

The Missing Homebuyers: Regional Heterogeneity and Credit Contractions *

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Abstract

This paper documents an unprecedented decrease in young homeownership since the Great Recession driven by regions with high house prices. 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 an aggregate credit contraction with heterogeneous local impacts rather than by local shocks. Lower millennial income and wealth amplify its effect. The impact of subsidies to first-time buyers is dampened, because they fail to stimulate regions that suffer from larger busts. Place-based subsidies achieve larger gains. (*JEL* E21, G11, G21, G51, J11, R30)

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Housing busts, like many recessions, affect demographic groups differently. In the period following the Great Recession, young homeownership collapsed, excluding many millennial buyers from the housing market. This decrease in homeownership, equivalent to 7.6 million missing purchases in the United States, has attracted widespread attention. Not only are first-time buyers a powerful engine of housing markets, accounting for 50% of new purchase mortgages every year, but their absence also calls into question the secular importance of real estate for households' balance sheets.¹

This paper investigates missing first-time homebuyers. I document an unprecedented decrease in young homeownership driven by regions with high house prices. I build an equilibrium spatial macro-finance model with overlapping generations of mobile households to explain these facts and analyze their consequences for housing markets. The key mechanism of the model relies on *regionally binding credit constraints*: payment-to-income (PTI) requirements bind tighter relative to desired housing in expensive regions, as buyers' income is not high enough relative to local house prices. It makes these households especially sensitive to changes in credit standards, leading them to postponing and sometimes never buying when credit contracts. As in the data, the regional distribution of house prices and rents in the model responds endogenously to local and aggregate shocks to income and credit. This novel setting allows to decompose the effects of shocks (period effect) and of household characteristics (age and cohort effects) using counterfactual experiments, while accounting for price and migration responses across regions. It addresses the identification challenge due to the endogeneity of house prices, credit constraints, and homeownership and delivers dynamic welfare estimates of mortgage policies that are robust to the Lucas critique.

My results highlight the importance of regional heterogeneity for credit contractions and the design of stabilization policies. House price differences between regions amplify the negative impact of tight credit standards on young homeownership, resulting in larger busts in expensive regions. Therefore, the heterogeneous impacts of aggregate credit shocks contribute more to the dynamics of local housing markets than local shocks themselves. In turn, subsidies to first-time buyers that are identical across regions have

¹Concerns range from central banks to government agencies, think tanks, and banks. See, for example, [Brainard \(2015\)](#). Housing being the largest asset on the average households' balance sheets and the main way in which most households accumulate wealth ([Goetzmann, Spaenjers, and Van Nieuwerburgh 2021](#)) has motivated numerous policies to stimulate homeownership ([Goodman and Mayer 2018](#)). In 2005, the average homeownership rate of U.S. households was 68.8%. In 2015, it was 62.7% for 124.6 million households, that is, $(0.688 - 0.627) \times 124.6\text{m} = 7.6$ million missing purchases. Relative to 1995, 2.9 million purchases were missing. *Source*: American Housing Survey.

little stabilizing effect, as they stimulate expensive regions which suffer larger busts by less. Place-based subsidies are more effective without being more expensive.

The model is motivated by new facts on young buyers based on historical time series and a panel of U.S. metropolitan areas in the post-Great Recession period. First, young homeownership fell deeply and persistently below its long-run average in the 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 homeownership. Second, the decrease in young homeownership 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 homeownership. Young homeownership fell by 25% in the top 10% of the house price distribution but by only 10% in the bottom 10%. Entry into homeownership decreased, with first-time mortgage originations falling by 55% in expensive versus 25% in cheap MSAs. Households located in expensive MSAs delayed buying by 6 more years relative to those in cheap MSAs. Third, and perhaps surprisingly, a larger credit contraction in expensive MSAs did not cause these differences. Credit standards contracted uniformly nationwide, with loan-to-value (LTV), payment-to-income (PTI) ratios, and credit scores displaying strong comovements across regions.

The model consists of regions with 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. Markets are incomplete, and cohorts have different income and wealth that affect their credit constraints. Millennials' income is lower because of the scarring effect of the recession, and their wealth is lower because of 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 choose to repay or default on their mortgages subject to a finite cost that captures unmodeled credit standards. The economy is subject to unanticipated local and aggregate shocks to income and credit standards. This setting captures features from which macro-finance models typically abstract: (a) the distribution of house prices and rents is endogenous; (b) households are mobile across regions; and (c) overlapping cohorts differ.² I map the steady state and dynamic responses in the model to the panel of MSAs and calibrate regional differences and mobility using indirect inference. I then use

²This paper is the first to relax the assumptions of exogenous prices and no mobility in such models (e.g., [Hurst et al. 2016](#); [Guren et al. 2020](#)).

several counterfactual experiments to identify the causes and consequences of missing 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. Local income shocks have little effect. The aggregate credit contraction explains the 10% decrease in young homeownership in cheap MSAs and the 20% decrease in expensive MSAs, without targeting them. As in the data, the decrease in homeownership is driven by young buyers and concentrated in expensive MSAs. In this context, changes in millennial preferences toward owning are not needed to explain their low homeownership. Tight credit 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 the transmission of these shocks. Credit contractions have a large impact because most first-time buyers are constrained by PTI and/or LTV 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 constraints: they have more PTI-constrained buyers than cheap MSAs, and the decrease in PTI limits itself is large. This refines popular narratives that focus on LTV constraints to explain low millennial homeownership.

What are the determinants of this mechanism? First, structural differences between regions generate differences in house price levels that lead credit constraints to bind more in expensive MSAs. I analyze them using counterfactual transitions that turn off regional parameters one by one. A better income process and amenities in expensive MSAs are key to generating higher house prices and hence more binding constraints and a larger bust. Without them, young homeownership would only fall by a sixth and half of its decrease in the baseline model. Housing supply restrictions have a lower effect. Together, these regional parameters provide a micro-foundation for credit constraint variations in the population.

Second, frictions to spatial arbitrage explain that despite higher income, expensive MSAs still have higher price-to-income ratios, thereby making constraints more binding. Moving costs prevent the perfect sorting of low-income buyers into cheap MSAs and of rich buyers into expensive MSAs. The option to rent allows households to enjoy better

³I 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.

amenities without owning. It results in the income of potential buyers being too low relative to house prices. Importantly, the response of housing markets depends on the extent to which buyers can move between MSAs, which generates a “migration accelerator” that is absent from single-region models. In spatial equilibrium, homeownership 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 homeownership and prices. Their impact persists in the long run, mostly because of income scarring in expensive MSAs. Interestingly, student debt increases homeownership in cheap MSAs because it leads some buyers to relocate from expensive MSAs. It also generates a rental boom in expensive MSAs as households who stay rent larger units. These results disentangle age and cohort from period effects.

Finally, I evaluate whether subsidies to first-time buyers relax regionally binding constraints during a recession. I study the First-Time Homebuyer Credit (FTHC), a tax incentive of \$8,000 given to most 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 homeownership and generates a sizable increase in aggregate welfare equivalent to 2.7% 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 that 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 homeownership. 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 being higher conditional on buying in expensive MSAs, the FTHC induces fewer renters to buy there than in cheap MSAs. Therefore, the total welfare impact is limited too. Because of 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 dollar cost of the policy. This suggests that housing stabilization policies should target expensive MSAs because they are more volatile in downturns.

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 and welfare effects.⁴

My work contributes to the literature on regional heterogeneity and financial shocks. I use a spatial macro-finance model to decompose the presumably different impacts of local and aggregate shocks (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 et al. (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 price distribution 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, Ludvigson, and Van Nieuwerburgh (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 regional characteristics. A local market does not need a larger credit shock to have a larger response (Johnson 2020) if it is more sensitive to credit standards in the first place. Landoigt, 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

Existing work has focused on exit from homeownership through foreclosures (Mian and Sufi 2009; Adelino, Schoar, and Severino 2016), but less is known about the entry of young buyers. By analyzing entry, my paper complements rich models focusing on mortgage default (Campbell and Cocco 2015; Guren, Krishnamurthy, and McQuade 2021). It focuses on the post-Great Recession period as in Guren and McQuade (2020) and Piskorski and Seru (2021). I use the model to study the welfare effect of first-time buyer sub-

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

⁵Favilukis, Mabile, and Van Nieuwerburgh (2022) study related housing affordability policies, but they focus on the long-run steady state of a single MSA.

sities (Berger, Turner, and Zwick 2019), an empirical challenge. My results on the place-based FTHC contribute to the nascent literature on place-based mortgage policy (Han et al. 2021).

Finally, I add to the literature on young buyers, whose importance was first emphasized by Mankiw and Weil (1989) for baby boomers and then by Ortalo-Magné and Rady (2006). I complement growing empirical work (Goodman and Mayer 2018) by estimating the contributions of popular explanations to the decline in millennial homeownership in a structural model. These include borrowing constraints (Acolin et al. 2016), income scarring, and student debt (Bleemer et al. 2021; Isen, Goodman, and Yannelis 2021).⁶

1 Evidence on Missing Young Homebuyers

This section documents stylized facts on young buyers and provides motivating evidence on the role of regional heterogeneity. There is little information about young buyers' access to credit and homeownership. One reason is that the distinction between borrower-level and loan-level data sets does not allow one 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 data sets.

1.1 Data

1.1.1 Description. I assemble a regional panel data set, in which I merge borrower-level and loan-level information on first-time buyers at the MSA level. In the next sections I use this panel to calibrate the steady state and dynamic responses in the model.

The panel tracks first-time mortgages across U.S. metro areas at an annual frequency since the Great Recession, from 2005 to 2017, the longest sample for which data are 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 US\$(2005) 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

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

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 United States. 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. The characteristics of first-time mortgages come from the Single-Family Loan-Level data set of Freddie Mac and the Single-Family Loan Performance data set of Fannie Mae (a total of 26.6 and 35 million loans). I focus on the flow of new loans in the loan origination and acquisition data sets. 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 come from the American Community Survey (ACS) of the U.S. Census Bureau. I use household-level information by MSA on population, age structure, homeownership, 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 are 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).

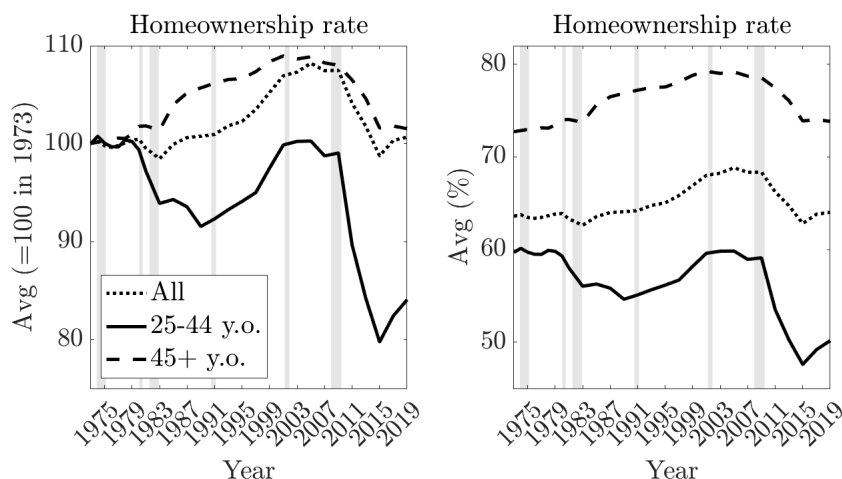
1.1.2 Classifying regions. I classify metro areas by the level of local house prices in 2005, and keep this classification fixed. Cheap regions in the bottom percentiles of the house price distribution are referred to as "Low-price MSA" (blue in figures and tables) and expensive regions in the top percentiles as "High-price MSA" (red). Nationwide 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. In the Internet Appendix, Figure A.1 plots them on a map. Cheap MSAs are concentrated inside the United States

(e.g., Detroit, MI), and expensive MSAs in coastal regions (e.g., San Francisco-Oakland-Fremont, CA). Figure A.2 shows 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 (US\$(2005)).

1.2 Missing homebuyers

1.2.1 Post-Great-Recession period. Figure 1 plots homeownership rates for 25–44 years old and 45+ years old households between 1975 and 2019, going back as far as housing data by age allows. Young homeownership 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 homeownership rate after the boom, a popular narrative among economists. This unprecedented decrease motivates the focus of the paper on this period. Starting with the year in 2005 allows to link the model to the regional panel, for which prior data are not available.

Figure 1: Homeownership by age



Homeownership rate by age group. Left panel: change, values normalized to 100 in 1973. Right panel: level. Population-weighted averages. Gray bands represent NBER recessions. *Source:* AHS.

Relative to 2005, the probability of being a homeowner fell by 20% for 25- to 44-year-old households and by 7% for 45+ year-old households. Figure A.5 decomposes this decrease across 10-year age groups. Homeownership broadly fell across all household

⁷In 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.

types below 65 years old, but the probability of being a homeowner 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 demographic factor associated with the largest decrease in homeownership, which motivates my focus on young buyers. A single sort against other factors (household composition, education, income, race) shows that homeownership only fell between -6.3 and -9.7 pp for other groups, versus -14.7 pp for the 25–34 years old (Table A.3).

1.2.2 Regional heterogeneity. Figure 2 shows large differences between regions in terms of changes in homeownership, mortgage originations, and age of first-time buyers.

Young homeownership. The decrease in young homeownership is concentrated in expensive MSAs. Regions are sorted by percentiles of the house price distribution. There is a strongly increasing relationship between initial price levels, and the subsequent drop in young homeownership. 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 regional divergence in young homeownership rates. There is no such relationship for older households, for which rates fell equally across regions by less than 5% (Figure A.4).

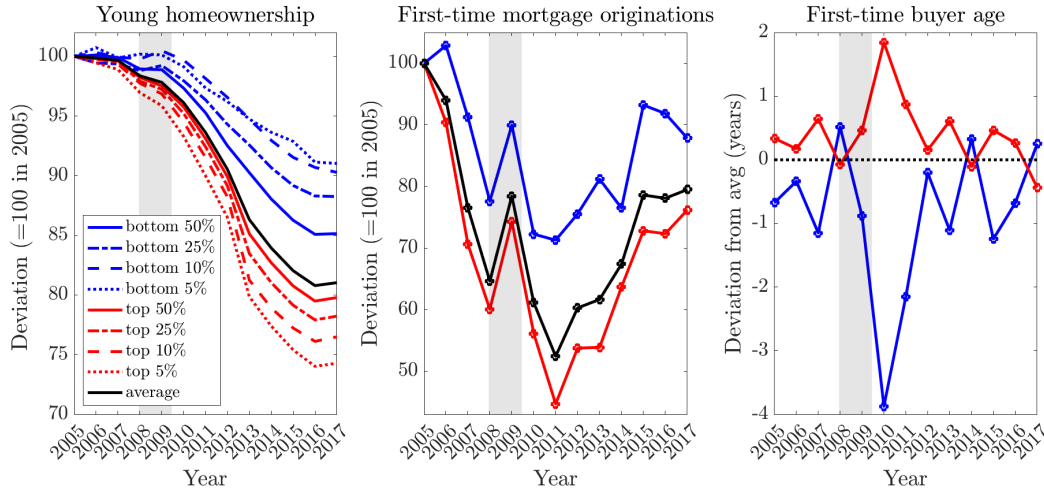
After documenting this relationship, I focus on the simplest partition of metro areas in the panel, between the top 50% and the bottom 50% of the house price distribution. This classification provides a lower bound on these effects, and it is the simplest setting to calibrate the model in the next section.

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 homeownership. Originations temporarily increased in 2008–2009, when the First-Time Homebuyer 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 first-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 ages of first-time buyer between regions reached 6 years in 2010 and then decreased.

⁸Figure A.8 reports the changes in mortgage application and acceptance rates behind this decrease.

Figure 2: Young buyers' access to homeownership by region



Left panel: Changes in 25- to 44-year-old homeownership 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- to 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 resultant plotted series are deviations from the economy average. Population-weighted averages. Values have been normalized to 100 for the year 2005. Gray bands represent NBER recessions. *Sources:* ACS, Zillow, and CCP/Equifax.

1.3 Credit contraction

1.3.1 Credit standards. Credit largely determines access to homeownership for first-time buyers because of their low income and wealth. However, the larger decrease in homeownership in expensive MSAs is not explained by a larger credit tightening in these MSAs. Credit standards tightened identically across regions, as suggested by Figure A.6, which provides evidence for conventional mortgages in Fannie Mae and Freddie Mac data.⁹ First-time buyers' average LTV, PTI ratios, and credit scores at origination comove strongly across regions. In relative terms, the largest and most persistent tightening is for PTI ratios in expensive MSAs (0.38 to 0.31), followed by an increase in credit scores (725 to 765), and a tightening in LTV ratios in cheap MSAs (0.83 to 0.80). These findings are the counterpart of [Hurst et al. \(2016\)](#), who report little regional variation in mortgage rates.

⁹While these data do not cover the universe of mortgage originations, they are the largest readily available source. GSE mortgages represent 30% of first-time buyer loans in 2005. They are the most widely held first-time mortgages before the boom and after the bust (43%). Private-label and FHA loans account for the remaining fractions. The rest of the paper focuses on credit standards for *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 loans.

1.3.2 Regionally binding credit constraints: Simple calculation. The fact that credit constraints bind more in high-house price MSAs can explain why young homeownership fell more there in response to an identical credit tightening across MSAs. I use a simple example to illustrate this point before turning to the quantitative model.

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

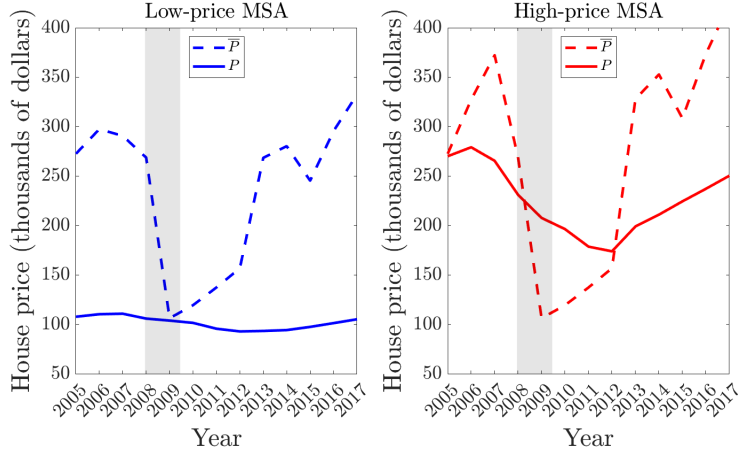
$$\bar{P} = \min \left[\frac{1 - (1 + r^b)^{-n}}{r^b} \theta_{PTI} Y + \text{down}, \frac{\text{down}}{1 - \theta_{LTV}} \right]. \quad (1)$$

Figure 3 plots the maximum affordable price \bar{P} and the actual price P for each group 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 United States. $\{r_t^b\}_t$ 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 United States, 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). $j = L, H$ are cheap and expensive MSAs. Variables are in US\$(2005).

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

Figure A.7 provides further evidence on regionally binding constraints. The figure reports the shares of first-time buyers by location and over time with LTV and PTI ratios as high as their respective limits of 0.76 and 0.33 during the credit contraction used in the model. At the beginning of the recession, most 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,

Figure 3: Regionally binding credit constraints



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

while the share of PTI-constrained buyers only remains high in expensive MSAs.

The paper provides a model which addresses key questions about regionally binding credit constraints: What is the impact of aggregate versus local shocks? What is the role of differences between regions and households? How do the options to rent and to move between regions affect credit constraints?

2 Spatial Macro-Finance Model

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

2.1 Environment

Two groups 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 popu-

lated 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

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

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

Owners enjoy higher benefits $\Xi_j^o = \zeta_j^r + \zeta_j^o$. They own a single home of size \bar{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 $\tilde{\Xi}_j^o = \zeta_j^r + \zeta_j^o + \tilde{\zeta}^o$.

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 logarithm of income of working-age household i with age a in region j is

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

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

¹⁰For simplicity, there are no idiosyncratic house price shocks that potentially make homeownership less

Cohort differences. Households enter the economy as renters. They are divided into millennials and nonmillennials. Nonmillennials 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 because of the scarring effect of entering the economy in a recession. They draw their initial income from a distribution first-order stochastically dominated by the nonmillennial distribution.

Household balance sheets. 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 interest rate schedule 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 nonrecourse. Defaulters exit homeownership 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 a probability of one in the next period (4 years). Homeowners 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 (Internet Appendix B.1).

Household choices. Every period, households rent or own. The rental and owner-occupied markets give access to different housing sizes. Owner-occupied units come in size \bar{h} at price P_j in region j , and rental size can be chosen continuously in $[\underline{h}, \bar{h}]$ 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-

attractive (Piazzesi and Schneider 2016; Giacoletti 2021).

¹¹The 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).

form function of the house price in region j ,

$$I_{j,t} = \bar{I}_j P_{j,t}^{\rho_j}. \quad (4)$$

The construction cost shifter \bar{I}_j and the price elasticity of housing supply ρ_j differ between regions. The lower \bar{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 $\delta P_j \bar{h}$.

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 $H_{j,t}^r = (1 - ho_j^{sqft}) H_{j,t}$.¹² With defaults, the housing supply is higher by an amount equal to the measure of houses going back to the market multiplied by their square footage.

2.2 Household problem

This section describes the household problem in recursive form. The individual state variables are homeownership $\mathcal{H} = r, o$, location $j = L, H$, age a , assets or debt b , and endowment y . A household in a given region makes discrete homeownership 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 .

2.2.1 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

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

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.

¹²This assumption is an approximation of the data that implies close to full segmentation (Greenwald and Guren 2021) and keeps the model tractable. Segmentation arises from the minimum size constraint, the absence of a property ladder, moving frictions between and within regions, and the absence of conversion between rentals and owner-occupied units.

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

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

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

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

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

$$b_{t+1} \geq 0, \quad h_t \in [\underline{h}, \bar{h}]. \quad (8)$$

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

Renters 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 :

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

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

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

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

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

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,

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

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,

$$b_{t+1} \geq \min [\tilde{\theta} b_t, 0]. \quad (13)$$

The lowest payment that households can make in a period therefore equals $(1+r^b-\tilde{\theta})b_t$. 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 $(1+r^b)b_{t+1} + P_{L,t}\bar{h}$.

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

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

subject to the budget and borrowing constraints

$$c_t + R_{L,t} h_t + F_m + P_{H,t} \bar{h} (1 + f_m) + b_{t+1} = y_t - T(y_t) + (1+r)b_t, \quad h_t \in [\underline{h}, \bar{h}], \quad (15)$$

$$b_{t+1} \geq -\theta_{LTV,t} P_{H,t} \bar{h} \quad \text{and} \quad b_{t+1} \geq -\frac{\theta_{PTI,t}}{(1+r^b-\tilde{\theta})} y_t.$$

2.2.2 Homeowner.

The owner problem is similar (Internet 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 .

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

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 $\tilde{\Xi}_L^o = \tilde{\zeta}_L^r + \tilde{\zeta}_L^o + \tilde{\zeta}^o$.

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:

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

subject to the budget and no-borrowing constraints

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

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

2.3 Equilibrium

A dynamic spatial recursive competitive equilibrium 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 $\{\eta_{US,t}, \theta_{LTV,t}, \theta_{PTL,t}\}$, an equilibrium consists of the following (for region $j = L, H$ and homeownership $\mathcal{H} = r, o$):

- (i) sequences of prices $\{P_t^j, R_t^j\}$,
- (ii) value functions $\{V_t^{j\mathcal{H}}, V_t^{j'\mathcal{H}'}\}$,
- (iii) policy functions $\{d_t^{j\mathcal{H}}, c_t^{j\mathcal{H}}, h_t^{j\mathcal{H}}, b_{t+1}^{j\mathcal{H}}\}$,

(iv) a law of motion for the cross-sectional distribution of households $\lambda_t(j, \mathcal{H}, a, b, y)$ 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

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

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

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

where $pop_{j,t} = pop_j(\mathbf{P}_t, \mathbf{R}_t)$ 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 homeownership 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.

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

3 Calibration and Baseline Results

This section describes how the spatial macro-finance model of Section 2 is linked to the regional panel data set from Section 1. 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.

3.1 Calibration

Table 1 summarizes the calibration. Parameters are first split into externally and internally calibrated parameters, and then into aggregate and regional parameters. 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 to \$47,000 per year as in the data. One period is 4 years.

3.1.1 External parameters.

Aggregate 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 $r^b = 2.5\%$, and the average 30-year fixed-rate mortgage rate in the United States in 2005 (Primary Mortgage Market Survey) minus the CPI inflation (BLS).

The LTV limit $\theta_{LTV} = 0.953$ is based on Landoigt, Piazzesi, and Schneider (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 $\tilde{\theta}$ is chosen such that the fraction of the principal to be repaid every year is 1.60% (Greenwald, Landoigt, and Van Nieuwerburgh (2021)).

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).

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 (Internet 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 would 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. The cost of action for owners in the housing market is higher because of behavioral reasons (Andersen et al. 2022) and the lock-in effect of leverage (Brown and Matsa 2020). To quantify the resultant increase in their moving costs, I extrapolate results from Andersen et al. (2020). Households with characteristics predicting homeownership (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.

Regional 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 1 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).

3.1.2 Internal parameters.

The following parameters are chosen to match aggregate moments.

Discount factor. β is chosen to match the ratio of aggregate wealth to 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 the average rent to average income ratio of 0.20 in the Consumer Expenditure Survey (including utilities). The minimum housing size \underline{h} is set to replicate the ratio of the average sizes between owner-occupied and rental housing of 1.5 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 changes in

¹³A 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 2008–2010, the unemployment rate rose by 5 pp from 5% to 10%. I extrapolate the lower bound of these estimates.

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

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
$F_{e_0}(\cdot)$	Millennial initial income distribution	see text	Based on Kahn 2010
θ_{LTV}	LTV limit	0.953	Landvoigt, Piazzesi, and Schneider 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, Landvoigt, and Van Nieuwerburgh 202
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%
$\tilde{\zeta}^o$	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
\bar{I}_L, \bar{I}_H	Construction cost shifter	0.210, 0.026	$P_L = \$111,500, P_H = \$267,600$
$\tilde{\zeta}_L^r, \tilde{\zeta}_H^r$	Amenity benefits	0.000, 0.820	$R_L = \$780, R_H = \$1,115$
$\tilde{\zeta}_L^o, \tilde{\zeta}_H^o$	Homeownership benefits	3.251, 5.404	$ho_L^{hh} = 69\%, ho_H^{hh} = 67\%$

One model period equals 4 years. Parameters and targets are annualized. Sources: SCF, Freddie Mac, Federal Reserve Board, ACS, RealtyTrac, Zillow, and CEX.

family composition. Shocks are i.i.d. and distributed according to a type I Extreme Value distribution with mean $\tilde{\zeta}^o$. 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 $\tilde{\zeta}^o = 2.5$ 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 United States (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).

Taxes and transfers. The progressivity parameter $\tau = 0.030$ is chosen to match the share of households receiving transfers in the United States (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%. A minimum income level is equal to 10% of average income, ensuring that choice sets are nonempty.

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 , $E_j [Y_{i,j,a,t}] / M_j [Y_{i,j,a,t}] = \exp\left(0.5 \times \sigma_j^2 / (1 - \rho_e^2)\right)$ under conditional lognormality. 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. Amenities $\{\Xi_j^r\}$, homeownership benefits $\{\Xi_j^o\}$, and construction cost shifters $\{\bar{I}_j\}$ in regions $j = L, H$ are jointly calibrated to match the levels of rents $\{R_j\}$, homeownership rates $\{ho_j^{hh}\}$, and house prices $\{P_j\}$. (i) Amenity benefits are higher in expensive than in cheap MSAs, as implied by higher rents. They represent a utility boost equivalent to 13.4% of households' average one period utility (4 years). (ii) The utility benefits from homeownership Ξ^o are sizable. They represent a boost equivalent to 83.8% of household average one period utility in cheap MSAs and 143.7% in expensive MSAs. Higher benefits in expensive regions are required to match similar homeownership 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

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

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 include equipment and materials costs (in RSMMeans data from construction cost provider Gordian, the New York MSA has a $1.6\times$ higher 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 index value). 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

In the Internet Appendix, 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

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

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

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.

3.2 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, homeownership statuses, ages, income, and wealth in 2005. The model matches targeted moments and the nontargeted 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

Upper panel: Moments targeted by the calibration. Lower panel: Not targeted. Annualized values. Sources: ACS, SCF, CEX, Flow of Funds, CCP/Equifax, RealtyTrac, [Landvoigt, Piazzesi, and Schneider \(2015\)](#), and [Greenwald \(2018\)](#).

The model replicates differences between MSAs, which determine the transmission of credit shocks. Table 3 reports regional averages, and Figures C.1 and C.2 in the Internet Appendix display life cycle profiles within regions. The model exactly matches the cross-section of house prices and rents, and closely matches homeownership 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 relatively as high as 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 replicates the selection of households into transactions in the data. This is important because the low frequency of 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 homebuyers by MSA. The shares of first-time buyers (50%) and their age (37 and 38) is similar in both MSAs. 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

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 a down payment using LTV ratios and house prices. Rents are monthly; incomes are annual. US\$(2005). Sources: ACS, Zillow, BLS, CCP/Equifax, and Freddie Mac.

4 Period Effect

This section presents the main findings on the regional transmission of local and aggregate shocks to young buyers. I use the model to study the dynamics of homeownership, house prices, and rents, which can be explained by regionally binding constraints in the post-Great Recession period. I also present out-of-sample evidence for this mechanism.

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

$\{P_{L,t}, P_{H,t}, R_{L,t}, R_{H,t}\}$.

4.1 Regional housing market dynamics

4.1.1 Shocks. The recession is modeled as a sequence of negative shocks to local income and nationwide credit standards. The first period before the housing bust is 2002–2005 ($t = 0$).

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, Ludvigson, and Van Nieuwerburgh 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

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

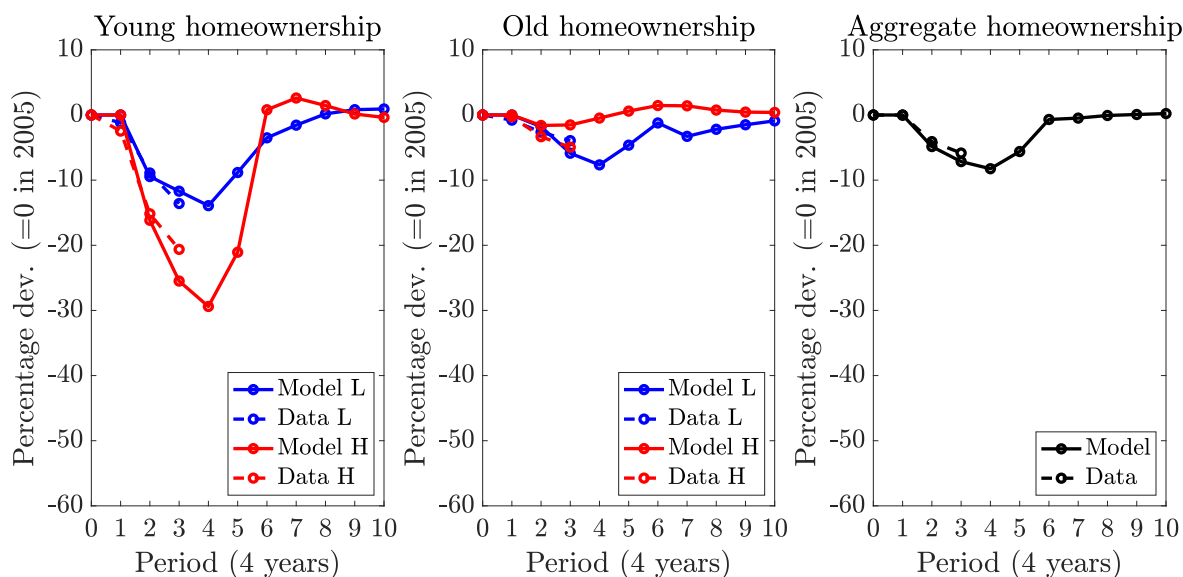
Homeownership. Figure 4 decomposes the change in homeownership between age and region groups. The model matches the data and generates different local responses to the recession despite regions being subject to the same credit shocks. First, the decrease in homeownership is concentrated among young buyers (25–44 years old). They rely more on credit to buy houses 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 buyers are explained by tighter credit standards rather than changes in millennial preferences toward owning, consistent with survey evidence (Internet Appendix A.3). Second, among young buyers the decrease is concentrated in expensive MSAs. From 2005 to 2015, young homeownership decreases by 10% in cheap MSAs and by 20% in expensive MSAs. Old

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

homeownership only falls by 5% in both MSAs. When aggregating MSAs, the model replicates the 8% decrease in average homeownership from peak to trough.

The decrease in young homeownership is persistent even after the shocks ($t > 4$), especially in expensive MSAs. Crucially, persistence comes from a decrease in households' entry rates into homeownership, with young buyers delaying homeownership (Internet Appendix, 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 homeownership with defaults only lasts 4 years as in the data (Figure D.2, right panel).

Figure 4: Homeownership response to recession with tight credit

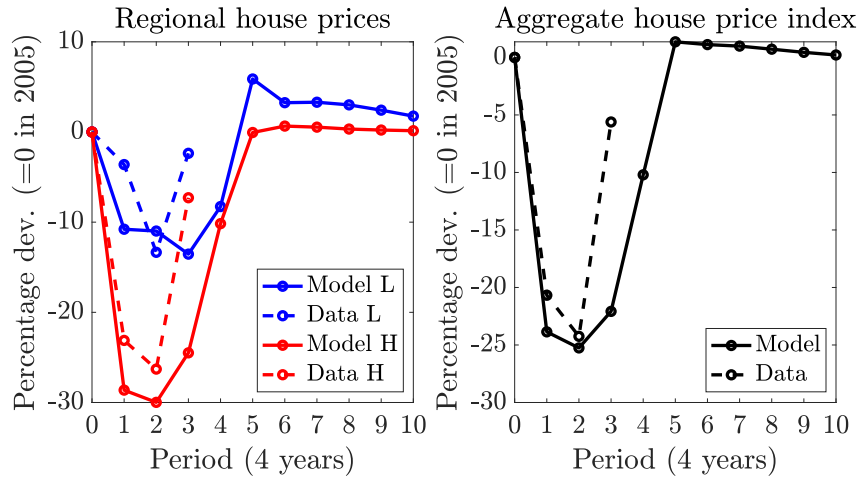


Homeownership changes for 25- to 44-year-old households (left panel), 45- to 85-year-old households (middle), aggregate (right). Low-price MSAs in blue, high-price MSAs in red, economy average in black. Model: solid lines. Data: dashed line (source: ACS). Changes in percentage terms relative to 2005.

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.

In the Internet Appendix, 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

Figure 5: House price response to recession with tight credit



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.

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 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 in expensive (-60%) than in cheap MSAs (-40%).

4.2 Regionally binding credit constraints

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

4.2.1 Income versus credit shocks. Figure D.3 decomposes the contributions of income and credit shocks to the responses of homeownership and house prices. 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 different responses between regions to the same credit shocks. Aggregate shocks to LTV and PTI limits alone can generate around 90% of the total decrease in young homeownership in expensive MSAs, while local income shocks alone can only generate 30% of it. Tighter LTV lim-

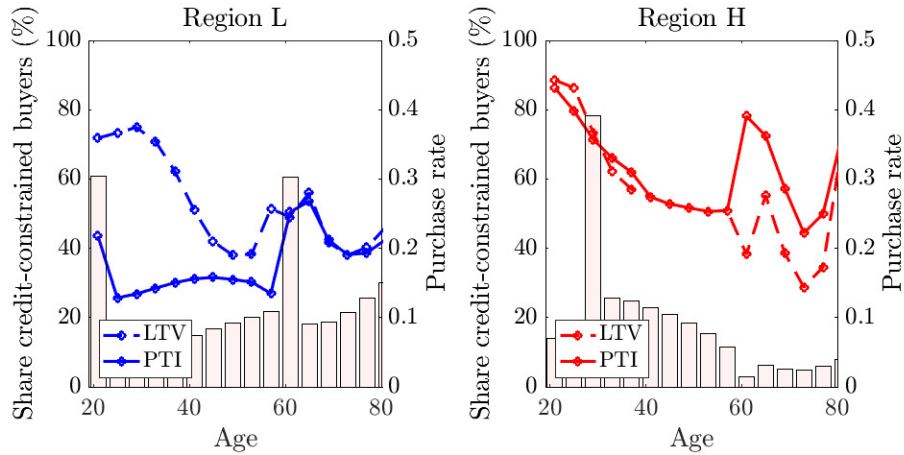
its have a higher impact in cheap MSAs than in expensive MSAs, where their effect is slightly dominated by PTI limits. This nuances popular narratives which solely attribute the decrease in homeownership to high down payments requirements.

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).

4.2.2 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 homeownership. 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 (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. It explains the larger impact on expensive MSAs, as PTI limits were tightened more than LTV limits.

4.2.3 Housing affordability. The higher price to income ratio in expensive MSAs makes credit constraints more binding. To illustrate how a lack of affordable housing 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 homeownership is twice lower than in the base-line in expensive MSAs, and the decrease in prices is one-third lower.

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



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).

4.3 Out-of-sample evaluation

The model captures broader patterns in housing markets outside the post-Great Recession sample of cheap and expensive MSAs. In Figure 7, the top panels evaluate cross-sectional out-of-sample validity 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, focusing on homeownership decreases in the 1980s and increases in the 1990s. In the three cases the model is fully recalibrated.

Cross-section: San Francisco MSA. In 2005, the San Francisco MSA had an average house price of \$669,780, which lies in the top 5% of the distribution. I compare this MSA 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 homeownership. 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 10 years. Income decreases by 3%, LTV limits from 0.87 to 0.80 and PTI limits from 0.55 to 0.50. The real mortgage rate increases from 3.1%

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

to 4.7% as in the data.²⁰ I use aggregate data for comparison because regional housing data by age is not available before 2005. The model explains well the decrease in young homeownership. It matches the price decrease, though it does not generate a sufficiently large trough.²¹

Time series: 1990s boom. In 1990, average house prices were \$63,676 in cheap and \$106,130 in expensive MSAs. The economy is subject to positive shocks over the next 15 years. Income increases by 12.7%, LTV limits are relaxed from 0.80 to 0.95 and PTI limits from 0.50 to 0.65. The real mortgage rate decreases from 4.7% to 2.5%. The model matches the increase in young homeownership and prices, except in the last period.²² Interestingly, the transmission of credit shocks into homeownership 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.

4.4 Sensitivity analysis

Figure E.1 in the Internet Appendix 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 housing in expensive MSAs. Therefore, more poor households locate there, and their credit constraints bind more. It makes them more sensitive to credit shocks and amplifies the housing bust. A lower elasticity of substitution $1/(1 - \epsilon)$ between consumption and housing dampens the bust. Introducing a warm-glow motive for bequests $U(b) \equiv \psi \frac{(b+b)^{1-\gamma}}{1-\gamma}$, or making them luxury goods has little effect.

5 Mechanism: Region and Cohort Effects

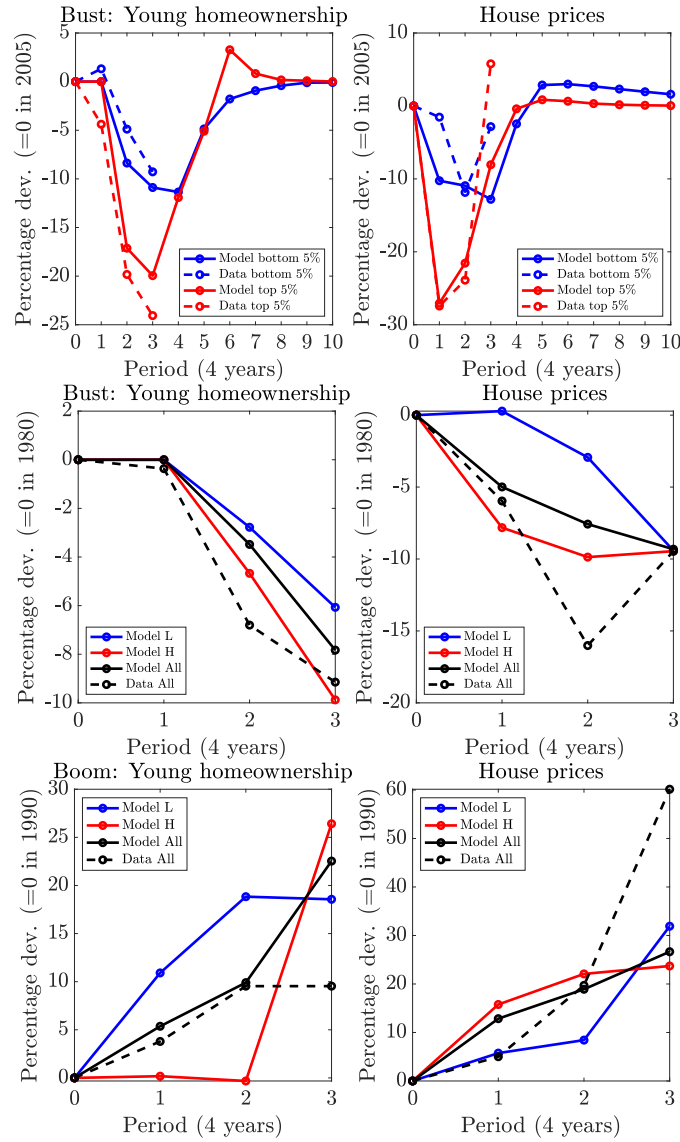
Using the model, this section investigates how differences between regions and cohorts of buyers contribute to the heterogeneous responses of housing markets to credit shocks.

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

²¹In this calibration of the model, housing markets are less segmented than in the baseline, a fact that would explain the lower effect of credit shocks.

²²The model abstracts from belief shocks, which could explain very high prices at the peak of the housing boom (Kaplan, Mitman, and Violante 2020).

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



Upper panels: Responses of top and bottom 5% house price MSAs to same decrease in income and credit supply as in benchmark. Middle panels: Responses of young homeownership rates and house prices to the combination of a decrease in income and credit supply and an increase in the mortgage rate. 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.

5.1 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, then 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 homeownership falls by 5% in expensive MSAs instead of 30% in the baseline (solid line with dots). The bust in homeownership 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 homeownership in expensive MSAs falls by half as less as in the baseline. The busts in homeownership 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.

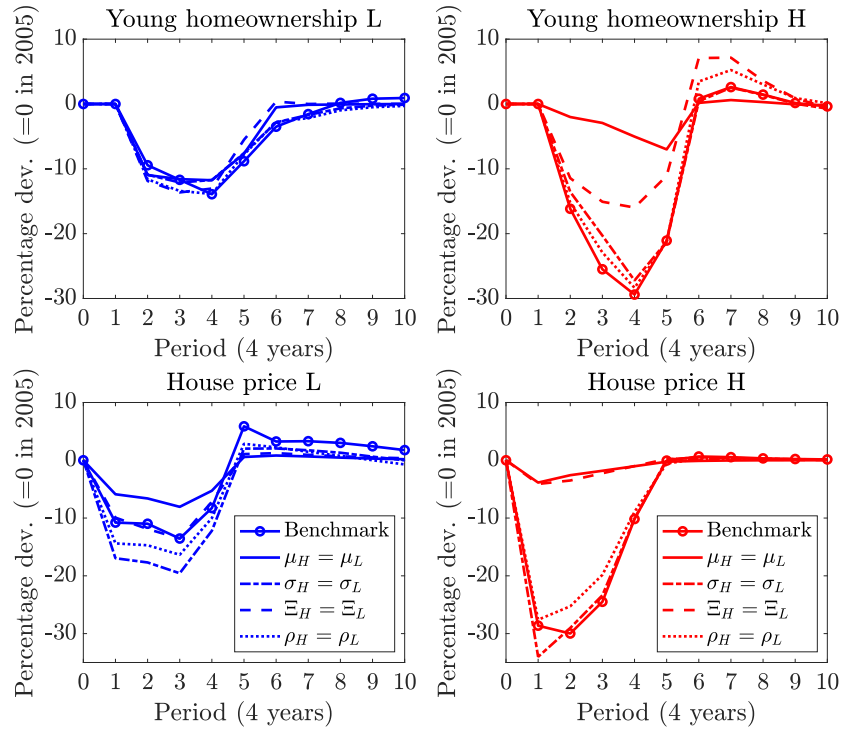
Setting the housing supply elasticity in expensive MSAs equal to its value in cheap MSAs $\rho_H = \rho_L$ (dotted line) has less effect, pointing to the role of credit constraints rather than supply. The busts in young homeownership and prices become more similar across MSAs, but not as much as with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

5.2 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 (Internet Appendix, Figure D.5).

These flows affect housing markets even when relatively small. In spatial equilibrium, young homeownership and prices decrease in expensive and increase in cheap MSAs partly as a result of young buyers moving from expensive into cheap MSAs. This mi-

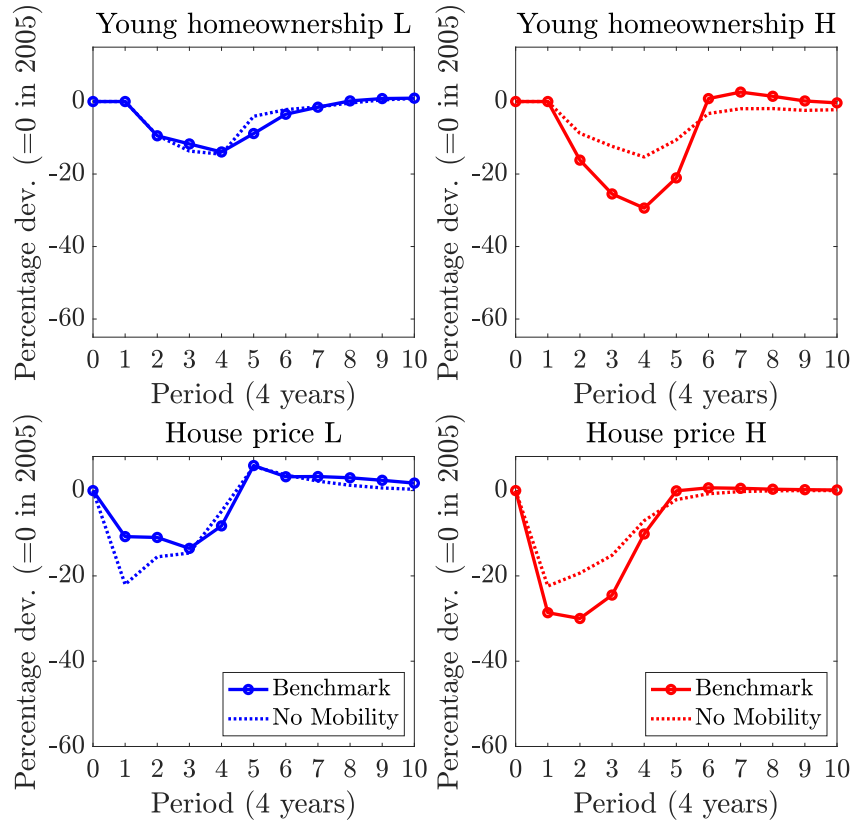
Figure 8: Effect of regional differences on homeownership and house price responses



Changes in young homeownership 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 elasticities (dotted) in high-price MSAs set equal to their values in low-price MSAs. Changes in percentage terms relative to 2005.

gration 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 homeownership falls by 30% versus 15% without migrations. House prices fall by 30% versus 20%, and by 17% versus 21% in cheap MSAs. The lower price decrease in cheap MSAs 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.

Figure 9: Effect of mobility on homeownership and house price responses



Upper panels: Responses of 25- to 44-year-old homeownership in the benchmark with mobility (solid lines) versus no mobility (dotted lines, $m = \infty$). Lower panel: house price responses. Blue, low-price MSAs. Red, high-price MSAs. Changes in percentage terms relative to 2005.

5.3 Cohort effect

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

In the Internet Appendix, 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 homeownership 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. Consistent with binding PTI constraints, the effect of income scar-

ring 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 homeownership by 1 pp, and income scarring decreases it by 7 pp. Income scarring lowers average prices by \$3,000. These effects are weaker in cheap MSAs because credit constraints bind less. Interestingly, student debt slightly increases homeownership 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.

6 First-Time Buyer Subsidies

Regional credit constraints affect the effectiveness of stabilization policies designed to mitigate housing busts. 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 that 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.

6.1 The First-Time Home Buyer Credit

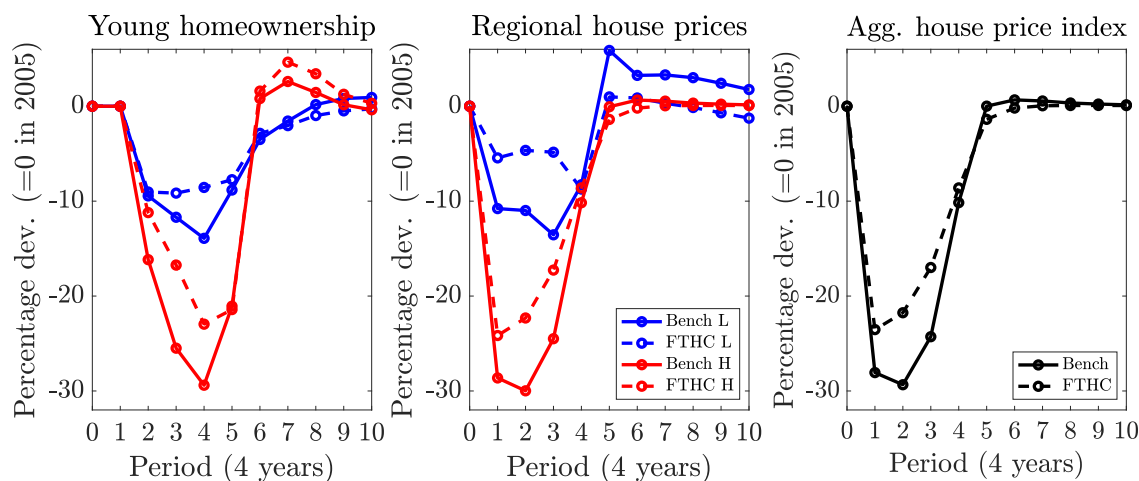
6.1.1 Background. The last version of the FTHC in the 2009 Worker, Homeownership, and Business Assistance Act is modeled as an \$8,000 unanticipated subsidy for households with income below \$125,000, which lasts for the length of the bust. The policy is financed by the issuance of long-term government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

6.1.2 Impact. *Estimates.* Figure 10 plots the dynamic impact of the policy. It stabilizes young homeownership (-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-time buyers need to borrow less. Home sales increase by 10%.²³ These effects are in line with empirical estimates (Berger, Turner, and Zwick 2019).

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

Dampening. Regional heterogeneity dampens the overall effectiveness of the FTHC. The policy stabilizes cheap MSAs by cushioning one-third of the decrease in young homeownership and half of the decrease in prices. However, it fails to stimulate expensive MSAs relatively as much. It cushions less than one-fourth of the decrease in young homeownership 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, so it represents a lower fraction of prices in expensive (3%) compared to cheap MSAs (7%). It relaxes credit constraints by more and for more buyers in the latter. However, since the decrease in homeownership is concentrated in expensive MSAs, the subsidy fails to stabilize these regions enough, while they are responsible for the bust.

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



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 homeownership (low-price MSAs in blue, high-price MSAs in red). Middle panel: House prices. Right panel: Aggregate house price index (black).

6.2 Dynamic welfare analysis

Instead of a “one-size-fits-all” subsidy across regions, I estimate the welfare impact of 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 welfare impacts of the uniform (“FTHC”) and place-based subsidies (“PB-FTHC”) over time. Consumption-equivalent variations measure the net gains of the policies in terms of one period of consumption of nondurables and housing (4 years).²⁴

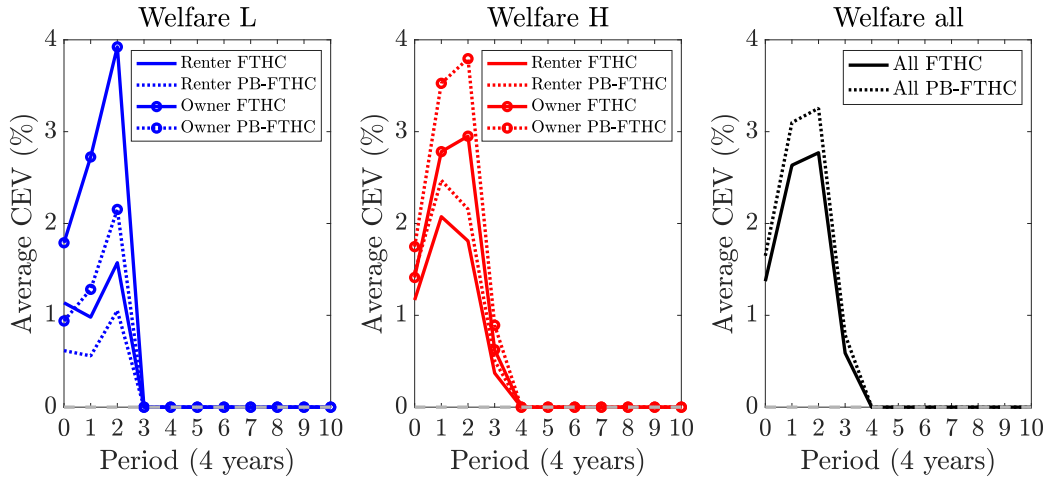
²⁴Internet Appendix B.3 contains the welfare calculations.

6.2.1 Uniform FTHC. The FTHC generates a sizable aggregate welfare gain (average, black lines), corresponding to a 2.7% increase in 4-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 homeownership is larger, and they are heterogeneous across households. The policy benefits renters (solid blue and red lines) because it improves their access to homeownership. 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) by cushioning them from the decrease in prices and hence in housing wealth. This general equilibrium effect is large, with owners' gains being between $1.5\times$ and $2.5\times$ higher than renters'.

6.2.2 Place-based FTHC. The place-based subsidy significantly increases aggregate welfare gains to 3.2%. This is achieved by increasing buyers' welfare in expensive MSAs (from 2% to 3%), and increasing 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 prices.

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 homeownership. Second, because of higher benefits Ξ_H^H in expensive MSAs, welfare gains are larger for a given increase in homeownership, 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 endogenously depend on their population, then these gains will be lower. Overall, these findings suggest that housing stabilization policies should not just consider buyers' income and wealth, which would lead to targeting only cheap MSAs. They should also account for house prices and location preferences, which then leads to also targeting expensive MSAs.

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



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 4 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.

7 Conclusion

Low homeownership rates among millennials are one of the main features of the post-Great Recession period. To understand their causes and their consequences for housing markets and households' balance sheets, it is critical to account for differences between regions. I obtain these findings in a novel setting that 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 young buyers from arbitraging local house price declines, which would generate high returns. Also, moving frictions prevent them from arbitraging regional price differences by moving en masse to affordable regions. The different dynamics of regional housing markets are not explained by different local shocks, but rather by the larger impact on expensive regions of the same credit shocks nationwide. Student debt and income scarring persistently reduce the importance of housing for millennials' finances. They are therefore detrimental to 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 re-

gions like the FTHC.

Place-based subsidies that 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 policies. Several first-time buyer programs offer lower rates, down payment requirements, or direct subsidies, all of which differ across regions (e.g., the “Achieving the Dream” Program in the New York State). Future work could use this framework to analyze them as well as other credit policies with a regional dimension. Understanding how buyers’ migrations to the suburbs and the countryside associated with the increase in remote work affect real estate would be another interesting direction.

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