The Missing Home Buyers: Regional Heterogeneity and Credit Contractions *

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Abstract

This paper demonstrates that the protracted decrease in young home ownership since the Great Recession was driven by high-house price regions, despite credit standards changing mostly nationally. Using a panel of U.S. metro areas, I calibrate an equilibrium spatial macro-finance model with overlapping generations of mobile households. The dynamics of regional housing markets is explained by the heterogeneous impacts of an aggregate credit contraction rather than by local shocks. Lower Millennial income and wealth amplify this effect. The impact of subsidies to first-time buyers is dampened, because they fail to stimulate regions that suffer larger busts. Place-based subsidies achieve larger gains.

JEL classification: E21, G11, G21, G51, J11, R30
Keywords: Spatial macro-finance, home ownership, first-time buyers, mortgages, credit standards, house prices, Millennials

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1 Introduction

Housing busts, like many recessions, affect demographic groups very differently. After the Great Recession, *young* home ownership fell deeply and persistently, leaving many Millennial buyers excluded from the housing market and leading to a large decline in total home ownership (Figure 1). This decrease, equivalent to 7.6 million missing purchases in the United States, has attracted widespread attention as it entails a potential shift in the importance of housing on households' balance sheets.[1]

While existing work has focused on heightened exit from home ownership through foreclosures (Mian and Sufi (2009), Adelino, Schoar and Severino (2016)), less is known about its decrease through the lower *entry* of young buyers, which represent 50% of new purchase mortgages. Especially puzzling is that it coincided with a large dispersion in house price busts between regions (Piskorski and Seru (forthcoming)) – in frictionless models of asset market participation, entering buyers should arbitrage price differences away. This paper studies the causes of lower entry into home ownership from young buyers and its consequences for housing markets. I calibrate a new macro-finance model of the cross-section of housing markets to U.S. household-level and regional panel data, and address two questions: (i) How do changes in households' environment (period effect) and differences between cohorts (cohort effect) account for this shift? (ii) What do they imply for stimulus policies targeting first-time buyers?

My results highlight the importance of regional heterogeneity for credit contractions. The decrease in young home ownership can be traced back to house price differences between regional housing markets, which amplified the nationwide tightening of credit standards through regionally-binding credit constraints. Young buyers' access to home ownership largely relies on credit because of the increasing life-cycle profile of income and wealth, especially for cohorts entering the economy in worse times. In areas with higher house prices, they are more constrained and often fail to move to affordable areas. Therefore they postpone buying more when credit contracts, leading in turn to larger price declines. First-time buyer subsidies that are identical across regions have little stabilizing effect, since they stimulate high-price regions which suffer larger busts by less.

[1] Concerns range from central banks to government agencies, think tanks, and banks. See e.g. "Coming of age in the Great Recession", Federal Reserve Board speech by Gov. Brainard, 2015. Housing is the largest asset on households' balance sheets and the main way in which they accumulate wealth (Goetzmann, Spaenjers and Van Nieuwerburgh (2021)), which has motivated numerous policies to stimulate home ownership (Goodman and Mayer (2018)). In 2005, the average home ownership rate of U.S. households was 68.8%. In 2015, it was 62.7% for 124.6m households, that is $(0.688 - 0.627) \times 124.6\text{m} = 7.6\text{m}$ missing purchases. Relative to 1995, there were 2.9m missing purchases in 2015. Source: American Housing Survey.

I motivate this mechanism by documenting new stylized facts on young buyers using historical time series and a panel of U.S. metropolitan areas in the post-Great Recession period. First, young home ownership after the recession fell deeply and persistently below its long-run average in data going back to 1975 (56.7%), much more than undoing the gains from the boom (47.6% in 2011, 50.2% in 2019). At the aggregate level, this pattern is masked by mean-reversion in total home ownership. Second, the decrease in young home ownership has been concentrated in expensive metro areas. There is a strongly increasing relationship between local house price levels prior to the housing bust and the subsequent drop in young home ownership. Young home ownership fell by 25% in the top 10% of the house price distribution but by only 10% in the bottom 10%. Entry into home ownership decreased, with first-time mortgage originations falling by 55% in expensive vs. 25% in cheap MSAs. Households delayed buying by 6 more years relative to cheap MSAs. Third, perhaps surprisingly, these differences were not caused by a larger credit contraction in expensive MSAs. Credit standards which determine access to home ownership contracted uniformly nationwide. Loan-to-value (LTV), payment-to-income (PTI) ratios, and credit scores displayed strong comovements across regions.

I develop an equilibrium spatial macro-finance model which explains these facts. The economy is subject to unanticipated local and aggregate shocks to income and credit standards. Regions have different income processes, amenity benefits from housing, construction costs, and price-elasticities of housing supply. Each region is populated by overlapping generations of risk-averse households who face idiosyncratic income and mortality risks. Cohorts have different income and wealth which affect their credit constraints. Millennial income is lower due to the scarring effect of entering the economy in a recession, and their wealth is lower due to student debt. Households consume and save; sort across regions subject to a moving cost; choose to rent or own housing subject to LTV and PTI limits and origination fees applying to long-term mortgages; and to repay or default on their mortgages subject to a finite cost which captures unmodeled credit standards.

The model accounts for three features from which spatial macro-finance models typically abstract: (i) the distribution of house prices and rents responds endogenously to local and aggregate shocks; (ii) households are mobile across regions; (iii) overlapping cohorts are different. This setting allows to disentangle the effects of local and aggregate shocks while accounting for local price and migration responses.[2] I map the steady

[2]This paper is the first to relax the assumptions of exogenous house prices and no mobility in such models (e.g., Hurst, Keys, Seru and Vavra (2016)), an important research avenue in macro-finance (Guren, McKay, Nakamura and Steinsson (2020)).

state and dynamic responses in the model to the panel of MSAs, and calibrate regional differences and mobility using indirect inference. I then use a series of counterfactual experiments to identify the causes and consequences of the missing home buyers.[3]

The dynamics of regional housing markets is explained by the heterogeneous impacts of aggregate shocks rather than by local shocks. Along the transition path, an *identical* tightening of credit standards across regions (chosen to match the decrease in household leverage after the recession) generates *heterogeneous* housing busts. Different local income shocks have little effect. The aggregate credit contraction fully explains the 10% decrease in young home ownership in cheap MSAs and the 20% decrease in expensive MSAs, without targeting them. As in the data, the decrease in home ownership is driven by young buyers and concentrated in expensive MSAs. In this context, changes in Millennial preferences towards owning are not needed to explain their low home ownership. The credit contraction also explains the 12% house price decrease in cheap MSAs and the 30% decrease in expensive MSAs, which are needed to match the 25% decrease in the aggregate house price index.

The decomposition of credit constraints over buyers' life-cycles explains how these shocks are transmitted. Credit contractions have a large impact because most first-time buyers are constrained by LTV and/or PTI limits. This is especially true in expensive MSAs where 90% of them are constrained (vs. 60% in cheap MSAs). Their housing bust is larger because of regionally-binding credit constraints: they have more PTI-constrained buyers than cheap MSAs, and the decrease in PTI limits itself is large. This refines popular narratives which focus on LTV constraints to explain low Millennial home ownership.

What are the determinants of this mechanism? First, structural differences between regions generate differences in house price levels which lead credit constraints to bind more in expensive MSAs. To analyze them, counterfactual transitions turn off regional parameters separately. A better income process and amenities in expensive MSAs are key to generate higher house prices, hence more binding constraints and a larger bust. Without them, young home ownership would only fall by a sixth and half of its decrease in the baseline model, at odds with the data. Housing supply restrictions have a lower effect. Together, these regional parameters provide a new microfoundation for variation in credit constraints in the population.

Second, frictions to spatial arbitrage explain that despite higher income, expensive MSAs still have higher price-to-income ratios which make constraints more binding.

[3] I develop a solution method to compute the transition dynamics of the price distribution in this class of models in response to unanticipated local and aggregate shocks.

Moving costs prevent the perfect sorting of poor buyers into cheap MSAs and of rich buyers into expensive MSAs. The option to rent allows households to enjoy better amenities without owning. This results in the income of potential buyers being too low to compensate for house prices. Importantly, the response of housing markets depends on the extent to which buyers can move between MSAs, which leads to a "migration accelerator" absent from single-region models. In spatial equilibrium, home ownership and prices decrease more in expensive MSAs and less in cheap MSAs because young buyers move from the former to the latter.

Third, differences between cohorts make Millennials' constraints more binding. Counterfactual transitions show that student debt and income scarring amplify the decrease in young home ownership and prices. Their impact persists in the long run even after the credit contraction, most of which is due to income scarring in expensive MSAs. Interestingly, student debt increases home ownership in cheap MSAs because it leads some buyers to move from expensive MSAs. It also generates a rental boom in expensive MSAs as those who stay rent larger units. These results disentangle cohort from period effects.

Finally, I evaluate whether subsidies to first-time buyers relax regionally-binding credit constraints during a recession. I study the First-Time Homebuyer Credit (FTHC), a tax incentive of $8,000 given uniformly to new buyers in 2009. I use the model to quantify the dynamic welfare impact of the policy, an open question for empirical analyses based on average treatment effects (Berger, Turner and Zwick (2019)). Along a counterfactual transition path, the FTHC increases young home ownership and generates a sizable increase in aggregate welfare equivalent to +2.7% of four years of consumption. Welfare gains come from four sources: owning allows buyers to live in larger units, enjoy higher amenity benefits, hedge against rent increases, and quickly accumulate wealth when the rate of return on housing increases.

The model highlights limitations of the policy which dampen its effectiveness. First, the "one size fits all" subsidy relaxes credit constraints more in cheap MSAs with lower house prices ($111,500) than in expensive MSAs ($267,600). It respectively cushions one third and less than one fourth of the decrease in home ownership. The total impact on housing markets is limited because the bust is driven by expensive MSAs. Second, households derive more utility from buying in expensive MSAs due to higher estimated amenity benefits. Despite welfare gains being higher conditional on buying in expensive MSAs, the FTHC induces fewer renters to buy than in cheap MSAs. Therefore the total welfare impact is limited. Due to these limitations, a *place-based* version of the FTHC where subsidies are proportional to local house prices improves the welfare gain to +3.2%, without increasing the total dollar cost of the policy. This suggests that housing stabilization policies should target expensive MSAs because they are more volatile in downturns.

Related Literature This paper connects two separate approaches in a spatial macro-finance framework: dynamic stochastic models with portfolio choices, which abstract from spatial variations; and empirical analyses using regional panel data for identification, which are silent on general equilibrium effects.[4]

My work contributes to the literature on regional heterogeneity and financial shocks. I decompose the impacts of local and aggregate shocks, which existing work suggests are different (Nakamura and Steinsson (2014)). Nationwide credit standards are a key determinant of regional housing dynamics, similar to interest rates in Hurst et al. (2016). My findings on regionally-binding constraints relate to Beraja, Fuster, Hurst and Vavra (2019), who show that the impact of interest rates on refinancing depends on the distribution of house prices. I depart from these papers by endogenizing the distribution of prices and allowing for mobility. Moving frictions make expensive MSAs more sensitive to a credit contraction, in contrast with frictionless models where buyers can move away from credit constraints. Prices respond more to shocks if local borrowing constraints are more binding as documented empirically by Lamont and Stein (1999).

I focus on credit constraints as in Favilukis et al. (2017), Greenwald (2018), and Justiniano, Primiceri and Tambalotti (2019). In addition to the time series, I analyze regional variation in these constraints and microfound them using local housing characteristics. A local market does not need a larger credit contraction to have a larger response (Johnson (2020)) if it is more sensitive to credit standards in the first place. Landvoigt, Piazzesi and Schneider (2015) and Carozzi (2020) find that buyers' sorting into housing markets within a region leads cheaper homes to have more volatile prices. I show that their location between regions lead expensive MSAs to be more volatile. This implies that real-world subsidies should target cheap homes in expensive MSAs.[5]

My analysis focuses on the post-Great Recession period as in Guren and McQuade (2020) and Piskorski and Seru (forthcoming). They focus on exit from home ownership.

[4]Examples of models with housing include Cocco (2005), Favilukis, Ludvigson and Van Nieuwerburgh (2017), Chen, Michaux and Roussanov (2020), Kaplan, Mitman and Violante (2020). Examples of regional identification include Mian and Sufi (2009), Mian, Rao and Sufi (2013), Mian and Sufi (2014), Stroebel and Vavra (2019). Ortalo-Magné and Prat (2015) study a stylized spatial asset pricing model.

[5]Favilukis, Mabille and Van Nieuwerburgh (forthcoming) study related housing affordability policies but they focus on the long run steady state of a single MSA.

By analyzing entry rates, my paper complements the rich literature focusing on mortgage default (Campbell and Cocco (2015), Guren, Krishnamurthy and McQuade (2021)). I use the model to study the welfare effect of first-time buyer subsidies (Berger et al. (2019)), an empirical challenge. My results on the place-based FTHC contribute to the nascent literature on place-based mortgage policy (Han, Lutz, Sand and Stacey (2021)).

Finally, I add to the literature on young buyers whose importance was first emphasized by Mankiw and Weil (1989) for the Baby Boom cohort and then Ortalo-Magné and Rady (2006). I complement a growing empirical literature (Goodman and Mayer (2018)) by estimating the contributions of popular explanations to the decline in Millennial home ownership in a structural model. These include borrowing constraints (Acolin, Bricker, Calem and Wachter (2016)), income scarring, and student debt (Bleemer, Brown, Lee, Strair and van der Klaauw (2021), Isen, Goodman and Yannelis (forthcoming)).[6]

Outline The rest of the paper is organized as follows. Section 2 documents stylized facts on young buyers. Section 3 presents the spatial macro-finance model. Section 4 describes the calibration which links the model to a panel of MSAs. Sections 5 analyzes the response of housing markets to a recession with regionally-binding constraints and Section 6 studies their determinants based on differences between regions and cohorts. Section 7 studies implications for stimulus policies, and Section 8 concludes.

2 Evidence on Young Home Buyers

This section documents stylized facts on young buyers and provides motivating evidence on the role of regional heterogeneity. There is little evidence on young buyers' access to credit and home ownership. One reason is that the distinction between borrower-level and loan-level datasets does not allow to identify the characteristics of loans taken by borrowers at various ages. To circumvent this limitation, I exploit data on first-time buyers, which are identified in both types of datasets.

2.1 Data

Description I assemble a regional panel dataset, in which I merge borrower-level and loan-level information on first-time buyers at the MSA level. In the next sections I use

[6] In recent work, Garriga, Gete and Hedlund (2020) and Ma and Zubairy (2021) study borrowing constraints while abstracting from differences between regions and cohorts.

this panel to calibrate the steady state and dynamic responses in the model. First-time buyers account for almost 50% of purchase mortgages originations (Consumer Credit Panel, Federal Reserve Bank of New York).

The panel tracks first-time mortgages in U.S. metro areas at annual frequency since the Great Recession, from 2005 to 2017, the longest sample for which the data is available. I merge information on mortgages, household demographics, and house prices at the MSA level, a close equivalent to a local labor market. Weighted averages are computed using local population sizes as weights. Nominal variables are expressed in 2005 dollars using the Bureau of Labor Statistics chained Consumer Price Index for all urban consumers.

Mortgage originations. Data on first-time purchase mortgages comes from the Consumer Credit Panel (CCP) of the Federal Reserve Bank of New York. The CCP is a borrower-level, 5% random sample of the U.S. population with credit files derived from Equifax. I use information on the number and balances of mortgages originated by age and for all households, aggregated at the MSA level. The data has information on 370 of the 384 MSAs in the U.S. A first-time buyer is defined as the first appearance of an active mortgage since 1999 with no indication of any prior closed mortgages on the borrower's credit report. First-time mortgage originations are large and volatile: 1.417 million loans were originated in 2005, 665,000 in 2011, and 1.059 million in 2017.

Credit standards. Information on the characteristics of first-time mortgages comes from the Single Family Loan-Level dataset of Freddie Mac and the Single Family Loan Performance dataset of Fannie Mae (26.6 and 35 millions total loans). I focus on the flow of new loans in the loan origination and acquisition datasets. I use the distribution of LTV, DTI ratios, and borrower credit score at origination to measure changes in credit conditions by region. Government-Sponsored Enterprises (GSE) and Federal Housing Administration (FHA) loans are the primary source of mortgage securitization for first-time buyers since the Great Recession. They represent around 50% of first-time mortgage originations.

Household demographics. Data comes from the American Community Survey (ACS) of the U.S. Census Bureau. I use household-level information by MSA on population, age structure, home ownership, migration flows, employment status and income.

House prices. I use the Zillow Home Value Index (ZHVI) and Rental Index (ZRI) for all homes at the MSA level to measure median house prices and rents. Since the data is monthly, I annualize it by taking the unweighted average across months in a given year. The ZHVI is available from 2005 to 2017. The ZRI is available after 2010; I extrapolate values from 2005 to 2010 by assuming that rents in each MSA grew at the same rate as the

U.S. consumer price index for rents from the BLS (Rent of Primary Residence in U.S. City Average, All Urban Consumers).

Classifying Regions I classify metro areas by the level of local house prices in 2005, and keep this classification fixed throughout the paper. Cheap regions in the bottom percentiles of the house price distribution are referred to as "Low-price MSA" (blue in figures and tables) and expensive regions in the top percentiles as "High-price MSA" (red). Economywide aggregates are in black. I then study changes in housing markets within these groups. For most of the analysis, I split the sample into the simplest partition of metro areas: the bottom 50% and the top 50% of the house price distribution. Figure A.1 plots these regions on a map. Cheap MSAs are concentrated inside the U.S. (e.g., Detroit MI). Expensive MSAs are concentrated in coastal regions (e.g., San Francisco-Oakland-Fremont CA). Figure A.2 shows that there is strong persistence over time in MSAs that have low and high prices. So my results do not depend on the date at which regions are sorted.[7] Figure A.3 plots house price levels and changes by MSA group. Average house prices are $111,500 in cheap and $267,600 in expensive MSAs in 2005 (2005 dollars).

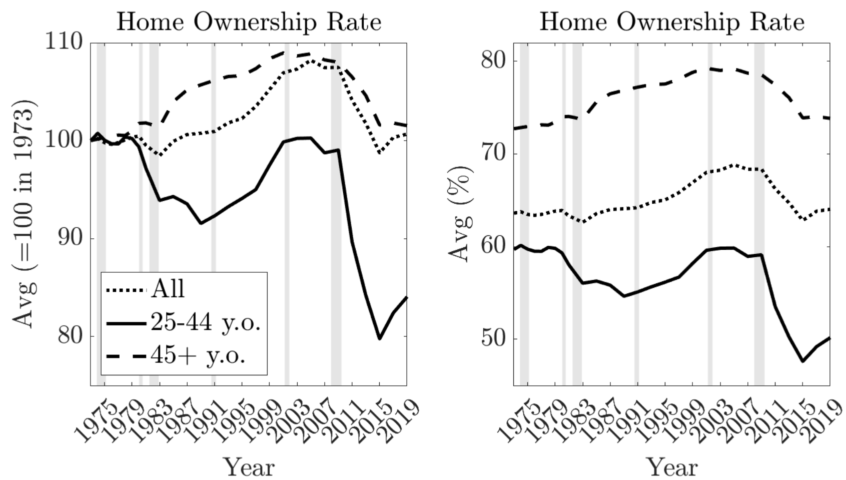
2.2 The Missing Home Buyers

Post-Great Recession period Figure 1 plots home ownership rates for 25-44 y.o. and 45+ y.o. households between 1975 and 2019, going back as far as housing data by age allows. Young home ownership after 2005 fell deeply and persistently below its long-run average, much more than undoing the gains from the boom. In the aggregate, this pattern is masked by mean-reversion in the average home ownership rate after the boom, a popular narrative among economists. This unprecedented decrease motivates the focus of the paper on the post-Great Recession period. In addition, starting in 2005 allows to link the model with the regional panel for which no prior data is available.

Relative to 2005, the probability of being a home owner fell by 20% for 25-44 year old households and 7% for 45+ year old households. Figure A.5 decomposes this decrease across ten-year age groups. Home ownership fell broadly for all households below 65 y.o. but the probability of being a home owner fell more for younger households, and this relationship is monotonic: it fell by 27% for the 25-34, 16% for the 35-44, 10% for the 45-54, 8% for the 55-64%, 5% for the 65-74, and 2% for the 75-84 age groups. Age is by far the

[7] In 1997, 83% of cheap and expensive MSAs are the same MSAs as in 2005. In 2017, 90% of them are the same as in 2005.

Figure 1: Home ownership by age



Notes: Home ownership rate by age group. Left panel: change, values normalized to 100 in 1973. Right panel: level. Population-weighted averages. Gray bands indicate NBER recessions. Sources: AHS.

demographic factor that is associated with the largest decrease in home ownership, which motivates my focus on young buyers. A single sort against other factors (household composition, education, income, race) shows that home ownership only fell between -6.3 and -9.7 pp for other groups vs. -14.7 pp for the 25-34 y.o. (Table A.3).

Regional heterogeneity Figure 2 shows that there are large differences between regions in changes in home ownership, mortgage originations, and first-time buyer ages.

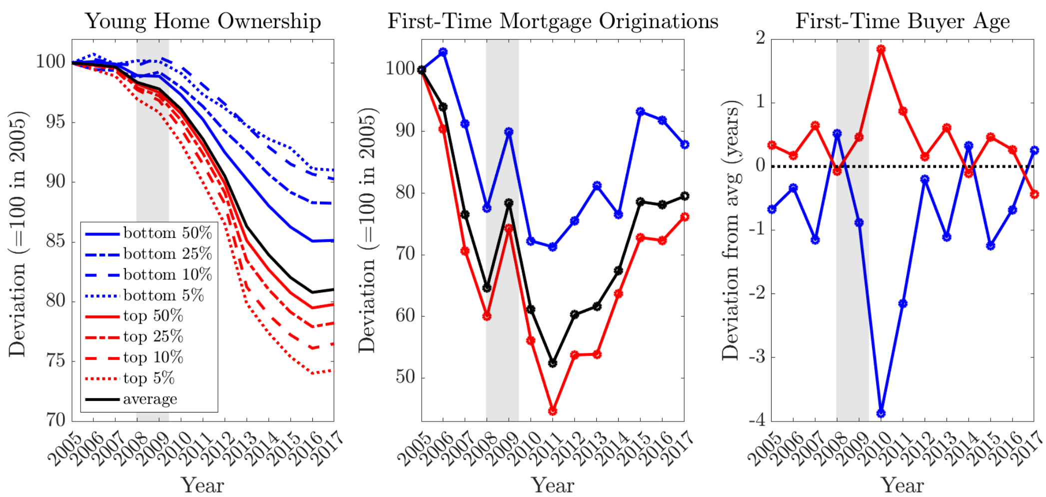
Young home ownership. The decrease in young home ownership is concentrated in expensive MSAs. Regions are sorted by percentiles of the house price distribution. There is a strongly increasing relationship between initial house price levels, and the subsequent drop in young home ownership. It fell by more than 25% in the top 10% of the price distribution but by only 10% in the bottom 10%. This relationship has led to a regional divergence in young home ownership rates. There is no such relationship for older households, for which rates fell equally across regions by less than 5% (Figure A.4).

After documenting this relationship, I focus on the simplest partition of metro areas in the panel, between the top 50% and the bottom 50% of the house price distribution. This classification provides a lower bound on these effects, and it is the simplest setting to calibrate the model in the next sections.

Mortgage originations. The flow of first-time mortgage originations has decreased more in expensive (-55%) than in cheap MSAs (-25%) since 2005, consistent with regional differences in young home ownership. Originations temporarily increased in 2008-2009 when the First-Time Home Buyer Credit (FTHC) was introduced. They stabilized in cheap MSAs, but decreased further in expensive MSAs. They have not fully recovered at the end of the sample.[8]

Age of first-time buyers. Households in expensive MSAs have delayed buying during the bust. Relative to 2005, the average age of fist-time buyers increased by 2 years in expensive MSAs, while it fell by 4 years in cheap MSAs (both from 37 years old) when the FTHC was introduced. The difference in first-time buyer ages between regions reached six years in 2010 and then decreased.

Figure 2: Young buyers' access to home ownership by region



Notes: Left panel: changes in 25-44 year old home ownership rate for various groups of MSAs in the house price distribution. Bottom and top 50% (solid lines), bottom and top 25% (dashed-dotted lines), bottom and top 10% (dashed lines), bottom and top 5% (dotted lines) in 2005. Black: economy average. Middle panel: changes in average flows of mortgages originated to first-time buyers in low- (blue) and high-price MSAs (red). Flows are normalized by local 25-44 year old population sizes. Right panel: for each MSA group, the age of first-time buyers is calculated as a weighted average of the various age groups using the number of loans originated in each age group as weights. The average age of first-time buyers in the economy is then subtracted from the average regional ages to control for long-run changes. Hence the resulting plotted series are deviations from the economy average. Population-weighted averages. Values normalized to 100 in 2005. Gray bands indicate NBER recessions. Sources: ACS, Zillow, CCP/Equifax.

2.3 Credit Contraction

Credit standards Credit largely determines access to home ownership for first-time buyers because of their low income and wealth. However, the larger decrease in home ownership in expensive MSAs is not explained by a larger credit tightening in these MSAs as credit standards contracted identically across regions. Figure A.6 provides suggestive evidence about credit standards based on conventional mortgages in Fannie Mae and

[8]Figure A.8 report changes in mortgage application and acceptance rates behind this decrease.

Freddie Mac data.[9] It reports first-time buyers' average LTV and PTI ratios and credit scores at origination. All display strong comovements across regions. In relative terms, the largest and most persistent contraction is for PTI ratios in expensive MSAs (0.38 to 0.31), followed by an increase in credit scores (725 to 765), and a contraction in LTV ratios in cheap MSAs (0.83 to 0.80). These findings are the counterparts for credit standards of Hurst et al. (2016), who report little variation in mortgage rates across regions.

Regionally-binding credit constraints: simple calculation Credit constraints binding more in regions with higher house prices can explain why young home ownership fell more in expensive MSAs, in response to an aggregate credit contraction which was identical across MSAs. I use a simple example to illustrate this point and convey the intuition before turning to the quantitative model.

A stylized mortgage contract has real interest rate r^b, loan maturity is n, and LTV and PTI limits θ_{LTV} and θ_{PTI}. The annuity formula implies that the maximum loan size arising from the PTI limit is PTI max loan size $= \frac{1-(1+r^b)^{-n}}{r^b}\theta_{PTI}Y$. The maximum loan arising from the LTV limit is $\theta_{LTV} \times$ price. Combining them, the maximum affordable house price for buyers is

$$\overline{P} = \min\left[\frac{1-(1+r^b)^{-n}}{r^b}\theta_{PTI}Y + \text{down}, \frac{\text{down}}{1-\theta_{LTV}}\right] \tag{1}$$

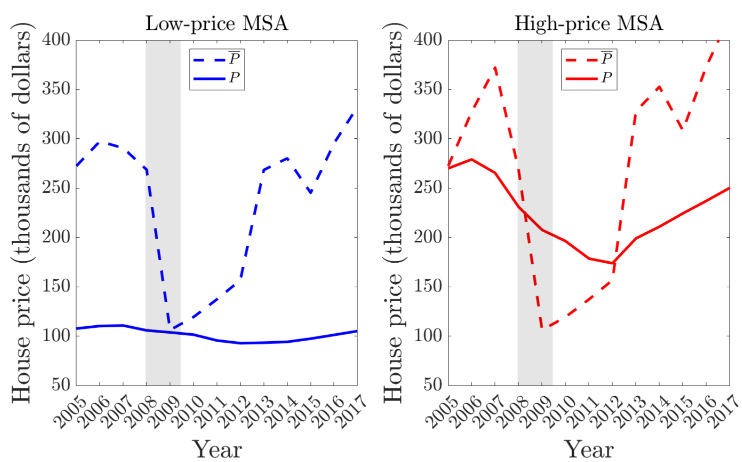
Figure 3 plots the maximum affordable price $\overline{P}$ and the actual price P for each set of metro areas, feeding in time series from the data for the variables in Equation 1. $n = 30$ years is the average maturity in the U.S. $\{r_t^b\}_t$ is the real mortgage rate, computed as the difference between the average annual rate on 30-year fixed rate mortgages (Primary Mortgage Market Survey, Freddie Mac) and the inflation rate (Consumer Price Index for the U.S., World Bank), $\{Y_{j,t}\}_t$ is median household income (ACS), $\{\theta_{PTI,j,t}\}_t$ and $\{\theta_{LTV,j,t}\}_t$ are PTI and LTV ratios (Fannie Mae, Freddie Mac), and $\{\text{down}_{j,t}\}_t$ are down payments with a median value of \$12,000 in 2005 (Residential Property Loan Origination Report, ATTOM Data Solutions). $j = L, H$ are cheap and expensive MSAs. Variables are

[9] While this data does not cover the universe of mortgage originations, it is the largest readily available source. GSE mortgages represent 30% of first-time buyer loans in 2005 (CCP/Equifax). They are the most widely held first-time mortgages before the boom and after the bust (43%). Private-label (PLS) and Federal Housing Administration loans (FHA) account for the remaining fractions. In the rest of the paper I focus on credit standards across *all* loans instead of selection between loan types. In the model, credit standards are calibrated to generate the same decrease in household leverage in the data, which accounts for changes in the composition of new mortgages.

in 2005 dollars.

First, maximum affordable prices $\overline{P}$ (dashed lines) are higher in expensive than in cheap regions, because buyers tend to have higher income and wealth. Second, actual house prices P (solid lines) are closer and intersect multiple times with $\overline{P}$ in expensive regions. Credit constraints are more binding than in cheap regions, where P is consistently below $\overline{P}$. Third, there is a strong covariance between P and $\overline{P}$ in expensive regions. Changes in equilibrium prices are associated with changes in credit and income.

Figure 3: Regionally-binding credit constraints



Notes: Left panel: actual median house price P (solid line) and maximum affordable price $\overline{P}$ (dashed line) in low-price MSAs (blue). Right panel: actual median house price P (solid line) and maximum affordable price $\overline{P}$ (dashed line) in high-price MSAs (red). $\overline{P}$ is calculated using Eq. 1 and time series from the data described in the main text. Gray bands indicate NBER recessions. 2005 dollars.

Figure A.7 provides further evidence on regionally-binding credit constraints. It reports the shares of first-time buyers by location and over time with LTV and PTI ratios that are as high as their respective limits of 0.76 and 0.33 during the credit contraction which are used in the model below. At the beginning of the recession, the majority of first-time buyers are constrained. The share of LTV-constrained buyers is identical in cheap and expensive MSAs (75%), while the share of PTI-constrained buyers is higher in expensive (70%) than in cheap regions (55%). After the recession, the share of LTV-constrained buyers increases in both MSAs, while the share of PTI-constrained buyers only remains high in expensive MSAs.

The rest of the paper develops a quantitative model which addresses key questions about regionally-binding credit constraints: What is the effect of aggregate shocks versus local shocks? What is the role of differences between regions and households? Do the options to rent and migrate between regions alleviate credit constraints?

3 Spatial Macro-Finance Model

This section describes an equilibrium model of the cross-section of housing markets in a small open economy with heterogeneous agents and incomplete markets. The model has three features: (i) The dynamics of the regional distribution of house prices and rents is endogenous and responds to local and aggregate shocks. (ii) Households are mobile across regions. (iii) Overlapping cohorts have different initial states. Solving such a model is numerically challenging. I develop a tractable solution method to calibrate this class of models and solve for the transition dynamics in response to unanticipated shocks.

3.1 Environment

Two sets of regions corresponding to cheap and expensive MSAs in the data ($j = L, H$) are connected by migrations. Regions have different income processes, amenity benefits from housing, construction costs, and price elasticities of housing supply. They are populated by overlapping generations of heterogeneous households with a life-cycle. Markets are incomplete. Population size is stationary, and there is a continuum of measure 1 of households. Households have rational expectations. Time is discrete.

Preferences Households have time- and state-separable preferences. They have a constant relative risk aversion (CRRA) utility function over a constant elasticity of substitution (CES) aggregator of nondurable consumption c_t and housing services h_t. Amenity benefits are modeled as additive utility shifters Ξ. The utility of a household in region j is

$$\frac{u\left(c_t, h_t\right)^{1-\gamma}}{1-\gamma} + \Xi_j^{\mathcal{H}} \equiv \frac{\left[\left((1-\alpha)c_t^{\epsilon} + \alpha h_t^{\epsilon}\right)^{\frac{1}{\epsilon}}\right]^{1-\gamma}}{1-\gamma} + \Xi_j^{\mathcal{H}} \tag{2}$$

The utility shifter $\Xi_j^{\mathcal{H}}$ depends on region $j = L, H$ and home ownership $\mathcal{H} = o, r$. It captures the amenity benefits accruing with different regions and owning. Renters in region j enjoy benefits $\Xi_j^r = \xi_j^r$, with the normalization $\xi_L^r = 0$. They consume continuous quantities of housing services $h_t \in \left[\underline{h}, \overline{h}\right]$.

Owners enjoy higher benefits $\Xi_j^o = \xi_j^r + \xi_j^o$. They own a single home of size $\overline{h}$. They are subject to exogenous moving shocks (as in Stein (1995)), which can lead them to sell and buy another house within the same region to enjoy higher benefits $\widetilde{\Xi}_j^o = \xi_j^r + \xi_j^o + \widetilde{\xi}^o$.

When moving between regions, households incur a utility cost m. Owners' cost moving is higher and equal to $m(1+\varphi)$.

Regional income processes and risk Households face idiosyncratic income risk and mortality risk. Regions have different income processes. The law of motion for the log income of working-age household i with age a in region j is

$$\begin{aligned} y_{i,j,a,t} &= g_a + e_{i,j,t} + \beta_j \eta_{US,t} \\ e_{i,j,t} &= \rho_e e_{i,j,t-1} + \varepsilon_{i,j,t}, \;\; \varepsilon \overset{iid}{\sim} \mathcal{N}\left(\mu_j, \sigma_j^2\right) \end{aligned} \tag{3}$$

g_a is the logarithm of the deterministic life-cycle income profile. $e_{i,j,t}$ is the logarithm of the persistent idiosyncratic component of income. μ_j is a regional shifter of the average of idiosyncratic income shocks and σ_j is their regional volatility. $\beta_j \eta_{US,t}$ is a local income shock which affects all households in region j and comes from an unanticipated shock $\eta_{US,t}$ and regional sensitivity β_j.

The survival probabilities $\{p_a\}$ vary over the life-cycle. Households leave accidental bequests when they die.[10]

Cohort differences Households enter the economy as renters. They are divided into Millennial and non-Millennial types. Non-Millennials enter the economy prior to 2005, draw a level of initial wealth equal to the average bequest, and their initial income from the stationary distribution. Millennials enter after 2005. Their wealth is lower by fixed amounts corresponding to student debt payments in the first periods of their lives. They have persistently lower earnings due to the scarring effect of entering the economy in a recession. They draw their initial income from a distribution that is first-order stochastically dominated by the non-Millennial distribution.

Household balance sheets Markets are incomplete as households only have access to housing and a one-period risk-free bond with an exogenous rate of return $r > 0$.

Renters who do not buy a home face a no-borrowing constraint. Renters who buy can use long-term amortizable mortgages to borrow, subject to LTV and PTI constraints which only apply at origination. They face an exogenous kinked interest rate schedule

[10] There are no idiosyncratic house price shocks for simplicity, which potentially make home ownership less attractive (Piazzesi and Schneider (2016), Giacoletti (2021).

which makes borrowing more costly: $\tilde{r}_t = r^b > r$ if $b_t < 0$, otherwise $\tilde{r}_t = r$. Because $r^b > r$, indebted households pay off their mortgages first before holding risk-free assets.[11]

Mortgages are defaultable and non-recourse. Defaulters exit home ownership and their houses return to the market as part of supply. They incur a utility cost d, are forced to rent in the same region, and can buy a new home with probability 1 in the next period (four years). Home owners cannot refinance.

Taxes and transfers Labor income is subject to taxes and transfers $T(Y) = Y - \eta Y^{1-\tau}$, with progressivity and level controlled by τ and η (Heathcote, Storesletten and Violante (2017)). Retirement income replicates the main features of U.S. pensions (Appendix B.1).

Household choices Every period, households rent or own. The rental and owner-occupied housing markets give access to different housing sizes. Owner-occupied units come in size $\overline{h}$ at price P_j in region j, and rental size can be chosen continuously in $\left[\underline{h}, \overline{h}\right]$ at rent R_j. Households choose whether to move between regions, and owners can move within regions. They choose nondurable consumption c_t, and save in one-period risk-free bonds or borrow with a long-term mortgage b_t. They inelastically supply one unit of labor.

Housing supply The housing stock in square feet $H_{j,t}$ depreciates at a constant rate, $H_{j,t} = (1-\delta)H_{j,t-1} + I_{j,t}$. Construction of new housing is supplied according to a reduced-form function of the house price in region j,

$$I_{j,t} = \overline{I}_j P_{j,t}^{\rho_j} \tag{4}$$

The construction cost shifter $\overline{I}_j$ and the price elasticity of housing supply ρ_j differ between regions. The lower $\overline{I}_j$, the higher the price required for a given level of construction. The lower ρ_j, the larger the price change required to induce a given change in construction. Every period, owners pay a maintenance cost in dollars $\delta P_j \overline{h}$.

Markets for owner-occupied housing and rentals are segmented. The housing stock $H_{t,j}$ is divided into a fraction ho_j^{sqft} of owner-occupied units and $1 - ho_j^{sqft}$ of rentals. Their respective supplies are equal to $H_{j,t}^o = ho_j^{sqft} H_{j,t}$ and $H_{j,t}^r = \left(1 - ho_j^{sqft}\right) H_{j,t}$.[12]

[11] The interest rate schedule arises from an unmodeled fixed financial intermediation wedge. The assumption that indebted owners cannot save is consistent with the large fraction of "wealthy hand-to-mouth" households with little liquid assets in the data (Kaplan and Violante (2014)).

[12] This assumption is an approximation of the data which implies close to full segmentation (Greenwald and Guren (2020)) and keeps the model tractable. Segmentation arises from the minimum size constraint,

With defaults, housing supply is higher by an amount equal to the measure of houses going back to the market multiplied by their square footage.

3.2 Household Problem

This section describes the household problem in recursive form. The individual state variables are home ownership $\mathcal{H} = r, o$, location $j = L, H$, age a, assets or debt b, and endowment y. A household in a given region makes discrete home ownership and location choices, then earns labor and financial income in its region of origin, and makes consumption, savings or debt, and housing choices. I describe the problem for region L.

3.2.1 Renter

$V_t^{rL}(a, b_t, y_t)$ denotes the date t value function of a renter of age a, with savings b_t and income y_t, who starts the period in the cheap region L. First, a renter chooses the location where to move at the end of the period, and whether to rent or own in this new location. The envelope value of the value functions for each option is:

$$V_t^{rL}(a, b_t, y_t) = \max \left\{ V_t^{rL,rL}, V_t^{rL,rH}, V_t^{rL,oL}, V_t^{rL,oH} \right\} \tag{5}$$

Then, given the policy function for the discrete choice problem renters choose consumption, housing services, and savings or mortgage debt if they borrow to buy a house.

Inactive renter. The value of staying a renter in region L is given by the Bellman equation

$$V_t^{rL,rL}(a, b_t, y_t) = \max_{c_t, h_t, b_{t+1}} \frac{u\left(c_t, h_t\right)^{1-\gamma}}{1-\gamma} + \Xi_L^r + \beta p_a \mathbb{E}_t \left[V_{t+1}^{rL}(a+1, b_{t+1}, y_{t+1}) \right] \tag{6}$$

subject to the constraint that expenses on nondurable consumption, rented housing services, and savings, must be no lower, and at the optimum equal to, resources from labor income net of taxes and transfers, and financial income from risk-free assets

$$c_t + R_{L,t} h_t + b_{t+1} = y_t - T\left(y_t\right) + (1+r) b_t, \tag{7}$$

the absence of a property ladder, moving frictions between and within regions, and the absence of conversion between rentals and owner-occupied units.

and subject to a no-borrowing constraint on assets and a constraint on the size of rentals

$$b_{t+1} \geq 0, \quad h_t \in \left[\underline{h}, \overline{h}\right] \tag{8}$$

Expectations are taken with respect to the conditional distribution of idiosyncratic income at date t. Accidental bequests left with probability $1 - p_a$ are financial wealth $(1+r)b_{t+1}$.

Renter moving between regions. When moving to region H to rent, a renter incurs a utility cost of moving m and faces the continuation value function in region H:

$$\begin{aligned}
&V_t^{rL,rH}(a, b_t, y_t) = \max_{c_t,h_t,b_{t+1}} \tfrac{u(c_t,h_t)^{1-\gamma}}{1-\gamma} + \Xi_L^r - m + \beta p_a \mathbb{E}_t \left[V_{t+1}^{rH}(a+1, b_{t+1}, y_{t+1})\right] \\
&\text{s.t. } c_t + R_{L,t}h_t + b_{t+1} = y_t - T(y_t) + (1+r)b_t \\
&b_{t+1} \geq 0, \quad h_t \in \left[\underline{h}, \overline{h}\right]
\end{aligned} \tag{9}$$

Home buyer. When buying a house in the same region, the renter's value function is

$$V_t^{rL,oL}(a, h_t, b_t, y_t) = \max_{c_t,h_t,b_{t+1}} \frac{u\left(c_t, h_t\right)^{1-\gamma}}{1-\gamma} + \Xi_L^r + \beta p_a \mathbb{E}_t \left[V_{t+1}^{oL}(a+1, b_{t+1}, y_{t+1})\right]. \tag{10}$$

In addition to rental services bought at rent $R_{L,t}$, the household buys a house at price $P_{L,t}$,

$$c_t + R_{L,t}h_t + F_m + P_{L,t}\overline{h}(1+f_m) + b_{t+1} = y_t - T\left(y_t\right) + (1+r)b_t, \quad h_t \in \left[\underline{h}, \overline{h}\right], \tag{11}$$

using a mix of savings accumulated over the life-cycle, and of long-term mortgage debt b_{t+1} borrowed at rate r^b, subject to fixed and proportional origination fees F_m and f_m, and to LTV and PTI constraints,

$$b_{t+1} \geq -\theta_{LTV,t}P_{L,t}\overline{h} \quad \text{and} \quad b_{t+1} \geq -\frac{\theta_{PTI,t}}{\left(1 + r^b - \tilde{\theta}\right)}y_t. \tag{12}$$

θ_{LTV} is the maximum fraction of the house price in region L which the household can borrow, so $1 - \theta_{LTV}$ is the down payment requirement. θ_{PTI} is the maximum fraction of income that can be spent on mortgage payments each period. These constraints only apply at origination, and may be violated in subsequent periods in response to shocks. Every period, owners with a mortgage pay interests and roll over their current debt subject to the requirement that they repay a fraction $1-\tilde{\theta}$ of the principal,

$$b_{t+1} \geq \min\left[\tilde{\theta} b_t, 0\right]. \tag{13}$$

The lowest payment that households can make in a period therefore equals $\left(1+r^b-\tilde{\theta}\right) b_t$. The LTV limit directly restricts the maximum mortgage balance of a buyer. By imposing a limit on the mortgage payment, the PTI limit restricts the maximum mortgage balance b_t of a buyer given its current income. Combined, they restrict the maximum house prices that buyers can afford. If prices differ between regions, credit contractions will have larger impacts in regions where these constraints are more binding.

Bequests left with probability $1-p_a$ now include housing wealth $(1+r^b)b_{t+1}+P_{L,t}\overline{h}$.

Home buyer in other region. The value of moving to region H and buying a house is similar with the moving cost m:

$$V_t^{rL,oH}(a, b_t, y_t) = \max_{c_t, h_t, b_{t+1}} \frac{u\left(c_t, h_t\right)^{1-\gamma}}{1-\gamma} + \Xi_L^r - m + \beta p_a \mathbb{E}_t\left[V_{t+1}^{oH}(a+1, b_{t+1}, y_{t+1})\right], \tag{14}$$

subject to the budget and borrowing constraints

$$\begin{aligned} & c_t + R_{L,t} h_t + F_m + P_{H,t}\overline{h}(1+f_m) + b_{t+1} = y_t - T\left(y_t\right) + (1+r)b_t, \quad h_t \in \left[\underline{h}, \overline{h}\right], \\ & b_{t+1} \geq -\theta_{LTV,t} P_{H,t}\overline{h} \quad \text{and} \quad b_{t+1} \geq -\frac{\theta_{PTI,t}}{\left(1+r^b-\tilde{\theta}\right)} y_t. \end{aligned} \tag{15}$$

3.2.2 Homeowner

The owner problem is similar (Appendix B.2). Owners face exogenous moving shocks within regions and higher moving costs between regions $m(1+\varphi)$. They can choose to repay their mortgages, sell, move within the same location or between locations, and default. $V^{oL}(a, b_t, y_t)$ denotes the date t value function of an owner in region L.

$$V_t^{oL}(a, b_t, y_t) = \max\left\{V_t^{oL,oL}, V_t^{oL,o\widetilde{L}}, V_t^{oL,oH}, V_t^{oL,rL}, V_t^{oL,rH}, V^{oL,d}\right\} \tag{16}$$

Mover within region. Owners move within region when the realization of the exogenous moving shock is high enough. They then sell their existing house and buy a new one. The shocks have the same average across regions and can be interpreted as an improvement in location within a region, resulting in higher utility benefits $\widetilde{\Xi}_L^o = \zeta_L^r + \zeta_L^o + \widetilde{\zeta}^o$.

Mover between regions. Owners moving to the other region H incur a higher moving cost $m(1+\varphi)$.

Defaulting owner. A defaulter does not repay its mortgage, incurs a utility cost d and becomes a renter in the same region in the next period:

$$V_t^{oL,d}(a, b_t, y_t) = \max_{c_t, b_{t+1}} \frac{u\left(c_t, \overline{h}\right)^{1-\gamma}}{1-\gamma} + \Xi_L^o - d + \beta p_a \mathbb{E}_t \left[V_{t+1}^{rL}(a+1, b_{t+1}, y_{t+1})\right], \tag{17}$$

subject to the budget and no-borrowing constraints

$$\begin{aligned} &c_t + b_{t+1} = y_t - T\left(y_t\right), \\ &b_{t+1} \geq 0 \end{aligned} \tag{18}$$

Because the owner loses its house during the period, bequests left with probability $1 - p_a$ only include financial wealth $(1+r)b_{t+1}$.

3.3 Equilibrium

This section defines a dynamic spatial recursive competitive equilibrium, which describes how the economy in steady state responds to unanticipated local and aggregate shocks.

Definition. Given exogenous time paths for unanticipated aggregate shocks to income and credit standards $\{\eta_{US,t}, \theta_{LTV,t}, \theta_{PTI,t}\}$, an equilibrium consists of the following (for region $j = L, H$ and home ownership $\mathcal{H} = r, o$):

(i) sequences of prices $\left\{P_t^j, R_t^j\right\}$,

(ii) value functions $\left\{V_t^{j\mathcal{H}}, V_t^{j'\mathcal{H}'}\right\}$,

(iii) policy functions $\left\{d_t^{j\mathcal{H}}, c_t^{j\mathcal{H}}, h_t^{j\mathcal{H}}, b_{t+1}^{j\mathcal{H}}\right\}$,

(iv) a law of motion for the cross-sectional distribution of households $\lambda_t\left(j, \mathcal{H}, a, b, y\right)$ across regions, ownership statuses, and idiosyncratic states,

such that households optimize given prices, the law of motion for the distribution of households' is consistent with their choices and with prices, and markets clear (below).

Housing markets. There are four market-clearing conditions. The market-clearing conditions for owner-occupied housing in regions $j = L, H$ are

$$\int_{\Omega_t^{oj}} \overline{h} d\lambda_t = \underbrace{pop_{j,t} \times ho_{j,t}^{hh} \times \overline{h}}_{\text{owner-occupied housing demand in } j} = \underbrace{ho_j^{sqft} \times H_{j,t}}_{\text{owner-occupied housing supply in } j} \tag{19}$$

The market-clearing conditions for rentals in regions $j = L, H$ are

$$\underbrace{\int_{\Omega_t^{rj}} h_{j,t} d\lambda_t}_{\text{rental demand in } j} = \underbrace{\left(1 - ho_j^{sqft}\right) \times H_{j,t}}_{\text{rental supply in } j} \tag{20}$$

$pop_{j,t} = pop_j(\mathbf{P_t}, \mathbf{R_t})$ denotes the population share of region j at date t and $ho_{j,t}^{hh} = ho_j^{hh}(\mathbf{P_t}, \mathbf{R_t})$ the home ownership rate. $\Omega_t^{oj} = \Omega^{oj}(\mathbf{P_t}, \mathbf{R_t})$ and $\Omega_t^{rj} = \Omega^{rj}(\mathbf{P_t}, \mathbf{R_t})$ are the sets of households who are owners and renters in region j at date t. These objects depend on the vectors of prices and rents in both sets of regions because of spatial sorting.

Appendix B.4 describes the numerical solution of the model, which exploits the homogeneity of the housing supply function in P_j.

4 Calibration and Baseline Results

This section describes how the spatial macro-finance model of Section 3 is calibrated and linked to the regional panel dataset from Section 2. The model starts in 2005. Local income shocks and aggregate credit shocks are chosen to match the decrease in household income and leverage in subsequent years.

4.1 Calibration

Table 1 summarizes the calibration. Parameters are first split into externally and internally calibrated parameters, and then into aggregate and regional parameters. As in the data, metro areas are split into two groups. Since house prices are determined in equilibrium, structural parameters are chosen to endogenously generate the same cheap ("Region L") and expensive MSAs ("Region H") as in the data. Average worker income Y is normalized as in the data to \$47,000 per year. One period is 4 years.

4.1.1 External Parameters

Aggregate parameters These parameters are common to the two sets of regions.

Preferences. The utility function is CRRA with $\gamma = 2$. The CES aggregator u has an elasticity of substitution between nondurable consumption and housing of 1.25 (Piazzesi, Schneider and Tuzel (2007)).

Labor income process. The persistence is $\rho_e = 0.6867$, as implied by estimates in Floden and Lindé (2001). The other parameters are calibrated internally.

Housing depreciation. The depreciation rate δ is the same across regions for simplicity. It is equal to 2.39% per year, the average depreciation rate for privately-held residential property in the BEA Fixed Asset tables for the period 1972-2016.

Mortgages. The real mortgage rate is $r^b = 2.5\%$, the average 30-Year Fixed Rate Mortgage Rate in the U.S. in 2005 (Primary Mortgage Market Survey, Freddie Mac) minus the CPI inflation (BLS).

The LTV limit $\theta_{LTV} = 0.953$ is based on Landvoigt et al. (2015). The PTI limit $\theta_{PTI} = 0.650$ is based on Greenwald (2018) and reflects the ability-to-repay rule from the 2000s.

The amortization rate $\widetilde{\theta}$ is chosen such that the fraction of the principal to be repaid every year is 1.60% (Greenwald, Landvoigt and Van Nieuwerburgh (forthcoming)).

The proportional transaction cost of selling a house is $f_s = 0.060$. The fixed and proportional mortgage origination fees are $F_m = \$1,200$ and $f_m = 0.6\%$ (Primary Mortgage Market Survey, Freddie Mac).

Student debt. Student debt is modeled as a negative lump-sum transfer which lowers the initial wealth of households entering the economy after 2005 in the first periods of their lives. Its value depends on age and income according to a realistic schedule constructed using data from the Survey of Consumer Finances and the U.S. Department of Education (Appendix B.1). At the end of the sample, more than 60% of graduating households have student debt, with an average of around $40,000.

Income scarring. I use empirical estimates for the effect on lifetime earnings of graduating during a recession to calibrate the initial Millennial income distribution $\{e_0\}$. Extrapolating estimates from Kahn (2010), their earnings should be $5 \times 2.5\% = 12.5\%$ lower 15 years later than if they had entered the economy in normal times.[13] Average initial income $\mu_{e_0} = -0.15$ replicates it when simulating a panel of these households.

Homeowner moving cost. Owners' cost of action in the housing market is higher because of behavioral reasons (Andersen, Badarinza, Liu, Marx and Ramadorai (2022)) and the lock-in effect of leverage (Brown and Matsa (2020)). To quantify the resulting increase

[13] A 1 pp increase in unemployment during a recession leads to 2.5-10% lower wages 15 years later for the cohorts that graduated during the recession. In 2008-10, the unemployment rate rose by 5 pp from 5% to 10%. I extrapolate the lower bound of these estimates.

in owners' moving costs, I extrapolate evidence from Andersen, Campbell, Meisner-Nielsen and Ramadorai (2020). Households with characteristics predicting home ownership (married, with children, higher wealth) have costs of action which are between 24% and 134% higher than other households. I choose an intermediate value $\varphi = 0.50$ which implies a 50% higher cost of moving.

Table 1: Calibration: main parameters

Parameter	Explanation	Value	Source/Target
	External: aggregate		
γ	Risk aversion	2.000	See text
ϵ	CES parameter housing/consumption	0.200	Elasticity of substitution=1.25
ρ_e	Autocorrelation income	0.914	Floden and Lindé (2001)
b_0	Student debt	see text	SCF, U.S. Department of Education
$F_{e_0}(.)$	Millennial initial income distribution	see text	Based on Kahn (2010)
θ_{LTV}	LTV limit	0.953	Landvoigt et al. (2015)
θ_{PTI}	PTI limit	0.650	Greenwald (2018)
r^b	Real mortgage rate	0.025	30-year FRM real interest rate
$\tilde{\theta}$	Mortgage duration	0.984	Greenwald et al. (forthcoming)
f_s	Transaction cost selling	0.060	See text
F_m	Fixed mortgage origination fee	0.007	Freddie Mac
f_m	Proportional mortgage origination fee	0.006	Freddie Mac
δ	Housing depreciation/maintenance	0.015	BEA
φ	Increase in owner moving cost	0.500	See text
	External: regional		
ρ_L, ρ_H	Housing supply elasticity	2.700,1.800	Saiz (2010)
ho_L^{sqft}, ho_H^{sqft}	Fraction owner-occupied sqft	0.759, 0.792	Homeownership sqft (AHS)
	Internal: aggregate		
β	Discount factor	0.914	Wealth/income=4.4 (bottom 80%)
α	Preference for housing services	0.522	Rent/income=0.20
$\underline{h}$	Min. housing size	0.500	Avg size owner-occupied/rental=1.5
ι	Mortgage spread	0.015	Agg leverage=0.42
d	Utility cost of default	2.333	Avg default rate=0.5%
m	Utility cost of moving	3.747	Avg moving rate L-H=1.7%
$\tilde{\xi}^o$	Avg exogenous moving shock	2.500	Fraction first-time buyers=50%
	Internal: regional		
μ_L, μ_H	Idiosyncratic avg income shifter	0.000, 0.200	Avg income ratio H/L=1.28
σ_L, σ_H	Idiosyncratic income volatility	0.140, 0.145	Mean/median income $L = 1.35, H = 1.38$
β_L, β_H	Local income sensitivity	0.250, 1.400	Avg income decrease 2005-2012
$\overline{I_L}, \overline{I_H}$	Construction cost shifter	0.210,0.026	$P_L = \$111,500, P_H = \$267,600$
ξ_L^r, ξ_H^r	Amenity benefits	0.000,0.820	$R_L = \$780, R_H = \$1,115$
ξ_L^o, ξ_H^o	Home ownership benefits	3.251,5.404	$ho_L^{hh} = 69\%, ho_H^{hh} = 67\%$

Notes: One model period is four years. Parameters and targets are annualized. Sources: SCF, Freddie Mac, Federal Reserve Board, ACS, RealtyTrac, Zillow, CEX.

Regional parameters These parameters differ between regions.

Regional business cycle sensitivity. Expensive MSAs have larger local income shocks than cheap MSAs. $\beta_H = 1.400 > \beta_L = 0.250$ are chosen to match the decrease in average income of 11% in expensive MSAs and of 2% in cheap MSAs in 2005-2012 (ACS).

Housing supply elasticity. I merge the panel from Section 2 with the MSA-level estimates of housing supply elasticities from Saiz (2010). I compute average elasticities for cheap and expensive MSAs using population sizes as weights. Expensive MSAs have a lower average elasticity of $\rho_H = 1.8$ than cheap MSAs with $\rho_L = 2.7$.

Owner-occupied housing. The fractions of square footage devoted to owner-occupied units are around 75% in both regions (AHS).

4.1.2 Internal Parameters

Aggregate moments The following parameters are chosen to match aggregate moments.

Discount factor. β is chosen to match a ratio of aggregate wealth to aggregate income of 4.4 for the bottom 80% of households (Survey of Consumer Finances).[14]

Housing. The CES weight α on housing services is chosen to match an average rent to average income ratio of 0.20 as measured in the Consumer Expenditure Survey (including utilities). The minimum housing size $\underline{h}$ is set to achieve the same ratio of the average sizes between owner-occupied and rental housing of 1.5 as in the data.

Moving shocks. Owners are subject to exogenous idiosyncratic moving shocks (as in Stein (1995)). They capture moves that cannot be explained by income such as those due to changes in family composition. Shocks are i.i.d. and distributed according to a type I Extreme Value distribution with mean $\widetilde{\xi}^o$. A high realization improves owners' utility if they sell and buy another house within the same region. Thus it determines the probability of being a repeat buyer. I set $\widetilde{\xi}^o = 2.5$ to match the fractions of repeat and first-time buyers of 50% in 2005-2012 (CCP/Equifax).

Mortgage spread. $\iota = r^b - r = 1.5\%$ is chosen to match aggregate leverage, measured as total mortgage debt outstanding to housing wealth. I use home mortgages outstanding and real estate at market value for households and nonprofit organizations from the Financial Accounts of the U.S. (Z.1., Federal Reserve Board). The ratio is 0.42 in 2005.

Mortgage default. The default cost $d = 2.333$ is chosen to match the average foreclosure rate of 0.5% in the cross-section of MSAs in 2005 (RealtyTrac).

[14]There is no mechanism in the model to generate high wealth inequality at the top (e.g., heterogeneity in discount factors, "superstar" income levels). For all households, the wealth/income ratio is 5.6.

Taxes and transfers. The progressivity parameter $\tau = 0.030$ is chosen to match the share of households receiving transfers in the U.S. (Congressional Budget Office (2012)). The level parameter $\eta = 0.930$ is chosen such that the ratio of net taxes used to finance wasteful government expenditures to income is 10%. There is a minimum income level equal to 10% of average income which ensures that choice sets are nonempty.

Regional moments The remaining parameters are chosen to match regional moments.

Regional income processes. The average idiosyncratic income shifter in expensive MSAs $\mu_H = 0.20$ is chosen to match the ratio of average household income relative to cheap MSAs of $\$51,554/\$40,185 = 1.28$. The shifter in cheap MSAs is normalized to $\mu_L = 0$.

To calibrate regional income risk, I exploit the model mapping between individual income volatility σ_j and the cross-sectional dispersion of income in steady state in each region. The latter is measured by the ratio of average to median income in region j, $E_j\left[Y_{i,j,a,t}\right]/M_j\left[Y_{i,j,a,t}\right] = \exp\left(0.5 \times \sigma_j^2/(1-\rho_e^2)\right)$ under conditional log-normality. Income volatilities $\sigma_L = 0.140$ and $\sigma_H = 0.145$ are chosen to match the ratios of average to median income of 1.35 and 1.38 in cheap and expensive MSAs.

Housing markets. Amenity benefits $\left\{\Xi_j^r\right\}$, home ownership benefits $\left\{\Xi_j^o\right\}$, and construction cost shifters $\left\{\bar{I}_j\right\}$ in regions $j = L, H$ are jointly calibrated to match the levels of rents $\left\{R_j\right\}$, home ownership rates $\left\{ho_j^{hh}\right\}$, and house prices $\left\{P_j\right\}$.

(i) Amenity benefits are higher in expensive than in cheap MSAs (where they are normalized to $\Xi_L^r = 0$), as implied by higher rents. They represent a utility boost equivalent to 13.4% of households' average one period utility (four years).

(ii) The utility benefits from home ownership Ξ^o are sizable. They represent a boost equivalent to 83.8% of households' average one period utility in cheap MSAs and 143.7% in expensive MSAs. Higher benefits in expensive regions are required to match similar home ownership rates across regions despite expensive regions being less affordable.[15] With Ξ^r, they create an incentive to locate in high-amenity regions, which results in higher rents and house prices through endogenous sorting of buyers by age, income, and wealth.

(iii) New construction is 2.4 times more costly in expensive than in cheap regions,[16] which reflects the sum of all tangible and intangible factors which make it harder to build in expensive MSAs. These factors include equipment and materials costs (in RSMeans data from construction cost provider Gordian, the New York MSA has a 1.6× higher

[15] Guerrieri, Hartley and Hurst (2013) emphasize the appeal of expensive MSAs before the recession.

[16] The marginal costs of a new housing unit is $\left(H_j/\bar{I}_j\right)^{1/\rho_j}$. In equilibrium, the ratio of the marginal construction costs is equal to the ratio of house prices. The average cost is $\left(\rho_j/(\rho_j+1)\right)\left(H_j/\bar{I}_j\right)^{1/\rho_j}$.

cost index than the San Antonio MSA); labor costs partly due to local laws (in Occupational Employment and Wage Statistics data from the BLS, the hourly construction wage is 2.20$\times$ higher in Illinois than in Arkansas); and local housing regulations such as project approval time, density and minimum lot or unit size restrictions, and developer exaction and impact fees (the difference between expensive and cheap MSAs in terms of the Wharton Residential Land Use Regulatory Index of Gyourko, Saiz and Summers (2008) is 3.5$\times$ higher than the average value of the index). They imply higher dollar and opportunity costs for developers. With amenities, they make expensive MSAs less affordable.

Migrations. Using ACS data on migrations between pairs of metro areas, I calculate an annual gross migration rate of 1.7% between cheap and expensive MSAs. The model matches that value. The implied utility cost of moving between regions $m = 3.747$ represents 90% of average one period utility. Table C.1 reports the equivalent dollar costs for various households. It amounts to taking away a bundle of nondurable consumption and housing with an average (median) value of \$61,800 (\$17,007). It is lower for younger (\$44,000), poorer households (\$30,290), and renters (\$12,230). It generates a decreasing life-cycle profile of migrations as in the data because an additive utility cost is relatively larger for older households with shorter horizons (Figure C.2).

m captures numerous frictions causing household inertia, such as the accumulation of neighborhood-specific capital (Diamond, McQuade and Qian (2019)), the lock-in effect of leverage (Brown and Matsa (2020)), reference dependence in the housing market (Andersen et al. (2022)), and the negative effect of distance on population flows between regions implied by a standard gravity model (Chaney (2018)) because cheap and expensive MSAs are usually far from each other and clustered geographically (Figure A.1).[17]

Table C.1 shows how the estimate of m depends on regional differences. m is lower when all house prices are equal to P_L because less buyers want to move from expensive to cheap MSAs to benefit from lower prices. m is lower when all income shifters are equal to μ_L because households from cheap MSAs do not want to move to expensive MSAs to benefit from a higher income. Then a lower cost is needed to match the average moving rate between MSAs in the data. m is higher when all rents are equal to R_L because buyers from cheap MSAs want to move more to expensive MSAs to benefit from better amenities without paying higher rents. Then a higher cost is needed to match the moving rate.

[17] This cost is lower than comparable estimates in structural models such as Kennan and Walker (2011), who estimate an average cost of \$278,570 (2005 dollars).

4.2 Baseline Results

The model replicates key moments of housing and mortgage markets at the aggregate, household, and regional levels in steady state.

Table 2 reports aggregate moments. They are obtained by aggregating variables using the cross-sectional distribution of households' locations, home ownership statuses, ages, income, and wealth in 2005. The model matches targeted moments and the non-targeted distribution of LTV and PTI ratios.

Table 2: Aggregate moments

Variable	Data	Model
Wealth/income	4.40	4.40
Avg. rent/ income	0.20	0.19
Leverage	0.42	0.40
Default Rate	0.005	0.005
Migration Rate	0.017	0.017
LTV P50	0.64	0.55
LTV P90	0.92	0.95
PTI P50	0.36	0.24
PTI P90	0.58	0.47

Notes: Upper panel: moments targeted by the calibration. Lower panel: not targeted. Sources: ACS, SCF, CEX, Flow of Funds, CCP/Equifax, RealtyTrac, Landvoigt et al. (2015), Greenwald (2018). Annualized values.

The model replicates differences between MSAs, which are crucial for the transmission of credit shocks. Table 3 reports regional averages, and Figures C.1 and C.2 display life-cycle profiles within regions. The model exactly matches the cross-section of house prices and rents, and closely matches home ownership rates and income. The population share of expensive MSAs is higher because the better income process and amenities attract more households. However, sorting is limited and households' income in expensive MSAs is not high enough to compensate for house prices. Limited sorting arises from the moving costs between MSAs required to match the migration rate of 1.7%. High prices arise from housing supply restrictions and amenities in expensive MSAs. Expensive MSAs are less affordable, with a price to income ratio of 5.2 (vs. 2.8 in cheap MSAs) which increases their sensitivity to PTI shocks.

Finally, the model generates the correct selection of households into transactions. This is important because the low frequency of housing transactions imply that few households are marginal for equilibrium prices (Piazzesi and Schneider (2009)). The bottom panel of Table 3 shows that the model matches the distribution of age, income, and wealth of home buyers by MSA. The shares of first-time buyers (50%) and their age (37 and 38) is similar in both MSAs and close to the data. Because of endogenous sorting and the better income process, their income and wealth are higher in expensive MSAs.

Table 3: Regional moments

Variable	Data L	Model L	Data H	Model H
Price per unit	111,500	111,500	267,600	267,600
Rent per unit	780	780	1,115	1,115
Homeownership rate	0.69	0.66	0.67	0.65
Avg income	40,185	38,512	51,554	52,479
Population share	0.42	0.41	0.58	0.59
First-time buyer share	0.52	0.50	0.46	0.50
First-time buyer age	37	38	37	37
First-time buyer income	19,631	17,028	43,271	45,433
First-time buyer wealth	6,500	4,600	16,300	19,500

Notes: Top panel: moments targeted by the calibration. Middle and bottom panels: not targeted. First-time buyer income is computed using PTI ratios and payment estimates, and wealth is computed as down payment using LTI ratios and house prices. Sources: ACS, Zillow, BLS, CCP/Equifax, Freddie Mac. Rents are monthly, incomes are annual. 2005 dollars.

5 Period Effect

This section presents the main quantitative findings on the regional transmission of local and aggregate shocks to young buyers. I study the dynamics of home ownership, house prices, and rents. I show that it can be explained by regionally-binding credit constraints in the post-Great Recession period, and I present out-of-sample evidence.

These results are obtained by solving for the nonlinear transition dynamics of the two-region economy in response to unanticipated shocks to income and credit standards, $\{\eta_{US,t}\}$ and $\{\theta_{LTV,t}, \theta_{PTI,t}, F_{m,t}, f_{m,t}\}$. It involves solving for the full paths of prices and rents $\{P_{L,t}, P_{H,t}, R_{L,t}, R_{H,t}\}$.

5.1 Regional Housing Market Dynamics

Shocks The recession is modeled as a sequence of negative shocks to local income and aggregate credit standards. The first period before the housing bust is 2002-05 ($t = 0$). *Local income shocks.* The income shock $\{\eta_{US,t}\}$ from 2006 to 2013 (from $t = 1$ to 2) is chosen to generate the same decrease in average real income of 10% relative to 2005 as in the data. $\beta_H > \beta_L$ are chosen to match the local income declines of 11% in expensive and 2% in cheap MSAs.

Aggregate credit shocks. Shocks to credit standards are identical across regions as in the data. The LTV and PTI limits $\{\theta_{LTV,t}, \theta_{PTI,t}\}$ from 2006 to 2021 (from $t = 1$ to 4) are chosen to match the 20% decrease in leverage from 2005 to 2014. The change in LTV limits is exogenously calibrated (Favilukis et al. (2017)) and the change in PTI limits is chosen to match the residual decrease in leverage. This generates a 20% decrease in $\theta_{LTV,t}$ (from 0.95 to 0.76) and a 50% decrease in $\theta_{PTI,t}$ (from 0.65 to 0.33). Fixed and proportional mortgage origination costs $\{F_{m,t}, f_{m,t}\}$ also increase from $1,200 to $2,000 and from 0.60% to 1%.[18]

Dynamic responses The model explains the dynamics of housing markets across regions, without targeting them.

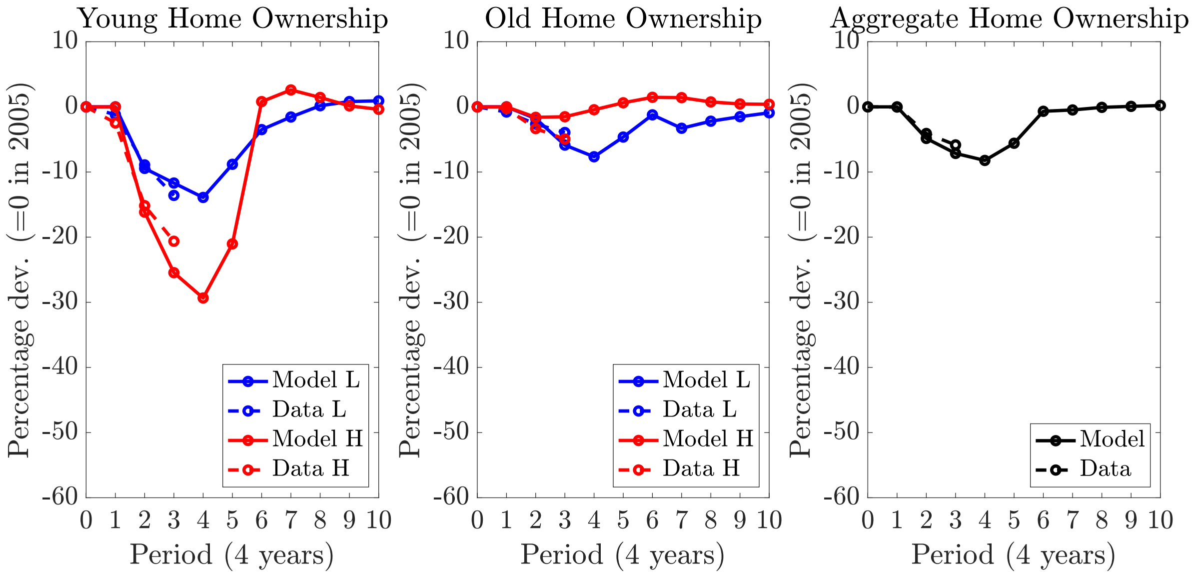
Home ownership. Figure 4 decomposes the change in home ownership between age and region groups. The model matches the data and generates regional heterogeneity in response to the recession despite regions being subject to identical credit shocks. First, the decrease in home ownership is concentrated among young buyers (25-44 y.o.). They rely more on credit to buy homes than older buyers who already own (and buy another house in the same or a different region) or have more savings. In this context, missing home buyers are explained by tighter credit standards rather than changes in Millennial preferences towards owning, consistent with survey evidence (Appendix A.3). Second, among young buyers the decrease is concentrated in expensive MSAs. From 2005 to 2015, young home ownership decreases by 10% in cheap MSAs and by 20% in expensive MSAs. Old home ownership only falls by 5% in both MSAs. When aggregating MSAs, the model replicates the 8% decrease in average home ownership from peak to trough.

The decrease in young home ownership is persistent even after the shocks dissipate ($t > 4$), especially in expensive MSAs. Crucially, persistence comes from a decrease in households' entry rates into home ownership, with young buyers delaying home ownership (Figure D.2, left panel). The average probability to buy for first-time buyer decreases by 75% in expensive MSAs and 20% in cheap MSAs. It stays low for 16 years. In contrast, the increase in households' exit rates from home ownership with defaults only lasts

[18] The model abstracts from other dimensions of credit standards as most quantitative models (e.g., FICO score requirements, asset and income verification as in Ambrose, Conklin and Yoshida (2016)). Figure D.2 shows that is able to generate an increase in credit risk followed by a decrease as in the data, which these dimensions control (Figure A.8).

4 years as in the data (Figure D.2, right panel).

Figure 4: Home ownership response to recession with tight credit



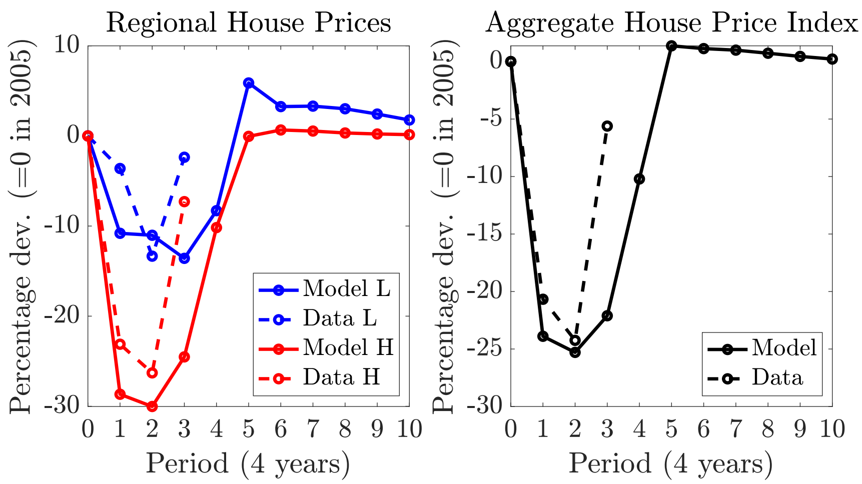
Notes: Home ownership changes for 25-44 year old households (left panel), 45-85 year old households (middle), aggregate (right). Low-price MSAs in blue, high-price MSAs in red, economy average in black. Model: solid lines. Data: dashed line (source: ACS). Changes in percentage terms relative to 2005.

House prices and rents. Figure 5 plots the response of regional and aggregate house prices. The model matches the 12% price decrease in cheap MSAs and the 30% decrease in expensive MSAs. The aggregate house price is constructed as a population-weighted index of regional prices. The model matches its 25% decrease in the data, most of which is driven by expensive MSAs.

Figure D.1 (upper panels) plots the response of rents. The recession initially generates a decrease in rents, and then a sustained increase in line with the data. This persistent increase of almost 20% in both MSAs is a general equilibrium response to lower income and tighter credit standards. Because young households delay buying but have a higher housing consumption target because of the upward-sloping life-cycle profiles of income and wealth, they consume more rental services. Thus rents recover two to three times faster than house prices. This is consistent with the evidence of a rental boom during the recovery from the Great Recession (Gete and Reher (2018)).

The model also matches well changes in housing supply (Figure D.1, bottom panels). In response to declining prices, new construction decreases and then slowly recovers. The decrease is larger is expensive (-60%) than in cheap MSAs (-40%).

Figure 5: House price response to recession with tight credit



Notes: Left panel, house price changes in low-price MSAs (blue) and high-price MSAs (red). Right panel, aggregate house price change. Aggregate house price index calculated as the population-weighted average of regional house prices. Solid lines: model. Dashed lines: data (source: Zillow). Changes in percentage terms relative to 2005.

5.2 Regionally-Binding Credit Constraints

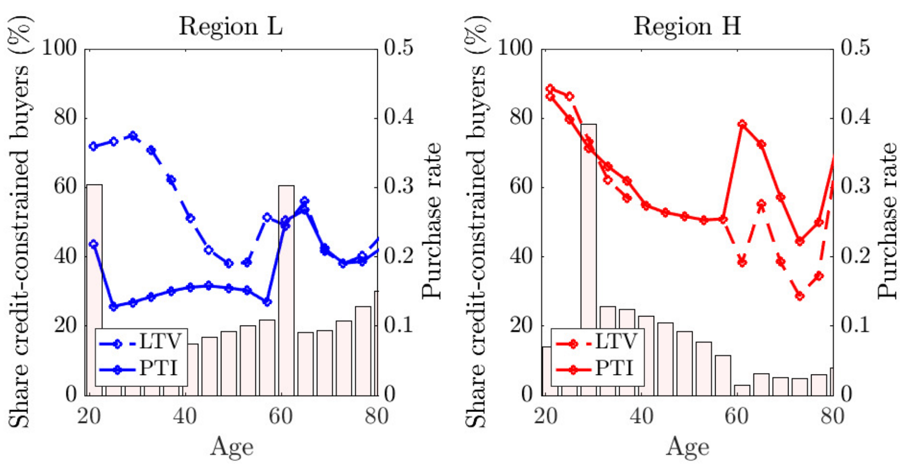
Aggregate credit shocks explain the responses of regional housing markets much more than local income shocks. They have a large impact because of a high fraction of credit-constrained first-time buyers in expensive MSAs.

Income vs. credit shocks Figure D.3 decomposes the contributions of income and credit shocks to the responses of home ownership and house prices across regions. The different dynamics of local housing markets are not driven by different local shocks as in most models of regional housing markets. Rather, they are driven by driven responses between regions to the same credit shocks. Aggregate shocks to LTV and PTI limits generate between 90% and 100% of the decrease in young home ownership in expensive MSAs, while local income shocks alone only generate 30% of it. Tighter LTV limits have a higher impact in cheap MSAs than in expensive MSAs, where their effect is slightly dominated by PTI limits. This nuances popular narratives which solely attribute the decrease in home ownership to high down payments requirements.

House prices respond to credit shocks in a similar way because housing markets are segmented. Income shocks have close to zero impact. They only amplify the impact of tighter credit because of their multiplicative interaction with PTI limits in buyers' credit constraints (Equation 1).

Credit constraints The impact of credit shocks is magnified by the large fraction of constrained first-time buyers. This is especially true in expensive MSAs where less affordable housing with a high price-to-income ratio makes PTI constraints more binding. Figure 6 plots the shares of LTV- and PTI-constrained buyers over the life-cycle (dashed and solid lines on the left axes) in cheap and expensive MSAs (left and right panels). Bars measure purchase rates (right axes), computed as the products of the average probability to buy times the fraction of renters conditional on age. The higher they are, the more buyers are affected by credit shocks. Three features determine the transmission of credit shocks into home ownership. First, the share of credit-constrained buyers decreases with age as income and wealth grow until retirement. It explains the large impact on young buyers. Second, there are more credit-constrained buyers in expensive MSAs (on average 90% vs. 60% in cheap MSAs). Third, more buyers are PTI-constrained in expensive (90%) than in cheap MSAs (40%), especially at ages when their probability to buy is high. This explains the larger impact on expensive MSAs, as PTI limits were tightened more than LTV limits.

Figure 6: Decomposition of first-time buyers' credit constraints



Notes: On left axes (both panels, in %), lines represent the shares of credit-constrained buyers at various ages for each type of constraint (PTI solid line, LTV dashed line). On right axes (both panels), bars represent purchase rates by age. Model values obtained using the stationary distribution of households in 2005. Left panel: low-price MSAs (blue). Right panel: high-price MSAs (red).

Housing affordability The higher price to income ratio in expensive MSAs makes credit constraints more binding. To show how lack of housing affordability affects the transmission of credit shocks, Figure D.4 plots counterfactual responses to the same shock under the house price distribution of 1997 when expensive MSAs were more affordable. Average house prices were $105,925 in cheap regions ($111,500 in 2005) and $122,650 in expensive regions ($267,600 in 2005). In this economy, the impact of credit shocks is muted. The decrease in young home ownership is twice lower than in the benchmark in expensive MSAs, and the decrease in prices is one third lower.

5.3 Out-of-Sample Evaluation

The model also captures broad patterns in housing markets outside the post-Great Recession sample of cheap and expensive MSAs. In Figure 7, the top panels evaluate out-of-sample validity in the cross-section by focusing on the top 5% of the distribution in the same period (instead of the top 50%), which corresponds to the San Francisco MSA. The middle and bottom panels evaluate out-of-sample validity in the time series by focusing on the decrease in home ownership in the 1980s and the increase in the 1990s. In the three cases the model is fully recalibrated.

Cross-section: San Francisco MSA. In 2005, the San Francisco MSA has an average house price of $669,780 which lies in the top 5% of the distribution. I compare it with the bottom 5%. Income and credit shocks are calibrated using the same approach as in the baseline. The model closely matches the decrease in young home ownership. It matches the house price decrease in the San Francisco MSA during the bust, and slightly understates its increase at the end of the sample.[19]

Time series: 1980s bust. In 1980, average house prices are $33,744 in cheap and $56,153 in expensive MSAs (bottom and top 50% of the distribution). The economy is subject to negative shocks over the next ten years, which are calibrated as in the baseline. Income decreases by 3%, LTV limits from 0.87 to 0.80 and PTI limits from to 0.55 to 0.50. The real mortgage rate increases from 3.1% to 4.7% as in the data.[20] Regional housing data by age is not available before 2005, so I use aggregate data for comparison. The model explains well the decline young home ownership. It matches the total decline in prices, though it does not generate a sufficiently large trough.[21]

Time series: 1990s boom. In 1990, average house prices are $63,676 in cheap and $106,130 in expensive MSAs. The economy is subject to positive shocks over the next fifteen years. Income increases by 12.7%, LTV limits are relaxed from 0.80 to 0.95 and PTI limits from to 0.50 to 0.65. The real mortgage rate decreases from 4.7% to 2.5%. The model matches

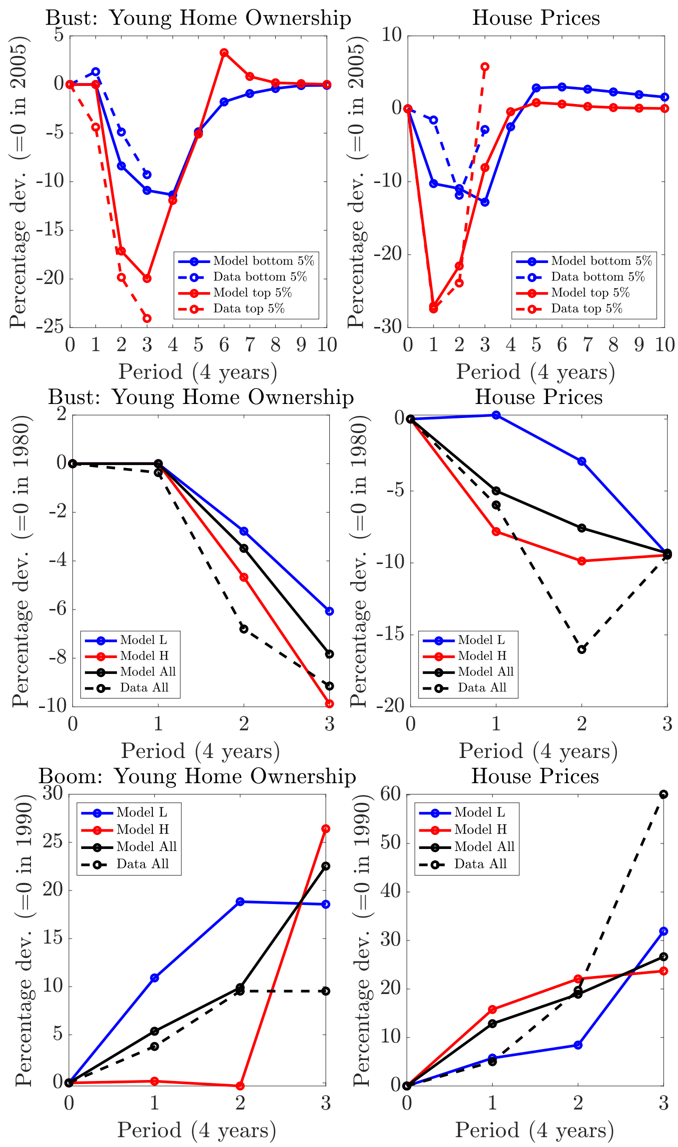
[19]The model abstracts from external investors entering expensive housing markets when prices are temporarily low, who would generate such an increase (e.g., Favilukis and Van Nieuwerburgh (2018)).

[20]The baseline model abstracts from changes in mortgage rates because it requires modeling households' refinancing decisions. Here, to keep the model tractable when varying the rate I assume that there are no refinancing frictions so that all mortgages pay the new rate.

[21]In this calibration of the model housing markets are less segmented than in the baseline, which would explain the lower effect of credit shocks.

the increase in young home ownership and prices, except in the last period.[22] Interestingly, the transmission of credit shocks into home ownership is asymmetric in expansions and contractions. The increase in the boom mainly comes from cheap MSAs, while the decrease in the bust mainly comes from expensive MSAs.

Figure 7: Out-of-sample responses: San Francisco MSA post-2005, nationwide housing bust post-1980, nationwide housing boom post-1990



Notes: On upper panels, responses of top and bottom 5% house price MSAs to same decrease in income and credit supply as in benchmark. On middle panels, responses of young home ownership rates and house prices to the combination of a decrease in income and credit supply and an increase in the mortgage rate. On lower panels, responses to the combination of an increase in income and credit supply and a decrease in the mortgage rate. Solid lines: model. Dashed lines: data. Blue: low-price MSAs. Red: high-price MSAs. Changes in percentage terms relative to reference year.

[22] The model abstracts from belief shocks which would explain very high prices at the peak of the housing boom (Kaplan et al. (2020)).

Sensitivity analysis Figure E.1 displays baseline responses under alternative parameters. A lower risk aversion γ induces less sorting by income between regions. When utility is less concave, it is less costly for households to give up consumption to pay for higher house prices in expensive MSAs. Therefore more poor households locate in expensive MSAs and their credit constraints bind more. It makes them more sensitive to credit shocks and amplifies the decrease in home ownership and prices. An elasticity of substitution ϵ between consumption and housing which makes them less substitutable dampens the decrease. Introducing a warm-glow motive for bequests $U(b) \equiv \psi \frac{(b+\underline{b})^{1-\gamma}}{1-\gamma}$ and making them normal vs. luxury goods has little effect.

6 Mechanism: Region and Cohort Effects

This section investigates how differences between regions and cohorts of buyers contribute to the heterogeneous responses of housing markets to credit contractions.

6.1 Regional Heterogeneity

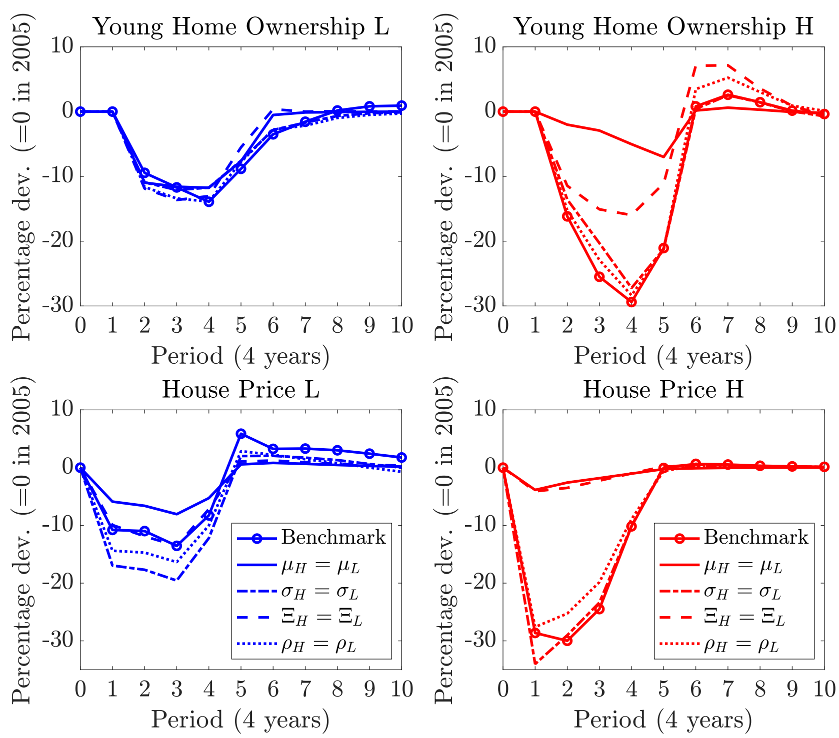
Regional parameters generate differences in house price levels which lead credit constraints to bind more in expensive MSAs, increasing their sensitivity to shocks. Figure 8 plots counterfactual transitions in response to the same shocks as in the baseline, which turn off the sources of regional heterogeneity one by one. Differences in income processes between regions are key to explain the dynamics of housing markets, followed in importance by amenities, and housing supply restrictions.

When the income shifter in expensive MSAs is set equal to its value in cheap MSAs $\mu_H = \mu_L$ (solid line), young home ownership falls by 5% in expensive MSAs instead of 30% in the benchmark (solid line with dots). The bust in home ownership becomes worse in cheap MSAs, at odds with the data. Regional differences in house price busts also vanish, with prices falling less than 5% in expensive MSAs. It makes it impossible for the model to generate an aggregate housing bust driven by expensive MSAs. In this economy, credit constraints do not bind more in expensive MSAs because a lower μ_H generates a lower price P_H, which relaxes credit constraints. Differences in regional income risk have a lower effect on the response of housing markets, as shown in an economy with $\sigma_H = \sigma_L$ (dashed-dotted line). This is because these differences are lower themselves than differences in income shifters.

When amenities in expensive MSAs are set equal to their values in cheap MSAs $\Xi^H = \Xi^L$ (dashed line), young home ownership in expensive MSAs falls by half as less as in the benchmark. The busts in home ownership become almost identical across regions, also at odds with the data. As with identical income shifters, prices decrease less in expensive than in cheap MSAs.

Setting the housing supply elasticity in expensive MSAs equal to its value in cheap MSAs $\rho_H = \rho_L$ (dotted line) has less effect, pointing to the role of credit constraints rather than supply. The busts in young home ownership and prices become more similar across MSAs, but not as much as with identical income processes and amenities.

Figure 8: Effect of regional differences on home ownership and house price responses



Notes: Changes in young home ownership and house prices in low-price MSAs (blue) and high-price MSAs (red). Solid lines with dots: benchmark. Other lines plot responses to the same shocks as in the benchmark when differences between regions are turned off individually: income shifter (solid), income risk (dashed-dotted), amenities (dashed), and housing supply elasticites (dotted) in high-price MSAs set equal to their values in low-price MSAs. Changes in percentage terms relative to 2005.

6.2 Moving Frictions

Differences in income, amenities, and housing supply induce buyers to sort endogenously between MSAs, leading to more binding constraints in expensive MSAs. In turn, the response of housing markets to a credit contraction depends on the extent to which buyers can move between MSAs. The model generates realistic population flows in response to the contraction, hence it produces credible estimates of spatial equilibrium effects. It matches the 2% population decline in expensive MSAs and the 1.5% increase in cheap MSAs (Figure D.5).

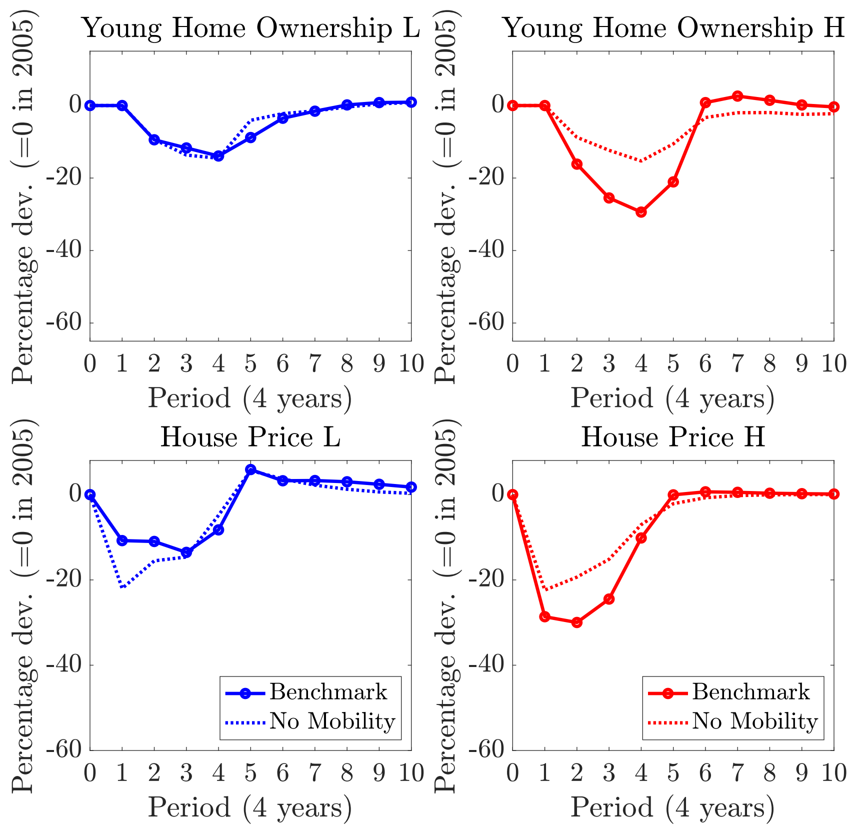
These flows affect housing markets even when relatively small. In spatial equilibrium, young home ownership and prices decrease in expensive and increase in cheap MSAs partly as a result of young buyers moving from expensive into cheap MSAs. This migration accelerator, which is consistent with empirical evidence (Howard (2019)), is absent from models without migrations. Figure 9 quantifies their impact on buyers' region of destination and origin, an empirical challenge. It compares responses in the baseline with migrations (solid line) to a counterfactual without migrations ($m = \infty$, dotted line). Moves exacerbate differences regional housing cycles by amplifying the bust in expensive MSAs and dampening it in cheap MSAs. In expensive MSAs, young home ownership falls by 30% vs. 15% without migrations. House prices fall by 30% vs. 15% without migrations, and by 17% vs. 21% in cheap MSAs. The relative price increase in cheap MSAs compared to the model without migrations is due to some households relocating to these areas. Around 15% of movers immediately become first-time buyers in cheap MSAs and contribute to a higher demand for owner-occupied units. The remaining movers increase rental demand and buy in subsequent periods. Conversely, less than 5% of movers from cheap to expensive MSAs buy to take advantage of the depressed house price. Endogenous sorting implies that most households from these MSAs are poorer in the first place.

6.3 Cohort Effect

Differences between cohorts worsen the credit constraints of young buyers entering in the recession. In the baseline, Millennials (i) have lower wealth when young, calibrated to reflect student debt payments; (ii) draw their initial income from a worse distribution, which persistently lowers their lifetime income.

Figure D.6 shows their effect on the response of housing markets, using counterfactual transitions without student debt and income scarring. Student debt directly lowers wealth and makes LTV limits more binding. Income scarring directly lowers income and makes PTI limits more binding; it indirectly makes LTV constraints more binding because it lowers savings. Both features amplify the decrease in young home ownership and prices by a factor of 1.5 in expensive MSAs where credit constraints bind more. In contrast, their effect is close to zero in cheap MSAs with responses close to the baseline.

Figure 9: Effect of mobility on home ownership and house price responses



Notes: On upper panels, responses of 25-44 year old home ownership in the benchmark with mobility (solid lines) vs. no mobility (dotted lines, $m = \infty$). On lower panel, house price responses. Blue: low-price MSAs. Red: high-price MSAs. Changes in percentage terms relative to 2005.

Consistent with binding PTI constraints, the effect of income scarring is larger.

Table D.1 shows that their impact persists in the long run when shocks vanish. In expensive MSAs, student debt permanently decreases young home ownership by 1 pp, and income scarring decreases it by 7 pp. Income scarring lowers average house prices by $3,000. These effects are weaker in cheap MSAs because credit constraints bind less. Interestingly, student debt slightly increases home ownership in cheap MSAs because it leads some buyers to relocate from expensive MSAs. It increases rental demand in expensive MSAs because those who stay rent larger units. It results in a rental boom with a sizable $300/month rent increase.

7 First-Time Buyer Subsidies

Regional credit constraints affect the effectiveness of housing stabilization policies implemented in response to the recession. I focus on the First Time Homebuyer Credit (FTHC) of 2009, which has not yet been evaluated in a structural model. I compute estimates of the impact of the policy which account for spatial and general equilibrium effects and complement empirical estimates of local average treatment effects. I use them to understand its impact on buyers' welfare. I then show how place-based subsidies can improve its effectiveness.

7.1 The First-Time Home Buyer Credit

Background The last version of the FTHC in the 2009 Worker, Homeownership, and Business Assistance Act is modeled as an $8,000 unanticipated subsidy for households with income below $125,000, which lasts for the length of the bust. The policy is financed by the issuance of long-term government bonds. I compare the response of housing markets with ("FTHC") and without the subsidy ("Bench").

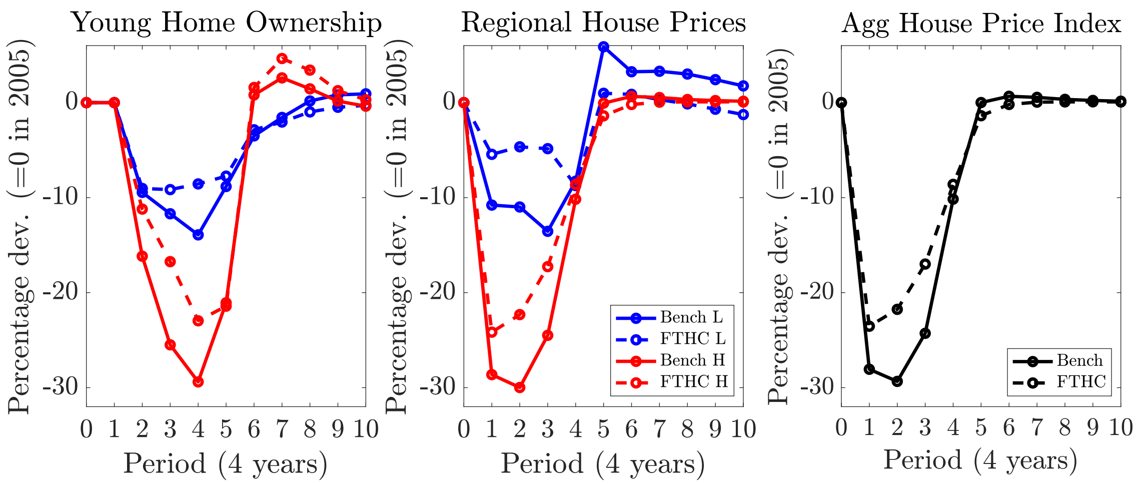
Impact *Estimates.* Figure 10 plots the dynamic impact of the policy. It stabilizes young home ownership (-9% vs. -13% in cheap MSAs and -23% vs. -30% in expensive MSAs) and house prices (-5% vs. -13% and -25% vs. -30%). The subsidy directly relaxes LTV limits. It indirectly relaxes PTI limits because first-buyers need to borrow less. It results in a 10% increase in home sales.[23] These effects are in line with empirical estimates (Berger et al. (2019)).

Dampening. Regional heterogeneity dampens the effectiveness of the FTHC. The policy stabilizes cheap MSAs by cushioning one third of the decrease in young home ownership and more than half of the decrease in house prices. However, it fails to stimulate expensive MSAs relatively as much. It cushions less than one fourth of the decrease in young home ownership and less than one sixth of the decrease in prices. Therefore its effect on the aggregate house price index is limited (it cushions less than one fifth of it) and mostly comes from dampening the price decline in cheap MSAs. The subsidy is identical across regions, therefore it represents a lower fraction of house prices in expensive MSAs (3%) compared to cheap MSAs (7%). It relaxes credit constraints by more and for more

[23] In the model, the increase in home sales consists of more sales from older to younger households and of more residential investment. In the data, the increase also came from a decrease in the stock of existing vacant homes.

buyers in the latter. However, since the decrease in home ownership is concentrated in expensive MSAs, the subsidy fails to stabilize enough these regions which are responsible for the bust.

Figure 10: Impact of First-Time Homebuyer Credit on home ownership and house prices



Notes: Solid lines: benchmark responses without the policy. Dashed lines: responses with the policy. In both cases the economy is subject to the same sequence of income and credit shocks as in the benchmark. Left panel: change in young home ownership (low-price MSAs in blue, high-price MSAs in red). Middle panel: house prices. Right panel: aggregate house price index (black).

7.2 Welfare Analysis

Instead of a "one size fits all" subsidy across regions, I estimate the welfare impact on a proportional subsidy which scales with local house prices. This place-based subsidy is chosen to have the same total dollar cost as the uniform FTHC. Figure 11 compares the dynamic welfare impacts of the uniform ("FTHC") and place-based subsidies ("PB-FTHC"). Consumption-equivalent variations measure the net gains of the policies in terms of one period of consumption of nondurables and housing (four years).[24]

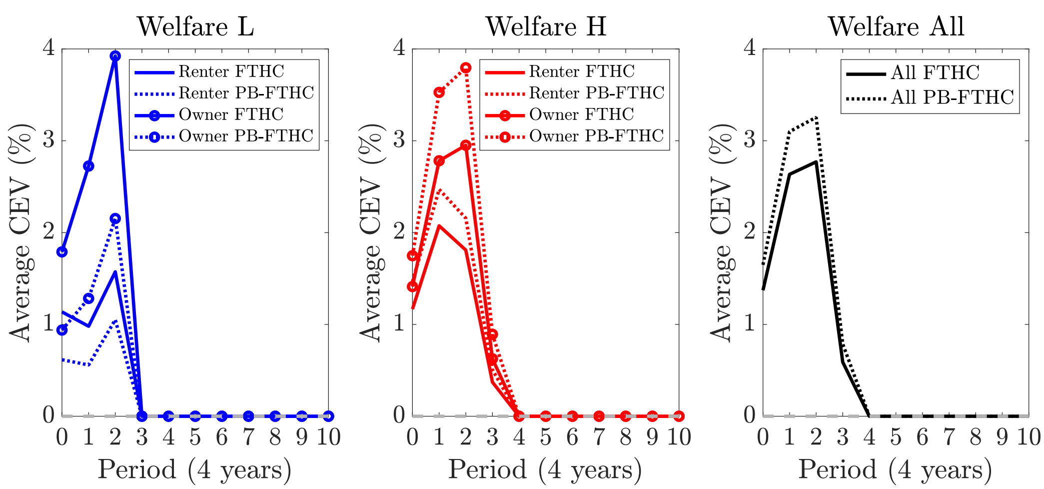
Uniform FTHC. The FTHC generates a sizable aggregate welfare gain (average, black lines), corresponding to a +2.7% increase in four-year consumption. Welfare gains come from four sources: owning allows buyers to live in larger units, enjoy higher amenity benefits, hedge against rent increases, and accumulate wealth faster than with risk-free assets when the rate of return on housing increases. The policy also slightly improves the recovery of nondurable consumption. Gains are larger several years into the recession when the decrease in home ownership is larger, and they are heterogeneous across households.

[24] Appendix B.3 details the welfare calculations.

The policy benefits renters (solid blue and red lines) because it improves their access to home ownership. Conditional on buying, it benefits them more in expensive MSAs because amenity benefits are larger. However it increases the number of buyers in these regions by less, which dampens its total welfare impact. Interestingly, the policy also benefits owners (solid blue and red lines with dots) because it cushions the decrease in prices, hence in housing wealth. This general equilibrium effect is large, with owners' gains being between 1.5× and 2.5× higher than renters'.

Place-based FTHC. The place-based subsidy significantly increases aggregate welfare gains from +2.7% to +3.2%. This is achieved by an increase in buyers' welfare in expensive MSAs (from +2% to +3%) and an increase in the size of this group because the policy makes buying more affordable. Even though it is not a Pareto improvement, these gains dominate the small losses for buyers in cheap MSAs (from +1.5% to +1%). Owners gain in expensive and lose in cheap MSAs because of the general equilibrium effects of the policy on house prices.

Figure 11: Welfare effect of First-Time Homebuyer Credit and place-based subsidy



Notes: Solid lines: conditional welfare gains from the policy. Dashed lines: gains from a place-based subsidy, defined as a fixed percentage of local prices in the steady state. In both cases the economy is subject to the same sequence of income and credit shocks as in the benchmark. Welfare effect of policies measured relative to the benchmark as consumption-equivalent variations (for four years). Left panel: welfare gains in low-price MSAs (blue). Middle panel: welfare gains in high-price MSAs. Conditional average gains are plotted separately for renters (dots) and owners (crosses). Right panel: aggregate welfare gains, computed with a utilitarian social welfare function.

Two features explain this improved effectiveness. First, the place-based subsidy is larger in expensive MSAs, so it relaxes regionally-binding credit constraints by more. This helps stabilizing young home ownership. Second, due to the higher benefits $\Xi_H^{\mathcal{H}}$ in expensive MSAs the welfare gains are larger for a given increase in home ownership, and these higher benefits are applied to a larger population. A caveat to this result is that such a policy also incentivizes household to locate in expensive MSAs. If the benefits of living and owning in these areas decrease with their total population (congestion externality), or if amenities in cheap MSAs can be improved, then these gains will be attenuated. Overall, these findings suggest that housing stabilization policies should not only account for buyers' income and wealth, which would lead to target cheap MSAs. They should also account for house prices and location preferences, which lead to target expensive MSAs.

8 Conclusion

Low home ownership rates among Millennials are one of the main features of the post-Great Recession period. This paper shows that to understand their causes and consequences for households' balance sheets, housing markets, and stimulus policies, it is critical to account for differences between regions. I obtain these findings in a novel setting, which explicitly connects an equilibrium spatial macro-finance model with heterogeneous buyers and incomplete markets to a panel of U.S. metro areas.

Because young buyers are more constrained in regions with higher house prices, they disproportionately respond to changes in credit standards by delaying house purchases, resulting in larger busts. Limited access to credit prevents them from arbitraging local house price declines which would generate high returns. But also, moving frictions prevent them from arbitraging regional price differences by moving en masse to cheap regions. The different dynamics of regional housing markets after the recession is not explained by different local shocks, but rather by the larger impact on expensive regions of the same credit contraction nationwide (period effect). Student debt and income scarring (cohort effect) persistently reduce the importance of housing on Millennials' balance sheets and they hamper housing markets, though they tend to benefit cheap regions and rentals. Subsidies to first-time buyers partly undo these negative effects, but not enough if they are identical across regions like the FTHC.

Place-based subsidies which target expensive regions with large busts are more effective. This is an important dimension in which housing stabilization policies differ from traditional place-based policies, which tend to target low-income regions. This result is, however, less surprising in light of real-world housing policies. Several first-time buyer programs offer lower rates, down payment requirements, or direct subsidies which differ across regions (e.g., "Achieving the Dream" in the New York State). Future work could use this framework to analyze them as well as other credit-ameliorating policies with a regional dimension. Understanding how buyers' migrations to the suburbs and the countryside associated with the recent increase in working from home affect real estate would be another interesting direction.

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Appendix

A Data Appendix

A.1 Dataset Construction

To construct the regional panel dataset, I merge public-use data from the U.S. Census Bureau (American Community Survey, County Business Pattern, Building Permit Survey), Zillow, the Consumer Credit Panel of the Federal Reserve Bank of New York, the Home Mortgage Disclosure Act, Fannie Mae and Freddie Mac, and proprietary data from RealtyTrac (purchased through ATTOM Data Solutions).

First, I extract the Census data through American FactFinder. I use ACS variables for which there is information for various age groups, and at the MSA level (Geographies: Metro Micro statistical areas: all MSA within US.) Variables are at the household level unless otherwise specified. When available, I use the ACS 5-year estimates.For each year, I used the following tables.

- Age group shares and total population. Topics: people: age and sex: age. Table: age and sex, ACS 5 year estimates.

- Homeownership rate by age. Topics: housing: occupancy characteristics: owner/renter (tenure in occupied units). Topics: housing: occupancy characteristics: age of householder. Table: tenure by age of householder.

- Income by age. Topics: people: age and sex: age of householder. Topics: people: income and earnings: income/earnings (households). Table: median household income in the past 12 months (in adjusted dollars for the corresponding year) by age of householder, ACS 5 year estimates. This is median income; it includes all sources of income; I construct labor earnings by MSA from the CBP data.

- Employment status by age. Topics: people: employment: employment (labor force) status. Table: employment status, ACS 5 year estimates.

- Aggregate house value by age. Topics: people: age and sex: age of householder. Table: aggregate value (dollars) by age of householder, ACS 5 year estimates.

- Construction: number of establishments, number of paid employees, first quarter payroll (in thousand dollars of the corresponding year), annual payroll (in thousand dollars). Industry codes: "construction": NAICS based industry: 23 construction. Table: geography area series: county business pattern (business pattern for the corresponding year). Available for all NAICS sub-categories.

Second, I complement the construction data from the CBP with data from the Building Permits Survey, directly downloaded from the Census website. It has information, by MSA and year, on the number and dollar amount of permits issued for various building sizes (structures with 1, 2, 3-4, and 5+ units). I use data from the 2014 and 2004 universes (the 2014 universe includes approximately 20,100 permit-issuing places and is used from January 2014 forward; the 2004 universe includes approximately 19,300 permit-issuing places and is used from January 2004 to December 2014.) I also use MSA-level data on local housing supply elasticities estimated by Saiz (2010), which are do not vary by year, and on the Wharton Residential Land Use Regulatory Index (WRLURI).

Third, I obtain data on median home prices and rents from Zillow's Home Value Index (ZHVI) and Rental Index (ZRI), which are seasonally-adjusted ideal price indices based on a machine-learning algorithm that uses the sale prices of a set of homes with a constant composition over time. I use Zillow's crosswalk between its regions and federally defined MSAs to obtain the data at the MSA level. The frequency is monthly. I annualize the data by calculating an unweighted average across months for each MSA.

Fourth, I obtain data on mortgage credit from HMDA, and Fannie Mae and Freddie Mac through Recursion Co, a financial analytics firm which aggregates the data at the MSA-level for research purposes. It includes information on the number of applications and of loans originated, their dollar values, application statuses, and the characteristics of originated loans. Application statuses are: whether the loan was originated, the application was approved but not accepted, denied by the financial institution, withdrawn by the applicant, the file closed for incompleteness, the loan purchased by the institution, the preapproval request denied by the financial institution, or the preapproval request approved but not accepted (optional reporting).

Fifth, I use the data on housing supply elasticity by MSA made publicly available by Albert Saiz.

Sixth, I use data on the number and balances of mortgages originated to first-time buyers, broken down by 10-year age bins and aggregated at the MSA level, from the New York Fed's CCP.

Seventh, to account for exit from homeownership through foreclosures, I use MSA-level proprietary foreclosure data from RealtyTrac. A foreclosure is defined as the union of the following events: notice of default, pending lawsuit, notice of trustee's sale, notice of foreclosure sale, Real Estate Owned property.

Then, I create a script to process the CSV and Excel tables for each of those variables for each year, and aggregate them across years. I thus obtain one table for each variable, which includes all years and MSAs. When the data is in long format, I reshape it to wide format to keep an (MSA,year) pair as the unique identifier for an observation. For the building permits data, some observations are on several consecutive rows in the Excel file because they are long, in this case I merge those rows into a single row corresponding to an observation.

Because of its specificity, the building permits data has a different treatment detailed in this paragraph. It is in text format, and before 2009 it does not have MSA codes, but it has MSA names, so I merge it with the post-2009 data that has both MSA names and codes, using the following text analysis algorithm. Using text recognition for ",", I split the MSA name between the metro area and the state names (e.g. for "New Orleans, LA", the state is "LA"). I do the same for the metro name itself when it combines several zones using hyphens. For instance, "Albany-Schenectady-Troy" produces three variables: MSA name 1, name 2 and name 3, with respective values "Albany", "Schenectady", and "Troy". All those names are inputs for the text recognition algorithm. Its goal is to fill in the missing MSA codes in the old universe data with help of the new universe data[25]. The steps are as follows. Step 1: look for rows with missing code in the entire table; when a missing value is found, identify the corresponding original MSA name and state, and look in the entire table if there is another row with a non-missing MSA code and the same name and state; if yes, stop, and declare a perfect match, and replace the missing value by the MSA code found; otherwise, do the same without the restriction that the states must be identical, and if a non-missing value is found, stop and declare a match based on CBSA name only; otherwise, go to step 2. Step 2: for unmatched MSA names, use a fuzzy string matching algorithm (based on the Levenshtein distance) to find matching original MSA names, either perfect or approximate. Replace missing values by the found MSA codes, and otherwise go to step 3. Step 3: re-do step 2, now using MSA name 1 (this helps with unmatched hyphenated CBSA names). If there are still unmatched values (this is not the case), then do it for name 2, etc. Finally, delete the unmatched observations (an alternative would be to exploit information based on the observations' values, but at the cost of increased computational complexity).

Then, I merge all those tables using an (MSA code,year) pair as a unique identifier.

Finally, I deflate all nominal variables using the chained CPI for all urban consumers (all items in US city average) from the BLS, equal to 100 in 2005.

I also perform various checks on the resulting dataset to ensure its consistency. For instance, check that the number of MSAs is between 384 (number of MSAs in the U.S. as defined by the Office of Management and Budget) and 392 (including Puerto Rico).

To account for exit from homeownership through foreclosures, I use MSA-level proprietary foreclosure data from RealtyTrac. A foreclosure is defined as the union of the following events: notice of default, pending lawsuit, notice of trustee's sale, notice of foreclosure sale, Real Estate Owned property.

To account for housing supply side factors, I collect data from the Building Permits Survey and from the County Business Patterns to proxy for residential investment and construction. It comprises the number and value of all building permits and broken down by type of structures (from

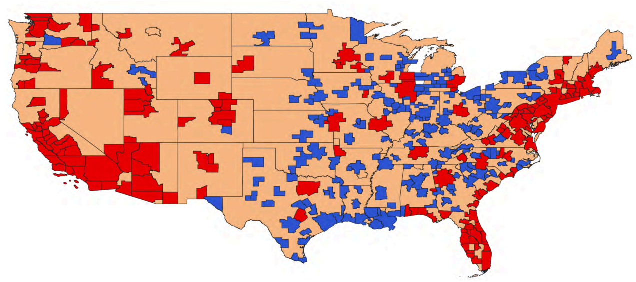
[25]One limitation is if MSA delineations have substantially changed between the old and new universes.

1 to 5+ units), as well as the total number of employees, payroll, and number of establishments in the construction sector (NAICS code 23 and subcodes). I also use MSA-level data on housing supply elasticity as estimated by Saiz, which are do not vary by year.

A.2 Classifying Regions

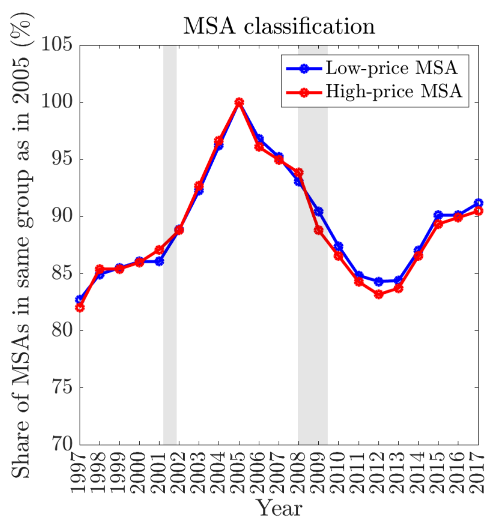
The first group includes regions with historically stable house prices, unconstrained housing supply, and in low demand from buyers. The second group includes regions with historically higher volatility and tight housing supply restrictions, and regions with historically stable prices that experienced high volatility during the 2000s. All high-price regions are in high demand.

Figure A.1: Regional distribution of house price levels



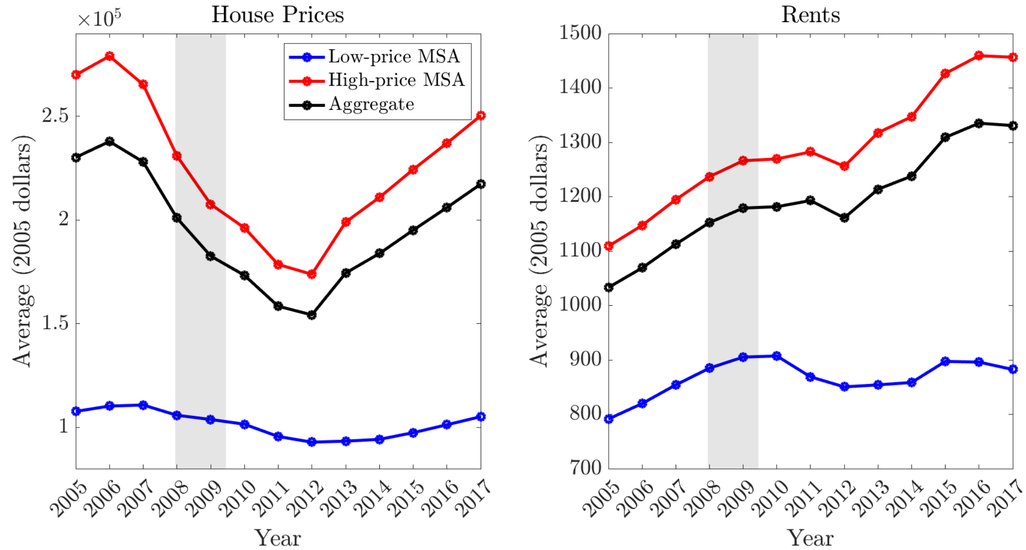
Source: Zillow. Distribution of MSAs sorted by house price levels in 2005, bottom 50% in blue and top 50% in red.

Figure A.2: Persistence of MSA classification into low- and high-price regions



Notes: In blue (red), share of MSAs which were in the bottom (top) 50% of the house price distribution in 2005 that were also in the bottom (top) 50% of the distribution in another given year. Shaded areas indicate NBER recessions. Sources: Zillow.

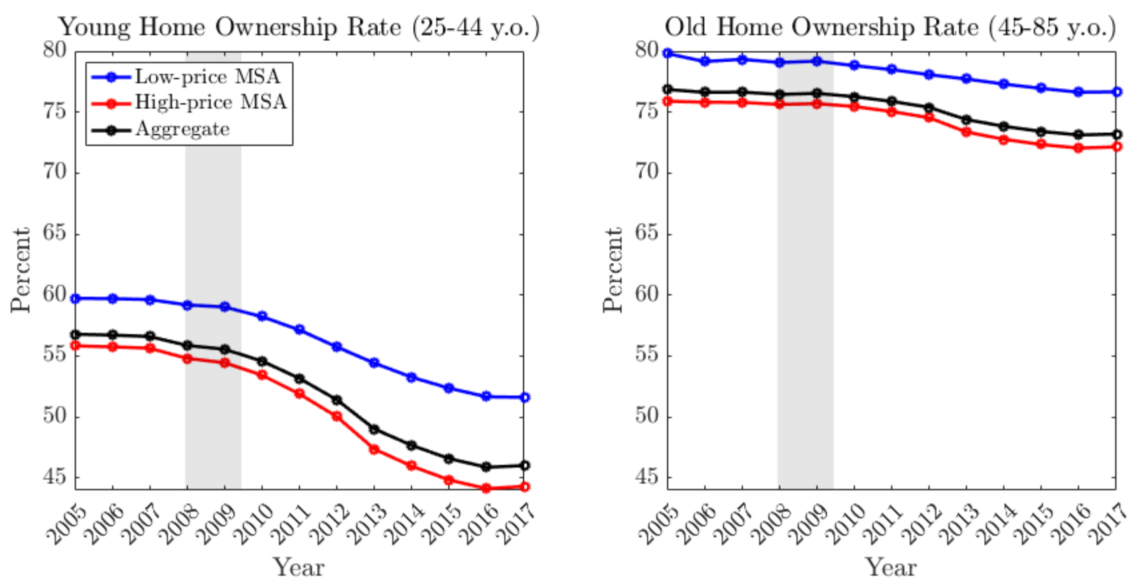
Figure A.3: House prices and rents by region



Notes: Levels, 2005 dollars. MSAs are sorted into two groups by the level of house prices in 2005 (bottom 50%, blue, and top 50%, red). Within each group, the weighted average rate for a given age group is calculated using the MSA total population in 2005. The shaded area indicates the NBER recessions. Sources: Zillow, ACS.

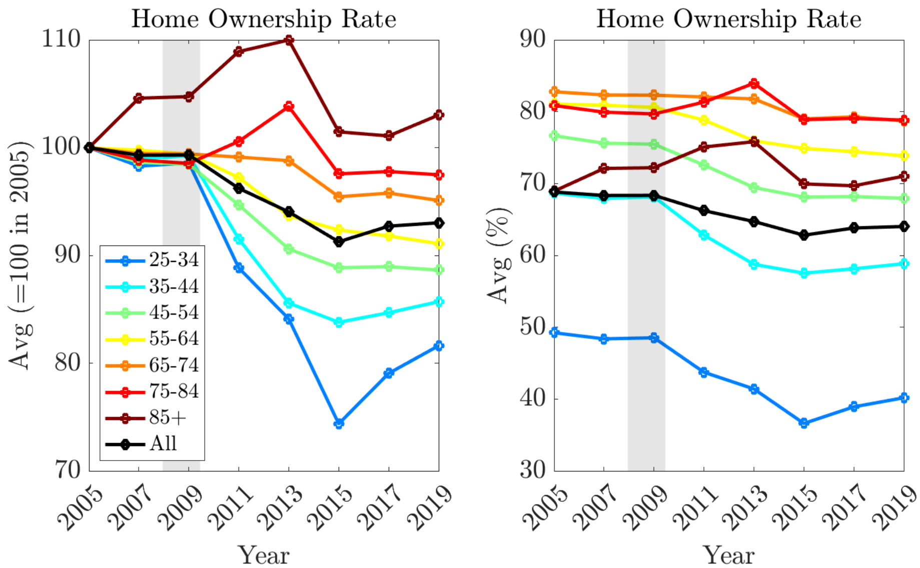
A.3 Home Ownership

Figure A.4: Home ownership by age



Notes: Left panel, home ownership rate for young households (25-44 y.o.) in low- (blue) and high-price MSAs (red). Right panel, home ownership rate for older households (45-85 y.o.). The black line depicts the economy average. Population-weighted averages. Gray bands indicate NBER recessions. Source: ACS, Zillow.

Figure A.5: Home ownership by age (10-year groups)



Notes: Home ownership rate by age group. Left panel: change, values normalized to 100 in 2005. Right panel: level. Population-weighted averages. Gray bands indicate NBER recessions. Sources: AHS.

Table A.1: Demographic groups with largest decrease in home ownership since 2005

Home ownership rate	2005-15 change (pp)
Age: 25-34 y.o.	-14.7
Household composition: single female with kids	-9.7
Education: less than high school	-8.5
Income: Q3	-7.4
Race: Black	-6.3
All	-6.1

Source: AHS. This table reports the result of a single unconditional sort of changes in home ownership rates (in percentage points) by population groups corresponding to the main demographic determinants of home ownership, in decreasing order of importance (Goodman and Mayer (2018)). For each group, the largest change is reported. Young households highlighted, as group for which home ownership fell the most.

Millennial Attitudes Towards Home Ownership Three different measures suggest that there is little role for changes in Millennials' preferences towards owning relative to previous cohorts to explain their low home ownership rates. Unlike attitudes towards financial markets after the Great Depression described by Malmendier and Nagel (2011), the Great Recession does not seem to have changed young households' attitudes towards home ownership.

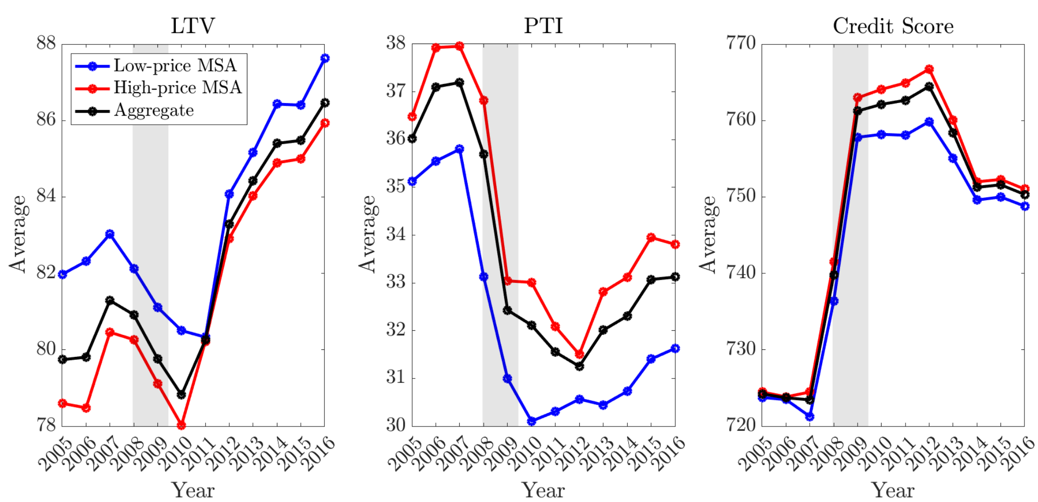
First, three surveys asking Millennial households about their preferences give direct suggestive evidence. In the Survey of Consumer Expectations' Housing Survey (Federal Reserve Bank of New York), the question "Would you like to own instead of rent your primary residence" gives 71.3% yes (19.4% no); "Compared to other financial investments, buying in your zip code today is" gives 64.9% good (9.1% bad). Responses are similar in the Housing Confidence Survey (Pulsenomics), which asks "Is housing a good long-term investment?", and in the National Housing Survey (Fannie Mae).

Second, indirect measures in household-level data also give suggestive evidence. If Millennial's preferences towards owning are lower, then financially-unconstrained households should have lower home ownership rates than previous cohorts. I find that this is not the case. I focus on prime-age white households in the ACS, aged 25-34 years old, married with children, and with annual income greater than $100,000. Their home ownership rate has decreased significantly less (-2.8 pp) than for all households in 1990-2015.

Third, in line with these findings, the quantitative analysis conducted in the model finds no residual role for changes in preferences to explain the decrease in home ownership, once the effect of credit conditions and objective cohort differences has been accounted for.

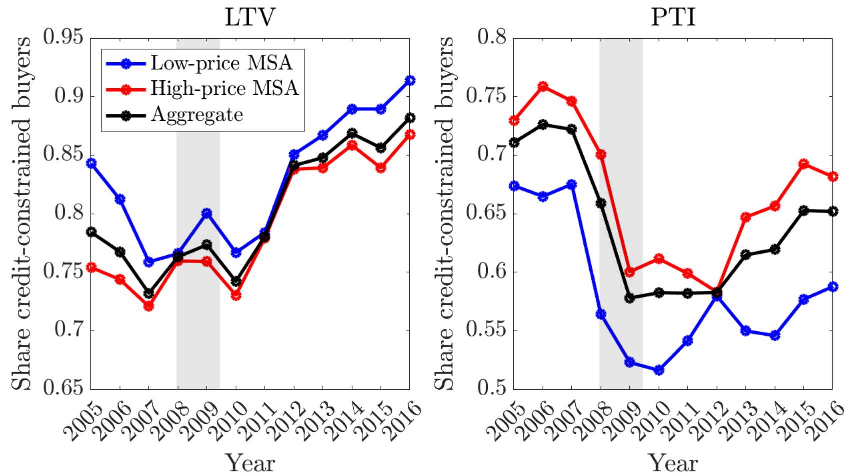
A.4 Credit Contraction

Figure A.6: Average credit conditions at origination for first-time buyers



Notes: For first-time buyers, average loan-to-value ratio (left panel), average payment-to-income ratio (middle), average credit score (right). At origination and averaged by region group using total MSA population as weights. Gray bands indicate NBER recessions. Sources: Fannie Mae, Freddie Mac, Zillow.

Figure A.7: Shares of credit-constrained first-time buyers at origination

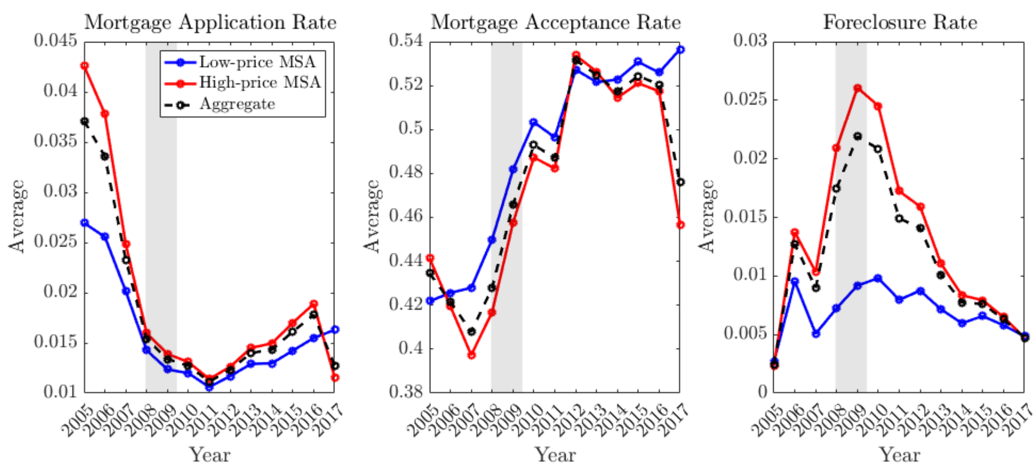


Notes: Shares of credit-constrained first-time buyers by region. Left panel: share of borrowers with a loan-to-value ratio higher than the nationwide limit. Right panel: share of borrowers with a payment-to-income ratio higher than the nationwide limit. Averages by region group computed using total MSA population as weights Gray bands indicate NBER recessions. Sources: Fannie Mae, Freddie Mac, Zillow.

Mortgage applications. Loan-level information on loan application and acceptance rates comes from the Home Mortgage Disclosure Act (HMDA). HMDA includes information from U.S. financial institutions, including most insured depository institutions and non-bank lenders. In 2017, the last year of my sample, it covered 92% of all originations in the U.S, and its coverage is stable over time. I exclude mortgages which are not for purchase and owner-occupying purposes (e.g., refinance or second home mortgages). Application rates are calculated as the number of applications divided by total MSA population. Denial rates are calculated as the number of applications denied divided by the total number of applications.

Lower originations to first-time buyers have largely been driven by a decrease in loan application rates, rather than an increase in rejection rates. The decrease in application rates is persistent, and larger in high-price MSAs, where application rates are 75% lower in 2017 than in 2005, compared to 40% lower in low-price MSAs. It is quantitatively important, of the same order of magnitude and more persistent that the increase in foreclosure rates during the same period. Acceptance rates only fell by 10% in 2006-2007.

Figure A.8: Mortgage application rate, rejection rate, foreclosure rate



Notes: Left panel: purchase mortgage application rates in low- (blue) and high-price MSAs (red), calculated as the ratio of the number of mortgage applications to buying-age population. Middle: purchase mortgage acceptance rates, calculated as the ratio of the number of mortgage applications accepted to the number of applications. Right: foreclosure rates. Black line depicts the economy average. Population-weighted averages. Gray bands indicate NBER recessions. Source: Fannie Mae, Freddie Mac, RealtyTrac, ACS, Zillow.

B Model Appendix

B.1 Environment

Pension schedule. The pension schedule replicates key features of the U.S. pension system by relating last period income to average income over the life-cycle to compute retirement benefits (Guvenen and Smith (2014)). Denote economywide average lifetime labor income as $\overline{Y}$, and household i's relative lifetime income as $\tilde{Y}_{i,R} = \widehat{Y}_{i,R}/\overline{Y}$, where $\widehat{Y}_{i,R}$ is the predicted individual lifetime income implied by a linear regression of i's lifetime income on its income at retirement age. Using income retirement to define pension benefits allows to save a state variable in the dynamic programming problem. Retirement income is equal to:

$$Y_{i,R} = \overline{Y} \times \begin{cases} 0.9\tilde{Y}_{i,R} & \text{if } \tilde{Y}_{i,R} \leq 0.3 \\ 0.27 + 0.32(\tilde{Y}_{i,R} - 0.3)\tilde{Y}_{i,R} & \text{if } 0.3 < \tilde{Y}_{i,R} \leq 2 \\ 0.81 + 0.15(\tilde{Y}_{i,R} - 2)\tilde{Y}_{i,R} & \text{if } 2 < \tilde{Y}_{i,R} \leq 4.1 \\ 1.13 & \text{if } 4.1 \leq \tilde{Y}_{i,R} \end{cases} \tag{21}$$

Student debt schedule. Average student debt levels by productivity and age groups are chosen to match their values by income percentiles in the 2016 Survey of Consumer Finances and by age in the 2020 Federal Student Loan Portfolio of the U.S. Department of Education.

Table B.1: Student debt by income percentiles

Income percentile	P0-P25	P25-P50	P50-P75	P75-P90	P90-P100
Average debt (dollars)	26,000	34,200	34,700	41,200	46,070

Source: Survey of Consumer Finances, 2016.

Table B.2: Student debt by age group

Age group	21-24	25-34	35-49
Average debt (dollars)	14,800	33,800	42,300

Source: U.S. Department of Education, 2020.

B.2 Home Owner Problem

Denote the date t value function of an owner starting the period in region L, as $V^{oL}(a, b_t, y_t)$. They have the options to pay down their mortgages, sell and move within the same location or between locations, rent, and default:

$$V_t^{oL}(a, b_t, y_t) = \max\left\{V_t^{oL,oL}, V_t^{oL,o\widetilde{L}}, V_t^{oL,oH}, V_t^{oL,rL}, V_t^{oL,rH}, V^{oL,d}\right\} \tag{22}$$

Denote the resulting policy function for the discrete choice problem as $d_t^{oL} \in \left\{oL, o\widetilde{L}, oH, rL, rH, d\right\}$.

Inactive owner. The value of staying a home owner in region L is given by the Bellman equation with fixed housing services $\overline{h}$,

$$V_t^{oL,oL}(a, b_t, y_t) = \max_{c_t, b_{t+1}} \frac{u\left(c_t, \overline{h}\right)^{1-\gamma}}{1-\gamma} + \Xi_L^o + \beta p_a \mathbb{E}_t\left[V_{t+1}^{oL}(a+1, b_{t+1}, y_{t+1})\right], \tag{23}$$

subject to a budget constraint including a proportional maintenance cost $\delta P_{L,t}\overline{h}$,

$$c_t + b_{t+1} + \delta P_{L,t}\overline{h} = y_t - T\left(y_t\right) + (1+\tilde{r})b_t, \tag{24}$$

and the loan amortization constraint described earlier,

$$b_{t+1} \geq \min\left[\tilde{\theta} b_t, 0\right]. \tag{25}$$

If the household has mortgage debt, the interest rate is $\tilde{r} = r^b$, otherwise the interest rate on risk-free assets is $\tilde{r} = r$. Accidental bequests left with probability $1 - p_a$ include housing wealth in the same region $(1+r^b)b_{t+1} + P_{L,t}\overline{h}$.

Mover within location buying. Owners moving within region L sell and buy another house, and enjoy higher total benefits from owning $\widetilde{\Xi_L}^o > \Xi_L^o$:

$$V_t^{oL,o\widetilde{L}}(a, b_t, y_t) = \max_{c_t, b_{t+1}} \frac{u\left(c_t, \overline{h}\right)^{1-\gamma}}{1-\gamma} + \widetilde{\Xi_L}^o + \beta p_a \mathbb{E}_t\left[V_{t+1}^{oH}(a+1, b_{t+1}, y_{t+1})\right] \tag{26}$$

The new house is purchased with a mix of housing equity, savings in risk-free bonds (if no debt), and a new mortgage b_{t+1}, subject to the same origination fees and borrowing constraints as a renter. In addition, there are sales transaction costs f_s and maintenance costs $\delta P_{t,L}\overline{h}$ on the previous house sold in region L,

$$\begin{aligned} &c_t + F_m + P_{L,t}\overline{h}(1+f_m) + b_{t+1} = y_t - T\left(y_t\right) + (1+\tilde{r})b_t + \left(1 - f_s - \delta\right) P_{L,t}\overline{h}, \\ &b_{t+1} \geq -\theta_{LTV,t} P_{H,t}\overline{h} \quad \text{and} \quad b_{t+1} \geq -\frac{\theta_{PTI,t}}{(1+r^b-\tilde{\theta})} y_t. \end{aligned} \tag{27}$$

Mover between locations buying. When moving to the other region H, an owner incurs the moving cost $m(1+\varphi)$. When selling its house and purchasing a house in the other region H, it receives

$$V_t^{oL,oH}(a,b_t,y_t) = \max_{c_t,b_{t+1}} \frac{u\left(c_t,\overline{h}\right)^{1-\gamma}}{1-\gamma} + \Xi_L^o - m(1+\varphi) + \beta p_a \mathbb{E}_t\left[V_{t+1}^{oH}(a+1,b_{t+1},y_{t+1})\right] \tag{28}$$

The new house is purchased with a mix of housing equity, savings in risk-free bonds (if it holds no debt), and a new mortgage b_{t+1}, subject to the same origination fees and borrowing constraints as a renter. In addition, there are sales transaction costs f_s and maintenance costs $\delta P_{t,L}\overline{h}$ on the house sold in region L,

$$\begin{aligned} &c_t + F_m + P_{H,t}\overline{h}(1+f_m) + b_{t+1} = y_t - T\left(y_t\right) + (1+\tilde{r})b_t + \left(1-f_s-\delta\right)P_{L,t}\overline{h}, \\ &b_{t+1} \geq -\theta_{LTV,t}P_{H,t}\overline{h} \quad \text{and} \quad b_{t+1} \geq -\tfrac{\theta_{PTI,t}}{\left(1+r^b-\tilde{\theta}\right)}y_t. \end{aligned} \tag{29}$$

Home seller renting. An owner selling its house and becoming a renter in the same region incurs the proportional selling transaction cost f_s and the maintenance cost $\delta P_{L,t}\overline{h}$:

$$V_t^{oL,rL}(a,b_t,y_t) = \max_{c_t,b_{t+1}} \frac{u\left(c_t,\overline{h}\right)^{1-\gamma}}{1-\gamma} + \Xi_L^o + \beta p_a \mathbb{E}_t\left[V_{t+1}^{rL}(a+1,b_{t+1},y_{t+1})\right], \tag{30}$$

subject to the budget and no-borrowing constraints

$$\begin{aligned} &c_t + b_{t+1} = y_t - T\left(y_t\right) + (1+\tilde{r})b_t + \left(1-f_s-\delta\right)P_{t,L}\overline{h}, \\ &b_{t+1} \geq 0 \end{aligned} \tag{31}$$

Because the owner sells its house during the period, accidental bequests left with probability $1-p_a$ only include financial wealth $(1+r)b_{t+1}$.

Mobile home seller renting. The value of selling its house to move and become a renter in the other region H is identical the previous one, with the addition of the moving cost $m(1+\varphi)$.

Defaulting owner. A defaulter does not repay its mortgage, incurs a utility penalty d and becomes a renter in the same region in the next period:

$$V_t^{oL,d}(a,b_t,y_t) = \max_{c_t,b_{t+1}} \frac{u\left(c_t,\overline{h}\right)^{1-\gamma}}{1-\gamma} + \Xi_L^o - d + \beta p_a \mathbb{E}_t\left[V_{t+1}^{rL}(a+1,b_{t+1},y_{t+1})\right], \tag{32}$$

subject to the budget and no-borrowing constraints

$$\begin{aligned} &c_t + b_{t+1} = y_t - T\left(y_t\right), \\ &b_{t+1} \geq 0 \end{aligned} \tag{33}$$

Because the owner loses its house during the period, accidental bequests left with probability $1-p_a$ only include financial wealth $(1+r)b_{t+1}$.

B.3 Welfare

Let $V(s, S_b)$ be the value function of a household with individual state $s = (e, b, t, l, a)$ (endowment, net asset position, tenure status, location, age) and when the aggregate state is S_b, the benchmark economy *without* policy. Let $V\left(s, S_p\right)$ be the value function of the same household type when the aggregate state is S_p, the benchmark economy *with* policy.

Now define the *one-period consumption equivalent variation* (CEV) $\omega(s)$ for this household as the one-time increase in current consumption in the benchmark economy S_b that makes the household indifferent between living in S_b and living in S_p, the economy with policy. $\omega(s)$ is defined by the following equality as an increase in consumption of non-durable goods and housing services.

$$V\left(s, S_p\right) = \frac{u((1+\omega(s))c(s,S_b),(1+\omega(s))h(s,S_b))^{1-\gamma}}{1-\gamma} + \Xi(s) + \beta\mathbb{E}\left[V\left(s', S_p\right)|s\right] \tag{34}$$

Solving for $\omega(s)$ using the definition of $V(s, S_b)$ gives:

$$\omega(s) = \left(\frac{V(s,S_p)-V(s,S_b)+u_b}{u_b}\right)^{\frac{1}{1-\gamma}} - 1 \tag{35}$$

where $u_b = \frac{u(c(s,S_b),h(s,S_b))^{1-\gamma}}{1-\gamma}$.

To compute it in steady state and over transitions, I keep track of value functions $V(., S_b), V(., S_p)$ and policy functions $c(., S_b), h(., S_b)$ (for owners, we simply have $h(., S_b) = \overline{h}$), and use the definition of u.

I use this measure of welfare changes rather than permanent CEV because the latter do not have comparable interpretations for young and old households in an OLG model, given that young households expect to live for more periods. Alternatively, computing permanent CEV would require to use a numerical nonlinear solver for ω, since the homogeneity of the CRRA function cannot be used with additive amenity benefits χ to compute ω as a transformation of the ratio of value functions in S_b and S_p, as is usually done. This is computationally feasible for steady state CEV, but untractable for the transitions.

Then, average CEVs for a given household type can be computed using the marginal distributions of $\lambda(s)$.

B.4 Numerical Solution

Steady state Fix the parameters $\overline{h}, \delta$ and ρ_j, ho_j^{sqft}, which are directly measured in the regional panel of Section 2. In steady state, the model is solved in three steps.

First, fix P_L^*, P_H^*, to exactly match the regional distribution of house prices in the data.

Second, vary rents R_L^*, R_H^* to target home ownership rates in the data, $ho_L^{hh}(\mathbf{P}^*, \mathbf{R}^*)$ and $ho_H^{hh}(\mathbf{P}^*, \mathbf{R}^*)$. Home ownership rates in the model are obtained by solving the household's problem with a global nonlinear solution method, computing the stationary distribution of households, and aggregating it across regions and tenure groups. For given local prices, home ownership rate are increasing in local rents. If migration rates are low, R_L and R_H can be separately chosen in regions L and H, otherwise they must be jointly solved for. Choose the amenity benefits ξ_j^r to match average rent levels, and benefits from owning ξ_j^o to match home ownership rates.

Third, R_L^*, R_H^* generate regional demands for rentals, $\int_{\Omega^{rj}(\mathbf{P}^*,\mathbf{R}^*)} h_j(\mathbf{P}^*, \mathbf{R}^*)\, d\lambda$. Given those, the market-clearing conditions can be inverted to solve for $\overline{I}_j$ in closed form:

$$\overline{I}_j = \frac{\delta \overline{h} ho_j^{hh} pop_j}{ho_j^{sqft} P_j^{\rho_j}}. \tag{36}$$

Given the new $\overline{I}_j$, go back to the first step and iterate until convergence.

Transition dynamics Households' value functions are subject to i.i.d. idiosyncratic taste shocks following a type I Extreme Value distribution, which cancel out in the aggregate. This is a classical assumption in the dynamic demand literature. Given value functions, it allows to compute closed forms for transition probabilities between discrete choices and for the expectations of continuation value functions, which are smooth functions of prices. This feature is key to solve for the dynamics of the regional distribution of prices and rents in response to unanticipated shocks, without generating jumps in marker-clearing conditions.

The value of each option of the discrete choice problem is subject to an idiosyncratic logit error taste shock. For instance, the value of renting in region L is equal to The value of being a region L renter is:

$$\tilde{V}^{rL}(a, b_t, y_t) = V^{rL}(a, b_t, y_t) + \tilde{\varepsilon}^{rL}(a, b_t, y_t) \tag{37}$$

where $\tilde{\varepsilon}$ follows a type I extreme value (Gumbel) distribution with location parameter 0 and scale 1.

(i) It smooths out the computation of the expectation of the continuation value function, which is the envelope value of the options available next period, given the household's current state (not the same options are available for owners and renters in the various regions). It smooths out policy and value functions, and makes them more monotonic with respect to prices when solving for them numerically. This allows to reduce the size of the state space and make the problem tractable. Without it, an extremely high number of grid points would be needed to avoid jumps in value functions over the transition. The expectation of the envelope value has a closed form, for instance for region L renters:

$$\mathbb{E}_{L,t}\left[V^r\right] = \mathbb{E}_{L,t}\left[\int \tilde{V}^r \mathbf{dF}\left(\tilde{\varepsilon}\right)\right] = \mathbb{E}_{L,t}\left[\log\left(\sum_{j=1}^{4} e^{\tilde{V}^{r,j}}\right)\right] \tag{38}$$

where $\tilde{V}^r = \max\left\{\tilde{V}^{r,j}\right\}_{j=1,\ldots 4}$. The outside expectation $\mathbb{E}_{L,t}\left[.\right]$ is taken over the distribution of idiosyncratic income shocks (identical across regions in the benchmark model). V^r now denotes the "ex-ante value function", after integrating over the vector of idiosyncratic errors (there is one realization for each individual state and option).

(ii) One obtains closed-form expressions for the probabilities of choosing the various options. Those are useful when computing the transition matrix for the law of motion of the cross-sectional distribution over location $\times$ tenure $\times$ income $\times$ cash-in-hand, which I approximate with a histogram. The probabilities have the multinomial logit closed-form, for instance:

$$\Pr\left(\tilde{V}^{r,j} = \tilde{V}^r\right) = \frac{e^{\tilde{V}^{r,j}}}{\sum_{j'=1}^{4} e^{\tilde{V}^{r,j'}}} \tag{39}$$

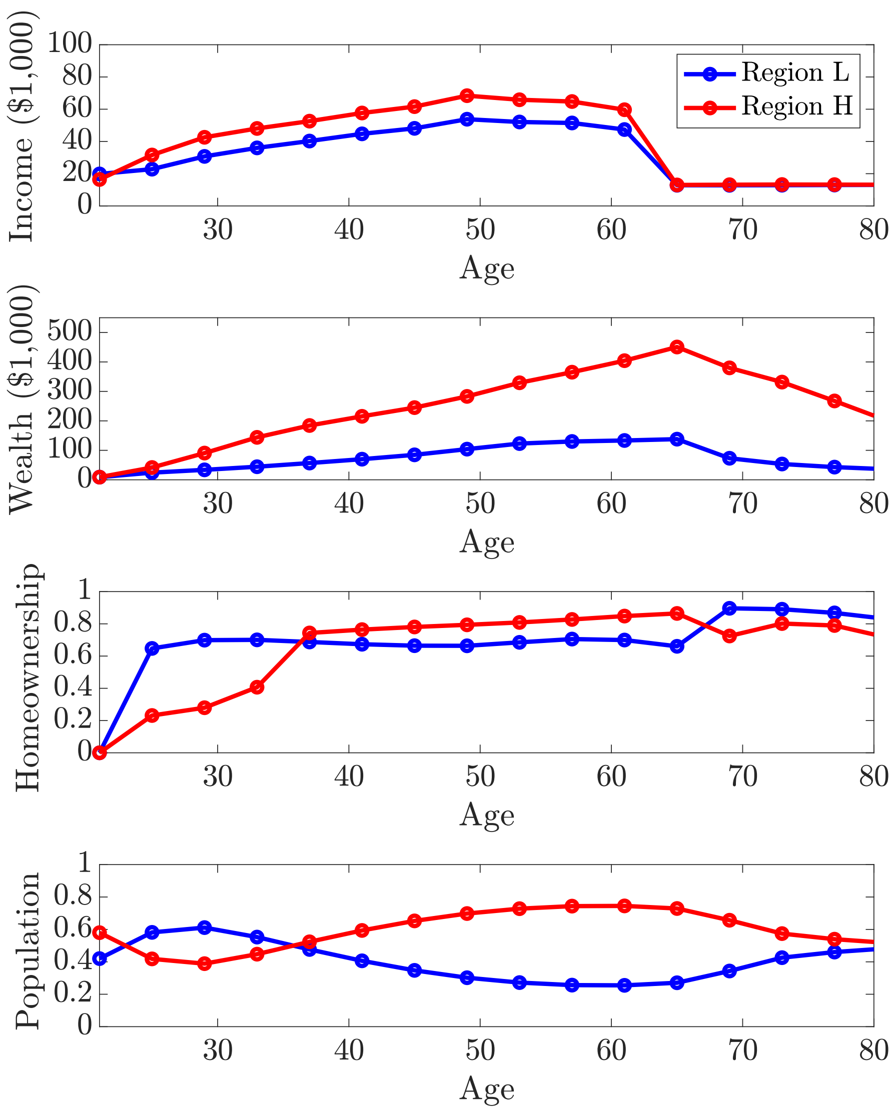
(iii) One can compute the dollar cost of policies in closed-form.

C Calibration

C.1 Life-Cycle

Figure C.1 displays the life-cycle profiles of income, wealth, home ownership, and population shares in each MSA. Average household wealth is higher in expensive MSAs due to higher savings (before 40 y.o.) and then higher housing wealth (after 40 y.o.). Households save more than in cheap MSAs because they have higher income and face higher down payment requirements when buying.

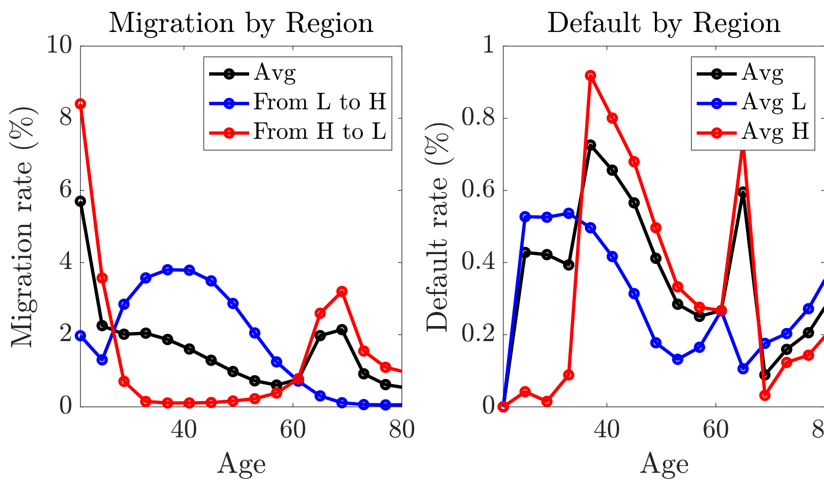
Figure C.1: Life-cycle profiles of income, wealth, home ownership, and population shares



Notes: Household life-cycle profiles from 21 to 80 years old in low-price (blue) and high-price MSAs (red). Upper panel: pretax annual labor income (including pensions). Upper middle panel: wealth (including housing). Lower middle panel: home ownership rate. Lower panel: regional population shares. Income and wealth in thousands of 2005 dollars.

Figure C.2 displays the life-cycle profiles of migration and default rates in each MSA. Young households migrate more as in the data.[26], and migrations reflect financial constraints. A large fraction of households below 30 y.o. move from expensive to cheap MSAs when they have low income and wealth. A lower fraction of households around 40 y.o. move from cheap to expensive MSAs when they can afford the better income process and amenities. A lower fraction of retirees after 60 y.o. move from expensive to cheap MSAs when their income falls. Households' default rates are higher in expensive MSAs as in the data (Figure A.8). They peak around 40 y.o. and around retirement.

Figure C.2: Life-cycle profiles of migrations and defaults by region



Notes: Household life-cycle profiles of steady state migration (left panel) and default rates (right panel) from 21 to 80 years old in low-price (blue) and high-price MSAs (red).

[26] 16-24 year old respondents are 40% more likely to move than 25-64 year olds (with average mobility rates of 2.75% versus 1.99%), and 280% more likely to move than 65+ year olds (0.72%). Source: Table 17 of the ACS in 2006-07 for Metropolitan Mobility of Persons 16 Years and Over, by Sex, Age, Race and Hispanic Origin, and Labor Force Status.

C.2 Moving Costs

Table C.1: Average moving costs for different household types and models

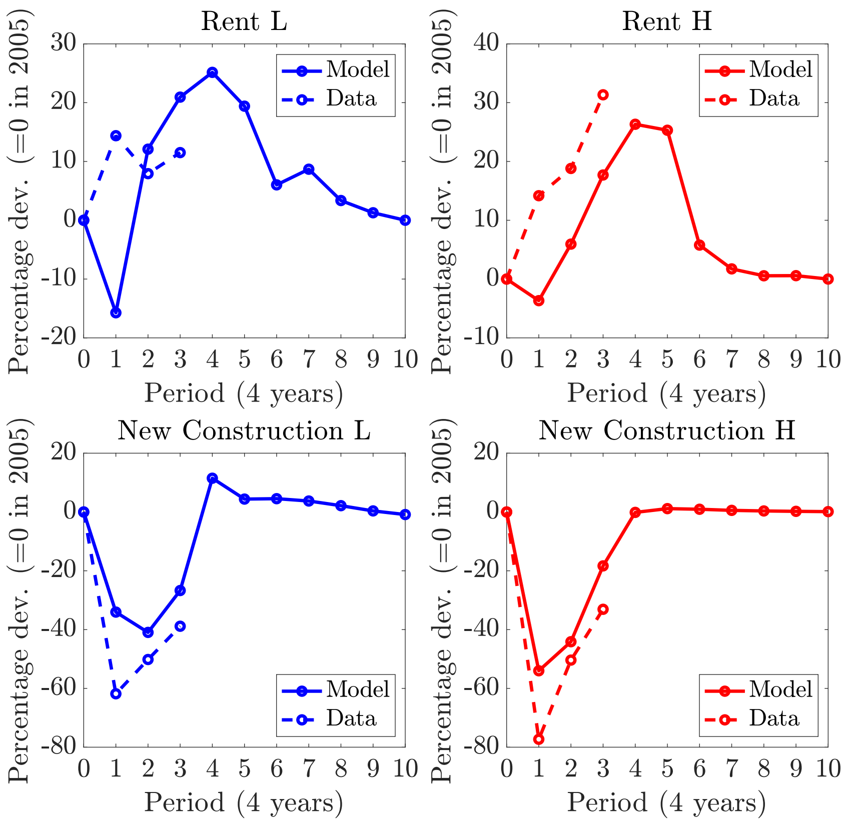
	Age		Wealth		Income		Renter		Owner		All (median)
	Young	Old	Bot 50	Top 50	Bot 50	Top 50	L	H	L	H	
Bench.	44,359	76,000	30,290	92,085	47,500	73,001	12,330	16,080	54,965	116,176	61,803 (17,007)
$P_H = P_L$	39,855	59,919	32,947	70,101	38,578	60,030	10,559	17,749	40,235	64,917	50,918 (14,000)
$R_H = R_L$	45,620	78,528	30,022	91,003	49,273	75,216	13,009	14,489	56,861	115,355	63,764 (17,545)
$Y_H = Y_L$	41,296	68,450	28,684	82,305	42,294	66,619	13,180	14,310	58,726	113,757	56,268 (15,485)

Notes: Average moving costs in 2005 dollars for different household types (columns): 25-44 vs. 45+ y.o., bottom vs. top 50% of wealth distribution, bottom vs. top 50% of income distribution, renter in low-price vs. high-price MSAs, owner in low-price vs. high-price MSAs, all. In benchmark and in models where differences between regions are turned off individually (rows): house prices, rents, average income set equal to their values in low-price MSAs. Median moving costs in parentheses for all households. Moving costs are measured as the dollar values of a one-period reduction in a bundle of nondurable consumption and housing services which is equivalent to the impact of the utility moving cost m on households' value functions. One model period is four years.

D Results

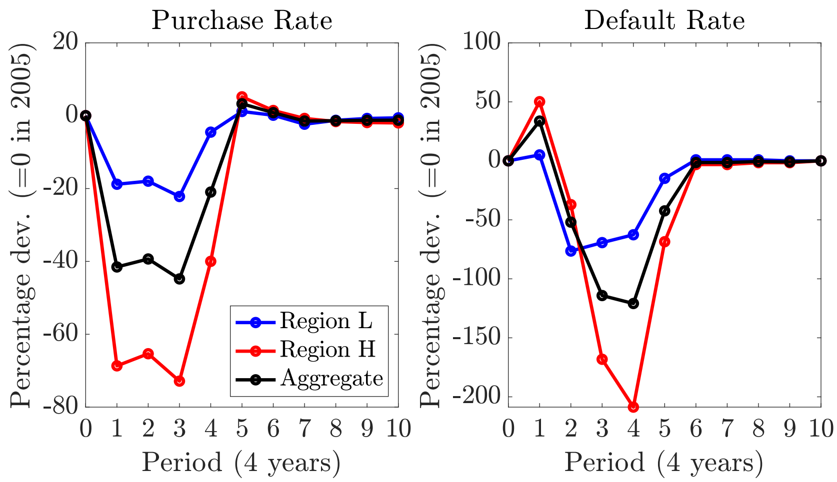
D.1 Dynamic Responses

Figure D.1: Rent and housing supply responses



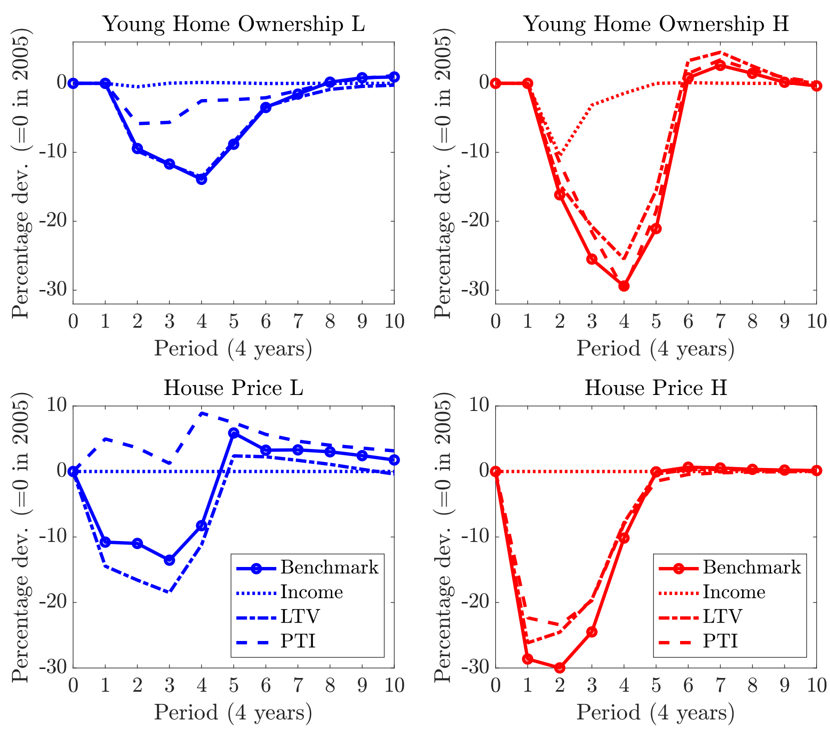
Notes: Changes in rents (upper panels) and in new construction (lower panels). Low-price MSAs in blue, high-price MSAs in red, economy average in black. Model: solid lines. Data: dashed line. In the data, rents are detrended to make them stationary as in the model (without detrending, raw rents always increase except in the first year after the recession). New construction is measured as new privately owned housing units authorized in the Building Permits Survey (U.S. Census), population-weighted average by MSA group. Changes in percentage terms relative to 2005. Sources: Zillow, U.S. Census.

Figure D.2: Responses of purchase and default rates



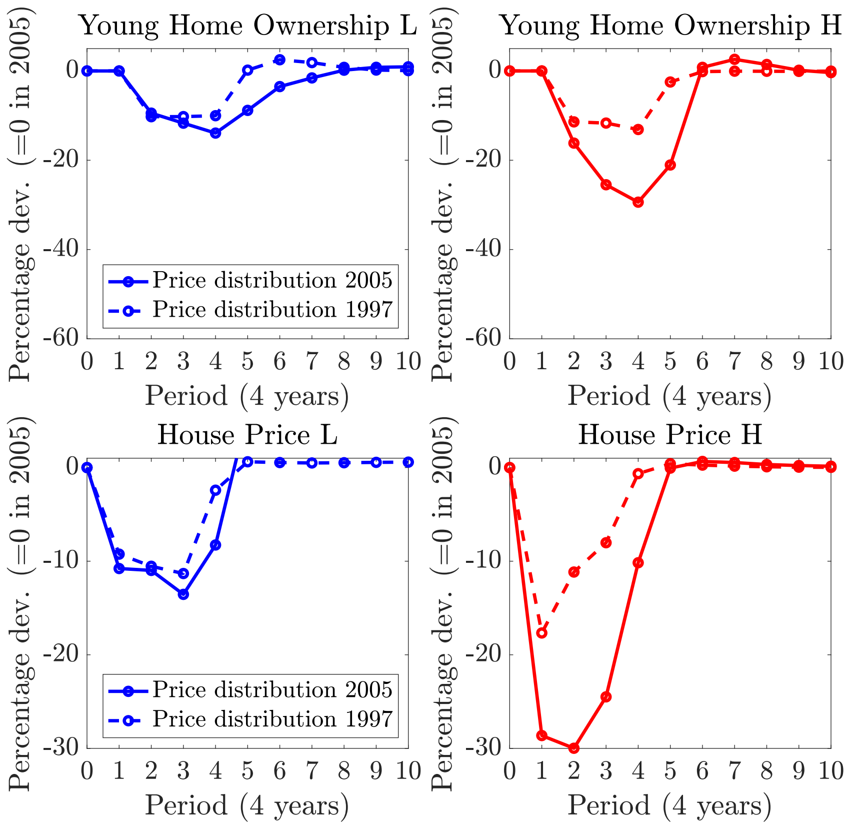
Notes: Left panel: renters' purchase rates are measured as conditional probabilities to buy for each region group. Right panel: default rates. Low-price MSAs in blue, high-price MSAs in red, economy average in black. Changes in percentage terms relative to 2005.

Figure D.3: Shock contributions to home ownership and house price responses



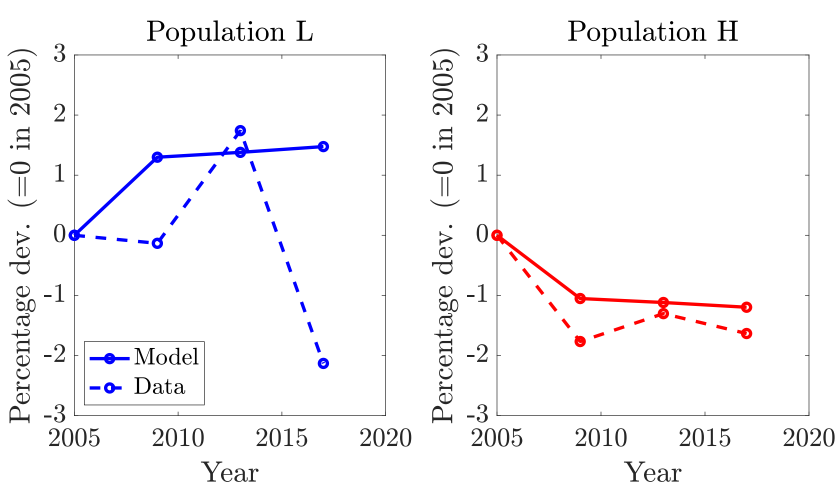
Notes: Changes in young (upper panels), old home ownership (middle), and house prices (lower) in low-price MSAs (blue) and high-price MSAs (red). Solid lines with dots: benchmark. Dotted: negative income shocks. Dotted-dashed: LTV tightening. Dashed: PTI tightening. Changes in percentage terms relative to 2005.

Figure D.4: Home ownership and house price responses with more equal price distribution



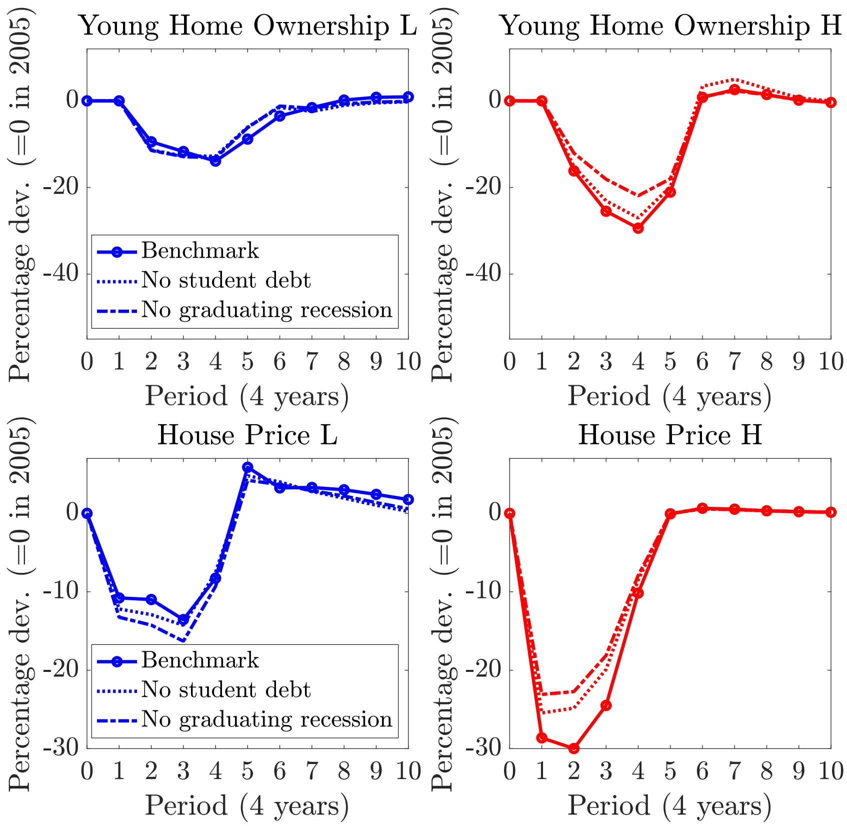
Notes: On upper panels, responses of 25-44 year old home ownership under the 1997 house price distribution (dashed lines) and the 2007 distribution (benchmark, solid lines). On lower panel, house price responses. Blue: low-price MSAs. Red: high-price MSAs. Changes in percentage terms relative to 2005.

Figure D.5: Population share responses



Notes: Model changes: solid lines. Data changes (dashed lines) are calculated as deviations from their 2005 values, from which the aggregate trend (also in deviation from 2005) is subtracted to control for the increase in total population. Thus the resulting series are normalized to 0 in 2005. Low-price MSAs in blue, high-price MSAs in red. Source: ACS.

Figure D.6: Effect of cohort differences on home ownership and house price responses



Notes: On upper panels, responses of young home ownership in benchmark (solid lines), benchmark without student debt (dotted lines), benchmark without scarring effect of recession on earnings (dashed lines). On lower panel, house price responses. Blue: low-price MSAs. Red: high-price MSAs. Changes in percentage terms relative to 2005.

D.2 Long run

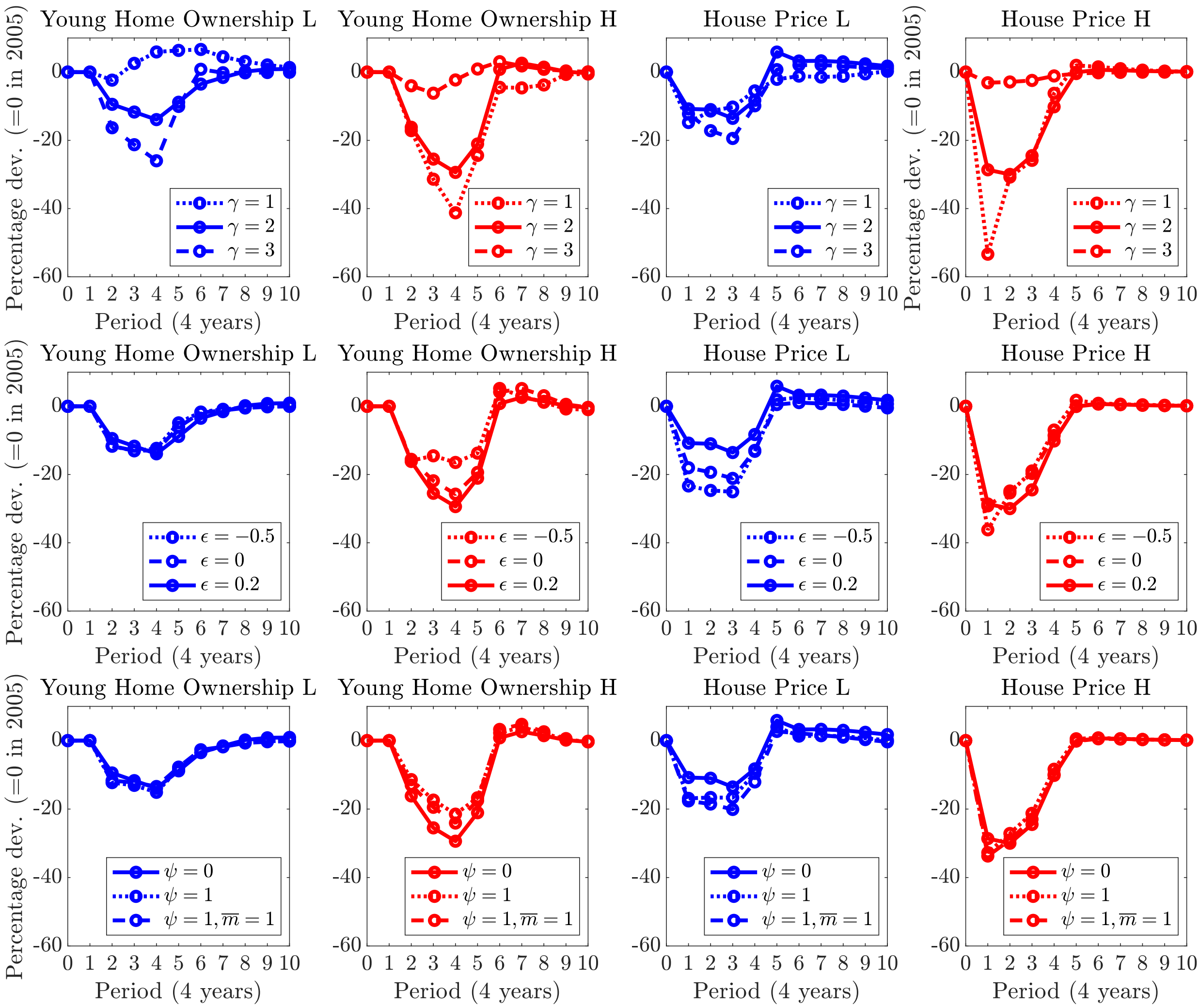
Table D.1: Long-run housing market impact of differences between cohorts

Variable	Benchmark	No student debt	No graduating in recession	No mobility
P_L	111,500	112,179	113,574	113,574
R_L ($)	780	714	643	597
ho_L^{young}	0.61	0.601	0.64	0.57
ho_L^{all}	0.67	0.66	0.68	0.69
P_H	267,600	263,831	270,566	243,248
R_H	1,115	792	733	1,056
ho_H^{young}	0.41	0.42	0.48	0.40
ho_H^{all}	0.66	0.66	0.68	0.56

Notes: In the benchmark model Millennial households have student debt, the scarring effect of the recession on their earnings, and households can migrate between regions subject to moving costs. Comparative statics analysis where columns report the steady state values of the same variables when turning off cohort differences and mobility ($m = \infty$). Prices and rents are in 2005 dollars.

E Sensitivity Analysis

Figure E.1: Home ownership and house price responses under alternative parameters



Notes: The baseline model has a relative risk aversion coefficient $\gamma = 2$, an intra-temporal elasticity of substitution between consumption and housing $1/(1-\epsilon)$ with $\epsilon = 0.2$, and no warm-glow bequest motive with $\psi = 0$ (solid lines). The dotted and solid lines correspond to alternative models where these parameters are changed individually. Changes in young home ownership and house prices are reported. Low-price MSAs in blue, high-price MSAs in red.