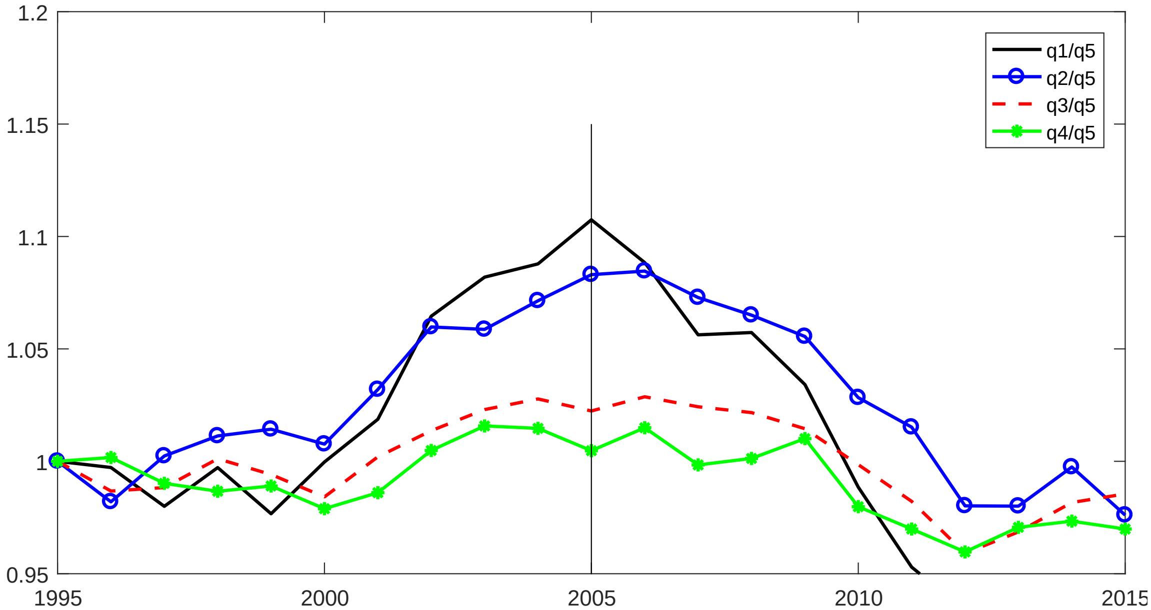

Figure A3: Variation in Homeownership by Age Quintile over 1995-2015
Note: This figure shows the relative variations in homeownership rates by age quintiles. The numbers report the homeownership rate of each quintile relative to fifth quintile, and they are also normalized by each measure in 1995.

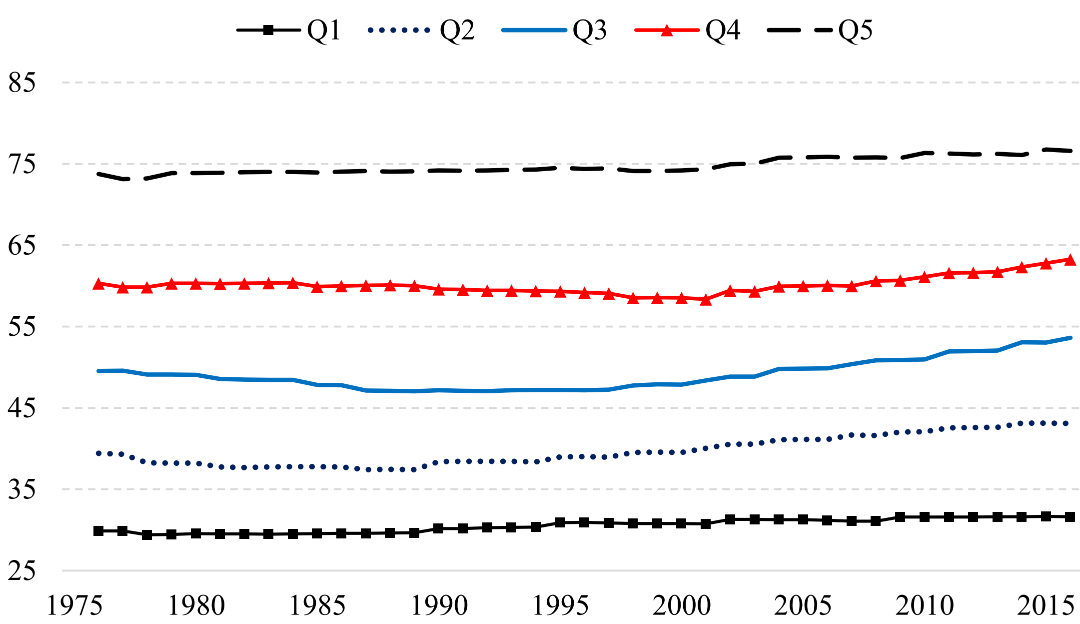

Figure A4: Trend of Mean Age in Each Quintile
Note: Y-axis is age. The data are taken from the CPS.

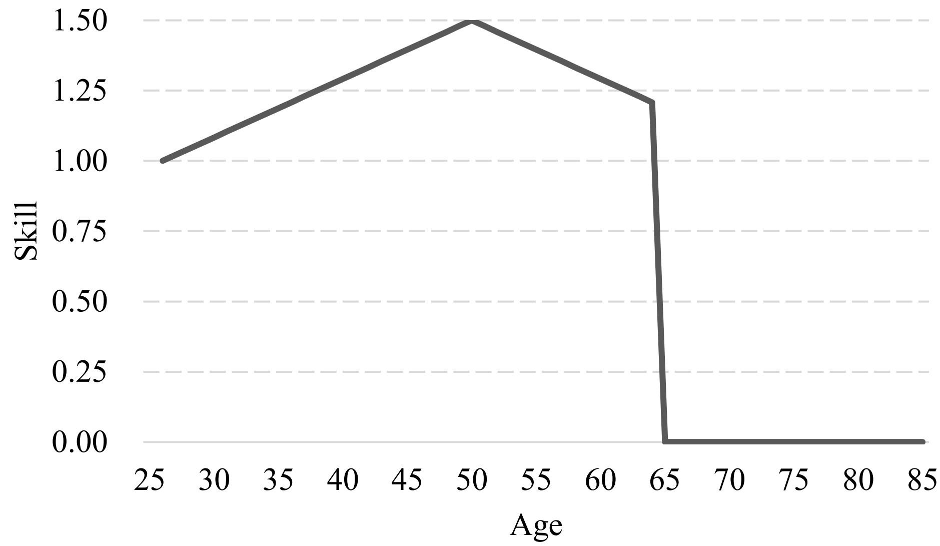

Figure A5: Deterministic Skill Profile over Age

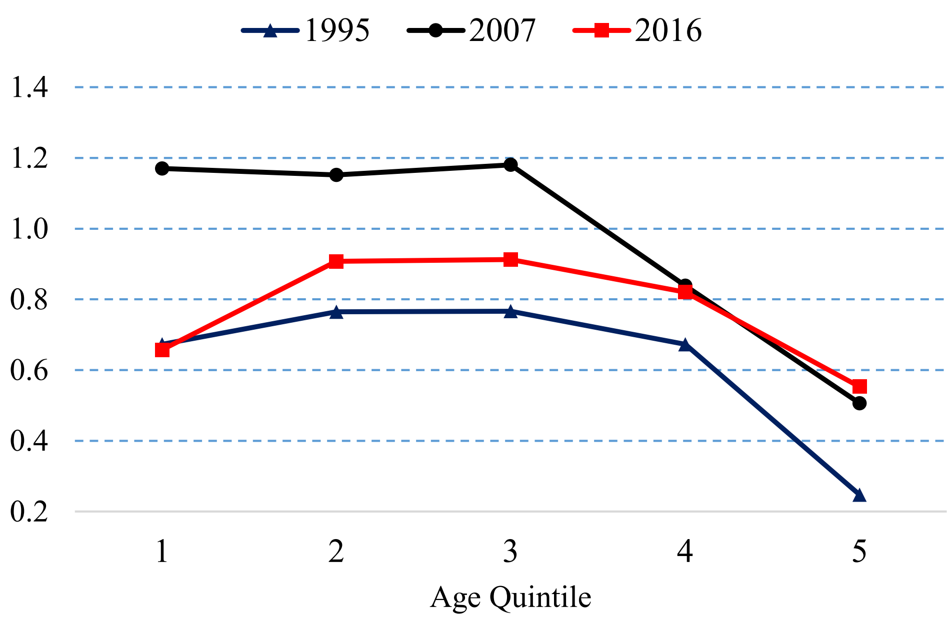

Figure A6: DTI Distribution across Age Quintiles over 1995-2016

Note: Y-axis is the DTI ratio, and x-axis represents age quintiles. The DTI ratio is defined as "Total value of mortgages and home equity loans secured by the primary residence held by household" divided by "Total amount of income of household."

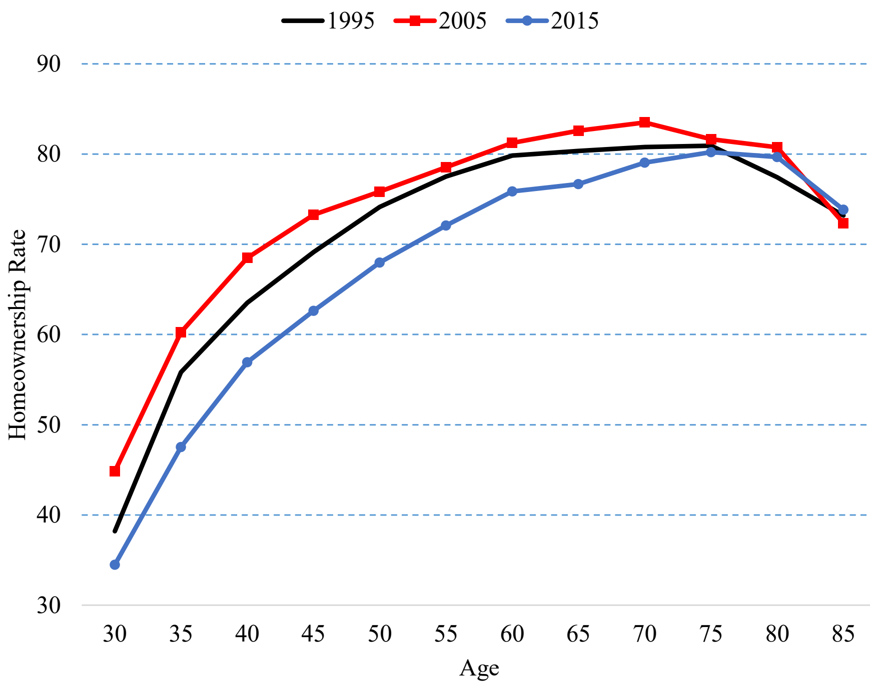

Figure A7: Homeownership Rate by Age for 1995, 2005 and 2015

Note: Y-axis is a homeownership rate. 5-year age bin is used where age for the largest values of the bin is shown in the graph. For example, the homeownership for 30 means the mean homeownership rate at age 26-30.