

# House Prices, Investors, and Credit in the Great Housing Bust

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## Abstract

This paper studies the role played by investors in stabilizing housing markets during the Great Housing Bust. Using transaction-level data, I distinguish between two types of housing investors that were active during this period: large, deep-pocketed corporate investors, and small household investors that rely on mortgage credit. I estimate that in response to a negative mortgage credit supply shock, house prices fell by 30 percent more in markets where household investors absorbed a larger share of house purchases than did corporate investors. To rationalize this result, I build a heterogeneous agent model of the housing market featuring both types of investors. In response to a negative mortgage credit shock, the model generates much larger equilibrium house price declines when household investors are required to absorb falling homeowner demand rather than corporate investors. To induce household investment as mortgage credit tightens, prices must fall to generate large enough returns to compensate households who are on average poorer and more indebted than previous investors. Additionally, in contrast to corporate investors, household investors are sensitive to changing credit conditions, the illiquidity of housing assets, and losses on primary property wealth. Finally, I show that the greater housing market stability associated with corporate investment activity results in higher household welfare. This is the case even though homeownership rates fall by more and housing returns accrue to outside firms rather than households.

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# 1. Introduction

In the mid 2000s, an unprecedented housing boom ended in the Great Housing Bust. Following a sharp contraction in the availability of mortgage credit, house prices fell rapidly.<sup>1</sup> The recent macroeconomic literature explains the magnitude of these declines with a range of factors affecting homeowner demand for housing during this period.<sup>2</sup> However, in many of the housing markets in which homeowner demand fell, housing investors purchased an increasing share of the properties available for sale.<sup>3</sup> If investors substitute for the decline in homeowner purchases, then the magnitude of the housing bust will depend on the determinants of investor demand. Yet, despite their large market share and apparent importance for housing market dynamics, housing investors have been little studied in the macroeconomic literature to date.

In this paper, I study the extent to which investors helped to stabilize housing markets in response to mortgage credit shocks during the Great Housing Bust. I show that investors substitute for falling homeowner demand, thereby dampening declines in house prices. However, the strength of this stabilization channel depends on certain characteristics of the investors themselves. I argue that corporate housing investors behave like large, deep-pocketed buyers, while household investors rely on mortgage credit to finance their purchases. Consistent with this view, I show that corporate investment activity is associated with significantly smaller house price declines than is household investment activity. As a result, variation in the composition of investors helps to account for the significant dispersion in house price changes across markets during the housing bust.<sup>4</sup>

In the first part of the paper, I present empirical estimates of the effect of investment on house prices in response to exogenous changes in mortgage credit. I find that an increase in the share of corporate investor purchases is associated with a 30 percent smaller decline in house prices than a similar sized increase in the share of household investor purchases. In the second part of the paper, I rationalize this result using a structural macroeconomic model of the housing market that features both types of investors. I show that house prices are much more stable following a mortgage credit shock when corporate investors absorb the decline in homeowner demand rather than household investors. This is because household investment

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<sup>1</sup>On the overall decline in mortgage originations, see Justiniano et al. (2017). On the relationship between mortgage credit and house prices in the bust, see Mian et al. (2009) and Mian et al. (2018).

<sup>2</sup>For example, changes in: mortgage rates (Garriga et al., 2019), borrowing constraints (Greenwald, 2018), housing liquidity (Hedlund, 2016), beliefs about future house prices (Kaplan et al., 2017), and risk-premia (Favilukis et al., 2017a).

<sup>3</sup>See Lambie-Hanson et al. (2018), Lambie-Hanson et al. (2019), Mills et al. (2019).

<sup>4</sup>For example, Mian et al. (2013) report that from 2006 to 2009 house prices grew by between 1 and -79 percent at the 10th and 90th percentiles of counties in the US.

demand is much less elastic with respect to house prices than is corporate investment demand. I show that this is because household investors are sensitive to changes in mortgage credit conditions, the illiquidity of housing assets, and fluctuations in wealth due to changes in the value of primary property. While corporate investment is associated with greater housing market stability, it is also associated with a much larger reallocation of the housing stock and thus a much larger decline in the homeownership rate. Nevertheless, households value stability so that total welfare is higher when corporate investors are more active in the housing market than are household investors.

Throughout the empirical analysis, I use housing transaction data from the Zillow Transaction and Assessment database (ZTRAX) to study housing investment activity during the bust. This detailed micro-data shows that corporate and household investors differ in important aspects of their investment behavior. For example: corporate investors buy many more properties than do household investors; corporate investors trade properties far more frequently than do household investors; and household investors are far more likely to use mortgage debt to finance their purchases. These stylized facts suggest that corporate and household buyers may differ in their ability to stabilize housing markets through investment in response to shocks.

To test whether housing investment helps to stabilize house prices, I use cross-sectional, zip code-level data on house prices, investment activity, and changes in mortgage credit. Because these housing market outcomes are likely to be endogenous to other shocks that occurred during the housing bust, I adopt an instrumental variables regression strategy. I instrument for corporate and household investment activity using their own lags. Changes in credit are instrumented using the share of mortgages sold to non-government sponsored enterprises (GSEs) in secondary mortgage markets prior to the housing boom and bust.<sup>5</sup> As non-GSE activity fell sharply following the housing boom, markets that relied more on mortgages that were sold to these institutions faced larger contractions in mortgage credit and thus larger shocks to housing demand.<sup>6</sup>

In instrumental variable regression results, I show that housing investment dampens house price declines due to mortgage credit shocks. On average, a one standard deviation decline in

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<sup>5</sup>The latter instrument resembles a mortgage credit supply shock, since rapidly rising non-GSE activity in the housing boom was associated with increases in mortgage borrowing and lower mortgage interest rate spreads. See Mian et al. (2009), Justiniano et al. (2017), and Mian et al. (2018).

<sup>6</sup>The mortgage credit instrument is constructed using Home Mortgage Disclosure Act (HMDA) data. A better measure of exposure to the mortgage credit supply shocks of the mid-2000s might come from mortgages sold directly into private label securitization (PLS), rather than to non-GSEs. However, the HMDA data appears to significantly undercount PLS mortgage purchases in the secondary market, as can be seen by comparing to the measures of total PLS activity reported in Justiniano et al. (2017). Nevertheless, in Section 4.4 I show that the main results are robust to using the more direct PLS measure.

mortgage credit is associated with an 8.5 percent decrease in house prices during the housing bust. However, prices decrease just 5.2 percent in housing markets facing a one standard deviation increase in the corporate investor share of house purchases. Prices decline 7.4 percent in markets facing a one standard deviation increase in the household investor share of purchases. Overall, an increasing share of corporate investment activity is associated with a 30 percent smaller decline in house prices than a similar sized increase in the share of household investor activity. This suggests that corporate housing investment provides a much stronger stabilizing force in housing markets than does household investment.

To rationalize these empirical results, I build a structural macroeconomic model of a housing market that features both types of investors. Absent more detailed data on individual investors and investment behavior, the model serves as a laboratory to study the causes and consequences of the housing investment stabilization channel. Following the recent macro-housing literature, the core of the model features heterogeneous, life-cycle households who face uninsurable income risk, choose to rent or buy houses, and use long-term mortgage debt to finance house purchases.<sup>7</sup> I introduce endogenous household investment decisions, which enable households to buy properties in addition to those in which they live. Like owner-occupied property, investment properties are traded subject to transaction costs and can be used as collateral for mortgage borrowing. In addition, investment property generates rental income and may earn capital gains as it is traded following aggregate shocks. Household heterogeneity and the life-cycle features of the model are important to produce a distribution of mortgage debt, which leaves homeowners exposed to mortgage credit shocks. In addition, these features help to generate a realistic supply of household investors, many of whom are themselves dependent on mortgage credit.

I also introduce a role for corporate housing investors. Corporate investment comes from a representative, deep-pocketed, risk-neutral firm that maximizes profits generated by leasing properties in the rental market as well as trading those properties in the housing market. Corporate investors face a convex housing portfolio holding cost, the curvature of which is governed by the elasticity of corporate investment demand with respect to housing returns. This assumption is motivated by the empirical finding that even corporate investment does not perfectly stabilize house prices in response to shocks. The cost reflects unmodeled frictions affecting corporate investment, from which I abstract in this paper.<sup>8</sup>

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<sup>7</sup>See recent examples in Favilukis et al. (2017a), Kaplan et al. (2017), Greenwald (2018), and Garriga et al. (2018).

<sup>8</sup>The discussion in Mills et al. (2019) suggests the possibility of decreasing returns to scale since corporate investment is concentrated in the market for multi-family residential property which is easier to manage than dispersed, single-family properties. Chinco et al. (2015) show that local housing market knowledge is important for

The model is calibrated to match key features of the US housing market prior to the the 2000s housing bust. I then use the model to study equilibrium responses to an exogenous, unexpected, temporary contraction of mortgage credit. The shock consists of an increase in the mortgage interest rate, an increase in mortgage origination costs, and a tightening of mortgage borrowing constraints.<sup>9</sup> Since homeowners are both dependent on mortgage credit and hold most of the housing stock in steady state, the primary effect of the shock is to decrease homeowner demand for housing. While this causes equilibrium house prices to fall, the size of this decline depends on the investors that are active in the housing market at the time of the shock. To study this channel, I alter the concentration of corporate investors in the housing market following the shock by varying the elasticity of corporate investment demand. When the elasticity is high (low), corporate (household) investors purchase an increasing share of houses and there are small (large) declines in house prices following the credit shock.

I compare two housing markets: one in which the corporate elasticity is zero, and one in which the elasticity of corporate investment is calibrated to match the estimated relative house price decline across investors following a mortgage credit shock. The housing market is significantly more stable in the economy where corporate investors are active during the housing bust. When household investors are active in the housing market, the marginal investor during the housing bust is younger, less wealthy, and more indebted than in the steady state. Moreover, household investment is sensitive to the rise in mortgage costs, the illiquidity of housing assets, and losses on primary housing wealth along the transition path. Thus, relative to the economy with active corporate investors, prices must fall further to generate large enough housing returns to compensate new household investors for reallocating resources towards additional housing.

Finally, I consider the welfare implications associated with the presence of corporate investors during a housing bust. Although corporate investment activity is associated with more stable house prices, the high elasticity of corporate investment demand leads them to purchase more houses which causes a much steeper decline in the homeownership rate.<sup>10</sup> Additionally, if investment firms are owned by outsiders, the capital gains and rents earned by corporate investors do not accrue to households during the bust. Overall, households are better off when corporate investors are active in the housing market. However, there is significant heterogeneity in welfare changes. Young and poor households gain the most from housing market stability,

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profitable residential investment, which may discourage out-of-town corporate investment activity. Additionally, significant disruptions in broader financial markets in the late 2000s may have affected the non-mortgage financing that corporate investors rely on for investment.

<sup>9</sup>Other housing boom and bust experiments using these shocks can be found in Justiniano et al. (2015), Favilukis et al. (2017a), and Greenwald (2018).

<sup>10</sup>Lambie-Hanson et al. (2019) present empirical evidence that the rise in corporate investment activity in the housing bust was associated with declining homeownership rates.

while older and wealthier households (those most likely to be housing investors) are typically worse off when corporate investors are active in the housing market.

**Outline:** The remainder of the paper is organized as follows. Section 2 presents a review of related literature. Section 3 discusses the housing transaction data used in the empirical analysis, and presents several stylized facts about housing investment activity in markets during the housing bust. Section 4 discusses the empirical strategy and results, in which I estimate the effects of investment activity on house prices in response to changes in mortgage credit during the housing bust. Section 5 introduces the structural macroeconomic model and reports the results of experiments that vary mortgage credit and the composition of household and corporate investors in the housing market. Section 6 concludes.

## 2. Related literature

In this paper, I study the role of corporate and household investment in housing markets during the 2000s housing bust. The empirical analysis in the first half of the paper follows a recent empirical literature that studies household investor behavior in the housing boom and corporate investment behavior in the housing bust.

Haughwout et al. (2011) and Adelino et al. (2016) show that as mortgage borrowing increased from 2000 to 2007, household investors accounted for an increasing share of that borrowing. Mian et al. (2018) show that cities more exposed to mortgage credit supply shocks experienced larger increases in household investment activity during the boom. Garcia (2019) uses geographic exposure to vacation homes as an instrument for investment activity and shows that household investment amplified house prices during this period. Haughwout et al. (2011), Adelino et al. (2016), and Mian et al. (2018) show that increasing household investor borrowing during the boom was subsequently associated with larger increases in mortgage defaults and decreases in house prices. However, these papers do not discuss the role of household investment activity that occurred during the housing bust itself.

Lambie-Hanson et al. (2018) and Mills et al. (2019) document that large, institutional investors purchased an increasing share of houses during the bust. Mills et al. (2019) attribute some of this increase to the entry of large buy-to-lease investors in the late 2000s, and provide OLS evidence that this investment activity supported house prices in this period. Lambie-Hanson et al. (2019) use an instrumental variables regression design that exploits changes in policies that favored purchases of foreclosed properties by household investors rather than corporate investors. They find that higher corporate investment activity is associated with higher house prices and lower homeownership rates. Consistent with these papers, I also find that cor-

porate investment activity stabilized house prices in the bust. I extend the analysis to show that household investors also supported house prices during this period, but by less than corporate investors.

In the second half of the paper I build a structural macroeconomic model of the housing market. I follow a large and growing literature that models key features of the 2000s housing boom and bust.<sup>11</sup> Most of these models have in common a heterogeneous household structure with several important features that help explain households' exposures to fluctuations in housing markets: age, income risk, housing illiquidity, and long-term mortgage debt. These models are then used to studying general equilibrium responses to mortgage credit shocks, among other aggregate shocks.

The primary innovation of the current paper relative to this literature is the introduction of a role for household and corporate investors in housing and rental markets. I show that the composition of investors in the housing market during a mortgage credit contraction affects the elasticity of investment demand, which determines the size of the house price response to the shock. In a recent paper, Greenwald et al. (2019) also study a model with housing investment in the boom and bust. They show that the degree of segmentation between housing markets for rental and owner-occupied property is important for explaining how credit affects housing demand. In the current paper, I assume no housing market segmentation, but study the factors that affect the housing demand of investors themselves. To do this, in contrast to Greenwald et al. (2019), I build a model with household heterogeneity, life-cycle dynamics, and endogenous household investment decisions. These model features generate a realistic supply of household investors, which accounts for the relatively low elasticity of household investment demand following a mortgage credit shock.

I allow for both endogenous household investment in separate, illiquid housing assets, and imperfectly elastic corporate housing investment demand. This approach generalizes many of the existing models of investment demand presented in the literature. For example, Kaplan et al. (2017) introduce perfectly elastic corporate firms that buy houses that are leased to renting households. Chambers et al. (2009a) allow homeowners to become landlords by leasing a fraction of their primary property to renters. They also introduce corporate landlords that produce housing services but do not trade property and so are insensitive to changes in house prices.<sup>12</sup> Favilukis et al. (2017b) study out-of-town housing investment demand in a model with

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<sup>11</sup>See recent papers by Iacoviello et al. (2013), Chen et al. (2013), Landvoigt et al. (2015), Hedlund (2016), Hurst et al. (2016), Favilukis et al. (2017a), Kaplan et al. (2017), Berger et al. (2017), Greenwald (2018), Garriga et al. (2018), Garriga et al. (2019), Diamond et al. (2019), and Greenwald et al. (2019).

<sup>12</sup>Sommer et al. (2018) abstract from corporate landlords but also allow homeowners to lease a share of their homes to renters.

both landlord households and out-of-town housing investors. In that model, housing wealth is liquid, suggesting a relatively elastic household investment demand function. Meanwhile, out-of-town investors are modeled as a source of inelastic housing demand who purchase properties that are neither lived in or leased to local renters in the rental market.

## 3. Data

### 3.1. Housing Data

Housing transactions data come from the Zillow Transaction and Assessment Dataset (ZTRAX), made available by Zillow Research.<sup>13</sup> The full ZTRAX dataset contains more than 370 million transactions from across the US, and reports information on sales, prices, buyers, mortgages, property characteristics, and geographic information for residential and commercial properties. I restrict analysis to transactions for regular sales of residential, single-family houses, which excludes foreclosure sales, intra-family transfers, and transactions featuring builders, developers, or real estate agents.

For the purposes of this analysis, I drop all transactions with missing buyer addresses or missing buyer description information. Reliable ownership information is not available in every location, so I restrict the analysis to data from states in which I observe buyers' addresses for at least 85 percent of transactions.<sup>14</sup> In the empirical analysis, I aggregate data by zip code and restrict the sample to observations with at least 100 house sales in a given year. The final sample used in the empirical analysis consists of zip codes containing approximately 40 percent of the US population as at the 2000 Census.

I determine ownership of purchased properties in two stages.<sup>15</sup> First, I infer owner-occupancy for each transaction by comparing the listed address of the buyer to the address listed for the property. I assume that owner occupiers are those whose address matches that of the property they purchased. Second, I separate purchases into those made by households and those made by corporate institutions. ZTRAX reports whether buyers are individuals, couples, trusts, legal partnerships, companies, government entities, or other kinds of organizations.

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<sup>13</sup>The conclusions drawn from the ZTRAX dataset are those of the researcher and do not reflect the views of Zillow. Zillow is not responsible for, had no role in, and was not involved in analyzing and preparing the results reported herein.

<sup>14</sup>These states are: Alaska, Arizona, California, Colorado, Delaware, Florida, Iowa, Idaho, Indiana, Hawaii, Kentucky, Maryland, Minnesota, Missouri, Montana, North Dakota, New Jersey, New York, New Mexico, Nevada, Ohio, Oregon, Pennsylvania, South Carolina, South Dakota, Texas, Utah, Washington, Wisconsin.

<sup>15</sup>See Appendix A for details.



I define household owner-occupiers as buyers who are listed as individuals or couples.<sup>16</sup> I define investors as house buyers that are not owner occupiers. Household investors are coded as individuals or couples, and corporate investors are companies, partnerships, builders, developers, agents, contract owners, individuals doing business, or individual officers of organizations.<sup>17</sup>

Figure 1 shows how the shares of houses purchased by owner occupiers, household investors, and corporate investors evolved during the housing bust. For illustration, I show house purchase shares for two housing markets that experienced especially large house price declines during this period: Maricopa County in Arizona, and Miami-Dade County in Florida.<sup>18</sup> In each housing market declining homeowner demand is represented by the fall in the owner-occupier share of purchases from 2007. However, investor shares responded differently in the two markets. In Arizona between 2007 and 2011, the household and corporate investor shares increased by 10 and 4 percentage points, respectively. In contrast, in Florida over the same period the household investor share fell 3 percentage points and the corporate investor share rose 21 percentage points. The goal of the empirical analysis is to assess whether house prices responded differently in markets such as these, where the fall in homeowner demand for housing was more likely to be absorbed by corporate or household investors.

Table 1 reports summary statistics across the three types of house buyers, pooled across locations and split into boom and bust samples. Panel A shows that in general owner occupiers purchase around twice as many properties as household investors, who in turn purchase around three times as many properties as corporate investors. Although the changes in aggregate purchase activity from boom to bust are less stark than in the local housing markets reported in Figure 1, the owner-occupier share of purchases declined three percentage points. Note that this decline in homeowner purchases is consistent with the national decline in the homeownership rate from 69 to 67 percent between 2005 and 2010. The decline in homeowner demand is reflected by a 1 percentage point increase in the household investor purchase share and a 2 percentage point increase in the corporate investor share.

Panel B presents a measure of the distribution of investor sizes. I report the fraction of investors buying different numbers of properties within each five-year period.<sup>19</sup> Household

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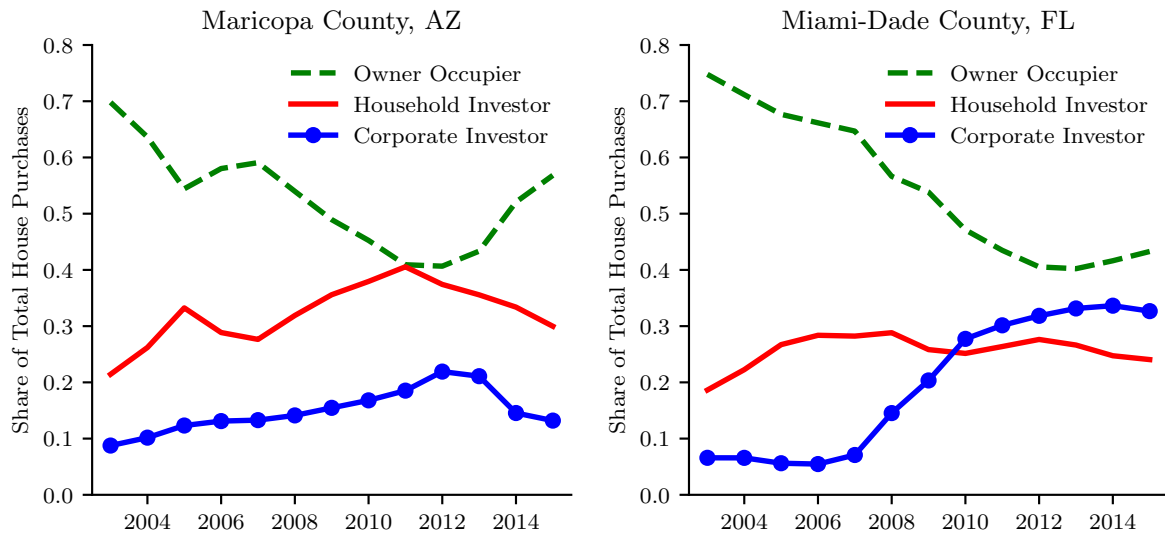
<sup>16</sup>Trusts and trustees are excluded. House purchases by these entities make up around one to two percent of all transactions.

<sup>17</sup>Government entities, non-profits, and religious organizations are excluded from this definition. Of these, only government purchases are significant, constituting around 0.5 percent of all transactions.

<sup>18</sup>A broader cross-section of the changes in investor purchase shares is shown in Figure B.1 in Appendix B. The figure presents histograms of the growth in corporate and household investor shares across zip codes from 2006 to 2010.

<sup>19</sup>These statistics are computed by tracking transactions associated with each listed buying addresses. Note that

Figure 1: Housing Market Buyer Composition Through the Housing Bust



*Note:* Total house purchases are the sum of owner occupier, household investor, and corporate investor purchases.

*Source:* Author's calculations using ZTRAX

investment is heavily concentrated among buyers purchasing a single property. This is consistent with Haughwout et al. (2011), who show that in the 2000s around 70 percent of mortgage borrowing associated with household investors accrued to those with just two mortgages (i.e. one mortgage against a primary property and one against a secondary property). In contrast, corporate investment is skewed towards large investors, such as those buying more than 25 properties.

Panel C reports statistics summarizing financing, resales, and location of house buyers. The first row reports the fraction of each buyer type using a mortgage to finance their purchase. Owner occupiers are more likely to use mortgage financing than household investors, who in turn are more likely to use mortgages than corporate investors. Reflecting tighter credit during the bust, mortgage financing dropped by 7 percentage points for both owner-occupiers and corporate investors, and by 14 percentage points for household investors.<sup>20</sup> The second and third rows of Panel C report the share of properties resold within 12 and 24 months. Owner occupiers and household investors are similar in that they are relatively unlikely to resell their

this will overstate the number of properties purchased by an investor if they happen to change address and if the new occupant of that address also makes purchases in the sample period. I suspect this bias is small, and indeed the numbers reported here are comparable to those reported in Mills et al. (2019), who track individual investors by name rather than address.

<sup>20</sup>Unfortunately, the data does not report on non-mortgage sources of financing. For this reason it is not clear if, for example, corporate investors were affected by tighter non-mortgage credit due to the broader financial crisis during this period.

Table 1: Summary Statistics

	Pooled, 2001-2005			Pooled, 2006-2010		
	Owner Occupier	Household Investor	Corporate Investor	Owner Occupier	Household Investor	Corporate Investor
<i>A. Share of Total Purchases</i>	0.64	0.28	0.08	0.61	0.29	0.10
<i>B. Buyer Size:</i>						
Number of Properties: 1		0.65	0.14		0.65	0.15
Number of Properties: 2-5		0.24	0.19		0.22	0.20
Number of Properties: 6-25		0.07	0.22		0.07	0.21
Number of Properties: 26+		0.04	0.45		0.06	0.43
<i>C. Financing, Resales, Location:</i>						
Using a Mortgage	0.77	0.56	0.21	0.70	0.42	0.14
Resold Within 12 Months	0.06	0.12	0.35	0.04	0.10	0.32
Resold Within 24 Months	0.12	0.20	0.47	0.07	0.15	0.41
Out of Town		0.24	0.22		0.25	0.31
Observations	14,987,559			14,045,690		

*Sources:* Author's calculations using ZTRAX.

properties within a short period of time. In contrast, nearly half of all corporate investors during the housing boom resold their properties within two years of initial purchase. These statistics are comparable to those in Mills et al. (2019), who report 12-month resale rates in 2012 for owner-occupiers, household investors, and small corporate investors of 0.04, 0.17, and 0.45, respectively. The final row of Panel C reports the share of out-of-town buyers among household and corporate investors.<sup>21</sup> Overall, around one quarter of all investment is due to out-of-town buyers. While the out-of-town buyer rate for household investors is little changed from boom to bust, the rate for corporate investors rises from 22 to 31 percent during this period.

In summary, corporate investors are much larger, trade housing assets more often, and rely

<sup>21</sup>I define an out-of-town purchase as one in which the buyer address is located in a different MSA to that of the property being purchased.

less on mortgage financing to purchase properties than household investors. These stylized facts are consistent with a view of corporate investors as large, deep-pocketed house buyers, and household investors as small, constrained house buyers. In that case, corporate investment activity should provide a much more stabilizing force on housing markets following a negative shock than does household investment activity. I present an empirical test this hypothesis in Section 4.

### **3.2. Mortgage Data**

The program for the Home Mortgage Disclosure Act (HMDA) provides loan-level data about all US mortgage applications and originations. I restrict the analysis to all originated mortgages issued for the purpose of buying a home. Using information about the location of each mortgage, I aggregate data to construct a zip code-level measure of annual mortgage origination activity. Note that total value of mortgage originations may be affected by changes in house prices as homeowners borrow against the value of their homes. To avoid this problem, I use the number of mortgage originations in each zip code. To construct instruments for mortgage credit, I use information on the resale of mortgages in the secondary mortgage market. For each originated mortgage that is resold, HMDA reports the type of institution that purchases it. I use this information to categorize mortgages sold to government sponsored enterprises (GSE), such as Fannie Mae or Freddie Mac, or to non-GSE institutions.

### **3.3. Additional Data Sources**

Zipcode-level house price indexes come from Zillow's publicly available house price indexes. Annual income statistics by zip code are reported in the IRS Statistics of Income (SOI). Annual within-zip code employment and payroll statistics are in the County Business Patterns (CBP) survey. Local demographics and characteristics of the housing stock are from the 2000 Decennial Census. All nominal variables are deflated by the CPI for all urban consumers from FRED. Refer to Appendix A for more details.

## **4. Empirical Analysis**

### **4.1. House Price Responses to Mortgage Credit and Housing Investment**

In this section I present an empirical analysis of the investment stabilization channel of housing markets. I test whether the response of house prices to negative mortgage credit shocks

depends on housing investment activity. If investment demand substitutes for the decline in homeowner demand following the shock, house prices should fall by less when investors buy a greater share of the houses available for purchase.

To estimate the effects of changes in mortgage credit and housing investment, I use an instrumental variables regression strategy with annual, zip code-level panel data over the period 2007 to 2010. The second-stage regression of the 2SLS specification is given by:

$$\begin{aligned}\Delta \log P_{z,t} = & \alpha_{c,t} + \gamma \Delta \log P_{z,t-1} + \zeta \Gamma_{z,t} + \beta \Delta \log M_{z,t} \\ & + \delta_1 (\Delta \log M_{z,t} \times \Delta \textit{Corporate Investor Share}_{z,t}) \\ & + \delta_2 (\Delta \log M_{z,t} \times \Delta \textit{Household Investor Share}_{z,t}) + \varepsilon_{z,t}\end{aligned}\quad (1)$$

where the subscripts  $z$  and  $t$  denote a given zip code and year,  $\Delta \log P_{z,t}$  is growth in real house prices,  $\Delta \log M_{z,t}$  is growth in mortgage originations, and  $\Delta \textit{Corporate Investor Share}_{z,t}$  and  $\Delta \textit{Household Investor Share}_{z,t}$  are annual changes in the fraction of houses purchased by each type of investor. A county-by-year fixed effect  $\alpha_{c,t}$  controls for county-specific trends in house price growth during the housing bust. I include the lag of the dependent variable  $\Delta \log P_{z,t-1}$  to absorb any serial correlation in house price growth. Finally, the vector  $\Gamma_{z,t}$  includes controls for changes in local income growth: per-capita pre-tax income, the growth in employment by firms within the zip code, and growth in real annual payrolls of firms within the zip code.<sup>22</sup>

In Equation (1), the effect of changes in mortgage credit is represented by changes in local mortgage originations.<sup>23</sup> To capture the effect of the investment stabilization channel, Equation (1) also includes interactions between the change in mortgage credit and changes in the local shares of houses purchased by corporate and household investors. Conditional on a negative mortgage credit shock, a shift in the composition of house buyers towards investors represents a substitution of homeowner demand for investor demand. The larger is this change in housing market composition and the smaller is the associated change in house prices, the stronger is the investment stabilization channel.

With respect to the estimated values of the coefficients  $\beta$ ,  $\delta_1$ , and  $\delta_2$ , we should expect that  $\beta \geq 0$ ,  $\delta_1, \delta_2 \leq 0$ , and  $|\delta_1| \geq |\delta_2|$ . First, since tightening mortgage credit decreases housing demand it should be associated with decreasing house prices. Second, if investment demand substitutes for falling homeowner demand, an increase in the investor share of house purchases should be associated with higher house price growth relative to the negative effect of tightening

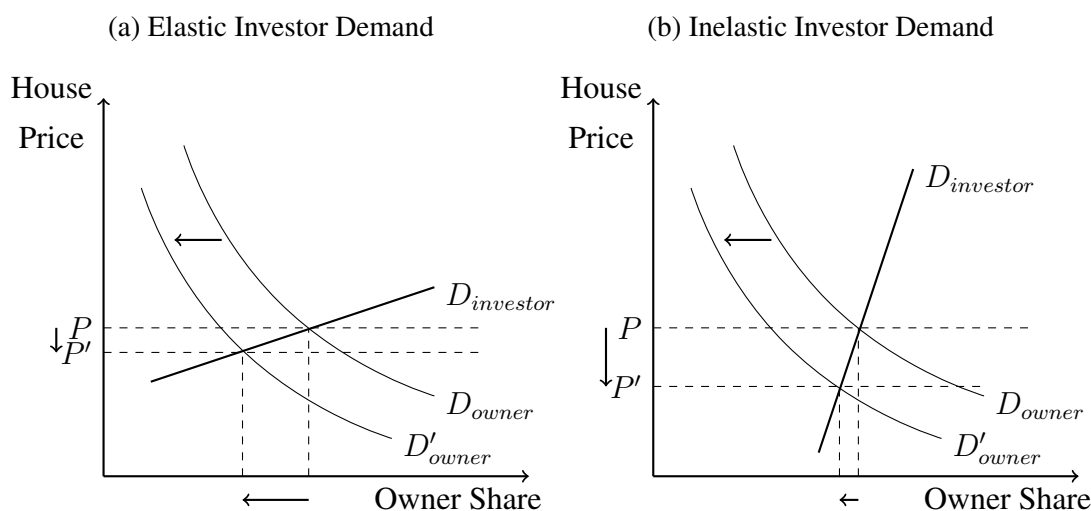
<sup>22</sup>See Section 4.4 for discussion of robustness exercises, including the addition of controls for other plausibly confounding factors.

<sup>23</sup>Estimates of the effect of mortgage credit on house prices are also reported in, for example, Favara et al. (2015), Mian et al. (2018), and Greenwald et al. (2019).

mortgage credit. Third, an increase in the corporate investor share should be associated with a larger increase in house prices than that associated with a similar sized increase in the household investor share. This latter is implied by the stylized facts about housing investment reported in Section 3.

Another way to understand the estimates provided by Equation (1) is to consider their relationship to the elasticities of corporate and household investment demand. To fix intuition, Figure 2 illustrates a simple model of a housing market subject to a housing demand shock. Suppose that market supply consists of a fixed number of houses that must be sold each period, and market demand consists of both homeowner and investor demand for houses. Because supply is fixed, homeowner demand can be expressed as a decreasing function of the homeowner share of houses purchased. Since investor demand is a decreasing function of the investor share of houses purchased, it can be expressed as an increasing function of the homeowner share.

Figure 2: Housing Market Equilibrium with Homeowners and Investors



Figures 2.a) and 2.b) show the housing market equilibrium responses to a decrease in homeowner demand caused by a tightening of mortgage credit. The figures represent two housing markets that differ only by the house price elasticity of investor demand. When investment demand is elastic, investors absorb a large fraction of the houses for sale, there is a large decline in the owner share of house purchases, and there is a small decline in house prices. When investment demand is inelastic, investors absorb a smaller fraction of houses purchased, the owner share changes very little, and prices decline by much more than in the elastic case.

In this simple model, a shock to homeowner demand traces out the slope of the investor demand curve. Conditional on this shock, observations on the change in house prices and the change in house purchase shares are sufficient to infer the elasticities of investor demand.

Thus, I use the 2SLS estimates of Equation (1) as sufficient statistics to calibrate elasticities of investment demand in the structural macroeconomic model presented in Section 5.

## 4.2. Instrumental Variables for Mortgage Credit and Investment

Changes in mortgage credit and investor purchase shares are likely to be endogenous to other determinants of local house prices. For example, a negative income shock decreases house prices, but is also associated with a decline in mortgage origination due to lower demand for houses. For this reason, I estimate Equation (1) via 2SLS using instrumental variables for the changes in mortgage credit and its interactions with the changes in investor purchase shares. The first stage regressions of the 2SLS procedure are given by

$$X_{z,t} = \alpha_{c,t} + \gamma \Delta \log P_{z,t-1} + \zeta \Gamma_{z,t} + \sum_j \eta_j Z_{z,t}^j + v_{z,t}^i \quad (2)$$

where  $X_{z,t}$  denotes one of the three explanatory variables in Equation (1). The instrumental variables  $Z_{z,t}^j$ , indexed by  $j$ , enter each of the first stage regressions. The first instrument, discussed in more detail below, is the share of mortgages sold in the secondary mortgage market to non-GSE institutions between 1998 and 2000, denoted  $\lambda_{z,98-00}^{nonGSE}$ . The second and third instruments are the interactions between the non-GSE share and the lagged corporate investor share  $\lambda_{z,98-00}^{nonGSE} \times \Delta Corporate\ Investor\ Share_{z,t-1}$  and the lagged household investor share  $\lambda_{z,98-00}^{nonGSE} \times \Delta Household\ Investor\ Share_{z,t-1}$ .

The first instrument,  $\lambda_{z,98-00}^{nonGSE}$ , represents local exposure to mortgage credit supply shocks, following Mian et al. (2009) and Mian et al. (2018). Justiniano et al. (2017) show that beginning in 2003, non-GSE institutions experienced a rapid increase in both the volume of mortgage purchases and market share in the secondary mortgage market. This culminated in a near-collapse of non-GSE activity in 2008.<sup>24</sup> Justiniano et al. (2017) argue that the rise and fall of non-GSE activity resembled a mortgage credit supply shock. This is because the timing of the increase in non-GSE activity was strongly associated with an increase in both mortgage originations and a decline in the mortgage interest rate spread over the risk-free rate. There was also geographic dispersion in the effects of this mortgage credit supply shock. Mian et al. (2009) show that locations with more exposure to non-GSE activity experienced more rapid growth in mortgage originations, more subprime mortgage borrowing, as well as higher mortgage default rates from 2005 to 2007. Mian et al. (2018) show that exposure to non-GSE activity predicted larger house price booms and busts, as well as more speculative investment activity during the boom.

<sup>24</sup>Drechsler et al. (2019) show that the market share of mortgages sold into private label securitization – those mortgages bought by non-GSEs and packaged into mortgage backed securities – began to slowly increase after 2012.

Both the growth in mortgage originations  $\Delta \log M_{z,t}$  and the non-GSE share instrument  $\lambda_{z,98-00}^{nonGSE}$  are constructed using HMDA data. First, I measure mortgage originations as all home purchase mortgages originated by one institution and sold to another institution within a reporting year. Then, following Mian et al. (2009), I compute the number of mortgages sold to non-GSE institutions. These institutions include: those purchasing explicitly for use in private securitization; commercial banks, savings banks, or savings associations; life insurance companies, credit unions, mortgage banks, or finance companies; purchases by affiliate institutions of the originator; and other types of purchaser.<sup>25</sup> The non-GSE share is computed for the period 1998 to 2000 to ensure that local exposures to mortgage credit supply shocks are uncorrelated with contemporaneous developments in housing markets during the housing bust. I choose the 1998 to 2000 period because it occurs before the significant increase in non-GSE activity in the mid-2000s, but not so early that it is unlikely to predict subsequent developments in mortgage markets.

The left panel of Figure 3 plots the distribution of non-GSE shares. There is significant cross-sectional variation in the instrument, with a mean value of 0.33 and a standard deviation of 0.11. The right panel of Figure 3 plots the national growth rates of total mortgage originations, mortgages sold to non-GSE institutions, and mortgages sold to the GSEs (i.e. Fannie Mae and Freddie Mac). Non-GSE mortgage purchase activity was significantly more volatile than overall mortgage origination growth during the boom and bust. Notice, however, that the national pattern of non-GSE activity was very similar to overall activity prior to the housing boom. To understand the significance of the cross-sectional heterogeneity in mortgage credit supply shock exposure, note that from 2006 to 2007 mortgage origination in zip codes at the 10<sup>th</sup> and 90<sup>th</sup> percentiles of the non-GSE share distribution would have contracted by 13 and 32 percent, respectively, if total originations had followed the national decline in non-GSE mortgage activity.

The results of the first stage regressions from Equation (2) are reported in Table C.1 in the Appendix, and illustrated in Figure 4. Each panel shows binned scatter plots of the instrument relevant to each explanatory variable, where all variables are residualized relative to the other controls in the regression. The dashed red line shows estimated first stage relationship between instrument and explanatory variable, with estimates also reported in Table C.1. The instruments strongly predict changes in mortgage originations and its interactions with the corporate and household investor shares of house purchases.

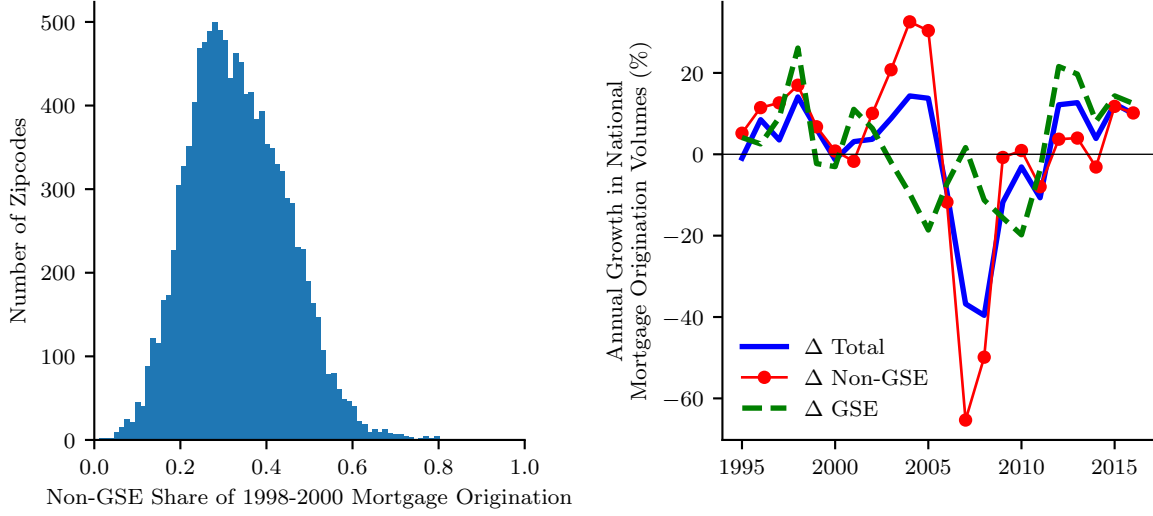
Two recent papers have made some progress in providing instrumental variables for hous-

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<sup>25</sup>See Appendix A for more details about the HMDA data. I also consider variations on this instrument in robustness exercises reported in Section 4.4.



Figure 3: Local Mortgage Origination Shares and National Mortgage Origination Volumes



*Notes:* Total mortgage origination growth includes mortgages that were originated but not sold to the secondary market within a given year.

*Source:* Author's calculations using HMDA.

ing investment activity. First, Garcia (2019) studies the effect of investment during the housing boom using the local fraction of vacation properties as an instrument. However, this instrument is less useful for studying investment by corporations or households that are landlords. Second, Lambie-Hanson et al. (2019) study the effect of corporate investor activity using variation in exposure to a program instituted by Fannie Mae and Freddie Mac giving preference to homeowners seeking to buy foreclosed properties.

### 4.3. Results

Table 2 reports the results of estimating Equation (1). All model specifications are estimated via 2SLS, using the instruments described in Section 4.2. Column (1) reports the average effect of changes in mortgage credit on local house price growth. I estimate an elasticity of 0.26, suggesting that a one standard deviation decrease in mortgage credit is associated with a 7.45 percent decline in house prices.

The estimated averaged effect of mortgage credit on house prices is consistent with previous estimates reported in the literature. Favara et al. (2015) produce estimates using changes in banking regulation as an instrument for the change in mortgage originations. With county-level data from 1994 to 2005, they estimate an elasticity of 0.14. Mian et al. (2018) also estimate the effect of mortgage credit on local house price growth. They report estimates for a reduced form

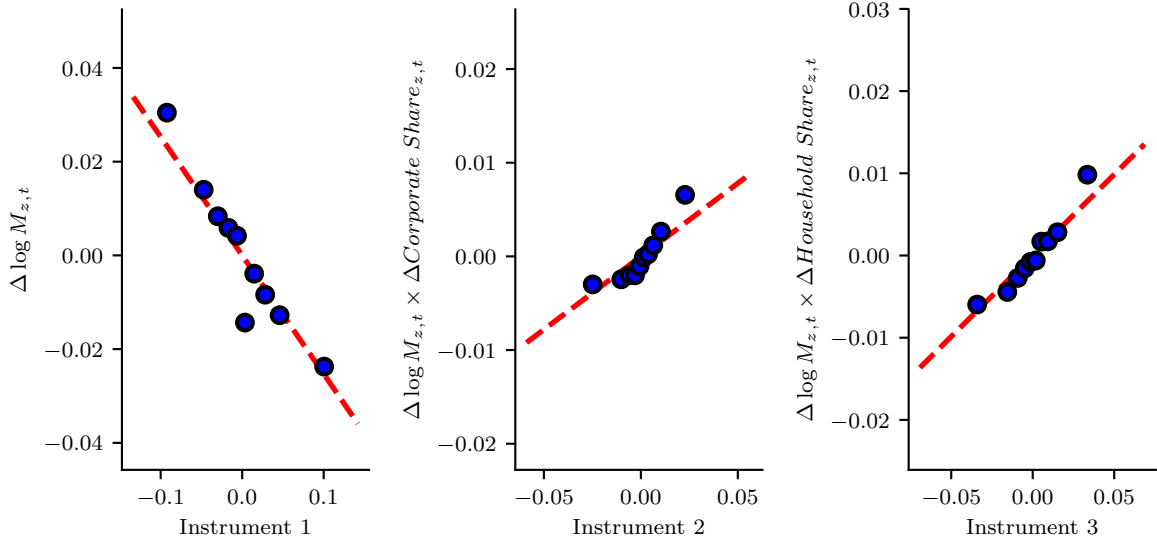
Table 2: Effect of Mortgage Credit and Investor Activity on Local House Prices

	$\Delta \log P_{z,t}$			
	(1)	(2)	(3)	(4)
$\Delta \log M_{z,t}$	0.260*** (0.053)	0.260*** (0.064)	0.266*** (0.053)	0.298*** (0.077)
$\Delta \log M_{z,t} \times$ $\Delta \text{Corporate Inv. Share}_{z,t}$		-2.147*** (0.530)		-2.599*** (0.665)
$\Delta \log M_{z,t} \times$ $\Delta \text{Household Inv. Share}_{z,t}$			-0.114 (0.243)	-0.716** (0.344)
Method	2SLS	2SLS	2SLS	2SLS
Sample	2007-2010	2007-2010	2007-2010	2007-2010
Observations	14,160	14,160	14,160	14,160
Zipcodes	3,960	3,960	3,960	3,960
Counties	470	470	470	470
Fixed Effects	County $\times$ Year	County $\times$ Year	County $\times$ Year	County $\times$ Year
Adjusted R-squared	0.44	0.39	0.43	0.27
F-statistics				
$F_{1 }$	22.16	28.06	33.65	34.88
$F_{2 }$	—	36.27	154.28	43.48
$F_{3 }$	—	—	—	75.56
Wald Statistic	—	—	—	13.85
p-value	—	—	—	0.00

*Notes:* All models estimated via 2SLS. The instrument for mortgage origination growth is local exposure to non-GSE mortgage purchases from 1998-2000. Changes in investor shares of house purchases are instrumented with their own lagged values. All models condition on: lagged house price growth; the contemporaneous shares of house purchases by each type of investor; the change in log-real per capita pre-tax zip code-level income; the change in log-employment by firms within the zip code; the change in log-real annual payroll by firms within the zip code. All models include county-by-year fixed effects. Column (1) reports the F-statistic for the first stage regression of the mortgage mortgage credit instrument on mortgage origination growth. Columns (2) through (4) report conditional F-statistics for the mortgage credit instrument and the instruments for the interactions between mortgage origination growth and the change in investor shares. Column (4) reports a Wald test for the hypothesis of equality between the coefficients on the interaction terms. Standard errors (reported in parentheses), F-statistics, and Wald test-statistics are clustered at the county level. \*, \*\*, \*\*\* denote significance at the 10%, 5%, and 1% levels.

*Sources:* Author's calculations using data from BLS, CBP, FRED, HMDA, IRS, Zillow, ZTRAX.

Figure 4: Effect of Mortgage Credit Instrument on Local Mortgage Origination Growth



*Notes:* Bin scatter plots of residualized explanatory variables and instruments, each representing a first stage regression in the 2SLS procedure. The residualized variables are reproduced from the fitted values from estimates of Equation (1). Each explanatory variable is plotted against the instrument that predicts it. These instruments are: instrument 1 =  $\lambda_{z,98-00}^{nonGSE}$ ; instrument 2 =  $\lambda_{z,98-00}^{nonGSE} \times \Delta Corporate Share_{z,t-1}$ ; instrument 3 =  $\lambda_{z,98-00}^{nonGSE} \times \Delta Household Share_{z,t-1}$ . The slopes of the red dashed lines report the first stage regression coefficients on the respective instruments.

*Sources:* Author's calculations using data from BLS, CBP, 2000 Census, FRED, HMDA, Zillow, ZTRAX.

specification, regressing differences in the local share of institutions with a high proportion of non-core liabilities on house price growth. Using zip code-level data from 2006 to 2010, they find that a one standard deviation greater exposure to high non-core liabilities lenders is associated with a 5 to 8 percent decline in house prices during this period.

Next I study how changes in investor activity are associated with the transmission of mortgage credit shocks to house prices. Columns (2) through (4) of Table 2 report the effect of the interaction between changes in mortgage credit and changes in the share of investor activity. Columns (2) and (3) include the interaction terms independently, while Column (4) jointly estimates the effects. The estimated coefficients for institutional investors are significantly more negative than for household investors. This is confirmed in the final rows of Column (5), which report a Wald test rejection of the null hypothesis of equality of the three interaction coefficients.

To interpret the negative value of the coefficients, note that a simultaneous decrease in mortgage credit and increase in the share of institutional investors, for example, is associated with an increase in house prices. Since the average effect of declining mortgage credit is

negative, the increase in the share of institutional investors results in a smaller decrease in house prices than would otherwise be the case. That is, an increase in investor activity dampens the effect of a negative mortgage credit shock on house prices. To interpret the magnitude of the coefficients, note that taking both the average and the interaction effects into account, a simultaneous one standard deviation decrease in mortgage credit and one standard deviation increase in institutional investor activity is associated with a 5 percent decline in house prices. And a one standard deviation increase in household investor activity is associated with a 7 percent decline in house prices. These estimates suggest that while increasing investor activity is generally associated with dampened house prices movements, institutional investors have a much stronger dampening effect than do household investors. On impact, for a similar sized mortgage credit shock, locations with an increase in the share of institutional investor activity are associated with 29 percent smaller declines in house prices than locations with an increase in the share of household investor activity.

#### 4.4. Robustness

To construct the instrument for mortgage origination growth, I follow Mian et al. (2009) in computing the share of non-GSE institution activity in the secondary mortgage market. However, it is not the case that every non-GSE institution packaged mortgages for PLS. For example, Figure B.5 in the Appendix shows that the HMDA-reported volume of mortgages originated for sale directly to PLS is less than a quarter of the volume sold to non-GSE institutions more broadly. It is worth noting, however, that the level of direct-to-PLS sales in HMDA appears to be significantly under-reported relative to more direct measures of PLS activity reported elsewhere (see, for example, Justiniano et al., 2017). Nevertheless, Table C.2 reports results using alternative definitions of the mortgage credit supply shock exposure instrument. Columns (1) and (4) report the benchmark results from Table 2; Columns (2) and (5) report results using the share of mortgages sold directly to PLS; and Columns (3) and (6) report results using the share of mortgages sold to PLS as well as non-banks.<sup>26</sup> The mortgage credit instrument constructed using only PLS activity is much weaker than either of the other instruments. However, I continue to find that corporate investor activity is associated with much smaller house price declines in response to credit shocks than is household investor activity.

Table C.3 in the Appendix explores whether the results are sensitive to the inclusion of controls for other plausibly confounding factors. Column (2) controls for the size of the run-up in

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<sup>26</sup>Non-banks are unlikely to hold individual mortgages for the purpose of balance sheet management, and so are more likely to have purchased mortgages for the purpose of securitization. See Appendix A for details about the definition of non-banks in HMDA data.

house prices between 2001 and 2006. Since exposure to mortgage credit supply shocks predicts the increase in house prices during the housing boom, it is possible that the subsequent fall in house prices is simply a function of the size of the boom rather than of tightening of mortgage credit during the bust. Column (3) controls for several measures of housing supply, including: county-level annual growth in the number of housing units permitted; the Saiz (2010) housing supply elasticity at the CBSA level interacted with year-dummies; and the fraction of houses built prior to 1990 and the fraction of houses with four or fewer rooms, both measured at the zip code level and interacted with year-dummies.<sup>27</sup> Housing supply may affect the volatility of house prices, which could influence both financial institutions' willingness to supply loans to a location and investors willingness buy into that location. Column (4) includes controls for the structure of the local banking market in 2000, including: the fraction of deposits held by banks that have a within-state headquarters; the Herfindahl index for deposits held across branches; and the Herfindahl index for deposits held across institutions. The structure of the local banking market may affect mortgage credit supply, as discussed in Drechsler et al. (2019) and Favara et al. (2015). Finally, Column (5) includes controls for local demographic factors in 2000 including: median age; fraction of households with no more than high school education; and the fraction of owner-occupiers. Demographics may predict mortgage credit supply, as discussed in Albanesi et al. (2017), but may also predict the evolution of the housing market during the housing bust.

Table C.3 shows little change in the estimates when conditioning on prior house price rises, local housing supply, and local banking competition. However, the inclusion of the demographic controls has some impact on the estimated coefficients. Although the changes are not statistically significantly different from the benchmark results, I find that the direct effect of mortgage credit is smaller, and the coefficients on the measures of investor activity are larger. Nevertheless, it is still the case that corporate investor activity is associated with smaller declines in house prices than household investor activity in response to credit shocks.

Table C.4 in the Appendix reports results using alternative data samples. Column (2) extends the sample period back to 2006 and through to 2012, which makes allowance for housing markets with slightly earlier or later turning points (see, for example, Ferreira et al., 2011). Column (3) increases the minimum number of house sales in a zip code in a year from 100 to 250. This restriction excludes smaller zip codes and those that had few house sales during the housing bust. Column (4) excludes the so-called Sand States, whose housing markets tended to have much larger fluctuations in house prices in the 2000s. I find little qualitative difference

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<sup>27</sup>Graham (2018) shows that the local composition of house characteristics is a strong predictor of local house price growth during the 2000s housing boom and bust

in results across these samples, although I find significantly more dampening of house prices associated with corporate investors in the large-zip codes sample. This is consistent with evidence presented in Mills et al. (2019) that large institutional investors were more active in large metropolitan areas during this period.

Finally, Table C.5 in the Appendix reports results using growth in the number of mortgage denials as the measure of mortgage credit, rather than growth in the number of mortgage originations. Again, the results of this exercise are quantitatively similar to those presented in the benchmark analysis.

## 5. Model

I build a macroeconomic model of the housing market in order to rationalize the main empirical findings of the paper. The model features heterogeneous, life-cycle households that make endogenous rental, homeownership, investment, and mortgage decisions. In addition, a corporate housing investment firm buys and sells properties, which it also leases to household renters. The interaction between owner-occupiers and investors in the housing market determines equilibrium house prices in response to a mortgage credit shock.

The life-cycle structure and household heterogeneity in the model are essential to produce realistic housing market responses to mortgage credit shocks. First, a rising income profile over the life-cycle encourages young households to borrow against future income in order to purchase homes. The life-cycle borrowing motive results in a distribution of debt across households as they pay down their mortgages over time. This reliance on mortgage debt ensures that an exogenous credit shock causes a significant contraction of homeowner demand for housing. Second, idiosyncratic income risk leads to a distribution of wealth since households save as a precaution against future income shocks. Because richer households are more likely to invest in residential real estate than poorer households, the distribution of wealth produces dispersion in the willingness to invest. This generates a realistic supply of potential investors across the population, and helps explain the low elasticity of household investment demand during a housing bust. Finally, the interaction of the life-cycle and household heterogeneity means that even many rich households hold mortgage debt against homes and investment properties. Thus, a shock to mortgage credit can affect the housing demand of current and potential investors, as well as homeowners.

In what follows, Section 5.1 describes the model setup in detail, Section 5.2 describes the model calibration, and Section 5.3 describes the results of model experiments featuring exogenous shocks to mortgage credit.

## 5.1. Environment

### Life-cycle

Households live for a finite number of periods with age indexed by  $j \in [1, \dots, J]$ . Households earn labor income throughout their working life, retire after age  $J_{ret}$ , and die with certainty at age  $J$ .

### Preferences

Household preferences are defined over non-durable consumption  $c$ , housing services  $s$ , and end-of-life bequests of wealth  $w$ . Lifetime utility is given by

$$\mathbb{E} \left[ \sum_{j=1}^J \beta^{j-1} u(c_j, s_j) + \beta^J v(w_{J+1}) \right]. \quad (3)$$

Period utility is given by

$$u(c, s) = \frac{(c^\chi s^{1-\chi})^{1-\sigma}}{1-\sigma}, \quad (4)$$

where  $\chi$  is the share of consumption in non-housing services. Housing services are chosen each period by renting households, and are adjusted infrequently by home-owning households. The bequests function  $v(\cdot)$  is defined over networth remaining at the end of life  $w_{J+1}$ . The function describes a warm-glow bequest motive following De Nardi (2004).<sup>28</sup> Bequests are given by:

$$v(w) = \psi \frac{(w + \underline{w})^{1-\sigma}}{1-\sigma},$$

where  $w$  is the amount of the bequest,  $\psi$  is the strength of the bequest motive, and  $\underline{w}$  governs the luxuriousness of bequests.

### Endowments

Households receive labor income during working-life, and a pension during their retirement. Labor income consists of a deterministic component, a persistent stochastic component, and a transitory stochastic component. During retirement households receive a fixed fraction of the deterministic and persistent components of income they received in the final period of working life. Log-income is

$$\log m_j = \begin{cases} g_j + y_j + z_j, & \text{for } j \leq J_{ret} \\ \log \omega + g_{J_{ret}} + y_{J_{ret}}, & \text{for } j > J_{ret}. \end{cases}$$

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<sup>28</sup>Kaplan et al. (2017) also use warm-glow bequests to motivate wealth holding. In order to match observed levels of wealth inequality, Favilukis et al. (2017a) assume that only a fraction of households possess a bequest motive.

During working life,  $g_j$  follows a deterministic age profile during working life,  $y_j$  follows an AR(1) process, and  $z_j$  is an IID shock. The replacement rate of income during retirement is  $\omega$ . This arrangement proxies for dispersal from retirement accounts accumulated during working life. Conditioning on the final period of deterministic and persistent income is a tractable way of modeling the relationship between the size of retirement accounts and recent working-life income.

## Liquid Assets

Households can save, but may not borrow, in a liquid asset  $a$ . The return on liquid assets  $r$  is fixed and determined in financial markets in the rest of the world. In the initial period of life households may receive bequests in the form of liquid assets.

## Housing

Housing services may be acquired by renting or owning property. In addition, households may purchase property for the purposes of investment.

Rental services  $s$  are a continuous choice each period, subject to the restriction that  $s \leq \bar{s}$ , where  $P_r$  is the price paid per rental unit. Both owner-occupied and investment properties are chosen from a finite set of available properties  $\mathcal{H}$ . Houses are purchased at the per-unit price  $P_h$ . All property sales are subject to a transaction cost  $f_s$  levied proportional to the total value of property sold. These costs represent closing and moving costs associated with house sales. Households pay for routine maintenance to avoid depreciation at rate  $\delta$ . The cost of depreciation is proportional to the market value of all properties.

Unlike owner-occupied properties, investment properties generate rental income. Investors receive the market rental rate  $P_r$  but must pay a per-period cost  $\phi$  proportional to the size of the investment property. This cost represents any additional maintenance or management costs associated with renting property to non-owner occupying tenants.

Note that in the steady state equilibrium house prices and rents are constant. However, in response to shocks prices adjust along the transition path. As a result, properties may earn capital gains for both homeowners and household investors.

## Mortgages

Households can finance property using mortgage debt. In order to economize on state variables, a single mortgage is secured against the combined value of owner-occupied and investment properties. Mortgages are long-term debt contracts during. During the mortgage



term, a fixed payment is required in every period unless the mortgage is refinanced or properties are sold and the mortgage is repaid. For tractability and following the literature, mortgages are amortized over the remaining life of a household. In this way, mortgage duration approximates the 30-year mortgage contracts common in the US housing market.

Let  $b$  denote an outstanding mortgage balance and  $r_b$  the mortgage interest rate. An age  $j$  household has  $J - j$  years remaining on the mortgage, which yields the following mortgage payment in the current period:<sup>29</sup>

$$\pi_j(b, r_b) = \frac{r_b(1 + r_b)^{J+1-j}}{(1 + r_b)^{J+1-j} - 1} b.$$

For a household making a mortgage payment, the end-of-period mortgage balance reflects accumulated interest during the period less the mortgage payment:  $b' = (1 + r_b)b - \pi(b, r_b)$ . The mortgage interest rate is larger than the risk-free interest rate,  $r_b > r$ , reflecting un-modeled term premia and default risk. Households can repay a mortgage more quickly than the schedule given by the constant amortization formula, however this requires refinancing which is costly.

At origination, mortgages are subject to a maximum loan-to-value (LTV) ratio constraint, given by

$$b \leq \theta_b P_h(h' + i'),$$

where  $\theta_b$  is the maximum LTV ratio, and  $P_h(h' + i')$  is the combined value of owner-occupied and investment property.

Following Greenwald (2018), new mortgages are also subject to a payment-to-income (PTI) constraint. Since investors earn rental income from their investment properties, the PTI constraint includes both labor income and gross rental income:

$$\pi_j(b, r_b) \leq \theta_m (m_j + P_r i').$$

where  $\theta_m$  is the maximum PTI ratio.

New mortgages require the payment of both fixed and proportional costs at origination. The fixed cost,  $F_b$ , is paid regardless of the size of mortgage, while the proportional cost  $f_b$  is levied on the amount of debt borrowed. The proportional cost reflects the discount points levied on new mortgages, while the fixed cost reflects other origination fees associated with new mortgages.

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<sup>29</sup>Note that the exponent term  $J + 1 - j$  ensures that households make mortgage payments in every period of life, including the final period  $J$ . The final payment is  $(1 + r_b)b$ , which is the entirety of remaining principal plus interest. This ensures that networth is always non-negative at the end of life.

## Household Decision Problems

Households enter a period with the state vector  $\mathbf{s} = \{a, h, i, b, y\}$ , where  $a$  is liquid assets,  $h$  is the owner-occupied house size,  $i$  is the investment property size,  $b$  is the outstanding mortgage balance, and  $y$  is the persistent component of labor income. A household chooses between renting ( $R$ ), maintaining its housing portfolio while making any required mortgage payments ( $N$ ), and adjusting its housing portfolio and mortgage debt ( $A$ ). The discrete choice of a household at age  $j$  with state  $\mathbf{s}$  is

$$V_j(\mathbf{s}) = \max \{V_j^R(\mathbf{s}), V_j^N(\mathbf{s}), V_j^A(\mathbf{s})\},$$

where  $V_j^R$  is the value function of a renter,  $V_j^N$  is the value function of an owner that does not adjust, and  $V_j^A$  is the value function of an owner that adjusts its property portfolio.

A renting household purchases housing services, consumes non-durable goods, and saves in liquid assets. If a house was previously owned, it is immediately sold and any outstanding mortgage is repaid from the proceeds. At the end of the period, renting households carry forward no housing assets or mortgage debt. The renter's problem at age  $j$  is

$$\begin{aligned} V_j^R(\mathbf{s}) = \max_{c, a', s} \quad & u(c, s) + \beta \mathbb{E}(V_{j+1}(\mathbf{s}')) \\ \text{s.t.} \quad & c + a' + P_r s + b(1 + r_b) = m_j + (1 + r)a + (1 - f_s)P_h(h + i) \\ & a' \geq 0, h' = 0, i' = 0, b' = 0 \end{aligned} \quad (5)$$

A non-adjusting household consumes non-durable goods, enjoys the housing services generated by the existing house, saves in liquid assets, pays housing maintenance costs, makes a mortgage payment on any outstanding mortgage debt, and receives rental income if it holds investment property. The problem of a non-adjusting household at age  $j$  is

$$\begin{aligned} V_j^N(\mathbf{s}) = \max_{c, a'} \quad & u(c, h) + \beta \mathbb{E}(V_{j+1}(\mathbf{s}')) \\ \text{s.t.} \quad & c + a' + \delta P_h(h + i) + \pi_j(b, r_b) = m_j + (1 + r)a + (P_r - \phi)i \\ & b' = b(1 + r_b) - \pi_j(b, r_b) \\ & a' \geq 0, h' = h, i' = i \end{aligned} \quad (6)$$

An adjusting household may consume non-durable goods, receive housing services generated by a newly purchased house, purchase new investment properties, sell any previously held properties, repay the entirety of any outstanding mortgage balance, originate a new mortgage, save in liquid assets, pay housing maintenance costs, and receive rental income on any new

investment property. The problem of an adjusting household at age  $j$  is

$$\begin{aligned}
V_j^A(\mathbf{s}) &= \max_{c, a', h', i', b'} u(c, h') + \beta \mathbb{E}(V_{j+1}(\mathbf{s}')) \\
\text{s.t. } & c + a' + \mathbb{1}_{h' \neq h} P_h(h' - (1 - f_s)h) + \mathbb{1}_{i' \neq i} P_h(i' - (1 - f_s)i) \\
& + \delta P_h(h' + i') + b(1 + r_b) = m_j + (1 + r)a + (1 - f_b)b' - \mathbb{1}_{b' > 0} F_b + (P_r - \phi)i' \\
& b' \leq \theta P_h(h' + i') \\
& \pi(b, r_b) \leq \theta_y (m_j + P_r i') \\
& a' \geq 0
\end{aligned} \tag{7}$$

Note that an adjusting household can refinance its mortgage by not adjusting its housing and investment properties:  $h' = h$ ,  $i' = i$ . Finally, for tractability I assume households must own a primary property before purchasing an investment property.<sup>30</sup>

### Corporate Rental Sector

An unconstrained risk-neutral corporate investment firm is also active in the housing market. The firm is held by outside owners that have access to the risk-free liquid asset. The firm trades property each period, rents out its housing stock, pays regular maintenance costs, and pays a convex portfolio holding cost associated with the number of houses held. The firm maximizes the present discounted value of profits via, where its problem is given by

$$\begin{aligned}
p(I) &= \max_{I'} P_r I' + P_h I - (1 + \delta) P_h I' - P_h Q(I') + \frac{1}{R} \mathbb{E}[p(I')] \\
\text{s.t. } & Q(I') = \kappa^{-(1+1/\varepsilon)} \frac{I'^{1+1/\varepsilon}}{(1 + 1/\varepsilon)}.
\end{aligned}$$

where  $Q(\cdot)$  is the convex holding cost function. The first order condition yields

$$I' = \kappa^{1+\varepsilon} \left( \frac{P_r + \frac{1}{R} \mathbb{E}[P_h'] - (1 + \delta) P_h}{P_h} \right)^\varepsilon. \tag{8}$$

which is the corporate firm's investment demand curve. The demand curve is a function of the return to housing before holding costs, so increases in returns due to rising rents or temporarily declining house prices induce greater corporate housing investment. The parameter  $\varepsilon$  represents the elasticity of corporate investment demand. When  $\varepsilon = \infty$ , demand is perfectly elastic and the rental rate is pinned down by  $P_r = (1 + \delta + 1/\kappa) P_h + \frac{1}{R} \mathbb{E}[P_h']$ . When  $\varepsilon = 0$ , corporate investment demand is perfectly inelastic and is given by  $I' = \kappa$ .

---

<sup>30</sup>In the Survey of Consumer Finances, around 13% of household with residential investment property report not owning a primary property.

The corporate investment firm presented here is closely related to models of corporate rental investment described in the literature. In Chambers et al. (2009b) the firm produces rental units each period subject to a convex cost function. But while their corporate firm plays a role in rental markets, it does not buy or sell property and so is not an active participant in housing markets. In Kaplan et al. (2017) the corporate firm buys and sells properties that it leases in the rental market. However, the firm faces a linear cost structure so that the first order condition generates the standard Jorgensonian user-cost formula for the rental rate. This case is nested by the current formulation, as can be seen when  $\varepsilon = \infty$ .

## Equilibrium

The solution of the model consists of general equilibrium in housing and rental markets. The households' state vector is  $\mathbf{s} = \{a, h, i, b, y\} \in \mathcal{S}$ . In what follows I drop the dependence of variables on the state vector. Let  $\iota^X$  be an indicator function equal to one when a household makes the discrete choice  $X \in \{R, N, A\}$ . Let  $\mu_j$  denote the measure of households aged  $j$ , defined on the state space  $\mathcal{S}$ . The total population across all cohorts is measure one:  $\sum_{j=1}^J \mu_j = 1$ . Let  $Q_{j,j+1}$  denote a matrix describing the transition of the distribution of households across states  $\mathbf{s}$  and from age  $j$  to  $j + 1$ .

A *stationary recursive competitive equilibrium* is a set of value functions  $\{V_j^R, V_j^N, V_j^A\}_{j=1}^J$ , decision rules  $\{\iota_j^R, \iota_j^N, \iota_j^A, c_j, a'_j, d_j, h'_j, i'_j, b'_j\}_{j=1}^J$ , corporate rental demand  $I'$ , a house price  $P_h$ , a rental rate  $P_r$ , the supply of houses  $\bar{H}$ , and stationary measures  $\{\mu_j\}_{j=1}^J$  such that:

- Given prices, households optimize and  $\{V_j^R, V_j^N, V_j^A\}_{j=1}^J$  and  $\{\iota_j^R, \iota_j^N, \iota_j^A, c_j, a'_j, d_j, h'_j, i'_j, b'_j\}_{j=1}^J$  are the value functions and decision rules associated with the solution to household Problems (5), (6), and (7),
- Given prices, corporate investment demand  $I'$  is given by the firm's first order condition, Equation (8).
- The rental rate  $P_r$  is consistent with rental market clearing:

$$\sum_{j=1}^J \left[ \int \iota_j^D d_j d\mu_j \right] = \sum_{j=1}^J \left[ \int (\iota_j^A + \iota_j^N) i'_j d\mu_j \right] + I'$$

where the expression on the left is household rental demand, and the expression on the right consists of the household and corporate investment properties supplied to the rental market.

- Given housing supply  $\bar{H}$ , the house price  $P_h$  is consistent with housing market clearing:

$$\sum_{j=1}^J \left[ \int (\iota_j^A + \iota_j^N) h_j' d\mu_j \right] + \sum_{j=1}^J \left[ \int (\iota_j^A + \iota_j^N) i_j' d\mu_j \right] + I = \bar{H}$$

where the expression on the left consists of the total number of owner-occupied houses held by households, and the total number of investment properties held by households and the corporate rental sector.

- The law of motion for the stationary distribution of households is

$$\mu_{j+1} = Q_{j,j+1} \mu_j$$

Details concerning the computational algorithm are discussed in Appendix D.

## 5.2. Steady State Calibration

I calibrate the model to capture salient features of US homeownership, investment ownership, and indebtedness in the mid 2000s, immediately prior to the housing bust. Panel A of Table 3 reports model parameters set according to external information. The model period is one year, households work for 41 periods (age 25 to 65) and die after 56 periods (age 80). The risk aversion parameter is set to 2, as is standard in the macroeconomics literature. The income process consists of the parameters for the deterministic age-profile, the persistent AR(1) component, and the transitory IID component of income. I follow a standard procedure for estimating the parameters of the deterministic and stochastic income processes using data from the Panel Study of Income Dynamics. The estimated persistence and volatility parameters are consistent with results reported in the literature (Floden et al., 2001; Storesletten et al., 2004; Guvenen, 2009; Heathcote et al., 2014). Details of the estimation are reported in Appendix D. The replacement rate for retirement income is set at 50 percent of final period non-transitory income following Díaz et al. (2008).

The risk-free interest rate  $r$  is set to 1.5%, which matches the real rate on 10-year Treasury bills reported in FRED from 2003 to 2006. The mortgage interest rate  $r_b$  is set to 3.15%, which corresponds to the real rate on 30-year mortgages over the same period. The proportional cost of originating a mortgage,  $f_b$ , is set at 0.5% of the size of the mortgage, consistent with the average size of mortgage origination fees and discount points in the mid 2000s. The proportional cost of selling a house,  $f_s$ , is set to 6%, in line with various estimates of property sales costs. The required maintenance (depreciation) rate for residential property  $\delta$  is set to 3%, consistent with the estimates reported in Harding et al. (2007). In order to discipline the set of house sizes

Table 3: Model Parameters

Description	Parameter	Value	Source
<b>A. Externally Calibrated Parameters</b>			
Length of life (years)	$J$	56	Standard
Retirement age (years)	$J_{ret}$	41	Standard
Risk aversion	$\sigma$	2	Standard
Persistence of income shocks	$\rho_y$	0.948	PSID, own calculations
Std. dev. of persistent income shocks	$\sigma_y$	0.178	PSID, own calculations
Std. dev. of transitory income shocks	$\sigma_z$	0.294	PSID, own calculations
Retirement income replacement rate	$\omega$	0.500	Díaz et al. (2008)
Risk free interest rate	$r$	0.0150	FRED
Mortgage interest rate	$r_b$	0.0315	FRED
Proportional mortgage origination cost	$f_b$	0.005	FRED
Proportional housing transaction cost	$f_s$	0.060	Standard
Housing depreciation rate	$\delta$	0.030	Harding et al. (2007)
Maximum LTV ratio	$\theta_b$	0.900	See text
Maximum PTI ratio	$\theta_m$	0.400	See text
Elasticity of corporate demand	$\varepsilon$	0.000	See text
<b>B. Internally Calibrated Parameters</b>			
Discount factor	$\beta$	0.891	Calibrated
Non-durable share	$\chi$	0.739	Calibrated
Bequest luxuriousness	$\bar{w}$	9.519	Calibrated
Bequest desirability	$\psi$	242.390	Calibrated
Minimum house size	$\underline{h}$	2.144	Calibrated
Fixed mortgage origination cost	$F_b$	0.026	Calibrated
Housing supply	$\bar{H}$	1.909	Calibrated
Landlord cost	$\phi$	0.014	Calibrated
Corporate rental cost	$\kappa$	0.005	Calibrated

Notes:

available for purchase, I make the strong simplifying assumption that only one house size (i.e.  $\underline{h}$ ) is available for purchase as either owner-occupied or investment property.<sup>31</sup> I set the maximum LTV and PTI ratios to 0.9 and 0.4, respectively. These values are consistent with the empirical evidence on the distribution of originated mortgages reported in Greenwald (2018).

To calibrate the size of bequests received by households at the beginning of life, I reproduce features of the observed distribution of networth for young households.<sup>32</sup> I use data for households aged 23 to 25 pooled across the SCF samples in 1998, 2001, 2004, and 2007. I split households into five income bins, and within each bin compute the fraction of households with positive networth. Within each bin, for households with positive networth I compute quantiles of the networth-to-income distribution. Liquid asset bequests are then allocated to households across the initial income distribution in the model according to the empirical distribution of networth-to-income.<sup>33</sup>

Finally, for the steady state calibration of the model I set the corporate elasticity  $\varepsilon$  to zero. All else equal the elasticity governs the response of corporate investment to changes in housing returns, which occur outside of the steady state. When  $\varepsilon = 0$ , I calibrate the corporate holding cost scale parameter  $\kappa$  to match the share of purchases made by corporate investors. As discussed in Section 5.3, a one-to-one mapping between  $\varepsilon$  and  $\kappa$  allows for experiments that keep the steady state constant while varying the elasticity of the corporate investor.

Panel B of Table 3 reports the model parameters calibrated via simulated method of moments (SMM). I use a SMM procedure that chooses the values of nine parameters  $\{\beta, \chi, \bar{w}, \psi, \underline{h}, F_b, \phi, \kappa, \bar{H}\}$  to minimize the distance between a set of model moments and their empirical counterparts. I choose an over-identified SMM procedure because many of the cross-sectional household statistics used as moments are correlated with each other (e.g. wealth, homeownership, and indebtedness). The discount factor  $\beta$  governs both household wealth accumulation and indebtedness. The weight on non-durable consumption in the utility function  $\chi$  determines the share of housing services in consumption, which indirectly affects both homeownership rates and indebtedness. The bequest parameters  $\psi$  and  $\bar{w}$  affect savings behavior and wealth inequality as households approach the end of their lives. The minimum housing size  $\underline{h}$  is associated with the affordability of housing relative to renting, which influences the homeownership rate of the young, investment ownership rates, and the indebtedness of both

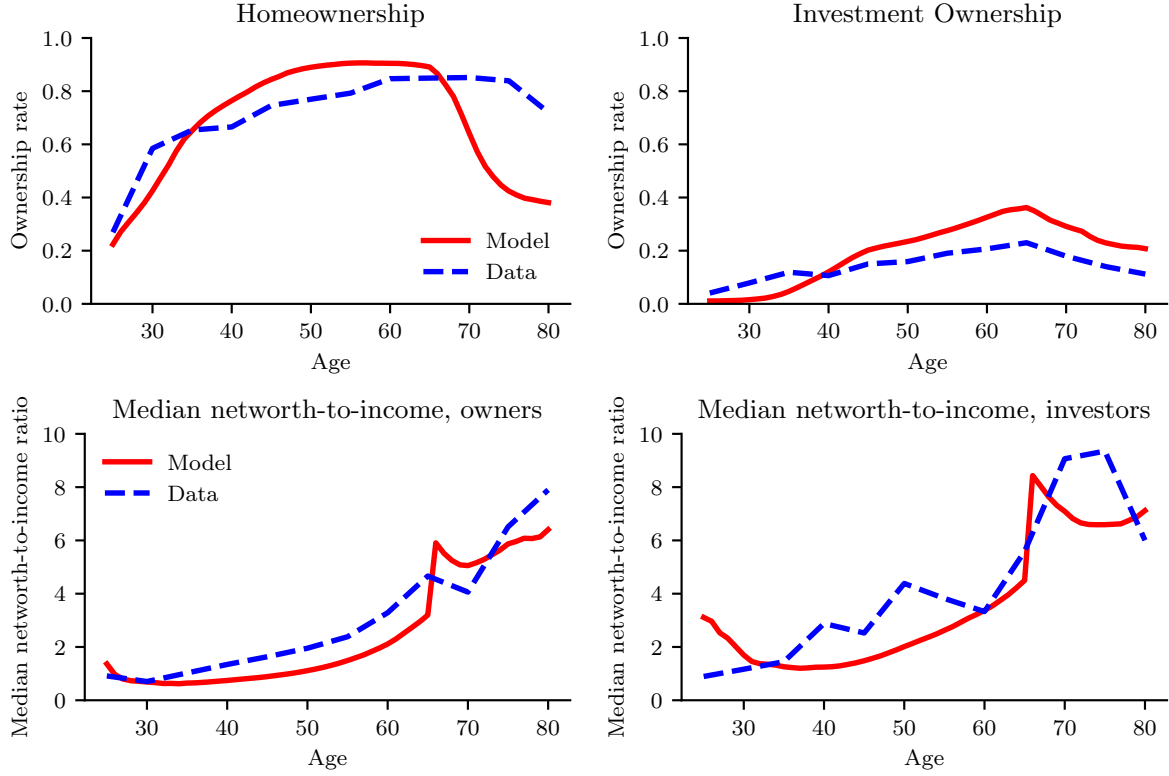
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<sup>31</sup>This is also a significant aid in computational tractability. In several unreported experiments, I verified that this assumption does not significantly affect the distribution of homeownership or indebtedness relative to, for example, making 2 or 3 house sizes available for purchase.

<sup>32</sup>This is similar to the procedure adopted elsewhere in the literature, for example, Chambers et al. (2009b) and Kaplan et al. (2017).

<sup>33</sup>I opt for this relatively simple procedure to avoid the difficulty of distributing observed liquid assets, houses, investment properties, and mortgage debt to households in the model.

Figure 5: Household Ownership and Network Over the Life-Cycle



*Notes:* Data moments are computed from the 2007 SCF. The data moments are computed for centered, five-year windows around the ages 25 to 80 at five-year intervals. For consistency with the model, network consists of liquid assets and equity in primary and secondary property.

homeowners and investors conditional on holding a mortgage. The landlord cost  $\phi$  enters the steady state rental return for household investors and so affects both investment ownership rates and indebtedness conditional on being an investor. The fixed mortgage origination cost  $F_b$  affects the illiquidity of housing since it makes equity extraction more costly.<sup>34</sup> The investment firm's holding cost  $\kappa$  sets the level of corporate housing demand, which determines the share of house purchases made by the corporate sector. Finally, the supply of housing  $\bar{H}$  affects the average cost of all housing services, which primarily determines the overall homeownership rate.

Table 4 reports the fit between the model and data for the targeted moments and a range of non-targeted moments. The majority of these statistics are computed from the 2007 wave of the SCF. For consistency with the definition of network in the model, I compute network in the SCF as owner-occupied and investor property less mortgage debt, plus liquid assets, and minus liquid liabilities. I measure investment ownership as the fraction of households that own

<sup>34</sup>For a discussion of the various determinants of housing illiquidity, see Gorea et al. (2017).

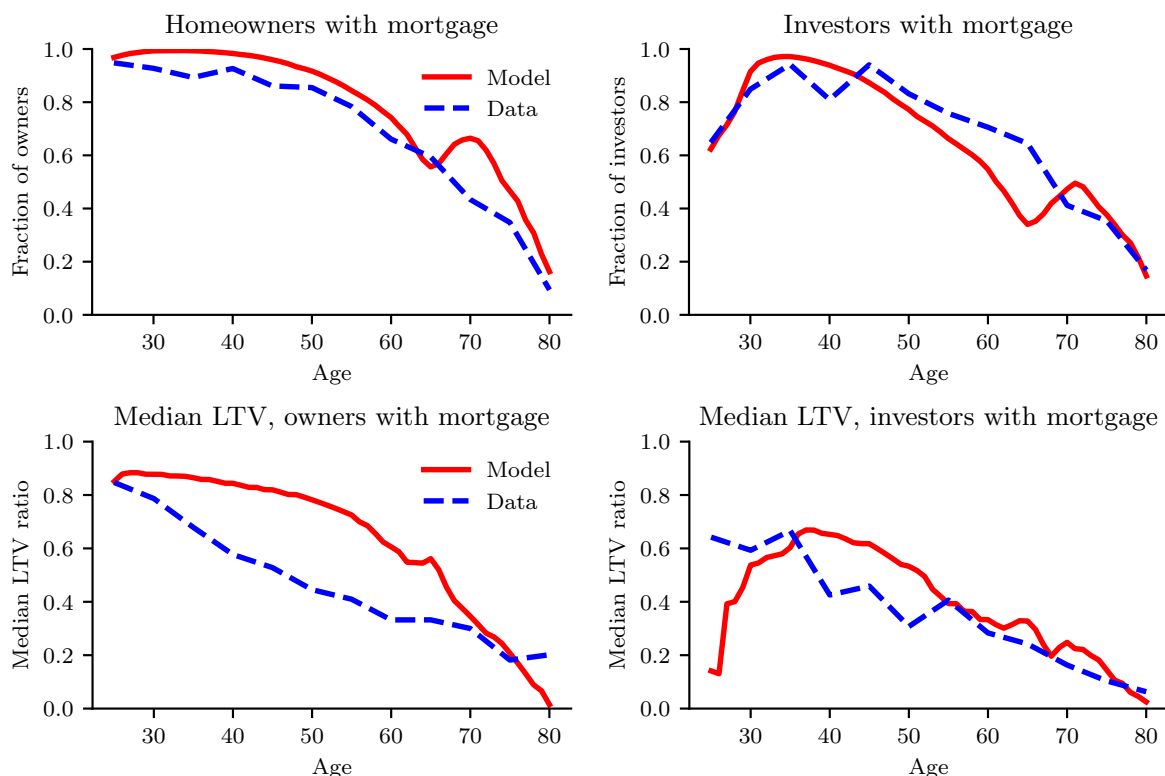


Table 4: Model Fit to Targeted and Non-Targeted Moments

Description	Model	Data	Source
<b>A. Targeted Moments</b>			
Homeownership rate	0.69	0.69	FRED, 2006
Investment ownership rate	0.20	0.15	SCF, 2007
Fraction of owners with mortgage	0.79	0.76	SCF, 2007
LTV ratio, owners with mortgage, p50	0.77	0.51	SCF, 2007
Mortgage debt/income, owners with mortgage, p50	1.98	1.53	SCF, 2007
Fraction of investors with mortgage	0.66	0.74	SCF, 2007
LTV ratio, investors with mortgage, p50	0.39	0.38	SCF, 2007
Mortgage debt/income, investors with mortgage, p50	1.55	1.52	SCF, 2007
House value/income, owners, p50	2.58	2.98	SCF, 2007
Networth/income, p50	0.98	1.18	SCF, 2007
Median networth ratio, ages 65-80 to 40-55	1.74	1.72	SCF, 2007
Homeownership rate, age $\geq 70$	0.46	0.83	SCF, 2007
Homeownership rate, age $\leq 35$	0.44	0.51	SCF, 2007
Annual mortgage refinancing rate	0.10	0.12	Bhutta et al. (2016)
Corporate investor share of purchases	0.08	0.07	ZTRAX, 2005-2007
<b>B. Non-Targeted Moments</b>			
Networth/income, p10	0.18	0.00	SCF, 2007
Networth/income, p90	5.25	7.66	SCF, 2007
Housing networth/networth, owners, p10	0.42	0.48	SCF, 2007
Housing networth/networth, owners, p50	0.76	0.95	SCF, 2007
Housing networth/networth, owners, p90	0.95	1.07	SCF, 2007
Investor share of total household-held housing	0.31	0.43	SCF, 2007
Household investor share of purchases	0.25	0.24	ZTRAX, 2005-2007
Annual fraction of houses sold	0.03	0.10	Ngai et al. (2019)
Household investor share of rental stock	0.99	0.88	Chambers et al. (2009a)
Corporate investor share of rental stock	0.01	0.12	Chambers et al. (2009a)

*Notes:* For consistency with the model, networth in the data is measured as total net housing wealth and net liquid assets. Following Kaplan et al., 2014, liquid assets are: checking, saving, money market and call accounts, plus directly held mutual funds, stocks, corporate bonds and government bonds. Liquid liabilities are: credit card balances.

Figure 6: Household Indebtedness Over the Life-Cycle



*Notes:* Data moments are computed from the 2007 SCF. The data moments are computed for centered, five-year windows around the ages 25 to 80 at five-year intervals. For consistency with the model, mortgage holding rates and LTV ratios are computed for homeowners and investors with either primary property or secondary property mortgage debt.

secondary residential property. While 15 percent of households do so, only half as many report receiving rental income in the past year. Although all households with secondary property in the model are landlords, I opt to target the higher rate of secondary property ownership since I cannot distinguish between household motivations for purchasing property in the housing transactions data reported in Section 3. All mortgage holding rates, LTV ratios, debt-to-income ratios, and networth statistics are computed using the combination of primary and secondary property mortgage debt. Data on mortgage refinancing is taken from Bhutta et al. (2016), who report an annual rate of 12 percent for 2007. The corporate and household investor shares of house purchases are computed as the median share across zip codes from 2005 to 2007.

Panel A of Table 4 shows that the model closely matches many of the targeted moments. However, the model somewhat overstates homeowner LTV and debt-to-income ratios. This occurs because the calibration also aims to match investor indebtedness, which is difficult to generate in the steady state of the model. In steady state, housing returns are much lower than in

US data where housing has produced substantial capital gains over time (see Jordà et al., 2019). A related issue is that the model fails to match the homeownership rate of older households. A much stronger bequest motive would be required to match this homeownership rate, but this strengthens the wealth accumulation motive which again decreases both homeowner and investor levels of mortgage debt. Panel B of Table 4 reports the model fit relative to a set of non-targeted moments. Notably, the model does well at matching dispersion in the distributions of both networth and homeowners' housing equity.

Figures 5 and 6 show the evolution of ownership, networth, and indebtedness over the life-cycle. Although these are untargeted model moments, they are important for understanding which households are likely to be affected by mortgage credit shocks, and which households are likely to supply resources for housing investment. Homeownership and investment property ownership rates trace out similar hump-shaped profiles in both the model and the data. Homeownership rates rise with age both as income increases and households accumulate savings for the down-payment on a house. Housing investment tends to occur later in life as households pay down their primary mortgage debt and begin to accumulate wealth for retirement and bequests. Note, too, that the rental income on investment properties is valuable to older households whose retirement income is much lower than the labor income they earned during working life.

Household wealth, as measured by networth relative to income, rises over the life-cycle in line with the data. Additionally, the model captures the fact that household investors of all ages tend to be wealthier than homeowners and also accumulate wealth more quickly as they age. The jump in networth-to-income at age 65 in the model is due to the sharp decline in income for all households at retirement. In contrast, households in the data retire at different ages which smooths through this sudden decline in income. Another discrepancy is that young household investors are much wealthier in the model than in the data. This is because investment in the model comes after households have purchased a home to live in. The only households in the model in a position to buy both primary and secondary property when young are those who received exceptionally large bequests relative to their income.

Figure 6 shows that the model matches rates of mortgage holding very well for both homeowners and investors. However, the model overstates the median LTV ratio of homeowners during middle age. The primary reason for this is that mortgages are amortized in the model at a much slower rate than in the data. In the model mortgages are repaid over households' entire lives, rather than the 30-year period that is typical of mortgage contracts held by households in the data. Given the constant amortization formula, households primarily repay mortgage interest during the early part of the mortgage contract and repay principal later in the contract.

### 5.3. Model Response to Mortgage Credit Shocks

I now use the model to study the role that investors play in stabilizing housing markets during the a mortgage credit contraction. To do this, the steady state of the model is perturbed by an exogenous, unexpected negative shock to mortgage credit supply. I then compare equilibrium responses across economies in which the elasticity of investment demand differs due to differences in the composition of investors following the mortgage shock. I first discuss the the mortgage credit supply shock, and then explain the way in which I vary the composition of investors.

To generate a mortgage credit supply shock, I exogenously change parameters in the model that capture the main features of the late 2000s mortgage credit contraction. This follows similar experiments conducted in the literature.<sup>35</sup> The mortgage credit supply shock is represented by temporary exogenous changes, as summarized in Table 5. First, the mortgage interest rate spread over the risk free rate,  $r_m - r$ , rises by 1 percentage point. This matches the increase in the average mortgage interest rate spread over the ten-year treasury rate observed in the data.<sup>36</sup> Second, the proportional mortgage origination cost  $f_b$  rises 0.25 percentage points, which is consistent with the increase in mortgage origination fees and discount points on 30-year mortgages observed in the data. Finally, both of the LTV and PTI constraints  $\theta_b$  and  $\theta_m$  decrease by 10 percentage points. This is consistent with evidence on changes in borrowing constraints reported in Greenwald (2018). I assume that the economy begins in the steady state, is hit by a negative shock lasting seven years, and then transitions back to the original steady state. The choice of seven years corresponds to the housing bust period between 2006 and 2012.<sup>37</sup>

In order to rationalize the empirical results in Section 4, I compare the equilibrium responses across economies with different compositions of investors following the credit shock. I do this by exogenously varying the elasticity of corporate investment demand  $\varepsilon$ . When  $\varepsilon$  is close to zero, the corporate investor does not respond to changes in house prices or rents. As housing demand from homeowners falls, household investment demand must rise in order to clear the housing market. When  $\varepsilon$  is greater than zero, the corporate investor is sensitive to changes in returns and invests more in response to changes in prices and rents. When  $\varepsilon$  is large, the corporate investor is much more sensitive to price changes than the household investor, and decreases in homeowner demand are entirely absorbed by increasing corporate investment

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<sup>35</sup>See Iacoviello et al. (2013), Hedlund (2016), Guerrieri et al. (2017), Kaplan et al. (2017), Favilukis et al. (2017a), Greenwald (2018), Garriga et al. (2018), and Garriga et al. (2019).

<sup>36</sup>This is also consistent with evidence in Justiniano et al. (2017), who estimate that the mortgage interest rate spread over the risk-free rate fell 80 basis points in response to the positive mortgage credit supply shock that drove the housing boom in the early 2000s.

<sup>37</sup>I study the effect of the different components of the mortgage credit shock separately in Appendix D.

Table 5: Exogenous Negative Mortgage Credit Supply Shock

Description	Parameter	Boom Value	Bust Value
Mortgage interest rate	$r_b$	0.0315	0.0415
Proportional mortgage origination cost	$f_b$	0.0050	0.0075
Maximum LTV ratio	$\theta_b$	0.90	0.80
Maximum PTI ratio	$\theta_m$	0.40	0.30

*Notes:* Exogenous changes to parameter values for a negative mortgage credit supply shock. The shock is unexpected and switches the parameters from the boom state to the bust state for seven years, and then reverts to the boom state.

activity.

I ensure that the only way in which economies with different investor compositions vary is via the elasticity of corporate investment demand. This means that responses to the shock are only due to differences in investor behavior following the shock, and not due to differences in the steady state distribution of ownership, networth, or mortgage debt. To do this, I employ a one-to-one mapping between the corporate investor cost parameter  $\kappa$  and the elasticity  $\varepsilon$ . For a given steady state equilibrium with prices  $P_h$  and  $P_r$  and corporate investment demand  $I'$ , Equation (8) yields

$$\kappa(\varepsilon) = (I')^{\frac{1}{1+\varepsilon}} \left( \frac{P_r + \frac{1}{R}P_h - P_h(1+\delta)}{P_h} \right)^{\frac{-\varepsilon}{1+\varepsilon}}. \quad (9)$$

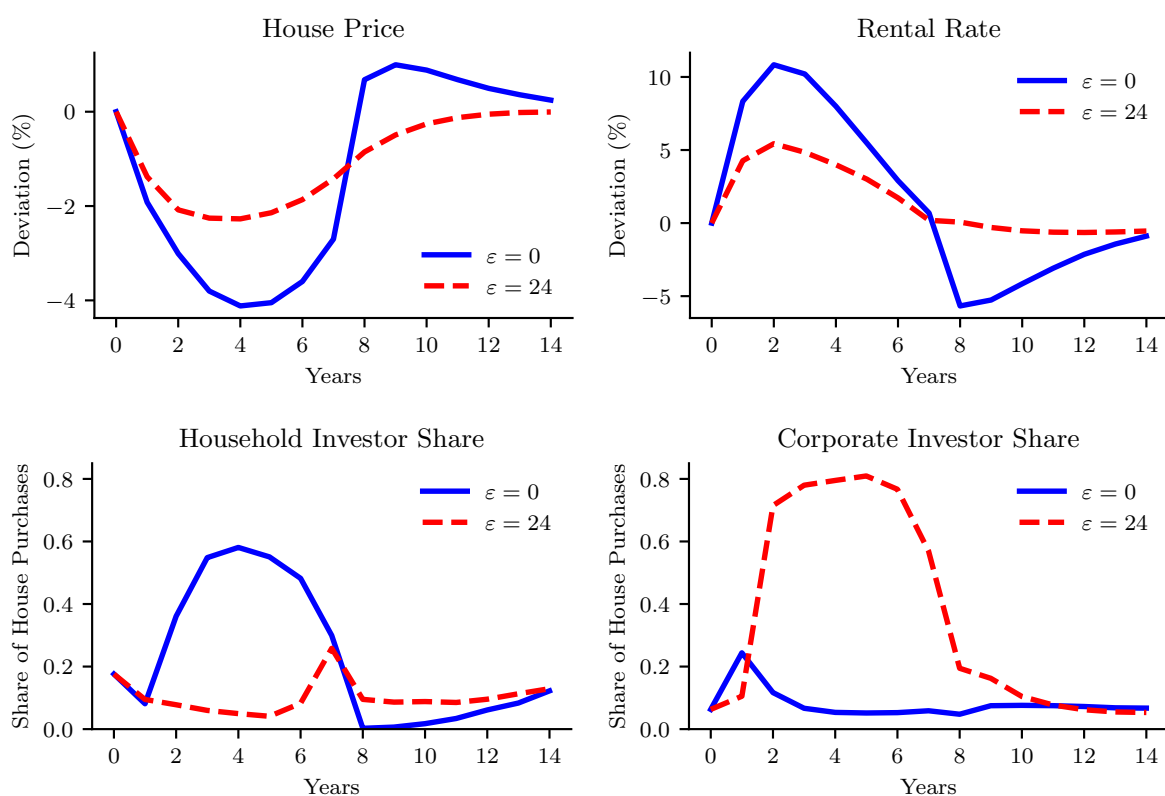
Thus,  $\kappa$  varies with  $\varepsilon$  so that the steady state of the economy remains unchanged.

I use the estimated house price responses associated with each type of investor to infer appropriate values of the corporate investment demand elasticity  $\varepsilon$ . In the first economy, I normalize  $\varepsilon$  to zero. This represents housing markets in which household investors absorbed a large share of house purchases, but where there was very little change in corporate investment demand. In the second economy, I choose  $\varepsilon$  so that the decline in house prices on impact is 30 percent smaller than in the economy with  $\varepsilon = 0$ . This corresponds to the estimated decline in prices for markets facing a one standard deviation increase in the share of corporate purchases relative to markets facing a one standard deviation increase in household investor purchases.<sup>38</sup> To match this relative change in prices, I set  $\varepsilon = 24$ .

<sup>38</sup>See Section 4.3.

Figure 7 presents impulse responses to the negative mortgage credit shock in the two economies. The primary result is that housing market outcomes are much more volatile in the economy that relies on household investment activity following the shock rather than corporate investment activity. The direct effect of the credit shock is to make mortgage borrowing more costly and to tighten borrowing constraints. The primary effect on housing demand comes through the homeowner channel, since in the steady state homeowners purchase 67 percent of all houses and virtually all of these purchases are made using a mortgage. As homeowner demand falls, however, the equilibrium response differs markedly across the two economies. When  $\varepsilon$  is high, house prices are much more stable than when  $\varepsilon = 0$ : on impact prices fall by 28 percent less, and after four years house prices fall by 45 percent less.

Figure 7: Impulse Responses to a Negative Mortgage Credit Supply Shock

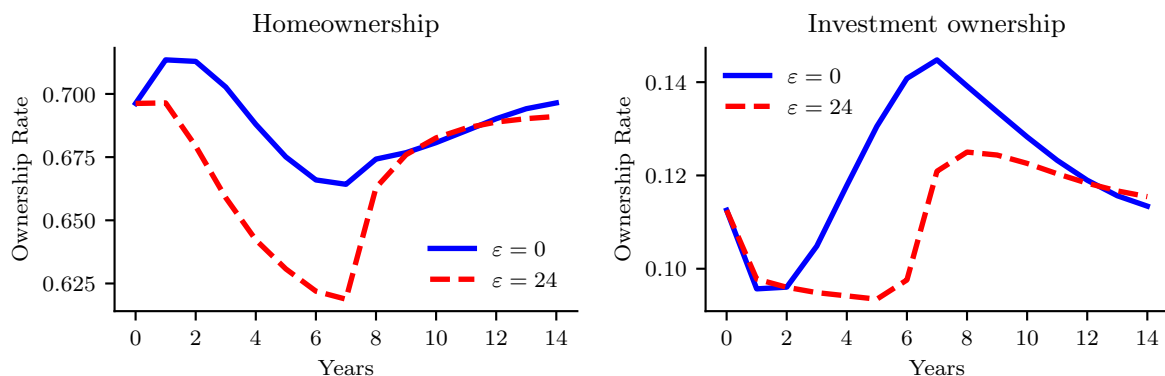


Notes: Impulse responses to a negative mortgage credit supply shock lasting seven years. Responses plotted for economies with  $\varepsilon = 0$  and 24.

The effect of changing the corporate elasticity can be seen in the differences in investor composition of house buyers over the course of the shock. When  $\varepsilon = 0$ , household investors absorb an increasing share of total house purchases, while the corporate purchase share is relatively flat. When  $\varepsilon$  is high, corporate investors purchase an increasing share of houses,

while the household investor share declines. Note, too, that the corporate investor share rises by much more in the latter economy than does the household investor share when  $\varepsilon = 0$ . Since corporate investment activity is also associated with smaller declines in house prices, the implied elasticity of household investment demand must be much lower than the elasticity of corporate investment demand. Thus, corporate investors provide a much better substitute for falling homeowner demand than do household investors. I discuss the reasons for this in 5.4.

Figure 8: Impulse Responses to a Negative Mortgage Credit Supply Shock



Notes: Impulse responses to a negative mortgage credit supply shock lasting seven years. Responses plotted for economies with  $\varepsilon = 0$  and 24.

Figure 8 shows that the differences in the composition of the housing market following the mortgage credit shock are large enough to affect overall property ownership rates. When the corporate investor dominates the housing market, for example, it purchases such a large fraction of the housing stock that the homeownership rate declines by more than six percentage points, and household investment ownership rates decline more than one percentage point. In contrast, when  $\varepsilon = 0$ , homeownership rises slightly at first and eventually decline by less than two percentage points, and household investment ownership rises by nearly two percentage points over the course of the shock. The large decline in homeownership rates associated with rising corporate investment activity is consistent with recent empirical analysis of the effects of corporate housing investment during the housing bust presented in Lambie-Hanson et al. (2019).

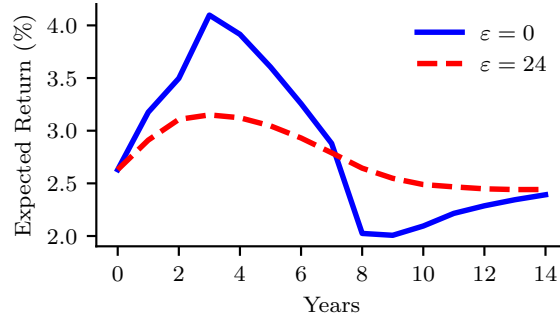
The differences in house prices and rental rate responses across economies is reflected in different equilibrium expected rates of return on housing. Figure 9 shows the annualized five-year expected return on housing in the two economies. I compute the expected return for a risk-neutral household investor who buys in cash, discounts at the risk-free interest rate, earns rental income, pays the landlord and maintenance costs, and incurs a transaction cost when the

property is resold. The return is given by:

$$ER_t^{5yr} = \frac{\sum_{k=0}^{T-1} \frac{1}{R^k} (P_{r,t+k} - \phi) + \frac{1}{R^T} \mathbb{E}_t [(1 - f_s) P_{h,t+T}] - P_{h,t} - \sum_{k=0}^{T-1} \frac{1}{R^k} \delta P_{h,t+k}}{P_{h,t}}$$

Note that returns differ for investors using mortgage finance to purchase a property. The larger decline in prices and rise in rents in the economy dominated by household investors results in higher expected housing returns over the course of the shock. In equilibrium, higher expected returns are necessary to attract additional household investors into the housing market. This is consistent with a much lower elasticity of investment demand for households than for corporate buyers. Section 5.4 discusses the factors that account for this low sensitivity of household investment demand.

Figure 9: Five-Year Expected Housing Return, Annualized



Finally, the results presented in this section are in contract to one of the primary conclusions of the analysis in Kaplan et al. (2017). In their model, credit shocks have no effect on house prices, but have significant effects on the homeownership rate. This is because the corporate investor that provides rental services in their model is equivalent to a corporate investor in the current model where  $\varepsilon \rightarrow \infty$ .<sup>39</sup> As credit shocks cause households to move out of owner-occupied housing and into rental housing, the perfectly elastic corporate investor absorbs the housing stock and rents it to new household tenants. Because the corporate investor is perfectly elastic, ownership of the housing stock changes hands, but prices do not change. Greenwald et al. (2019) try to resolve the lack of price movement in response to credit shocks by introducing segmented housing markets. This market segmentation prevents prospective investors from purchasing owner-occupied property in order to stabilize house prices. In the current paper, when corporate investors are not perfectly elastic, house prices must fall in order to induce additional investment. The decline in prices is largest when inelastic household investors are

<sup>39</sup>See the discussion of the corporate investor in Section 5.1.



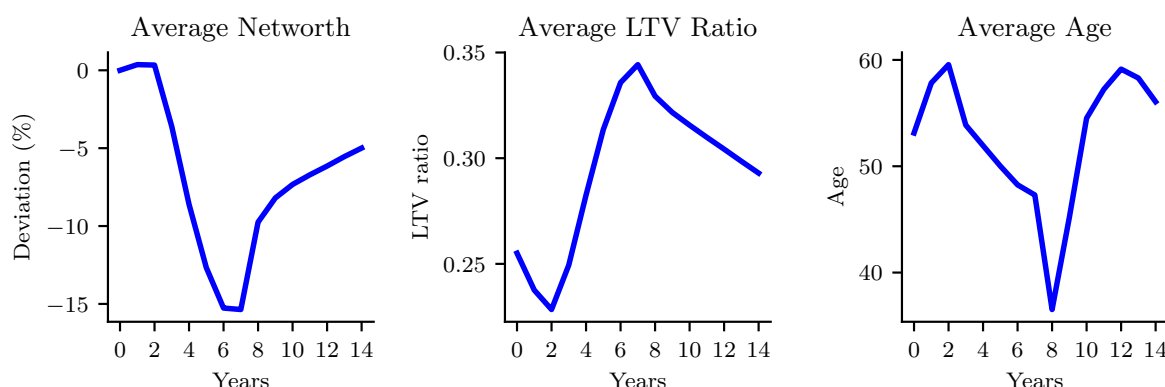
required to absorb the fall in homeowner demand. As discussed in the next section, the inelasticity of household investors is due to certain characteristics of investors that affect investment demand, rather than due to characteristics of the houses being traded.

## 5.4. The Determinants of Household Investment in the Housing Bust

House prices decline by much more following a mortgage credit shock when household investors are required to purchase the housing stock. In equilibrium, prices must fall further because household investors are much less sensitive to house prices and returns than are corporate investors. In this section I study why households require such large returns on housing in order to induce additional investment during a housing bust. I consider how household investment activity is influenced by wealth and indebtedness, house prices and rental rates, the illiquidity of housing, and losses on primary property wealth. Each of the following model experiments is conducted relative to the benchmark economy in which  $\varepsilon = 0$ .

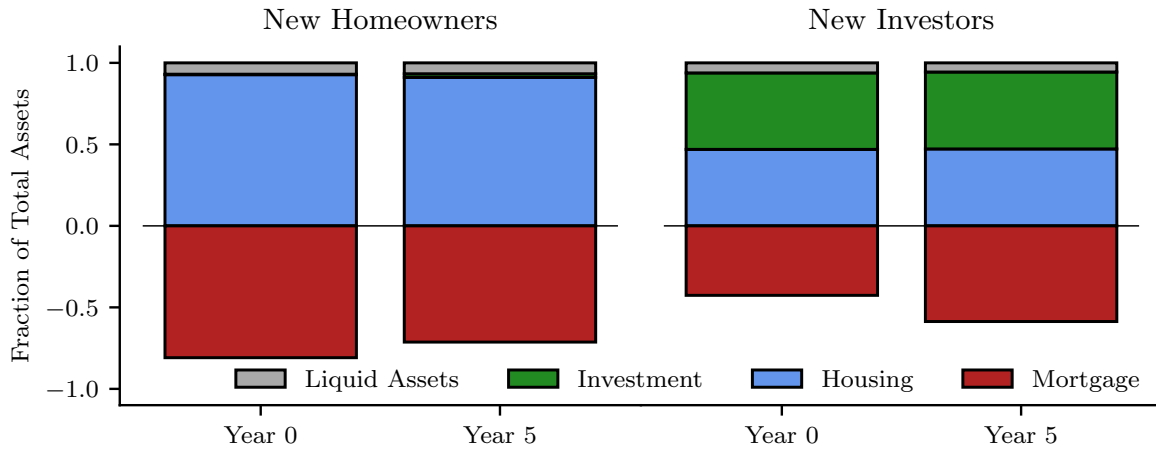
Figure 10 shows that housing investors change markedly over the course of the mortgage credit shock. The figure reports the average networth, LTV ratio, and age of households that purchase an investment property within the given period. As the household investor share of purchases begins to rise in the third year of the shock (see Figure 7), the typical investor is younger, less wealthy, and more indebted. Figure 11 reemphasizes these facts by showing the change in the balance sheets of new property buyers. By the fifth year of the housing bust, new investors are much more indebted than new investors in the steady state. This contrasts with new home buyers in the bust, who are much less indebted than new home buyers in the steady state.

Figure 10: Wealth and Indebtedness of the Marginal Household Investor



Throughout the course of the mortgage credit shock, homeowner demand falls and household investors are required to purchase properties. At the steady state rate of return, all house-

Figure 11: Change in Balance Sheets of New Property Buyers from Steady State to Bust



*Notes:* The figure shows the balance sheet composition of new home and investment property buyers in the steady state and in the fifth year of the mortgage credit shock. Balance sheets are pooled across all home buyers and investment property buyers, respectively.

holds for which housing investment is an attractive option have already invested. Additional household investment during the bust must come from younger, poorer, and more indebted households. But to induce these households to invest, prices must fall to generate large enough returns to compensate for the reallocation of resources towards investment property as well as the higher cost of financing this investment.

The effect of higher mortgage costs on households' willingness to invest can be seen by comparing investment behavior in partial and general equilibrium, under the same mortgage credit shock. Table 6 reports the responses of different measures of house purchase activity in partial and general equilibrium. In partial equilibrium, the mortgage credit shock causes investment activity to fall well below steady state. For example, investment purchases remain 52 percent below steady state in the fifth year of the shock (first column), and investment ownership rates remain 23 percent below steady state (second column). In general equilibrium, the decline in house prices and rise in housing returns cause investment purchases to rise rapidly from the third year of the shock. Similarly, from the third year forward investment ownership rates also rise in general equilibrium relative to partial equilibrium. Note, too, that housing investment purchases are much more sensitive to the change in returns than are home purchases. The third column shows that the decline in house prices in general equilibrium has a very muted effect on home purchase activity relative to partial equilibrium.

Figure 12 shows that the increase in housing returns that induces household investment in general equilibrium is related to the change in house prices, not to the change in rental rates.

Table 6: The Sensitivity of Property Purchases to a Mortgage Credit Supply Shock

Year	$\Delta$ Investment Purchases (%)		$\Delta$ Investment Ownership (%)		$\Delta$ Home Purchases (%)		$\Delta$ Home Ownership (%)	
	<i>p.e.</i>	<i>g.e.</i>	<i>p.e.</i>	<i>g.e.</i>	<i>p.e.</i>	<i>g.e.</i>	<i>p.e.</i>	<i>g.e.</i>
1	−89.3	−88.1	−10.5	−15.0	−84.3	−77.1	−5.1	2.5
2	−77.8	10.7	−15.3	−14.7	−70.5	−62.9	−9.2	2.4
3	−69.5	195.0	−18.6	−6.8	−58.2	−52.1	−12.5	0.9
4	−62.3	289.5	−21.0	4.7	−45.2	−43.3	−14.9	−1.2
5	−51.5	282.6	−22.7	16.0	−29.7	−36.1	−16.5	−3.0

*Notes:* Housing market activity in response to the mortgage credit supply shock under general equilibrium (*g.e.*) and partial equilibrium (*p.e.*). All variables measured as percent deviations from steady state.

Each of the lines represents a different partial equilibrium experiment: the solid blue line holds both house prices and rental rates constant, the dashed red line holds rents constant but allows house prices to follow their general equilibrium path, and the green circled line hold prices constant but allows rents to follow their general equilibrium path. When house prices fall as they do in general equilibrium, both the investment ownership rate and the investor share of house purchases rise significantly over the course of the shock. In contrast, when only the rental rate changes, investment activity is largely unchanged relative to the partial equilibrium in which no prices adjust. Thus, household investment responses are primarily due to the higher expected capital gains that generated by the sharp decline in house prices during the housing bust.

As new household investors enter the housing market during the bust, they must reallocate liquid assets to illiquid investment property. An important source of housing illiquidity is the housing resale cost  $f_s$ . Although households can earn capital gains on housing by buying properties during the housing bust and reselling during the recovery, transaction costs reduce the net return on holding investment property during this period. Therefore, the path of equilibrium house prices in response to the credit supply shock embeds a housing liquidity premium.<sup>40</sup>

To assess the importance of this liquidity premium, I re-compute impulse responses to the

<sup>40</sup>Gorea et al. (2017) stress the importance of the illiquidity of owner-occupied property for explaining household consumption responses to income shocks. Hedlund (2016) studies endogenous housing liquidity premia in a search and matching model of the housing market.

Figure 12: Household Investment in Partial Equilibrium

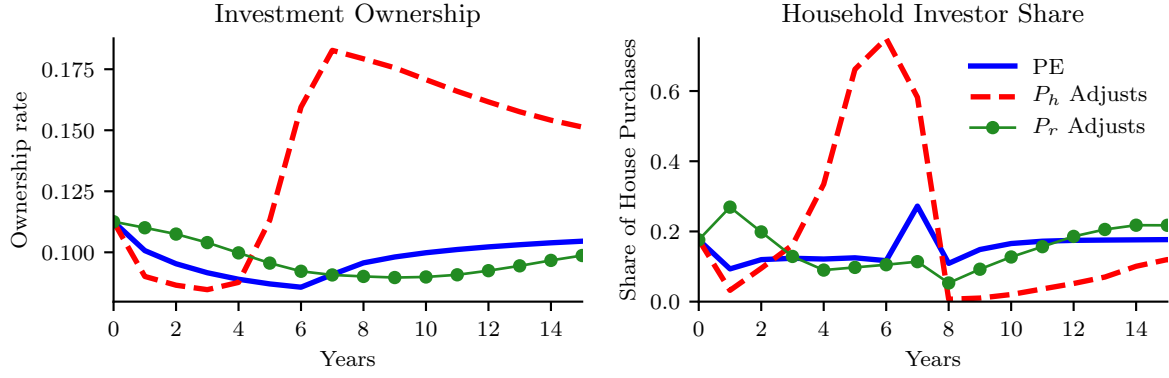
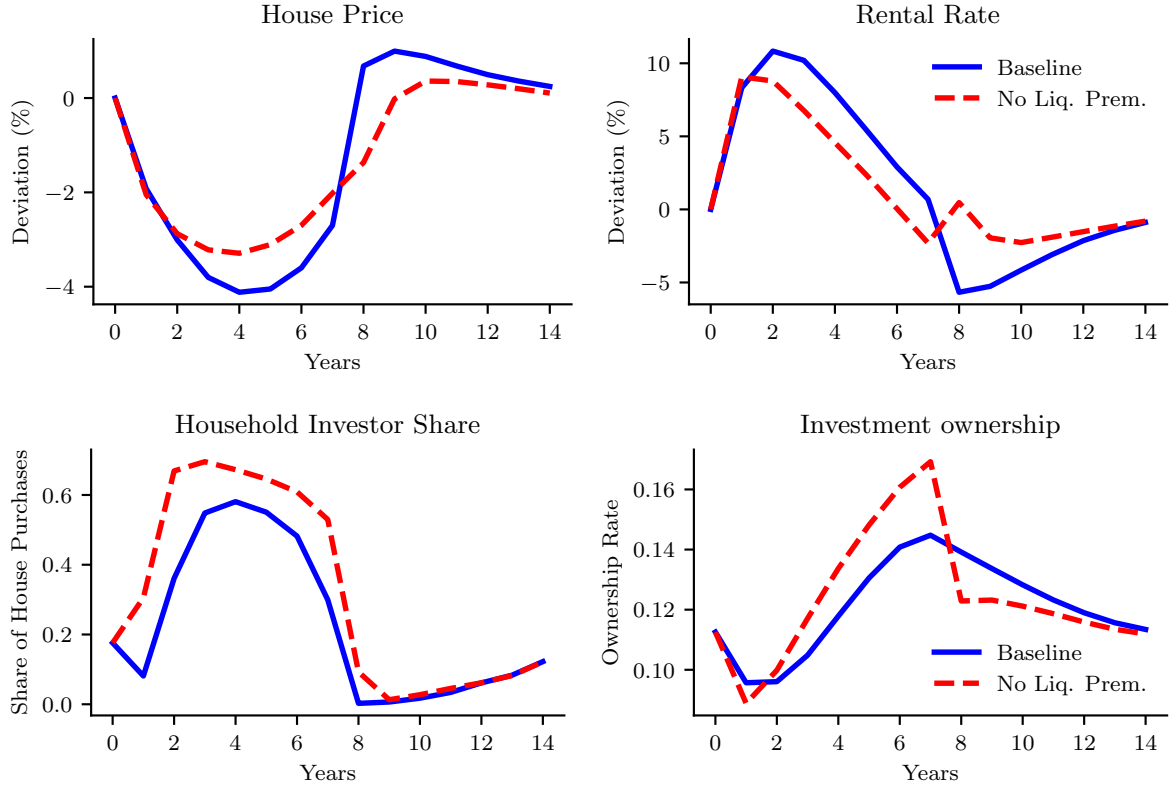


Figure 13: Impulse Responses With Lower Investment Property Transaction Costs

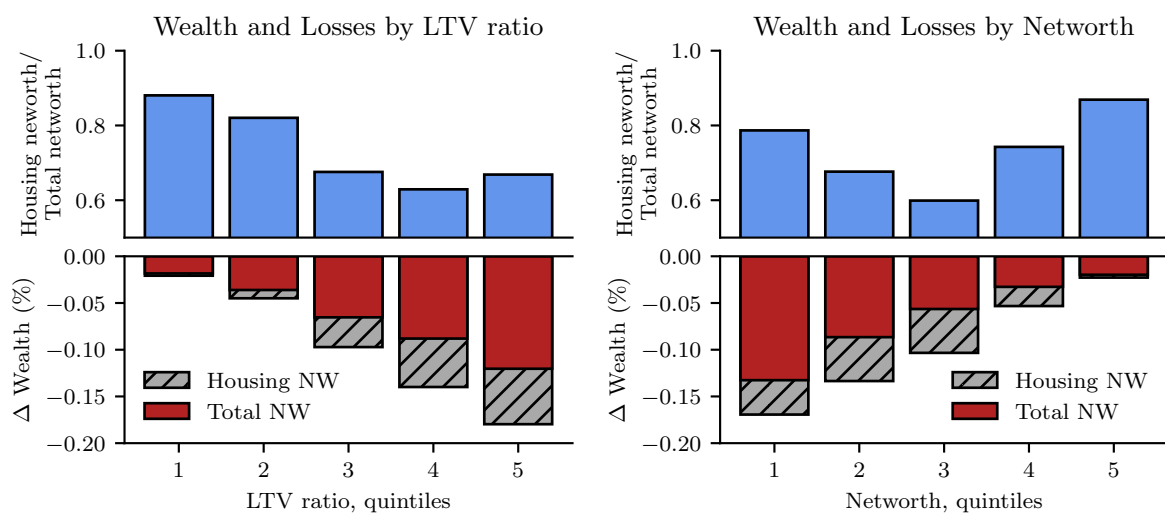


Notes: Impulse responses to a negative mortgage credit supply shock lasting seven years. Both sets of responses are for economies with  $\varepsilon = 0$ . The red dashed lines show responses for an economy in which the property transaction cost for investment properties  $f_s$  is set to zero for eight years.

mortgage credit shock while also setting  $f_s = 0$  specifically for investment properties. I set  $f_s = 0$  for eight years, which enables investors to resell their properties costlessly during the first year of the housing recovery. Figure 13 shows that in comparison to the baseline economy,

house prices fall by less, and household investment activity rises by more and more rapidly during the course of the shock. Temporarily lower investment transaction costs encourage household investors to purchase properties during the housing bust, but also encourage them to resell properties before costs rise again. This results in a sharp drop in investment ownership rates at the end of the housing bust. However, this is also when homeowner demand for houses rises, so the reallocation of properties from investors to homeowners prevents house prices from overshooting, as occurs in the baseline economy. By the fourth year of the credit shock, house prices fall by one fifth less in the model with lower investment transaction costs. This suggests that the liquidity premium on investment properties accounts for as much as 20 percent of the decline in house prices in economies where household investors are marginal house buyers.

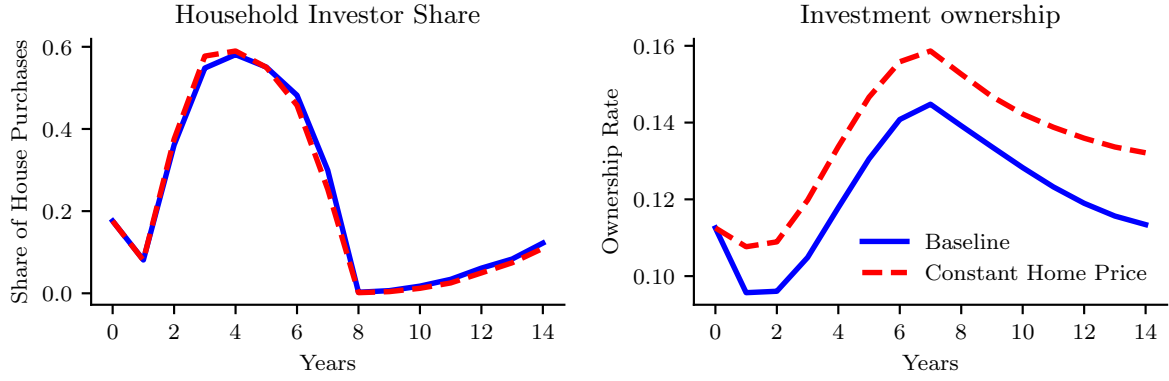
Figure 14: Homeowner Wealth Losses Given Initial House Price Decline After Credit Shock



*Notes:* The upper panels of each figure show the average fraction of network held in housing network. The lower panels of each figure show the average percentage decrease in housing and total network following the decline in house prices in the first period after the mortgage credit shock (see Figure 7). The left and right panels report values for quintiles of the distributions of homeowner LTV ratios and network, respectively.

Finally, I study the effect of the changes in household wealth along the transition path on households' willingness to invest in additional housing. Figure 14 shows the wealth losses experienced by homeowners in the first period following the mortgage credit shock, before further decisions are made. Although house prices decline by only two percent on impact, both housing wealth and total wealth decline by much more when households are indebted. For example, homeowners in the highest quintile of the LTV distribution lose more than 15 percent of their housing network and more than 10 percent of their total network following the shock. Since homeowners invest in secondary property as their wealth rises, the decreases in primary

Figure 15: Impulse Responses With the Home Prices Held Constant



*Notes:* Impulse responses to a negative mortgage credit supply shock lasting seven years. Both sets of responses are for economies with  $\varepsilon = 0$ . The red dashed lines show responses for an economy in which the price of investment property follows the equilibrium path associated with the baseline economy, but where the price of owner-occupied property is held constant.

housing wealth may discourage households from investing even when expected returns are high.

Figure 15 illustrates a partial equilibrium experiment in which the price of investment property follows the equilibrium house price path, but the price of owner-occupied property remains at its steady state value. This means that existing homeowners do not lose wealth along the transition path, but can purchase investment properties at a discount relative to the steady state price of housing. The impulse responses show that investment ownership initially falls by less and then rises by more over the course of the credit shock. However, the household investor share of house purchases is largely unchanged relative to the baseline. This suggests that while the loss of primary property wealth causes many household investors to disinvest, it does not discourage households from becoming investors. Nevertheless, the experiment shows that net household investment demand is decreases when households face losses in wealth due to declining house prices.

## 5.5. Housing Investment and Household Welfare

The previous results show that housing investment plays an important role in stabilizing housing markets during a housing bust. Because corporate investors are much more elastic than household investors, house prices and rental rates are much more stable when corporate investors are more prevalent in the housing market following a mortgage credit shock. However, greater corporate investment activity is also associated with much larger declines in the

homeownership rate. Moreover, the profits earned by corporate investment in housing does not accrue to households since the investment firms are not owned by households within the economy.

I now evaluate whether the housing market stability associated with corporate investors is welfare improving for households. Household welfare is measured by the consumption equivalent value (CEV) of moving from the economy in which household investors dominate the housing market following a shock ( $\varepsilon = 0$ ), to the economy in which corporate investors dominate the housing market following a shock ( $\varepsilon = 24$ ). The CEV is computed for all households alive in the first period of the mortgage credit supply shock.<sup>41</sup> Note that in the steady state of the model, household welfare is identical in both economies, since the elasticity of the corporate investor only affects household and equilibrium outcomes along the transition path in response to a shock.

Table 7: Household Welfare Improvement with Elastic Corporate Investors

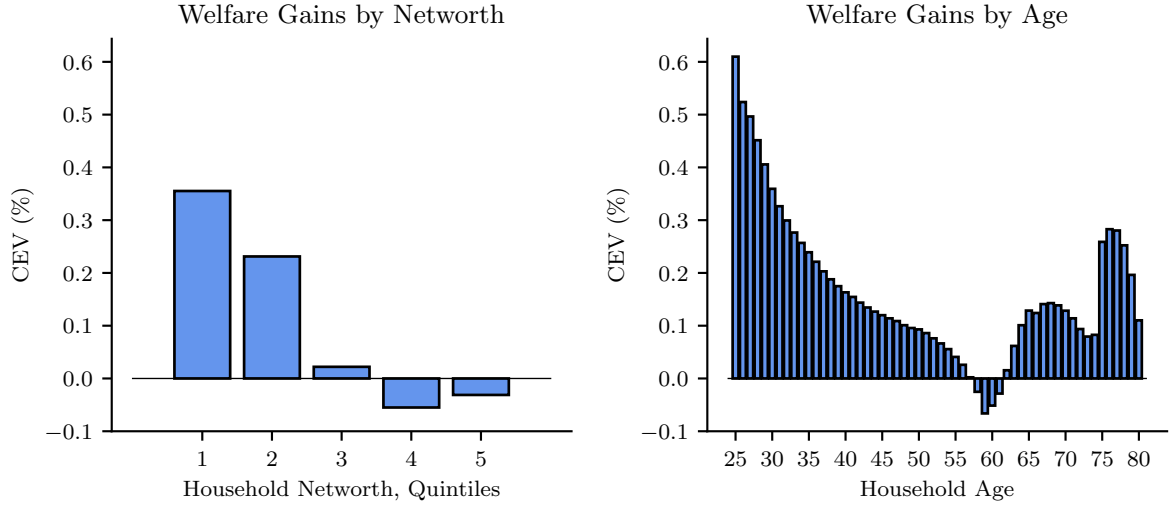
	All	Renters	Homeowners	Investors
CEV	0.166	0.320	-0.002	-0.158
Fraction with $CEV \geq 0$	0.464	0.983	0.230	0.167

*Notes:* Welfare comparisons are made for households that are alive in the first period of the shock. Consumption Equivalent Value (CEV) is the percentage gain in life-time consumption by moving from the economy with  $\varepsilon = 0$  to the economy with  $\varepsilon = 24$ . A positive CEV indicates that households prefer outcomes in the latter economy. Group welfare comparisons are for households that would have been renters, homeowners, or investors in the first period of the shock in the baseline economy with  $\varepsilon = 0$ .

Table 7 reports the welfare gains of moving from the economy with household investors to the economy with corporate investors. The first column shows that overall households enjoy a 0.17 percent gain in life-time consumption due to the stabilizing effect of corporate housing investment. However, this gain is spread unequally, as only 46 percent of households are better off. The remaining columns show that renters gain significantly from the housing market stability, while owners and investors are somewhat worse off. Renters benefit from the much slower increase in rental rates associated with corporate investment (see Figure 7). When housing

<sup>41</sup>Corporate investment firms are held by owners that live outside of the local economy, so that corporate profits do not contribute to household welfare. This is similar to the analysis in Favilukis et al. (2017b), where assessment of city-level housing policy excludes the effects on out-of-town buyers.

Figure 16: Household Welfare by Wealth and Age



*Notes:* Consumption Equivalent Value (CEV) is the percentage gain in life-time consumption by moving from the economy with  $\varepsilon = 0$  to the economy with  $\varepsilon = 24$ . A positive CEV indicates that households prefer outcomes in the latter economy. Within-group welfare comparisons are for households that would have been in a given quintile of the networth distribution or of a given age in the first period of the shock in the baseline economy with  $\varepsilon = 0$ .

markets are less stable, homeowners experience larger losses of wealth on their homes. However, because the mortgage credit shock is temporary, welfare losses are small for the majority of homeowners that do not expect to sell their house during this period. Household investors prefer the economy with less stable housing markets, since they earn higher rents and pay lower depreciation costs due to lower house prices. Additionally, some homeowners and household investors benefit from the more unstable housing market by selling their properties at a profit when house prices overshoot their steady state value after the housing bust (see Figure 7).

Figure 16 shows how the welfare gains are distributed across networth and age. Both poorer and younger households gain the most from housing market stability. This is because younger households are more likely to be renters, and because poorer households spend a larger fraction of income and resources on rent. Households entering retirement also gain from housing market stability, as they are likely to sell their houses and return to renting in the near future. Unstable housing markets mean both lower selling prices and higher rents for these households.

## 6. Conclusion

In this paper I studied the stabilization role of investors in housing markets during the Great Housing Bust. I used transaction-level housing data to show that both corporate and household



investors absorbed larger shares of the housing market as homeowner demand declined in the late 2000s. Using this data, the observed relationship between the change in the investor share of housing and the decline in house prices can be used to infer the elasticities of investor demands for housing. In the formal empirical analysis, I estimated heterogeneous house price responses to exogenous changes in mortgage credit given differences in corporate and household investor activity across housing markets. I showed that both types of investor activity are associated with dampened house price responses to mortgage credit. However, an increase in corporate investor activity is associated with a 30 percent smaller decline in house prices than an increase in household investor activity. This relative price decline suggests that corporate investment activity is much more elastic than household investor activity, meaning that corporate investment played a more effective stabilization role than household investment during the bust.

In the second half of the paper, I presented a structural macroeconomic model of the housing market to rationalize these differences in corporate and household behavior. Following the recent macro-housing literature, the core of the model features heterogeneous households that choose housing and mortgage financing in the face of uninsurable income risk. I build on that literature by introducing both household and corporate investors. The way in which these investors are modeled is motivated by micro-evidence showing that corporate investors are larger, trade housing more frequently, and rely much less on mortgage credit than do household investors. I calibrate the model to match the estimated relative decline in house prices associated with variations in the shares of corporate and household investors. In line with these estimates, I show that in response to an exogenous mortgage credit shock, house prices decline by much more when household investors are the marginal buyers of houses rather than corporate investors. I show that the much lower implied elasticity of household investment is due to the effect of changes in mortgage credit conditions, the illiquidity of housing assets, and changes in wealth due to the decline in the value of primary property. Following the mortgage credit shock, higher corporate investment activity is associated with more stable prices and rents, smaller fluctuations in networth and consumption, but larger declines in homeownership rates. In a final exercise I show that household welfare is higher when housing markets are more stable, despite the lower equilibrium rates of homeownership.

One limitation of the model is that the magnitude of equilibrium house price responses to mortgage credit shocks are too small. For example, when household investors are marginal house buyers the model only generates about 25 percent of the estimated total decline in house prices in response to a one standard deviation mortgage credit shock. This low volatility of house prices suggests that the elasticity of household investment demand is too high. Several

extensions to the model could help to address this problem: property and capital gains taxes would reduce the returns to housing; idiosyncratic and aggregate house price risk would generate housing risk premia (see Landvoigt et al., 2015); and assets with higher returns such as stocks and equities would increase the opportunity cost of housing investment (see Favilukis et al., 2017a). I leave each of these extensions to future research.

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## A. Data

### Data Sources

- Individual housing transaction data comes from Zillow’s Assessment and Transaction Database (ZTRAX). This data is proprietary, but is available from Zillow by request. For information regarding access, contact see <http://www.zillow.com/ztrax>.
- Zipcode house prices come from Zillow’s publicly available house price data at <http://www.zillow.com/data>.
- Zipcode income is from the IRS Statement of Income (SOI) statistics at <https://www.irs.gov/statistics/>.
- Zipcode demographic characteristics are from the 2000 Census, available at <https://factfinder.census.gov/>.
- Zipcode employment and county employment by industry is from the County Business Patterns data, available at <https://www.census.gov/programs-surveys/cbp/data/datasets.html>.
- Census tract-to-zipcode crosswalk files are retrieved from the Department of Housing and Urban Development at [https://www.huduser.gov/portal/datasets/usps\\_crosswalk.html](https://www.huduser.gov/portal/datasets/usps_crosswalk.html).
- County unemployment data is from the Bureau of Labor Statistics, available at <https://www.bls.gov/lau/data.htm>.

### Zillow Transaction and Assessment Database

The full ZTRAX dataset contains more than 370 million public records from across the US for residential and commercial properties. Each transaction in ZTRAX contains information on the characteristics of a property and sale including transaction date, property type, sale type, buyer type, and so on.

The ZTRAX data is held in state-level files, each of which contains the entire set of assessment records and transactions for that state. The availability of information associated with each transaction varies by state, but also may vary across counties within states. Three states – Rhode Island, Tennessee, and Vermont – have various missing data in the ZTRAX database, and are excluded from the analysis entirely. For several other states, non-mandatory disclosure

and outright prohibitions on the reporting of transactions prices mean that a very large proportion of transactions feature sales with prices reported as zero or missing.<sup>42</sup> For these states, property deeds and assessment records may still be reported to the ZTRAX database. I collect data on housing characteristics for these states, but I cannot use the transaction data on sales prices.<sup>43</sup> Instead, for these states I use publicly available, geographically aggregated Zillow house price indexes.

## Identifying Ownership Status in ZTRAX

ZTRAX contains several variables describing ownership characteristics for house buyers. The two most important are a *Buyer Description* and *Occupancy Status*.

The buyer description variable indicates whether the buyer in a given transaction is an individual, a couple, a trust, a legal partnership, a company, a government entity, or some other kind of organization. The variable is populated in ZTRAX for virtually every transaction. I identify household owners as those buyers who are individuals, couples, and trusts. I identify institutional owners as those buyers who are legal partnerships, companies, government entities, or other organizations.

The occupancy status variable describes the stated or inferred occupancy status of the buyer of a property. Unfortunately, this variable is missing for a large number of transactions, is altogether unavailable for several states, and varies in quality over time and space within states. Instead of using the occupancy status variable, I identify occupancy from other information available in ZTRAX. ZTRAX provides a character string describing the street address of every property sold. Additionally, the street address of the buyer of a property is also provided. In many states over 90 percent of transactions are accompanied by a buyer address. I identify owner-occupiers as those whose listed buyer address exactly matches the address of the purchased property.<sup>44</sup>

Finally, I identify household owner-occupiers as household owners from their buyer description information and who are owner-occupiers from their address information. I identify household property investors as household owners who are not owner-occupiers. And I identify institutional property investors as non-household owners.

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<sup>42</sup>See <http://www.zillowgroup.com/news/chronicles-of-data-collection-ii-non-disclosure-states/> for more details.

<sup>43</sup>The states with large numbers of missing transaction data are: Alaska, Idaho, Indiana, Kansas, Maine, Mississippi, Montana, New Mexico, Texas, Utah, and Wyoming

<sup>44</sup>I also tried a fuzzy matching algorithm to compare addresses. Fuzzy matching enables identification of owner-occupiers when one of the listed addresses is mis-spelled. I found that this did not make a large difference to the number of identified owner-occupied properties.



## Home Mortgage Disclosure Act Database

HMDA provides loan-level data on the universe of mortgage applications and originations in the US. A variety of information is reported about each loan. Location information about each loan is reported at the Census tract, county, MSA, and state levels. Zip code information is not provided, so I match Census tracts to zip codes using a tract-to-zip code crosswalk file provided by the Department of Housing. Because tracts may fall into more than one zip code, I use information on the share of tract residences in each zip code to weight each variable. To construct my measures of mortgage credit, I use the following variables associated with each loan in HMDA: Loan Purpose, Action Taken, Type of Purchaser, and Loan Amount.

**Loan Purpose** indicates whether a mortgage was used for a home purchase, home improvement, or refinancing. The main results only use home purchase mortgages.

**Action Taken** indicates whether the reporting institution originated a particular mortgage, denied an application for the mortgage, or purchased the mortgage from another institution. I only use mortgages that were originated by the reporting institution. Note that mortgages purchased by an institution need not have been originated in the reporting year. Additionally, these mortgages are likely to have been reported by originating institutions already, and so their inclusion would likely lead to double-counting.

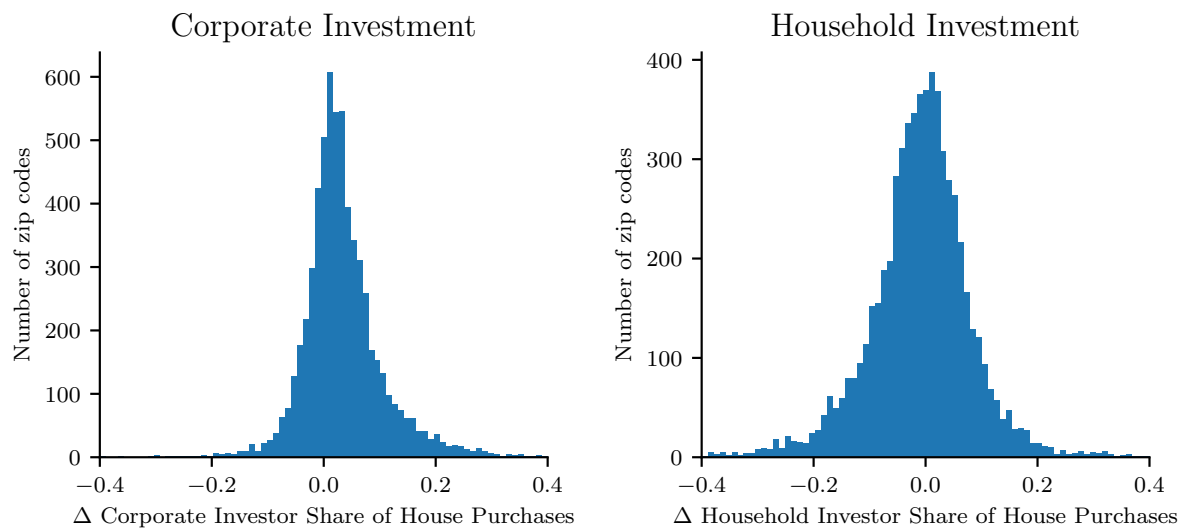
**Type of Purchaser** indicates whether and to which institution a mortgage was sold. The first categorization includes mortgages that were not originated or were not sold within the year (HMDA code: 0). Conditional on having been originated, these are mortgages that the originator has chosen to keep on its balance sheet, at least for the time being. Note that nothing precludes the originator from selling this mortgage in the future. The remaining categories specify the type of institution that purchased the mortgage. The first four institutions are the GSEs: Fannie Mae, Ginnie Mae, Freddie Mac, and Farmer Mac (HMDA codes: 1,2,3,4). The remaining five categories cover non-GSEs: institutions purchasing explicitly for use in private securitization (HMDA code: 5); purchases by commercial banks, savings banks, or savings associations (HMDA code: 6); purchases by life insurance companies, credit unions, mortgage banks, or finance companies (HMDA code: 7); purchases by affiliate institutions of the originator (HMDA code: 8); and other types of purchaser (HMDA code: 9). This final category includes banks and thrift holding companies. See <https://www.ffiec.gov/hmda/faqreg.htm#purchaser>. Both Mian et al. (2009) and Mian et al. (2018) define non-GSE purchases as those associated with these final five categories of purchaser.

I use three measures of exposure to credit supply shocks. First, I use only mortgages sold explicitly into private label securitization (HMDA code: 5). Second, I use a broader measure that also includes mostly non-banks that are unlikely to hold mortgages for balance sheet man-

agement and so are likely to be purchasing mortgages for the purpose of securitization (HMDA codes: 5, 7, 9). Finally, I use the broad, non-GSE measure used in Mian et al. (2009) and Mian et al. (2018) (HMDA codes: 5, 6, 7, 8, 9).

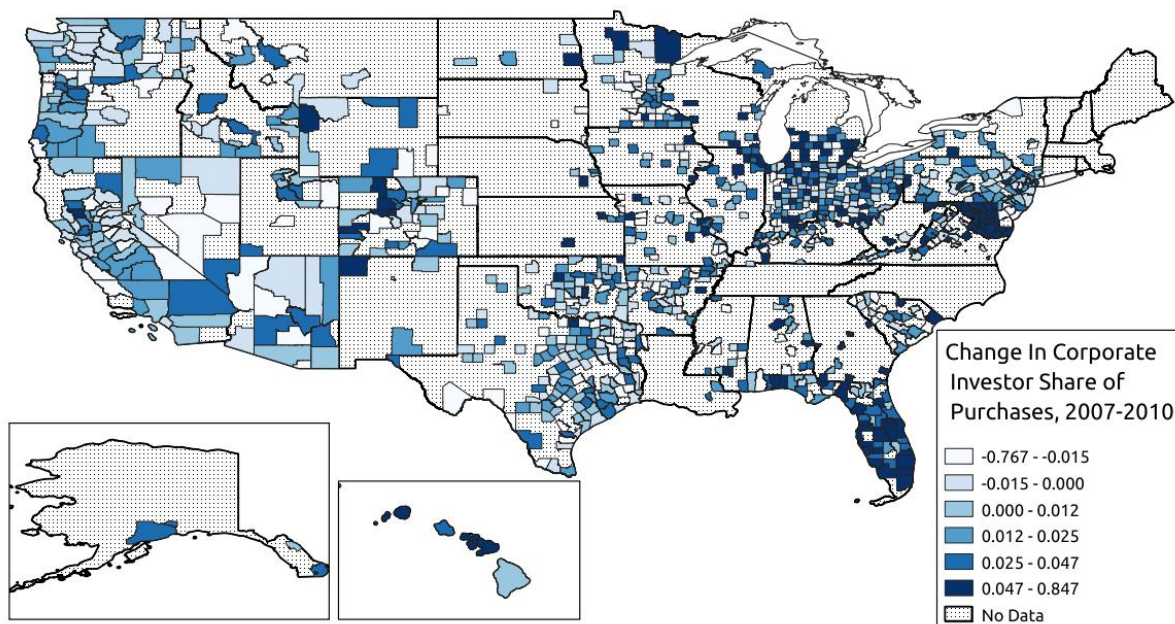
## B. Additional Figures

Figure B.1: Change in Investor Shares of House Purchases Across Zip Codes, 2006-2010



Source: Author's calculations using ZTRAX

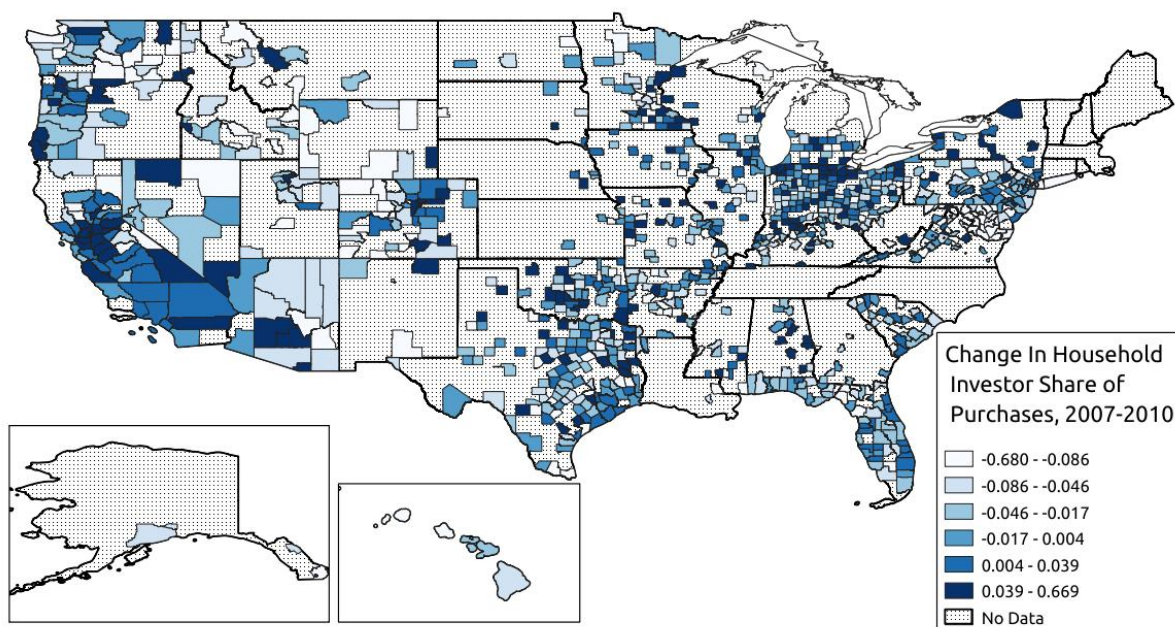
Figure B.2: Changes in Corporate Investor Share of Purchases Across Counties, 2006-2010



Source: Author's calculations using ZTRAX

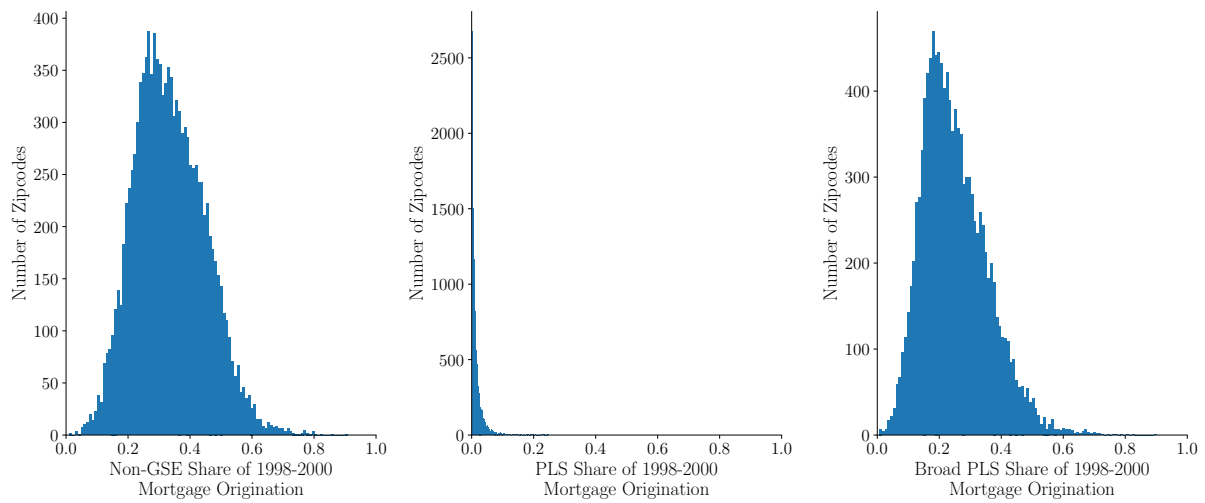
Figure B.3: Changes in Household Investor Share of Purchases Across Counties, 2006-2010

(a) Change in Household Investor Purchases



Source: Author's calculations using ZTRAX

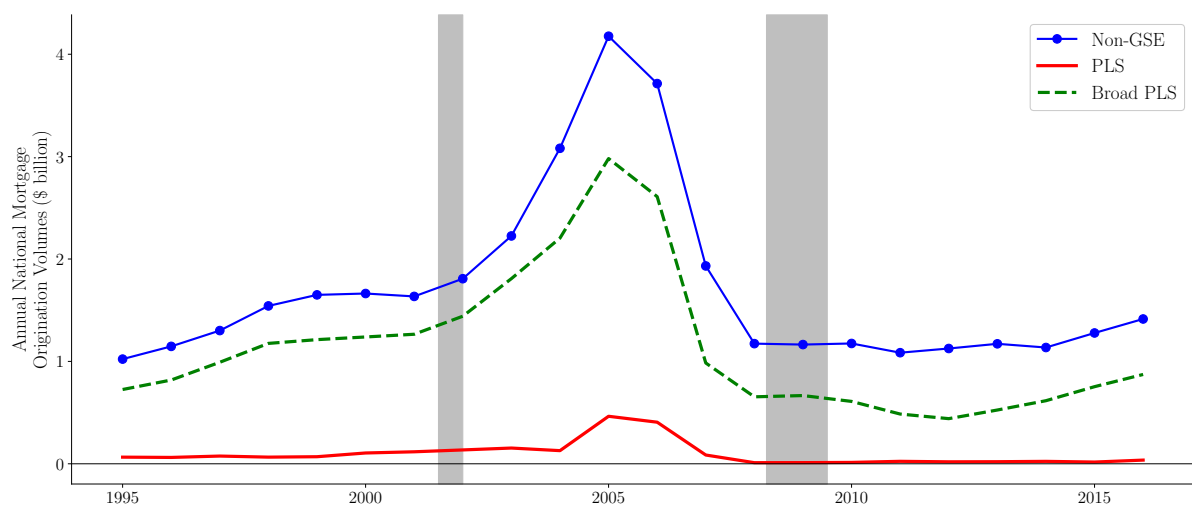
Figure B.4: Local Mortgage Origination Shares



*Notes:* Local mortgage origination shares by purchaser type between 1998 and 2000: non-GSE purchasers; direct-to-PLS purchasers; direct-to-PLS and non-bank purchasers.

*Source:* Author's calculations using HMDA.

Figure B.5: National Mortgage Origination Volumes



*Notes:* Annual national mortgage origination volumes by purchaser type.

*Source:* Author's calculations using HMDA.

## C. Additional Tables

Table C.1: First Stage Regressions of the 2SLS Procedure

	(1)	(2)	(3)
$\lambda_{z,98-00}^{nonGSE}$	-0.253*** (0.052)	-0.003 (0.003)	-0.008 (0.005)
$\lambda_{z,98-00}^{nonGSE} \times$ $\Delta Corporate Investor Share_{z,t-1}$	0.904*** (0.236)	0.156*** (0.047)	0.056 (0.044)
$\lambda_{z,98-00}^{nonGSE} \times$ $\Delta Household Investor Share_{z,t-1}$	0.350*** (0.118)	0.025 (0.027)	0.197*** (0.029)
Sample	2007-2010	2007-2010	2007-2010
Observations	14,149	14,149	14,149
Zipcodes	3,960	3,960	3,960
Counties	470	470	470
Fixed Effects	County $\times$ Year	County $\times$ Year	County $\times$ Year
F-statistic	23.59	11.04	45.07

*Notes:* First stage regressions for the 2SLS procedure following the specification in Equation (2). Column (1) reports the first stage regression for growth in mortgage originations. Column (2) reports the first stage regression for growth in mortgage originations interacted with the change in the corporate investor share of house purchases. Column (3) reports the first stage regression for growth in mortgage originations interacted with the change in the household investor share of house purchases. All models condition on: lagged house price growth; the contemporaneous shares of house purchases by each type of investor; the change in log-real per capita pre-tax zip code-level income; the change in log-employment by firms within the zip code; the change in log-real annual payroll by firms within the zip code. All models include county-by-year fixed effects. Each column reports the F-statistic for the instrument associated with the explanatory variable of that first stage regression. Standard errors (reported in parentheses) and F-statistics are clustered at the county level. \*, \*\*, \*\*\* denote significance at the 10%, 5%, and 1% levels.

*Sources:* Author's calculations using data from BLS, CBP, FRED, HMDA, IRS, Zillow, ZTRAX.

Table C.2: Effect of Mortgage Credit and Investor Activity on Local House Prices: Alternative Instruments

	$\Delta \log P_{z,t}$					
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \log M_{z,t}$	0.260*** (0.053)	0.282*** (0.081)	0.358*** (0.043)	0.298*** (0.077)	0.428* (0.223)	0.515*** (0.107)
$\Delta \log M_{z,t} \times$ $\Delta \text{Corporate Inv. Share}_{z,t}$				-2.599*** (0.665)	-3.938* (2.113)	-4.616*** (1.373)
$\Delta \log M_{z,t} \times$ $\Delta \text{Household Inv. Share}_{z,t}$				-0.716** (0.344)	-0.665 (0.493)	-1.000* (0.528)
Method	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
Mortgage Instrument	Non-GSE	PLS	Broad PLS	Non-GSE	PLS	Broad PLS
Sample	2007-2010	2007-2010	2007-2010	2007-2010	2007-2010	2007-2010
Observations	14,160	14,160	14,160	14,160	14,160	14,160
Zipcodes	3,960	3,960	3,960	3,960	3,960	3,960
Counties	470	470	470	470	470	470
Fixed Effects	County $\times$ Year	County $\times$ Year	County $\times$ Year	County $\times$ Year	County $\times$ Year	County $\times$ Year
F-statistics						
$F_{1 }$	22.16	12.85	26.22	34.88	5.85	36.00
$F_{2 }$	—	—	—	43.48	5.33	37.00
$F_{3 }$	—	—	—	75.56	7.56	57.99
Wald Statistic	—	—	—	13.85	2.59	8.50
p-value	—	—	—	0.00	0.11	0.00

Notes: All models estimated via 2SLS. The instruments for mortgage origination growth consist of: local exposure to non-GSE mortgage purchases from 1998-2000 (Columns (1) and (2)); local exposure to mortgages sold directly into PLS from 1998-2000 (Columns (2) and (4)); local exposure to mortgages sold into PLS or to non-banks from 1998-2000 (Columns (3) and (6)). In all models, changes in investor shares of house purchases are instrumented with their own lagged values. All specifications include the same set of controls as in Table 2. All models include county-by-year fixed effects. Columns (1) to (3) report F-statistics for the first stage regression of the relevant mortgage mortgage credit instrument on mortgage origination growth. Columns (4) to (6) report conditional F-statistics for the mortgage credit instruments and the instruments for the interactions between mortgage origination growth and the change in investor shares. Columns (4) to (6) also report Wald tests for the hypothesis of equality between the coefficients on the interaction terms. Standard errors (reported in parentheses), F-statistics, and Wald test-statistics are clustered at the county level. \*, \*\*, \*\*\* denote significance at the 10%, 5%, and 1% levels.

Sources: Author's calculations using data from BLS, CBP, FRED, HMDA, IRS, Zillow, ZTRAX.

Table C.3: Effect of Mortgage Credit and Investor Activity on Local House Prices: Additional Controls

	$\Delta \log P_{z,t}$				
	(1)	(2)	(3)	(4)	(5)
$\Delta \log M_{z,t}$	0.298*** (0.077)	0.306*** (0.069)	0.291*** (0.059)	0.262*** (0.073)	0.179** (0.090)
$\Delta \log M_{z,t} \times$ $\Delta \text{Corporate Inv. Share}_{z,t}$	-2.599*** (0.665)	-2.789*** (0.675)	-3.233** (1.266)	-2.353*** (0.586)	-1.709*** (0.476)
$\Delta \log M_{z,t} \times$ $\Delta \text{Household Inv. Share}_{z,t}$	-0.716** (0.344)	-0.869*** (0.314)	-0.232 (0.660)	-0.746** (0.361)	-0.457** (0.216)
Method	2SLS	2SLS	2SLS	2SLS	2SLS
Sample	2007-2010	2007-2010	2007-2010	2007-2010	2007-2010
Additional Controls	Benchmark	$\Delta \log P_{z,01-06}$	Housing Supply	Bank Competition	Demographics
Observations	14,160	13,670	9,735	12,584	13,706
Zipcodes	3,960	3,960	3,960	3,960	3,960
Counties	470	470	470	470	470
Fixed Effects	County $\times$ Year	County $\times$ Year	County, Year	County $\times$ Year	County $\times$ Year
F-statistics					
$F_{1 }$	34.88	32.51	34.00	45.36	17.48
$F_{2 }$	43.48	38.92	25.30	55.10	27.85
$F_{3 }$	75.56	60.10	44.48	84.54	77.94
Wald Statistic	13.85	13.36	5.23	13.78	9.74
p-value	0.00	0.00	0.02	0.00	0.00

*Notes:* All models estimated via 2SLS. The instrument for mortgage origination growth is local exposure to non-GSE mortgage purchases from 1998-2000. Changes in investor shares of house purchases are instrumented with their own lagged values. All specifications include the same set of controls as in Table 2. Additionally, Column (2) controls for local house price growth between 2001 and 2006. Column (3) includes controls for local housing supply: the change in log-number of total housing units permitted at the county level; the Saiz (2010) housing supply elasticity at the MSA level interacted with year-dummies; the fraction of houses built prior to 1990 and the fraction of houses with four or fewer rooms, both measured at the zip code level and interacted with year-dummies. Because the supply elasticity is interacted with time and MSAs frequently overlap with counties, this specification include county and year fixed effects, rather than county-by-year fixed effects. Column (4) includes controls for the structure of the banking market measured in the year 2000 at the zip code level and interacted with year-dummies: the fraction of deposits held by banks that have a within-state headquarters; the Herfindahl index for deposits held across branches; the Herfindahl index for deposits held across institutions; Column (5) includes controls for local demographic factors measured in the year 2000 at the zip code level and interacted with year-dummies: median age; fraction of households with no more than high school education; the fraction of owner-occupier households. Each column reports conditional F-statistics for the mortgage credit instrument and the instruments for the interactions between mortgage origination growth and the change in investor shares. Additionally, Wald statistics report test results for the hypothesis of equality between the coefficients on the interaction terms. Standard errors (reported in parentheses), F-statistics, and Wald test-statistics are clustered at the county level. \*, \*\*, \*\*\* denote significance at the 10%, 5%, and 1% levels.

*Sources:* Author's calculations using data from BLS, BPS, CBP, Census, FDIC, HMDA, IRS, Zillow, ZTRAX.

Table C.4: Effect of Mortgage Credit and Investor Activity on Local House Prices: Alternative Samples

	$\Delta \log P_{z,t}$			
	(1)	(2)	(3)	(4)
$\Delta \log M_{z,t}$	0.298*** (0.077)	0.234** (0.107)	0.351*** (0.134)	0.182*** (0.065)
$\Delta \log M_{z,t} \times$ $\Delta Institutional\ Inv.\ Share_{z,t}$	-2.599*** (0.665)	-2.029 (1.459)	-5.035*** (1.641)	-1.115* (0.609)
$\Delta \log M_{z,t} \times$ $\Delta Household\ Inv.\ Share_{z,t}$	-0.716** (0.344)	-0.275 (0.369)	-1.054* (0.613)	-0.270 (0.385)
Method	2SLS	2SLS	2SLS	2SLS
Sample	Benchmark	2006–2012	$N_{sales,z,t} \geq 300$	No Sand States
Observations	14,160	24,953	8,268	6,673
Zipcodes	3,960	4,494	2,562	2,010
Counties	470	511	361	297
Fixed Effects	County $\times$ Year	County $\times$ Year	County $\times$ Year	County $\times$ Year
F-statistics				
$F_{1 }$	34.88	6.71	21.23	51.73
$F_{2 }$	43.48	5.95	21.84	29.64
$F_{3 }$	75.56	237.56	27.41	61.64
Wald Statistic	13.85	2.05	10.07	3.83
p-value	0.00	0.15	0.00	0.05

*Notes:* All models estimated via 2SLS. The instrument for mortgage origination growth is local exposure to non-GSE mortgage purchases from 1998-2000. Changes in investor shares of house purchases are instrumented with their own lagged values. All specifications include the same set of controls as in Table 2. Each column reports results using the same model specification, but with alternative data samples: Column (2) expands the sample period to 2006 through 2012; Column (3) includes only zip codes with at least 250 house sales in any given year; Column (4) excludes data from the “Sand States” and Florida (AZ, CA, CO, FL, NM, NV, TX, UT). Each column reports conditional F-statistics for the mortgage credit instrument and the instruments for the interactions between mortgage origination growth and the change in investor shares. Additionally, Wald statistics report test results for the hypothesis of equality between the coefficients on the interaction terms. Standard errors (reported in parentheses), F-statistics, and Wald test-statistics are clustered at the county level. \*, \*\*, \*\*\* denote significance at the 10%, 5%, and 1% levels.

*Sources:* Author’s calculations using data from BLS, BPS, CBP, Census, FDIC, HMDA, IRS, Zillow, ZTRAX.



Table C.5: Effect of Mortgage Denials and Investor Activity on Local House Prices

	$\Delta \log P_{z,t}$			
	(1)	(2)	(3)	(4)
$\Delta \log M_{z,t}$	0.217*** (0.059)	0.218*** (0.065)	0.217*** (0.056)	0.235*** (0.068)
$\Delta \log M_{z,t} \times$ $\Delta \text{Corporate Inv. Share}_{z,t}$		-1.249*** (0.364)		-1.445*** (0.450)
$\Delta \log M_{z,t} \times$ $\Delta \text{Household Inv. Share}_{z,t}$			-0.002 (0.170)	-0.327 (0.221)
Method	2SLS	2SLS	2SLS	2SLS
Sample	2007-2010	2007-2010	2007-2010	2007-2010
Observations	14,149	14,149	14,149	14,149
Zipcodes	3,960	3,960	3,960	3,960
Counties	470	470	470	470
Fixed Effects	County $\times$ Year	County $\times$ Year	County $\times$ Year	County $\times$ Year
F-statistics				
$F_{1 }$	23.10	25.90	29.62	27.40
$F_{2 }$	—	47.25	175.22	46.36
$F_{3 }$	—	—	—	140.28
Wald Statistic	—	—	—	10.24
p-value	—	—	—	0.00

*Notes:* All models estimated via 2SLS. The instrument for the growth in mortgage denials is local exposure to non-GSE mortgage purchases from 1998-2000. Changes in investor shares of house purchases are instrumented with their own lagged values. All specifications include the same set of controls as in Table 2. Column (1) reports the F-statistic for the first stage regression of the mortgage mortgage credit instrument on mortgage origination growth. Columns (2) through (4) report conditional F-statistics for the mortgage credit instrument and the instruments for the interactions between mortgage origination growth and the change in investor shares. Column (4) reports a Wald test for the hypothesis of equality between the coefficients on the interaction terms. Standard errors (reported in parentheses), F-statistics, and Wald test-statistics are clustered at the county level. \*, \*\*, \*\*\* denote significance at the 10%, 5%, and 1% levels.

*Sources:* Author's calculations using data from BLS, CBP, FRED, HMDA, IRS, Zillow, ZTRAX.

## D. Additional Model Details

### Income Process

During their working life, household income is constituted by deterministic and stochastic components. The deterministic component of income follows a hump-shaped life-cycle profile. The stochastic component of income follows a standard composite of persistent and transitory elements. The persistent component of log-income follows an AR(1) process, and the transitory component is an IID shock. Thus, log-income at any age  $j$  is given by

$$\log m_j = \log g_j + \log y_j + \log z_j$$

where  $g_j$  is the deterministic life-cycle component,  $y_j$  is an AR(1) process following  $\log y_j = \rho \log y_{j-1} + \varepsilon_j$  with  $\varepsilon_j \sim \mathcal{N}(0, \sigma_y^2)$ , and  $z_j$  is an IID shock where  $\log z_j \sim \mathcal{N}(0, \sigma_z^2)$ . To calibrate this income process, I follow a standard minimum-distance estimation procedure from the literature (see Floden et al. (2001), Storesletten et al. (2004), Guvenen (2009), and Heathcote et al. (2014)).

I gather data on individual earnings from the Individual Data File from the 1999 to 2007 waves of the PSID. I filter observations according to the following criteria. I keep male household heads between the ages of 25 and 65 who were respondents in a given panel year. I drop observations for individuals who were retired, permanently disabled, home-makers, and students. I keep only individuals who were in families (or their split-offs) that were in the 1968 core sample, which was constructed as a representative cross-sectional sample of the population. I drop observations with missing information on age, education, and labor income, or for which labor income is non-positive. To measure earnings I use the annual earnings variable. Note that income is reported for the 2 years prior to the sampling date. For example, income reported in 1999 is actually annual earnings from 1997. I deflate this earnings measure using annual CPI from the associated reporting year (i.e. not the sample year). To remove the influence of outliers on my estimates, I remove observations in the top and bottom one percent of real earnings. Finally, the filtering procedure yields 2150 individuals with a total of 6930 observations across the sample period.

First, I estimate the life-cycle profile  $g_j$  by regressing log-earnings on a cubic polynomial in age, conditional on sample year dummies, and dummies for the number of years of education. This yields the polynomial coefficients:  $\{\beta_{age}, \beta_{age^2}, \beta_{age^3}\} = \{0.27007, -0.00484, 0.00028\}$ . Second, I take the residuals from the previous regression and compute several cross-sectional statistics to provide moment conditions for the GMM estimation. Specifically, I compute the cross-sectional variance of log-income, as well as the two-, four-, and six-year auto-covariances of log-income. These moments are reported in Table D.6.

Table D.6: Cross-sectional moments of individual earnings in the PSID

Variance	2-Year Auto-cov	4-Year Auto-cov.	6-Year Auto-cov
0.3977	0.2808	0.2483	0.2273

*Notes:* Cross-sectional moments computed using the residuals from a regression of log-income on a polynomial in age and dummies for sample year and years of education.

*Source:* Author's calculations using data from PSID waves 1999-2007.

The model for the income process generates the following variance and auto-covariance statistics:

$$\text{var}(\log m_j) = \frac{\sigma_y^2}{1 - \rho^2} + \sigma_z^2, \quad \text{cov}(\log m_j, \log m_j + n) = \rho^n \frac{\sigma_y^2}{1 - \rho^2}$$

Thus, the structure of auto-covariances in the data help to disentangle the relative volatility of the persistent and transitory components of income. I estimate the parameters  $\{\rho, \sigma_y, \sigma_z\}$  by minimizing the difference between the set of moments generated by the model and the moments in the data. This yields  $\{\rho, \sigma_y, \sigma_z\} = \{0.9479, 0.1777, 0.2942\}$ . These estimates are very similar to those used elsewhere in the literature.

## Computational Details

For computational convenience, I solve the model using a slightly modified set of state variables. The state space used in computations consists of cash on hand, primary property, secondary property, the current mortgage loan to value ratio, and the persistent component of income. In notation,  $\mathbf{s} = [x, h, i, q, y]$ , where  $x = aR + m_j$  and  $q = \frac{b}{P(h+i)}$ . For this formulation, an adjusting household's problem becomes:

$$\begin{aligned} V_j^A(\mathbf{s}) &= \max_{c, a', h', i', q'} u(c, h') + \beta \mathbb{E}(V_{j+1}(\mathbf{s}')) \\ \text{s.t. } & c + a' + P_h(\mathbb{1}_{h' \neq h} h' + \mathbb{1}_{i' \neq i} i') + \delta P_h(h' + i') + bR_b \\ &= x + (1 - f_s)P_h(\mathbb{1}_{h' \neq h} h + \mathbb{1}_{i' \neq i} i) + (1 - f_b)b' - \mathbb{1}_{b' > 0} F_b + (P_r - f_i)i' \\ & q' \leq \theta \\ & q' \leq \frac{\theta_y m_j}{P_h(h' + i')\pi(1, r_b)} \\ & b \equiv qP_h(h + i), \quad b' \equiv q'P_h(h' + i') \end{aligned}$$

Notice that the household chooses the mortgage loan-to-value ratio directly. A non-adjusting household's problem becomes:

$$\begin{aligned}
V_j^N(\mathbf{s}) &= \max_{c, a'} u(c, h) + \beta \mathbb{E}(V_{j+1}(\mathbf{s}')) \\
\text{s.t. } & c + a' + \delta_h P_h(h + i) + \pi(b, r_b) = x + (P_r - f_i)i \\
& q' = q(R_b - \pi(1, r_b)) \\
& b \equiv qP_h(h + i)
\end{aligned}$$

A renting household's problem becomes:

$$\begin{aligned}
V_j^R(\mathbf{s}) &= \max_{c, a', d} u(c, d) + \beta \mathbb{E}(V_{j+1}(\mathbf{s}')) \\
\text{s.t. } & c + a' + P_r d + bR_b = x + (1 - f_s)P_h(h + i)
\end{aligned}$$

The model solution is computed on a finite grid space that approximates the true state space. The accuracy of the solution is improved when the distribution of points within this grid space are chosen carefully. As is the case in any standard model of consumption under uncertainty with borrowing constraints, the consumption policy function is increasing and concave in  $x$ . Approximations to the consumption function, then, benefit from clustering points in the  $x$  grid near zero. I use 50 grid points, distributed on the interval  $[0, 85]$  using an inverse-exponential scaling function. Households with large loan to value ratios also exhibit significant curvature in their policy functions, suggesting that points in the  $q$  grid should be clustered near the maximum LTV ratio. I use 25 grid points, distributed on the interval  $[0, \theta_b]$  using an exponential scaling function. As discussed in Section 5.2, I only allow households to purchase one size of house and investment property. This means the grid space for each of these state variables is  $0, \underline{h}$ . I use five grid points for the Markov chain representing the persistent component of income  $y$ , and I use Gaussian quadrature with five nodes to approximate the IID component of income.

## Computation of Equilibrium

In the stationary equilibrium, two market clearing conditions must be satisfied: rental demand equals rental supply, and housing demand equals housing supply. To find the equilibrium, first define the excess demand functions:

$$\begin{aligned}
ERD(P_r, P_h) &= \sum_{j=1}^J \left[ \int \iota_j^D(\mathbf{s}) s_j(\mathbf{s}) d\mu_j(\mathbf{s}) \right] - \sum_{j=1}^J \left[ \int (\iota_j^A(\mathbf{s}) + \iota_j^N(\mathbf{s})) i'_j(\mathbf{s}) d\mu_j(\mathbf{s}) \right] \\
EHD(P_r, P_h) &= \sum_{j=1}^J \left[ \int (\iota_j^A(\mathbf{s}) + \iota_j^N(\mathbf{s})) (h'_j(\mathbf{s}) + i'_j(\mathbf{s})) d\mu_j(\mathbf{s}) \right] - \bar{H}
\end{aligned}$$

Then define the sum over the squared deviations from each market clearing condition:  $Z(P_r, P_h) = ERD(P_r, P_h)^2 + EHD(P_r, P_h)^2$ . Notice that a zero of the function  $Z$  corresponds to simultaneous zeros of the two excess demand functions,  $ERD$  and  $EHD$ . I can then use a nonlinear minimization routine over  $Z$  to find the market clearing prices  $P_r$ , and  $P_h$ .

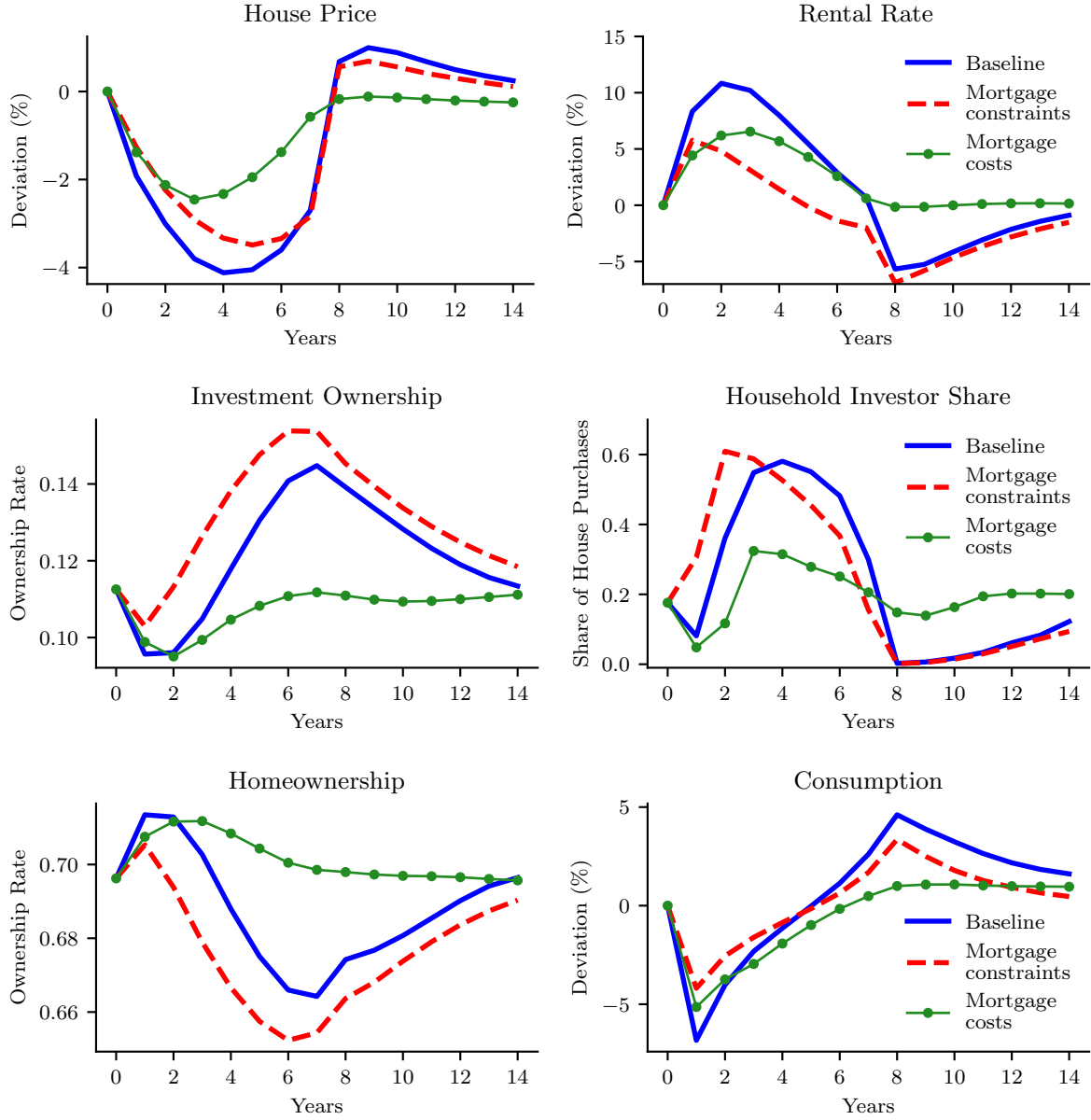
Finally, to help with calibrating the model I employ a trick inspired by Boppart et al. (2018). This involves replacing the housing market clearing conditions with one of the SMM moment conditions. Specifically, rather than calibrating the model by guessing values  $\bar{H}$  to match the observed homeownership rate, I solve for equilibrium by varying the house price  $P_h$  to match the homeownership rate directly. The market clearing housing supply  $\bar{H}$  is then backed out from the housing market clearing condition.

## Decomposition of the Effects of the Mortgage Credit Shock

Figure D.1 compares the equilibrium effects of the mortgage credit shock discussed in Table 5 to separate shocks to mortgage constraints and mortgage costs. The red dashed lines illustrate a shock to mortgage borrowing constraints only  $(\theta_b, \theta_y)$ , and the green circled line shows a shock to mortgage costs only  $(r_b, f_b)$ . All experiments are conducted with  $\varepsilon = 0$ .

The main result is that the household investment ownership rate and share of house purchases rise significantly more when only mortgage constraints are affected, and are significantly dampened when only mortgage costs are affected. Recall that households choosing to invest are both wealthier and borrow with smaller LTV ratios than other homeowners (see Panel B of Table 4, and Figures 5 and 6). This means that potential household investors are further from the borrowing constraints when they tighten, and so are less exposed to that component of the mortgage credit shock than potential homeowners. In contrast, the shock to mortgage interest rates directly affects potential household investors since it reduces the returns to holding investment property while borrowing.

Figure D.1: Impulse Responses to Components of the Mortgage Credit Supply Shock



Notes: Impulse responses to different components of the mortgage credit shock. Responses plotted for the economy with  $\varepsilon = 0$ .