Housing Wealth Reallocation between Subprime and Prime Borrowers during Recessions

Ayse Sapci and Nam Vu*

January 23, 2018

Abstract

We find evidence that prime borrowers are more likely to own investment homes during recessions than during recoveries, while subprime borrowers are less likely to do so. We develop and estimate a general equilibrium framework that distinguishes between prime and subprime borrowers through the credit channel. The relative ease of credit access can explain the divergence in homeownership seen in the data. Furthermore, this divergence is amplified when subprime borrowers are previously subjected to lax credit conditions and when the nominal interest rate is constrained at the zero lower bound. An expansionary monetary policy, however, can bridge this observed gap in housing wealth across borrowers.

Keywords: investment home; housing; credit access; subprime borrowers; prime borrowers
JEL Classification: E21, E22, E0

*Miami University of Ohio, Farmer School of Business. Email: vunt@miamioh.edu. Ayse Sapci: Colgate University, Department of Economics. Email: asapci@colgate.edu. We are particularly grateful for comments from Kimberly Berg, Mario J. Crucini, Matthew Jaremski, Seth Neumuller, Yang Song, Herald Uhlig, Jonathan Wolff, and participants of the seminars and conferences in Miami University, Colgate University, Fordham University, Lafayette College, Federal Reserve Bank of Dallas, Fall 2016 Midwest Macroeconomics Meetings, and 2016 Southern Economics Association Conference.
1 Introduction

The Great Recession reminded us how integrated the housing market and the rest of the economy are. As the United States slipped into the worst recession since World War II, many homeowners, particularly subprime borrowers, defaulted on their mortgages. This wave of defaults, combined with massive fire sales from banks and other homeowners, put a significant downward pressure on house prices. Despite considerable losses in the overall housing wealth, such declines in house prices might have opened up ample investment opportunities for prime borrowers who still had relatively easy access to credit. In this paper, we study the effects of credit access - or the lack thereof - on the reallocation of housing wealth among subprime and prime borrowers during recessions.

Using data from the U.S. Census and the Survey of Consumer Finances, we show that prime borrowers are more likely to own investment homes during recessions than during recoveries. In contrast, subprime borrowers are less likely to do so. We differentiate these two types of borrowers by their first mortgage loan rates and find that our empirical results are robust to various demographic and financial characteristics of the homeowners.

To understand this asymmetry in investment homeownership, we study a dynamic setting in which borrowers experience different levels of credit access. In particular, we construct two DSGE models - with and without nominal rigidity - that feature collateral constraints, debt accumulation, and an occasionally binding zero lower bound. Analogous to our empirical setup, we classify borrowers into “subprimers” and “primers,” whose borrowing are constrained by the value of their homes. We estimate the model to match the important features of the data using Bayesian methods and show that an adverse financial shock makes borrowing disproportionately costlier for subprimers who have higher risk premia. Since primers can sustain better access to credit than subprimers during recessions, they are better positioned to capitalize on the declining house prices.

We further find that the asymmetry in housing investment patterns is significantly amplified in a model with nominal rigidity and that credit access plays an important role in the interplay of the housing market and business cycles. In particular, we demonstrate that the asymmetry in housing wealth across borrowers becomes more significant when the financial shock follows a period in which the subprimers are subject to lax credit conditions. We also find that the zero lower bound amplifies the negative effects of financial frictions on aggregate housing demand while increasing the asymmetry in housing wealth distribution. We show that expansionary monetary policy is effective in ameliorating the negative effects of financial frictions and therefore in mitigating the investment homeownership gap across borrowers.

Our paper belongs to a vast literature on the interplay of financial frictions, housing market, and the business cycle. In particular, many papers in this literature seek to highlight the importance of house prices and collateral constraints in promoting and amplifying recessions (see, for example, Iacoviello (2005), Iacoviello and Pavan (2013a), Iacoviello and Pavan (2013b), among others).1 We

---

1Liu et al. (2013) study the amplification effect on macroeconomic fluctuations generated from the positive
complement this literature by studying the contrasting responses in investment homeownership across prime and subprime borrowers during recessions. In particular, our paper is the first, to the best of our knowledge, to reconcile this asymmetry seen in the data with an estimated DSGE model.

Furthermore, as Mian and Sufi (2009, 2016) demonstrate, the heterogeneity of borrowers plays an important yet under-appreciated role in understanding macroeconomic fluctuations. Along this line, we highlight the role of credit access heterogeneity across borrowers in creating housing wealth reallocation during recessions. Supporting the findings of Justiniano et al. (2016), we show that when subprimers are subject to lax credit conditions, a subsequent financial shock creates a larger asymmetry in housing wealth distribution. This result closely resembles the credit environment before the Great Recession. As subprimers gain better access to credit, they tend to accumulate more leverage and therefore can accrue larger losses.

The rest of the paper is organized as follows. Section 2 lays out the empirical motivation of this paper by documenting the contrasting movements of investment homeownership rates across prime and subprime borrowers using U.S. data from the mid-1990s. Complementing this empirical finding, Section 3 introduces a simple model to explain the extent to which an increase in risk premium can lead to a significant asymmetry in housing investment decisions across borrowers. Section 4 presents and estimates an extended model with a more realistic production sector, nominal rigidity and an occasionally binding zero lower bound. Section 5 discusses our results and highlights the importance of credit access in creating the asymmetry in housing investments across prime and subprime borrowers both in the model and in the data. Section 6 concludes the paper.

2 Empirical Motivation

In this section, we present the empirical evidence that prime borrowers are more likely to own investment homes during recessions than during recoveries, while subprime borrowers are less likely to do so. Figure 1 plots the total number of second home units since the late 1980s, as measured by the number of “units whose residence is elsewhere” from the American Housing Survey conducted by the U.S. Census. The figure shows that the number of second home units increases at the start of the three most recent recessions.\(^2\)

\(^2\) The correlation between land prices and business investment. Favilukis et al. (2013) show that the relaxation of collateral constraints and the decline in risk premia were the major reasons for the boom periods before 2007, while Mian et al. (2013) and Kaplan et al. (2016) find that the plunge in house prices was the main driving force in generating the Great Recession.

\(^3\) Krueger et al. (2016) show that including wealth heterogeneity across borrowers into standard models amplifies the aggregate consumption drop during recessions. Guerrieri and Lorenzoni (2017) and Philippon and Midrigan (2011) introduce heterogeneity in productivity across agents and find the drop in consumption to be larger for more constrained agents. Huo and Ríos-Rull (2016) argue that adverse financial shocks can generate large decreases in house prices.

\(^3\) We use the starting times of the three recent contractions as designated by the National Bureau of Economic Research (NBER).
Motivated by this observation, we next study the heterogeneity in housing wealth reallocation among subprime and prime borrowers using repeated cross-sectional data from the *Survey of Consumer Finances* (SCF, henceforth). The SCF consists of a triennial set of detailed questions about family income, real estate assets, and financial and demographic characteristics of the respondents for the period from 1995 to 2013.\(^4\) We differentiate between prime and subprime borrowers by the loan rates on their primary home mortgages. In particular, primers are classified as borrowers whose loan rates are less than the prime rate in the corresponding year. On the other hand, subprimers are those whose current mortgage loan rates fall into the highest one-third of the loan rate distribution in a given survey year.\(^5\) Our choice of cutoffs follows Justiniano et al. (2016), who document that the ratio of prime to subprime borrowers is about 36 percent using micro-level data from the *FRBNY Consumer Credit Panel/Equifax (CCP)* and *CoreLogic*.

Using the repeated cross-sectional data from the SCF, we next estimate the following Probit regression for the two groups of borrowers.\(^6\)

\[
Investment\ Homeownership_{b,i,t} = \beta_0 + \beta_1 Survey\ Year_t + \beta_2 Survey\ Year_t \times Credit\ Rejected_{b,i,t} + \beta_3 Credit\ Rejected_{b,i,t} + \beta_4 House\ Value_{b,i,t} + \beta_5 Demographic\ Controls_{b,i,t} + \nu_{b,i,t}
\]

(1)

for \(b \in \{\text{primers}, \text{subprimers}\}\).\(^7\) Here *Investment Homeownership* is a binary variable indicating

---

\(^4\)We exclude survey data before 1995 in our regression analysis because standardized survey weights are not publicly available for earlier years. Also SCF does not have any information on the location of the houses in the public database. Therefore, we abstract from spatial characteristics of housing.

\(^5\)Please see Table A2 and Figure A.1 in the Appendix for summary statistics of the dataset.

\(^6\)The results are qualitatively identical when a Linear Probability Model is used instead of Probit.

\(^7\)Please refer to Table A1 in the Appendix for the specific questions used in the survey.
Table 1: Probit Regression Results: The Asymmetry in Homeownership Rates

<table>
<thead>
<tr>
<th></th>
<th>Subprime Borrowers</th>
<th>Prime Borrowers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>0.002</td>
<td>0.009***</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>2001 Recession</td>
<td>-0.016***</td>
<td>0.020***</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>2004</td>
<td>0.027***</td>
<td>0.098***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>2007</td>
<td>0.083***</td>
<td>0.072***</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Great Recession</td>
<td>0.050***</td>
<td>0.118***</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.006)</td>
</tr>
<tr>
<td>2013</td>
<td>0.056***</td>
<td>0.098***</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Credit Rejected</td>
<td>-0.032***</td>
<td>-0.087***</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>18,422</td>
<td>25,307</td>
</tr>
</tbody>
</table>

Note: Values in parentheses show the standard errors. We report the marginal effects at the means using 1995 as the base year. Here ***, **, and * denote the 1%, 5%, and 10% levels of significance, respectively.

whether household \( i \) owns an investment home in year \( t \).\(^8\) Credit Rejected indicates whether the household was turned down for a credit application by a lender, and therefore measures credit access for the two groups of borrowers. To control for initial wealth, we include House Value, which is the current value (in log level) of the primary home owned by the household. Demographic Controls include employment status, gender, age, education level of the household head, household size, and 5-year economic expectations of the household.\(^9\) We restrict the sample to exclude households whose total income is below the Federal poverty level (i.e., $19,530 in 2013 U.S. Dollars), because these households are highly unlikely to invest in housing.\(^10\) Table 1 presents the results of the Probit regression specified in Equation 1.

Keeping the backward-looking nature of the surveys in mind, Table 1 shows that prime borrowers are more likely to own investment homes during recessions than recoveries, while subprime borrowers are less likely to do so.\(^11\) For instance, prime borrowers are more likely to own investment

---

\(^8\)Adelino et al. (2017), Foote et al. (2016), Ferreira and Gyourko (2015), and Albanesi et al. (2017) show that foreclosures by prime borrowers were at least as important as those by subprime borrowers in causing the Great Recession. Our paper, however, cannot address the foreclosures because of the data unavailability. The main focus of this paper is the investment homeownership across borrowers during recessions rather than understanding the reasons of the Great Recession.

\(^9\)The education variable is classified so that it captures people who could not complete high school, who are high school graduates, who have college degree, and who have higher education degree (masters or doctorate) rather than years of education.

\(^10\)Not surprisingly, the results hold stronger when we include households whose income are under the poverty line.

\(^11\)Due to the backward-looking nature of data collection, the 2010 survey documents the negative effects of the Great Recession. Whereas the 2007 survey is highly unlikely to reflect any substantial effects given that the recession started in the last month of the year. Because of the lag it takes to collect data and the short span of the recession, the 2004 survey can display some of the effects from 2001 Recession. Additionally, the all-time high
homes during the Great Recession (11.8%) than during the previous (7.2%) or the following (9.8%) recoveries. Unlike prime borrowers, subprime borrowers tend to buy more investment homes during recoveries. In particular, subprime borrowers are less likely to own investment homes during the Great Recession (5.0%) than during the previous (8.3%) or the following (5.6%) recoveries.

The asymmetry for subprime and prime borrowers across recessions and recoveries persists even after controlling for wealth differences and a wide range of idiosyncratic characteristics showing the importance of credit access across borrowers. In fact, the negative coefficients of Credit Rejected for each group as well the one for the full sample (-0.08) suggest that individuals who have insufficient credit access are much less likely to own an investment home. While not reported in the table, the interaction term of Survey Years and Credit Rejected show that among prime borrowers those who are more credit constrained particularly suffer during the recessions.\textsuperscript{12}

Additionally, households who are more educated, have male household head, are employed, have a smaller household size, are older, and are less optimistic on the economy are more likely to be homeowners. As expected, households who have higher wealth are also more likely to own a house throughout the sample period.

3 A Simple Model with Heterogeneity in Credit Access

To understand the underlining mechanism of the asymmetry in housing wealth distribution seen in the data, we study a simple model with collateralized borrowing by different types of borrowers. In particular, this stylized economy is populated by households, entrepreneurs, and house producers. Households are further divided into patient households (savers), prime borrowers (primers) and subprime borrowers (subprimers).

3.1 Households

There are two fundamental differences among the households in the model. First, patient households assign a greater value to the future than the borrowers which is similar to Iacoviello (2005). Specifically, the discount factor of the patient households is larger than that of subprime and prime borrowers. This assumption guarantees an equilibrium in which there is a positive wedge between the risk-free rate and the loan rate. Second, only borrowers engage in the housing market through mortgages. This assumption allows us to account for individuals who do not want to, or are not able to, buy real estate. Given that the homeownership rate has been averaging about 65% since the end of the Great Recession, patient households represent the remaining 35% of the

\footnote{The results are robust to various cutoffs for prime and subprime borrowers. We also control for federally backed mortgages to homogenize the loans across prime and subprime borrowers. Even after excluding the federally backed mortgages, our conclusions persist. Please refer to Appendix B for more details on the robustness checks.}
3.1.1 Patient Households

Denoted with the subscript $h$, patient households optimize their consumption, $C_{h,t}$, and leisure, $1 - l_{h,t}$, at time $t$ where the time endowment is normalized to one. They also decide how much to save, $D_t$, for a return at the gross deposit rate, $R_t$. The patient households use the following objective function to maximize their lifetime utility from consumption and leisure.

$$\max_{C_{h,t}, l_{h,t}, D_t} E_t \left\{ \sum_{k=0}^{\infty} \beta_h^k \left[ \ln(C_{h,t+k}) - \frac{l_{h,t+k}^{1+\xi}}{1+\xi} \right] \right\}$$

The maximization is subject to the Walrasian budget constraint that equates household’s spending to their income as follows.

$$C_{h,t} + D_t = R_{t-1}D_{t-1} + w_t l_{h,t}$$

where $w_t$ denotes the real wage.

3.1.2 Prime Borrowers

Prime borrowers engage in housing market activities by making a debt contract with the bank. Represented by the subscript $p$, primers buy real estate, $H_{p,t+1}$, for the price $q_{h}^t$ at time $t$. They maximize their utility from consumption, leisure and housing services subject to the flow of funds constraint in Equation 3 and the collateral constraint in Equation 4 as follows.

$$\max_{C_{p,t}, H_{p,t+1}, D_{p,t}, B_{p,t}} E_t \left\{ \sum_{k=0}^{\infty} \beta_p^k \left[ \ln(C_{p,t+k}) + \Gamma \ln(H_{p,t+k}) - \frac{l_{p,t+k}^{1+\xi}}{1+\xi} \right] \right\}$$

subject to

$$C_{p,t} + q_{h}^t (H_{p,t+1} - H_{p,t}) + Z_{p,t-1}B_{p,t-1} = B_{p,t} + w_t l_{p,t}$$

where $\Gamma$ governs the weight of housing services in the utility function, $Z_{p,t}$ denotes the gross lending rate for prime borrowers, and $m_p$ represents the loan-to-value ratio. Primers can use the amount borrowed from banks, $B_{p,t}$, and their labor income, $w_t l_{p,t}$, to finance their consumption, new housing investment, and debt repayment, as outlined in Equation 3. The bank, however, requires some of their assets to be collateralized, which restrains the amount of available credit to the borrowers. The borrowing constraint in Equation 4 shows that the repayment of household’s debt cannot exceed the expected future value of the real estate bought at time $t$.\(^\text{14}\)

$$Z_{p,t}B_{p,t} \leq m_p E_t \left\{ q_{h}^t H_{p,t+1} \right\}$$

\(^{13}\) Homeownership rate for the United States is obtained from the U.S. Bureau of Economic Analysis.

\(^{14}\) For the borrowing constraints to bind in equilibrium, discount factors of borrowers must be lower than the inverse of the gross loan rate.
3.1.3 Subprime Borrowers

Similar to prime borrowers, subprime borrowers can use their houses as collateral to engage in the housing market. However, subprimers are subject to higher borrowing rates. The risk premium, \( f_t \), between the gross loan rates of the prime and subprime borrowers is given by the following equation.

\[
Z_s = Z_p + f_t
\]  

where \( f_t \) is characterized by a mean reverting process as follows:

\[
f_t = (1 - \rho_f)\bar{f} + \rho_ff_{t-1} + \varepsilon_t^f
\]  

Here the \( \rho_f \) denotes the persistence of the risk premium and \( \varepsilon_t^f \) is assumed to follow \( N \left( 0, \sigma_f^2 \right) \).

Subprimers optimize their consumption and leisure, subject to the budget constraint in Equation 7 and the borrowing constraint in Equation 8.

\[
C_{s,t} + q^h_t (H_{s,t+1} - H_{s,t}) + Z_{s,t-1}B_{s,t-1} = B_{s,t} + w_t \ell_{s,t}
\]  

\[
B_{s,t}Z_{s,t} \leq m_s E_t \left\{ q^h_{t+1} H_{s,t+1} \right\}
\]

3.2 Entrepreneurs

Entrepreneurs produce a homogeneous good, \( Y_t \), using only labor input through the following aggregate production function.

\[
Y_t = A_t L_{e,t}
\]

where \( L_{e,t} = \nu (\varrho L_{p,t} + (1 - \varrho)L_{s,t}) + (1 - \nu)L_{h,t} \). Here \( L_{e,t} \) represents the total labor demand in the economy, \( \nu \) denotes the relative size of borrowers to patient households, and \( \varrho \) shows the relative mass of prime borrowers to subprime borrowers. \( A_t \) is the total factor productivity (TFP) that follows the AR (1) process in Equation 10.

\[
\log A_t = \rho_A \log A_{t-1} + \varepsilon_t^A
\]

where \( \rho_A \) is the persistence of the TFP shock, and \( E \left( \varepsilon_t^A \right) = 0 \).
3.3 House Construction

House producers maximize their profits subject to the quadratic housing adjustment cost, \( \frac{\chi}{2} \left( \frac{\Delta H_t}{H_t} \right)^2 H_t \).\(^{15}\)

In particular, the house producers maximize the following function:

\[
\max_{H_t} E_t \left\{ q_h^H \Delta H_t - \Delta H_t - \frac{\chi}{2} \left( \frac{\Delta H_t}{H_t} \right)^2 H_t \right\}
\]

where \( \Delta H_t = H_{t+1} - H_t \) denotes the housing investment at time \( t \) and \( H_t = H_{p,t} + H_{s,t} \).\(^{16}\)

3.4 Market Clearing Conditions

The economy-wide resource constraint is

\[
Y_t = C_t + \Delta H_t
\]

In Equation 11, \( C_t \) represents the aggregate consumption, which can be shown as \( C_t = C_{h,t} + C_{p,t} + C_{s,t} \). The following labor market clearing condition guarantees that the demand for and supply of labor will be equal.

\[
L_{e,t} = l_{h,t} + l_{s,t} + l_{p,t}
\]

Lastly, the loans market clears when the supply of deposits is equal to the demand for funds by subprimers and primers as outlined in Equation 13.

\[
D_t = B_{p,t} + B_{s,t}
\]

3.5 Parametrization

The values for all the parameters are presented in Table 2. We set the discount rates of patient households, primers, and subprimers to be 0.970, 0.965, and 0.950, respectively. These values are in line with the values found by Lawrance (1991) and Samwick (1998). The order of the discount factors (i.e., \( \beta_h > \beta_p \geq \beta_s \)) guarantees that there is a positive wedge between risk-free rate and the loan rate. We pick the weights of housing in utility functions, \( \Gamma \), to ensure that the steady state level of prime rate matches the data (i.e., 6.3% annually from the St. Louis FRED database) for the periods from 1984:Q1 to 2016:Q2.

Following the literature using micro-level data (e.g., Krause et al. (2008) and Aaronson and French (2009)), we set the inverse of the Frisch elasticity equal to 3. The relative size of primers to subprimers, \( \varrho \), is set to 0.64 following Justiniano et al. (2016), and the relative size of borrowers to patient households, \( \nu \), is set to 0.65 using the homeownership data from the U.S. Bureau of

\(^{15}\)The model does not distinguish between the intensive and extensive margins of home investment. We leave this topic for future research.

\(^{16}\)The housing depreciation rate is assumed to be equal to zero to match the findings in Iacoviello (2005)
Table 2: Calibrated Parameters: Real Model

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_h$</td>
<td>Discount rate for patient households</td>
<td>0.99</td>
</tr>
<tr>
<td>$\beta_p$</td>
<td>Discount rate for primers</td>
<td>0.97</td>
</tr>
<tr>
<td>$\beta_s$</td>
<td>Discount rate for subprimers</td>
<td>0.95</td>
</tr>
<tr>
<td>$\xi$</td>
<td>Inverse of Frisch elasticity</td>
<td>3</td>
</tr>
<tr>
<td>$\nu$</td>
<td>Relative size of borrowers</td>
<td>0.65</td>
</tr>
<tr>
<td>$\varrho$</td>
<td>Relative size of primers to subprimers</td>
<td>0.64</td>
</tr>
<tr>
<td>$\chi_h$</td>
<td>Housing adjustment cost</td>
<td>0.10</td>
</tr>
<tr>
<td>$m_s = m_p$</td>
<td>Loan-to-value ratios</td>
<td>0.765</td>
</tr>
<tr>
<td>$f$</td>
<td>SS level of risk premium (annualized)</td>
<td>2%</td>
</tr>
<tr>
<td>$\rho_f$</td>
<td>Persistence of financial friction</td>
<td>0.96</td>
</tr>
<tr>
<td>$\sigma_f$</td>
<td>Std. deviation of financial shock</td>
<td>0.01</td>
</tr>
<tr>
<td>$\rho_A$</td>
<td>Persistence of TFP</td>
<td>0.90</td>
</tr>
<tr>
<td>$\sigma_A$</td>
<td>Std. deviation of TFP shock</td>
<td>0.01</td>
</tr>
</tbody>
</table>

**Economic Analysis.** We choose the loan to value ratio to be 0.765 which is the average of the 2014 public database for Fannie Mae and Freddie Mac by the Federal Housing Finance Agency. The steady state level of risk premium is calculated from the SCF dataset using long run mortgage rates for prime and subprime borrowers and is equal to 2% in the steady state. Similar to Ngo (2015), the housing adjustment cost is assumed to be 0.1. Like most of the other key parameters, housing adjustment cost will be estimated using Bayesian methods in the extended model.

### 3.6 Implications for the Housing Market under the Real Model

Figure 2 plots the impulse responses of housing investment to (1) an adverse financial shock (a one percent increase in the innovation to the risk premium $f_t$) and (2) an adverse TFP shock (a one percent decrease in the innovation to TFP). Here prime borrowers increase their housing investment in the presence of an increase in risk premium, while subprime borrowers cut back on theirs. Intuitively, when there is an increase in the risk premium $f_t$ - as observed during recessions - subprime borrowers are constrained in their ability to borrow and therefore have to reduce their housing investment. Prime borrowers, on the other hand, are not subject to this risk premium and thus can increase their housing investments. This asymmetry in the responses of prime and subprime borrowers in the model is qualitatively in line with the asymmetry that we observed in the data. Turning to the magnitude of the impulse response, one percent increase in the financial shock is able to generate a 2.5% divergence in housing investments across the two types of borrowers (1% increase for the prime borrowers and 1.5% decrease for the subprime ones). Such contrasting responses of housing investments to the financial shock highlight the importance of the credit channel in explaining housing investments.

Turning to the sub-figure on the right of Figure 2, a negative TFP shock affects the two types...
Figure 2: Responses of the Housing Market under the Real Model

(a) Adverse Financial Shock

(b) Adverse TFP Shock

Note: The figure plots the impulse responses of housing investment of prime and subprime borrowers to a one standard deviation change in the innovation of the financial friction, $\varepsilon_f^t$ and TFP. All responses are normalized so that the units of the vertical axes represent percentage deviations from the steady state.

of borrowers similarly, even though subprimers pay 2% (annualized) more on their loan rates in equilibrium. Thus, the TFP shock is not able to generate the asymmetry in housing investment that we have documented with the financial shock $f_t$. Because of the inherent differences in the steady state levels of loan rates, subprimers become worse off compared to primes in the housing market following an adverse TFP shock.

4 An Extended Model with Nominal Rigidity

The real model in Section 3 demonstrates the extent to which the differences in credit access among borrowers can lead to asymmetric responses in house purchase decisions during recessions. While helpful in providing the basic intuition, this model lacks many features of a full-scale DSGE model. In this section, we augment the model in Section 3 with nominal rigidity, a more realistic production sector, a Taylor-rule monetary policy, and an occasionally binding zero lower bound (ZLB). We also allow firms to borrow, subject to their collateral constraints. We then estimate the model using Bayesian methods to U.S. data.

In this framework, the economy is populated by six types of agents: households, entrepreneurs, retailers, capital producers, house producers and the central bank. Similar to the model in Section 3 households are divided into patient households, prime borrowers and subprime borrowers. Entrepreneurs are assumed to own the goods producers, and the retailers. The model features a Taylor-style monetary policy with an occasionally binding ZLB to account for the near zero interest rates during the Great Recession.

For simplicity, we only highlight the differences from the real model in Section 3. A detailed list of equations for this extended model can be found in the Appendix C.
4.1 Households

We keep all types of households same with the real model in Section 3 and relax the assumption that subprime and prime borrowers receive the same utility from housing services. We further add a preference shock in the form of a mean reverting process, in which $\varepsilon_t^{\beta_h}$ follows $N(0, \sigma_{\beta_h}^2)$.

$$\log \beta_{h,t} = (1 - \rho_{\beta_h}) \beta_h + \rho_{\beta_h} \log \beta_{h,t-1} + \varepsilon_t^{\beta_h} \quad (14)$$

4.2 Entrepreneurs

Entrepreneurs own the good producers. They rent capital from capital producers and provide it to the firms. Firms produce a homogeneous good, $Y_t$, using capital, labor, and commercial real estate through the following aggregate Cobb-Douglas production function.

$$Y_t = A_t K_{et}^\alpha H_{et}^\kappa (L_{et})^{(1-\alpha-\kappa)} \quad (15)$$

where $\alpha \geq 0$ and $\kappa \geq 0$ denote the shares of capital and commercial real estates in production, respectively. Here, $H_{et}$ can be interpreted as land. Firms maximize their consumption with respect to Equations 10 and 15, as well as their flow of funds in Equation 16, and the borrowing constraint in Equation 17.

$$\max_{C_{e,t},K_{t+1},H_{e,t+1},L_{e,t},B_{e,t}} E_t \left\{ \sum_{k=0}^{\infty} \beta_e^k \ln(C_{e,t+k}) \right\}$$

$$C_{e,t} + q_t^h H_{e,t+1} = \frac{Y_t}{X_t} + q_t^h H_{e,t} - w_t L_{e,t} - q_t I_t + B_{e,t} - \frac{Z_{e,t-1} B_{e,t-1}}{\pi_t} + F_t \quad (16)$$

where $\pi_t$ denotes the gross inflation rate, $\pi_t = (P_t/P_{t-1})$, and $F_t$ represents the lump-sum profits from retailers. $X_t$ is the markups in period $t$, $q_t^h$ denotes the real house price $q_t^h = Q_t^h/P_t$, and $q_t = Q_t/P_t$ is the real capital price. Similar to subprimes and primes, firms can only borrow up to the expected future value of their total assets, which includes their physical capital as well as their commercial real estate. Following Liu et al. (2013), the borrowing constraint of the entrepreneurs is given by

$$B_{e,t} \leq m_e E_t \left\{ (q_{t+1}^h H_{e,t+1} + q_{t+1} I_{t+1}) \frac{\pi_{t+1}}{Z_{e,t}} \right\}, \quad (17)$$

where $m_e$ is the loan-to-value ratio for firms.

4.2.1 Retailers

There is a continuum of monopolistically competitive retailers owned by entrepreneurs. They buy intermediate goods from the firms at the wholesale price $P_t^w$ in a competitive market and
distribute the final goods $Y_t = \left( \int_0^1 Y_t(z)^{(\varepsilon-1)/\varepsilon} dz \right)^{\varepsilon/(\varepsilon-1)}$. The demand curve for each retailer is:

$$Y_t(z) = \left( \frac{P_t(z)}{P_t} \right)^{-\varepsilon} Y_t$$

(18)

In each period retailers have a probability of $(1 - \theta)$ to change their price. Thus the aggregate price level is,

$$P_t = \left[ \theta P_{t-1}^{1-\varepsilon} + (1 - \theta) \left( P_t^* \right)^{1-\varepsilon} \right]^{1/\varepsilon}$$

(19)

where $\varepsilon > 1$, and $P_t^*$ is the symmetric optimal price that equates expected discounted marginal revenue and marginal cost. Retailers’ profit, $F_t = \left( 1 - \frac{1}{\varepsilon} \right) Y_t$, are distributed back to the patient households. The markups, $X_t$, is equal to $\frac{1}{\varepsilon}$ in the steady state.

### 4.3 Capital Producers

Capital producers produce new capital goods, which replace the depreciated capital and contribute to the capital stock. Capital producers maximize their profit subject to the quadratic capital adjustment cost, $\chi_2 \left( \frac{I_t}{K_t} - \delta \right)^2 K_t$.

$$\max_{I_t} E_t \left\{ q_t x^i_t I_t - I_t - \frac{\chi}{2} \left( \frac{I_t}{K_t} - \delta \right)^2 K_t \right\}$$

Here $x^i_t$ is the investment specific technology shock, which follows the auto-regressive process in Equation 20 where $\varepsilon_t x^i_t \sim N(0, \sigma^2_{x^i_t})$.

$$\log x^i_t = \rho x^i \log x^i_{t-1} + \varepsilon_t x^i_t$$

(20)

The law of capital motion is:

$$x^i_t I_t = K_{t+1} - (1 - \delta) K_t$$

(21)

### 4.4 House Construction

Similar to capital producers, house producers maximize their own profits subject to the quadratic housing adjustment cost, $\chi_h \left( \frac{\Delta H_t}{H_t} \right)^2 H_t$, and the housing supply shock, $x^h_t$, where

$$x^h_t \Delta H_t = H_{t+1} - H_t$$

(22)
and \( H_t = H_{p,t} + H_{s,t} + H_{e,t} \) and \( \Delta H_t \) denotes the total housing investment. The housing supply shock follows the auto-regressive process below:\(^\text{17}\)

\[
\log x_t^h = \rho_x \log x_{t-1}^h + \varepsilon_t^x
\]  

(23)

The house producers maximize their profits as follows.

\[
\max_{H_t} E_t \left\{ q_t^h x_t^h \Delta H_t - \Delta H_t - \frac{\chi}{2} \left( \frac{\Delta H_t}{H_t} \right)^2 H_t \right\}
\]

4.5 Monetary Policy

We posit that monetary policy follows a Taylor rule as specified in Equation 24, in which \( b_1 \) and \( b_2 \) are the parameters that govern the central bank’s weights on the output gap and inflation gap target.

\[
R_t = \bar{R} \left[ \left( \frac{Y_t}{\bar{Y}} \right)^{b_1} \left[ \frac{1 + \pi_t}{1 + \bar{\pi}} \right]^{b_2} \right] e_t^R
\]  

(24)

The monetary policy shock, \( e_t^R \), follows

\[
\log(e_t^R) = \rho_e \log(e_{t-1}^R) + \varepsilon_t^R
\]  

(25)

in which \( \varepsilon_t^R \) is i.i.d. with \( N(0, \sigma_R^2) \). Additionally, the nominal interest rate is bounded by zero as expressed below.

\[
R_t - 1 \geq 0
\]  

(26)

4.6 Market Clearing Conditions

The economy-wide resource constraint is shown below, where \( I_t \) denotes the gross capital investment.

\[
Y_t = C_t + I_t + \Delta H_t
\]  

(27)

In Equation 27, \( C_t \) represents the aggregate consumption and is the sum of households, borrowers, and entrepreneurs’ consumption. The labor market clearing condition is the same with the model in Section 3 and guarantees that the demand for and supply of labor will be equal. The loans market clears when the supply of deposits is equal to the demand for funds by subprimers, primers, and entrepreneurs as follows:

\[
D_t = B_{p,t} + B_{s,t} + B_{e,t}
\]  

(28)
Table 3: Calibrated Parameters: Extended Model

<table>
<thead>
<tr>
<th>Par.</th>
<th>Description</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\xi$</td>
<td>Inverse of Frisch elasticity</td>
<td>3</td>
<td>Aaronson and French (2009)</td>
</tr>
<tr>
<td>$\varrho$</td>
<td>Relative size of of primers to subprimers</td>
<td>0.64</td>
<td>Justiniano et al. (2016)</td>
</tr>
<tr>
<td>$\nu$</td>
<td>Relative size of borrowers to patient households</td>
<td>0.65</td>
<td>U.S. Bureau of Economic Analysis (BEA)</td>
</tr>
<tr>
<td>$\bar{f}$</td>
<td>Steady-state level risk premium</td>
<td>2% (annualized)</td>
<td>Our calculations from SCF</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Share of capital in production</td>
<td>0.33</td>
<td>Literature</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Capital depreciation</td>
<td>0.025</td>
<td>Literature</td>
</tr>
<tr>
<td>$b_1$</td>
<td>Taylor Rule Output Weight</td>
<td>0.5</td>
<td>Taylor (1993)</td>
</tr>
<tr>
<td>$b_2$</td>
<td>Taylor Rule Inflation Weight</td>
<td>1.5</td>
<td>Taylor (1993)</td>
</tr>
</tbody>
</table>

4.7 Calibration and Estimation

We estimate a number of important parameters while calibrating the rest to values that are either common in the literature or to values obtained from data. Table 3 presents the set of parameters that we calibrate. The parameters for the Frisch elasticity, the relative size of primers to subprimers, the relative size of borrowers to patient households, and the steady state level of risk premium are identical to the values used in the real model as demonstrated in Table 2. These values generate a steady state level of prime rate that matches the long run average prime interest rate for the past 22 years (i.e., 6.3%, annually).

We choose standard values for the technology and policy parameters. In particular, the capital share in production and the depreciation rate are set to 0.33 and 0.025, respectively. We pick the commercial housing share in the production function of the firms so that the entrepreneurial loan rate matches the data for our time period.\(^{18}\) Following Taylor (1993), we select neutral values for the weights on output ($b_1$) and inflation ($b_2$) targeting that match U.S. data since 1984. In particular, the coefficients for the Taylor rule are set to be 0.5 for the output weight and 1.5 for the inflation weight.

We estimate the rest of the parameters using a variety of sources as guesses for priors. While erring on the side of having priors that are as non-informative as possible, we based many of our guesses on the current literature. For the choices of prior distributions, we follow Iacoviello (2015a), wherever appropriate. The values of the capital and housing adjustment costs are taken from Christensen and Dib (2008) and Ngo (2015) which are 0.59 and 0.1, respectively. Our initial guesses for the weights of housing in utility functions are set so that in the steady state subprimers’ housing is 40% of the GDP, whereas the ratio of primers’ housing to GDP is equal to 2.4. We obtain these values from the SCF, Federal Reserve Bank of St. Louis and U.S. Bureau of Economic Analysis databases.

\(^{17}\)Housing is a predetermined variable. Therefore, the housing supply shock should be interpreted similarly with the investment specific technology shock.

\(^{18}\)In equilibrium, the share of housing in production is $\kappa = (((1 - (m_e/Z_e))(1/\beta_e)) - (1 - m_e))(qH_eX/Y)$. Therefore, $\kappa$ can be calculated using the estimations of $(q^bH_e/Y) = e$ and $Z_e$. 

14
Table 4: Priors and Posteriors of Estimated Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Prior</th>
<th>Mean</th>
<th>Post.</th>
<th>Mode</th>
<th>Low</th>
<th>High</th>
<th>Prior</th>
<th>Post. Std.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_H$</td>
<td>0.99</td>
<td>0.9865</td>
<td>0.9798</td>
<td>0.9960</td>
<td>beta</td>
<td>0.005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta_S$</td>
<td>0.95</td>
<td>0.9505</td>
<td>0.9432</td>
<td>0.9593</td>
<td>beta</td>
<td>0.005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta_P$</td>
<td>0.97</td>
<td>0.9676</td>
<td>0.9624</td>
<td>0.9774</td>
<td>beta</td>
<td>0.005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta_e$</td>
<td>0.98</td>
<td>0.9810</td>
<td>0.9741</td>
<td>0.9886</td>
<td>beta</td>
<td>0.005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\rho_A$</td>
<td>0.90</td>
<td>0.8993</td>
<td>0.8669</td>
<td>0.9291</td>
<td>beta</td>
<td>0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi_K$</td>
<td>0.59</td>
<td>0.5901</td>
<td>0.5853</td>
<td>0.5948</td>
<td>beta</td>
<td>0.003</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi_H$</td>
<td>0.10</td>
<td>0.1015</td>
<td>0.0948</td>
<td>0.1046</td>
<td>beta</td>
<td>0.003</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$m_e$</td>
<td>0.80</td>
<td>0.8024</td>
<td>0.7442</td>
<td>0.8442</td>
<td>norm</td>
<td>0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$m_s$</td>
<td>0.80</td>
<td>0.8076</td>
<td>0.7525</td>
<td>0.8504</td>
<td>norm</td>
<td>0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$m_p$</td>
<td>0.80</td>
<td>0.7946</td>
<td>0.7487</td>
<td>0.8436</td>
<td>norm</td>
<td>0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\theta$</td>
<td>0.75</td>
<td>0.7459</td>
<td>0.7145</td>
<td>0.7805</td>
<td>norm</td>
<td>0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$e$</td>
<td>0.60</td>
<td>0.6003</td>
<td>0.5528</td>
<td>0.6516</td>
<td>norm</td>
<td>0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$s$</td>
<td>0.40</td>
<td>0.4021</td>
<td>0.3496</td>
<td>0.4514</td>
<td>norm</td>
<td>0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$p$</td>
<td>2.50</td>
<td>2.5064</td>
<td>2.4508</td>
<td>2.551</td>
<td>norm</td>
<td>0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\rho_f$</td>
<td>0.50</td>
<td>0.5351</td>
<td>0.4108</td>
<td>0.6686</td>
<td>beta</td>
<td>0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\rho_X$</td>
<td>0.50</td>
<td>0.5024</td>
<td>0.3174</td>
<td>0.6960</td>
<td>beta</td>
<td>0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\rho_{XI}$</td>
<td>0.50</td>
<td>0.5232</td>
<td>0.3572</td>
<td>0.6750</td>
<td>beta</td>
<td>0.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Standard Deviation of Shocks

<table>
<thead>
<tr>
<th>Shocks</th>
<th>Prior</th>
<th>Mean</th>
<th>Post.</th>
<th>Mode</th>
<th>Low</th>
<th>High</th>
<th>Prior</th>
<th>Post. Std.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\varepsilon_A$</td>
<td>0.01</td>
<td>0.0362</td>
<td>0.0328</td>
<td>0.0398</td>
<td>invg</td>
<td>Inf</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\varepsilon_e$</td>
<td>0.01</td>
<td>0.0486</td>
<td>0.0383</td>
<td>0.045</td>
<td>invg</td>
<td>Inf</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\varepsilon_f$</td>
<td>0.02</td>
<td>0.0079</td>
<td>0.0051</td>
<td>0.0107</td>
<td>invg</td>
<td>Inf</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\varepsilon_X$</td>
<td>0.01</td>
<td>0.0383</td>
<td>0.0334</td>
<td>0.041</td>
<td>invg</td>
<td>Inf</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\varepsilon_{XI}$</td>
<td>0.01</td>
<td>0.0267</td>
<td>0.0241</td>
<td>0.0293</td>
<td>invg</td>
<td>Inf</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\varepsilon_P$</td>
<td>0.01</td>
<td>0.0095</td>
<td>0.0085</td>
<td>0.0103</td>
<td>invg</td>
<td>Inf</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: We estimate the model to fit to five series: real output growth (GDPC96), bank prime loan rate (MPRIME), growth rate of the private residential investment (PRFI), the growth rate of house prices (MS-PUS), and real consumption growth (PCECC96) from the Federal Reserve Bank of St. Louis database. Data are all seasonally adjusted, HP filtered, and transformed in a way such that the variable definitions match ours in the model. Please see the Appendix D for more details. Here e, s, and p denote the steady state levels of commercial real estate relative to output, subprimers’ housing to output, and primers’ housing to output, respectively. High and low denote the upper and lower bounds for the 90% HPD interval.

Table 4 presents the sets of estimated parameters, along with the posteriors and our choices of priors. We match the extended model to five series: real output growth, real consumption growth, growth rate of the private residential investment, growth rate of house prices, and bank prime loan rate. We obtain data after the Great Moderation (1984:Q1 to 2016:Q2) from the Federal Reserve Bank of St. Louis database, where all data series are seasonally adjusted and filtered using Hodrick-Prescott filter. We estimate the model using Bayesian methods with Metropolis-Hastings algorithm and make sure the Markov Chain Monte Carlo (MCMC) converges to its ergodic distribution.

Our estimates of the discount factors in Table 4 are consistent with the findings in Lawrance (1991) and Samwick (1998) which shows the accuracy of our estimation. In particular, while
Lawrance (1991) estimates the quarterly discount rate of borrowers (or the less patient households) to be between 0.95 and 0.98, Samwick (1998) finds the discount factors for all agents to be between 0.91 and 0.99. In line with these findings, we estimate 0.99, 0.95, 0.97 and 0.98 to be the means of the discount rates of patient households, subprimers, primers, and entrepreneurs, respectively.

5 Results: The Extended Model with Nominal Rigidity

This section presents the implications of the extended model in Section 4. An increase in the financial friction, or equivalently an increase in the risk premium for the subprime borrowers, can significantly affect housing wealth reallocation across borrowers. We also examine the effects of non-financial shocks, such as TFP, capital and housing supply shocks, and monetary policy shocks on the housing wealth distribution. As expected, the non-financial shocks have little effect on the housing wealth distribution because they tend to affect borrowers similarly.

Since the recent financial crisis coincided with a period of near zero interest rates and lax borrowing conditions, we examine the effects of an adverse financial shock at the ZLB and study the role of collateral constraints. We show that the ZLB amplifies the negative effects of financial frictions on aggregate housing demand over the case in which the ZLB does not bind, while increasing the asymmetry in housing wealth distribution. To examine the role of credit constraints, we study how variations in the loan-to-value (LTV) ratio of subprimers can amplify the effects of an adverse financial shock on the housing wealth across borrowers.

5.1 The Effects of the Financial Shock

Our starting point is to document the responses of the housing market and other macroeconomic aggregates to an adverse financial shock. To do so, we estimate the model in Section 4 under the calibration presented in Section 4.7 and initiate a one standard deviation adverse shock to the financial friction, $f$. Figure 3 presents the responses to this financial shock which are normalized such that they represent the percentage deviations from their respective steady-state values.

An increase in the risk premium between primers and subprimers can lead to an increase of over 1% in the housing investment for primers and a decrease of around 7% for subprimers. The intuition is as follows. An adverse financial shock significantly increases the relative cost of obtaining additional housing for the subprimers, compared to the primers. Since subprimers are subjected to disproportionately higher loan rates, their collateral constraint binds faster than that of primers, causing a decrease in their housing demand. This stark decrease in subprimers’ demand pushes house prices down. Since primers still have relatively better access to credit and more favorable loan rates, they can increase their housing investment.

Turning to the responses of macroeconomic aggregates, an adverse financial shock can have significant ramifications on the economy. Specifically, output, consumption, and capital decrease following the shock as the overall demand for real estate investment declines. While primers can
Figure 3: Responses to an Adverse Financial Shock

(a) Housing Market

(b) Macroeconomic Aggregates

(c) Borrowings

(d) Loan Rates

(e) Consumption

(f) Wage and Hours of Work

Note: The figure plots the impulse responses of selected variables to a one standard deviation (one percent) increase in the innovation of the financial friction, $\varepsilon_f$. All responses are normalized so that the units of the vertical axes represent percentage deviations from the steady state.

...take advantage of their relatively better access to credit, their gains are far from being able to make up for the decreases in the housing demand of subprime borrowers. Thus, the economy as a whole experiences a further decrease in output, consumption, and capital as a result of an increase in risk premium for the subprime borrowers.

The role of financial shock We next investigate the extent to which each shock can contribute to overall fluctuations of the model. To do so, we present the variance decomposition of financial friction, TFP, monetary policy, housing supply, and capital supply shocks to the variations in selected variables in Table 5. The table shows that the financial shock accounts for 26.27% and 9.94% of variations in housing investment for subprimers and primers, respectively. Across prime and subprime borrowers, higher fractions of variations in consumption can be explained by the financial shock (8.86%) than by housing supply (7.63%) and capital supply (7.55%) shocks. These results highlight the significance of the financial shock in explaining the variations in housing investment.

5.2 The Effects of Non-Financial Shocks

The Effects of the TFP Shock Figure 4a presents the responses of housing market to a one standard deviation decrease in the TFP shock. While both borrowers are affected similarly, the
Table 5: Variance Decomposition: Baseline Extended Model

<table>
<thead>
<tr>
<th>shocks</th>
<th>Financial Shock</th>
<th>TFP</th>
<th>Monetary</th>
<th>Housing Supply</th>
<th>Capital Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B_p$</td>
<td>1.03</td>
<td>75.98</td>
<td>17.73</td>
<td>2.55</td>
<td>2.65</td>
</tr>
<tr>
<td>$B_s$</td>
<td>24.54</td>
<td>56.65</td>
<td>15.54</td>
<td>0.90</td>
<td>2.37</td>
</tr>
<tr>
<td>$\Delta H_s$</td>
<td>26.27</td>
<td>48.94</td>
<td>16.81</td>
<td>0.47</td>
<td>7.63</td>
</tr>
<tr>
<td>$\Delta H_p$</td>
<td>9.94</td>
<td>58.23</td>
<td>18.21</td>
<td>4.89</td>
<td>8.63</td>
</tr>
<tr>
<td>$C_p$</td>
<td>0.62</td>
<td>69.49</td>
<td>23.96</td>
<td>2.55</td>
<td>3.38</td>
</tr>
<tr>
<td>$C_s$</td>
<td>8.24</td>
<td>61.53</td>
<td>20.97</td>
<td>5.08</td>
<td>4.17</td>
</tr>
<tr>
<td>$L_p$</td>
<td>0.67</td>
<td>72.38</td>
<td>21.73</td>
<td>3.15</td>
<td>2.05</td>
</tr>
<tr>
<td>$L_s$</td>
<td>7.62</td>
<td>66.07</td>
<td>20.25</td>
<td>3.45</td>
<td>2.62</td>
</tr>
<tr>
<td>$q^h$</td>
<td>0.05</td>
<td>8.71</td>
<td>2.58</td>
<td>88.49</td>
<td>0.16</td>
</tr>
<tr>
<td>$\eta$</td>
<td>0.17</td>
<td>20.93</td>
<td>5.63</td>
<td>0.60</td>
<td>72.67</td>
</tr>
</tbody>
</table>

Note: The table presents the variance decomposition of selected variables to financial shock, TFP shock, expansionary monetary policy shock as well as housing and capital supply shocks. We exclude preference shock in this exercise as it serves the purpose of keeping the economy at the ZLB and is not used in the estimation.

Figure 4: Effects of Non-financial Shocks

(a) Adverse TFP Shock

(b) Capital Supply Shock

(c) Housing Supply Shock

(d) Expansionary Monetary Policy

Note: The figure plots the impulse responses of the housing investment to a one percent decrease in the innovations of the TFP, capital supply, and housing supply shocks, as well as an expansionary monetary policy shock. Aggregate housing demand shows the total demand of subprime and prime borrowers. All responses are normalized so that the units of the vertical axes represent percentage deviations from the steady state. The inherent difference in loan rates causes subprimers to be significantly worse off in the housing sector.
market. This result shows that the risk premium between borrowers is an important source of heterogeneity contributing to the asymmetry in housing wealth distribution observed in the data.

The Effects of Capital and Housing Supply Shocks We next investigate the effects of negative capital supply (i.e., the investment specific technology shock, \( x^i_t \)) and negative housing supply shocks (i.e., the housing specific technology shock, \( x^h_t \)). In particular, we initiate a one standard deviation decrease in the innovations of each shock, the results of which are plotted in Figure 4 (b and c). As expected, a negative shock on capital supply causes the entrepreneurs to substitute away from capital. Thus, while capital demand decreases due to high prices in the economy, entrepreneurs demand more housing. On the other hand, decreases in income and low amount of available credit cause subprimers and primers to demand less housing. A negative housing supply shock (Figure 4c), however, causes a spike in house prices, increasing the collateral value of households’ real estate holding. Relaxed collateral constraints encourage borrowers to invest in the housing market. Neither shock, however, generate a wealth reallocation between subprime and prime borrowers since both borrowers are similarly affected.

The Effects of Monetary Policy Shock Figure 4d presents the responses of housing market to a one hundred basis point decrease in the nominal interest rate. While housing investment of both primers and subprimers increase significantly (more so for latter), the responses of primers are more persistent. The finding that subprimers enjoy the low interest rates more due to being able to afford larger mortgages is not surprising given the findings from Justiniano et al. (2016). However, our result suggests that an expansionary monetary policy can help ameliorate the asymmetry in housing wealth reallocation during recessions.

5.3 The Role of the Zero Lower Bound

We next explore the effects of an adverse financial shock when the economy is at the ZLB. In particular, we keep the risk-free interest rate \( R_t \) at the ZLB for two periods using a negative preference shock to \( \beta_{ht} \) and initiate a one standard deviation adverse financial shock to the economy. We solve the model using piece-wise approximation as in Iacoviello (2015b). Figure 5 presents the impulse responses of housing investment, output, house prices, and consumption for the cases when the nominal interest rate is kept at the zero lower bound and when it is not.\(^{19}\)

This exercise demonstrates that the effects of an increase in risk premium across the two types of borrowers on the aggregate housing are amplified when the economy is constrained at the ZLB. Intuitively, when the nominal interest rate is constrained by the ZLB under an adverse financial shock, it becomes increasingly costly to save using the risk-free bond with the presence of inflation. As a result, the amount of available funds in the economy decreases, making it harder to borrow

\(^{19}\)While we did not use a global method to solve for the policy function, the piece-wise method presented by Iacoviello (2015b) provides a reasonably close approximation of the policy function to the one that is solved using global methods.
Note: The figure plots the impulse responses of selected variables to a one standard deviation increase in innovation to the financial friction, $\varepsilon^f_t$. All responses are normalized so that the units of the vertical axis are percentage deviations from the steady-state. Aggregate housing demand shows the total demand of subprime and prime borrowers. We solve the model using piecewise approximation, following Iacoviello (2015b).

for everyone, especially for subprime borrowers. This decrease depresses housing demand and therefore house prices. Overall, the ZLB amplifies the negative effects of financial frictions on aggregate housing demand compared to the case in which the ZLB does not bind, increasing the asymmetry in housing wealth distribution about 1%.

5.4 The Role of Credit Access

As previously demonstrated, the collateral constraints serve as an important channel in our model. Because the loan-to-value (LTV) ratios directly affect collateral constraints, in this section we study the extent to which LTVs can impact the housing wealth reallocation. Decreases in LTVs can cause tighter borrowing conditions for all borrowers. For instance, consider the following borrowing constraint for the subprime borrowers:

$$B_{s,t} \leq m_s E_t \left\{ q_{t+1}^H H_{s,t+1} \frac{\pi_{t+1}}{Z_{s,t}} \right\}$$

Here the LTV ratio for the subprimers, $m_s$, creates a constraint on the value of assets and limits the amount that a subprime borrower can obtain using his housing as collateral. If LTV ratios differ across borrowers, then their housing investment decisions could vary as a result of their borrowing conditions. A static exercise on the housing and consumption trade-off can provide the
Note: The figure plots the responses of selected variables to an adverse financial shock. In particular, we initiate a one standard deviation adverse shock to the innovation of the risk premium between the prime and subprime borrowers, $\varepsilon_f^t$.

necessary intuition.

\[
E_t \beta_p \Gamma_s \frac{H_{s,t+1}}{C_{s,t}} = E_t \left\{ \frac{q_h}{C_{s,t}} + (m_s - 1) \frac{\beta_s q_{h,t+1}}{C_{s,t+1}} - \frac{m_s q_{h,t+1}}{Z_{s,t+1} \pi_{t+1} C_{s,t}} \right\} \tag{29}
\]

Analyzing the consumption and housing trade-off in Equation 29 yields the following rule in the steady state

\[
\begin{cases}
\frac{\partial \left( \frac{C_s}{q_h H_s} \right)}{\partial m_s} > 0 & \text{if } Z_s > \frac{1}{\beta_s} \\
\frac{\partial \left( \frac{C_s}{q_h H_s} \right)}{\partial m_s} < 0 & \text{if } Z_s < \frac{1}{\beta_s}
\end{cases}
\]

This analysis shows that when subprimers are subject to an adverse financial shock, their loan rates will increase disproportionately more than those of the prime borrowers. Therefore, a financial shock increases the value of $Z_s$ and pushes subprimers into the case in which $Z_s > \frac{1}{\beta_s}$ holds. Thus, under lax credit constraints (high values of $m_s$), subprimers prefer consumption over housing investment in the equilibrium.

To understand the role of credit access in a dynamic setting, we collect micro-level evidence on plausible values of the LTV ratios using the public database for Fannie Mae and Freddie Mac
by the Federal Housing Finance Agency. In 2014, across a total of 34,300 loans in the database, the average LTV ratio is about 0.765 with the standard deviation of 0.16. Using the range of values obtained from this dataset, Figure 6 presents the responses of housing demand, output, and consumption to an adverse financial shock. We only vary the loan to value ratio for subprime borrowers $m_s$, while keeping everything else in line with the baseline calibration.

Figure 6 shows that higher LTV ratios for subprimers, or equivalently laxer credit constraints, magnify the asymmetry in housing wealth distribution between subprimers and primers. Despite this negative effect, laxer credit constraints cause a smaller decrease in consumption and output. Intuitively, when subprimers have better credit access (higher LTV ratios), they can better smooth out the adverse effects of financial shocks. As a result, the effects of these adverse shocks on consumption (and therefore output) would be more subdued. Moreover, lax credit conditions further cause subprimers to have excess leverage, yielding higher losses in the housing market under a credit crunch, which is along the line of the findings in Justiniano et al. (2016).

This exercise highlights the importance of credit access in amplifying the housing wealth distribution asymmetry across agents during recessions. In particular, tighter credit constraints for subprimers can dampen the asymmetry in housing wealth distribution across borrowers at the cost of having larger decline in output and aggregate consumption.

To verify the implications of Figure 6, we investigate the effects of credit access and leverage on the risk premium in the data. To do so we return to the Survey of Consumer Finances and regress the individual risk premia for subprime borrowers (in basis points) on the leverage and credit access, controlling for a number of demographic characteristics such as employment status, gender, age, education level of the household head, household size, and 5-year economic expectations of the household, as well as time fixed effects, $\mu_t$. In particular, we use the following specification:

$$
\text{Risk Premium}_{it} = \beta_0 + \beta_1 \text{Leverage}_{it} + \beta_2 \text{Credit Rejected}_{it} + \beta_3 \text{Demographic Controls}_{it} + \mu_t + \varepsilon_{it} 
$$

in which the leverage ratio is calculated from the data as:

$$
\text{Leverage} = \frac{\text{Borrowed Amount}}{\text{Total Value of the House}}
$$

Table 6 presents the regression results for subprime borrowers using Equation 30, with the same classification for borrowers as in our baseline regressions in Section 2. As Table 6 shows, leverage has a significant and positive effect on risk premium. This exercise suggests that when subprime borrowers accumulate leverage, possibly due to previous lax credit conditions, their risk premia increase, which dovetails nicely with the implications of Figure 6. Additionally, Table 6 highlights the importance of credit access in the sense that when subprimers are more credit rejected, their risk premia increase significantly.
Table 6: Effects of Leverage and Credit Access on Risk Premium

<table>
<thead>
<tr>
<th></th>
<th>Risk Premium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leverage</td>
<td>0.888***</td>
</tr>
<tr>
<td></td>
<td>(0.152)</td>
</tr>
<tr>
<td>Credit Rejected</td>
<td>50.919***</td>
</tr>
<tr>
<td></td>
<td>(0.455)</td>
</tr>
<tr>
<td>Demographic Controls</td>
<td>Yes</td>
</tr>
<tr>
<td>Time Fixed Effects</td>
<td>Yes</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>17,394</td>
</tr>
</tbody>
</table>

Note: In this table, we regress the risk premium on the individual leverage ratios and credit access for subprime borrowers. Values in parentheses show the standard errors. Here we control for time fixed effects as well as demographics of the households. ***, **, and * denote the 1%, 5%, and 10% levels of significance, respectively.

6 Conclusion

In this paper, we investigate the effects of the heterogeneity in credit access among borrowers on the housing wealth distribution during recessions. We first document that second home purchases increase significantly during recessions. To differentiate and control for idiosyncratic characteristics of borrowers, we use micro-level survey data from the Survey of Consumer Finances. We classify the borrowers as prime and subprime borrowers based on their mortgage loan rates and control for a rich set of demographic and financial characteristics. We find that prime borrowers are more likely to own investment homes during recessions compared to recoveries, whereas subprimers are more likely to invest during expansions. These results point to a dramatic difference between subprimers and primers: while subprimers are harmed by the collapse of the housing market, primers can partially take advantage of it.

To explain this reallocation of housing wealth across borrowers, we study a general equilibrium framework with heterogeneity in terms of credit access across borrowers. As observed in the data, subprimers are subject to a risk premium. A financial shock that increases this risk premium causes the more constrained agents, subprimers, to decrease their housing demand significantly. In stark contrast, borrowers who have relatively better access to credit benefit from lower house prices and thus can increase their investment home purchases. We also find that credit access plays an important role in propagating the risk premium across these two types of borrowers, both in the model and in the data. Moreover, when a financial shock follows a period in which the subprimers experience lax credit conditions, as in Great Recession, the asymmetry in housing wealth distribution between prime and subprime borrowers becomes larger.

When the nominal interest rates are constrained by the zero lower bound, the negative effects of financial frictions on aggregate housing demand is amplified which increases the asymmetry in housing wealth distribution. An expansionary monetary policy, however, can help decrease this asymmetry in home purchases, ameliorating the undesired effects of increases in financial frictions during recessions.
References


A Data Appendix

We use survey data from the Survey of Consumer Finances and combine the surveys conducted in 1995, 1998, 2001, 2004, 2007, 2010, and 2013 into one single dataset. While data before 1995 are available, we exclude them from the combined dataset because standardized weighting files are not publicly available. Table A1 presents the survey questions of the selected variables.

Table A1: SCF Survey Questions for Selected Variables

<table>
<thead>
<tr>
<th>Variables:</th>
<th>Definitions and Questions:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment Homeownership</td>
<td>Do you own any investment real estate such as a lot, vacation home, timeshare, apartment building, commercial property, or other investment property, including properties owned in partnership with other people? 1. Yes 0. No</td>
</tr>
<tr>
<td>Credit Rejected</td>
<td>In the past five years, has a particular lender or creditor turned down any request you made for credit, or not given you as much credit as you applied for? 1. Yes 0. No</td>
</tr>
<tr>
<td>Expectations</td>
<td>Over the next five years, do you expect the U.S. economy as a whole to perform better, worse, or about the same as it has over the past five years? 0. Worse 1. Same 2. Better</td>
</tr>
<tr>
<td>Gender</td>
<td>Sex of the respondent 1. Male 2. Female</td>
</tr>
<tr>
<td>Education</td>
<td>What is the highest grade of school or year of college the household head completed? 0. No Grades, 1. Until 12th Grade, 2. College (1-4 years), 3. Masters and higher</td>
</tr>
<tr>
<td>Household Size</td>
<td>Number of people in the household according to the HHL. Excludes people included in the household listing who do not usually live there and who are financially independent.</td>
</tr>
<tr>
<td>Age</td>
<td>What is your year of birth?</td>
</tr>
</tbody>
</table>

Table A2 presents the first and second moments of selected variables from the dataset. As expected, subprimers are characterized by a higher rate of credit rejection and a higher rate of unemployment. These borrowers are also more likely to have a female household head and are relatively less educated. In terms of economic expectations, they are only slightly more optimistic about the current state of the economy than their prime counterparts.

Similar to Table A2, Figure A.1 plots the means of selected variables over time. Prime borrowers are more likely to own investment homes, are less likely to have their credit applications rejected, and tend to own more expensive homes. They are also more likely to be employed and are more educated throughout the entire sample period.
Table A2: Descriptive Statistics

<table>
<thead>
<tr>
<th></th>
<th>Subprime</th>
<th>Prime</th>
<th>Full Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment Homeownership (%)</td>
<td>30.76</td>
<td>44.65</td>
<td>38.80</td>
</tr>
<tr>
<td></td>
<td>(46.15)</td>
<td>(49.71)</td>
<td>(48.73)</td>
</tr>
<tr>
<td>Credit Rejected (%)</td>
<td>31.55</td>
<td>15.64</td>
<td>21.44</td>
</tr>
<tr>
<td></td>
<td>(46.47)</td>
<td>(36.32)</td>
<td>(41.04)</td>
</tr>
<tr>
<td>Current House Price (log)</td>
<td>11.24</td>
<td>12.44</td>
<td>12.09</td>
</tr>
<tr>
<td></td>
<td>(3.349)</td>
<td>(2.102)</td>
<td>(2.608)</td>
</tr>
<tr>
<td>Economic Expectations (Highest=2)</td>
<td>1.156</td>
<td>1.052</td>
<td>1.168</td>
</tr>
<tr>
<td></td>
<td>(0.764)</td>
<td>(0.741)</td>
<td>(0.759)</td>
</tr>
<tr>
<td>Employed (%)</td>
<td>87.95</td>
<td>90.65</td>
<td>89.49</td>
</tr>
<tr>
<td></td>
<td>(32.55)</td>
<td>(29.12)</td>
<td>(30.67)</td>
</tr>
<tr>
<td>Retired (%)</td>
<td>6.682</td>
<td>6.136</td>
<td>6.286</td>
</tr>
<tr>
<td></td>
<td>(24.97)</td>
<td>(24.00)</td>
<td>(24.27)</td>
</tr>
<tr>
<td>Male Household Head (%)</td>
<td>85.87</td>
<td>91.22</td>
<td>89.08</td>
</tr>
<tr>
<td></td>
<td>(34.83)</td>
<td>(28.30)</td>
<td>(31.19)</td>
</tr>
<tr>
<td>Education (Years)</td>
<td>13.95</td>
<td>14.98</td>
<td>14.64</td>
</tr>
<tr>
<td></td>
<td>(2.482)</td>
<td>(2.210)</td>
<td>(2.354)</td>
</tr>
<tr>
<td>Household Size</td>
<td>3.040</td>
<td>3.097</td>
<td>3.078</td>
</tr>
<tr>
<td></td>
<td>(1.484)</td>
<td>(1.395)</td>
<td>(1.444)</td>
</tr>
<tr>
<td>Number of Households</td>
<td>22,730</td>
<td>29,202</td>
<td>70,412</td>
</tr>
</tbody>
</table>

**Note:** The data are from the *Survey of Consumer Finances*. Standard deviations are in parenthesis. Prime and subprime borrowers are differentiated based on the loan rates of their first mortgages.
Figure A.1: Descriptive Statistics Over Time

Note: This figure plots the descriptive statistics for selected variables over time. Prime and subprime borrowers are classified based on their primary home mortgage rates. Here log home price is the log of current price of the primary residence.
B Robustness Checks

The results in Section 2 on the divergence in homeownership between the two types of borrowers remain consistent after a number of robustness checks. For instance, Table B1 columns (1) estimate the Probit regression in Equation 1 with a 5% decrease in the loan rate cutoffs for subprime and prime borrowers. To illustrate, suppose that the prime rate - the cutoff in the baseline model for primers - is 600 basis points in a given year. A decrease of 5% means that the new cutoff for the prime borrowers would be 570 basis points for that year. This change in the cutoff rates causes a 43% increase in the number of subprimers, and a 16% decrease in primers. The results on the asymmetry in housing investment ownership across borrowers are robust to these new cutoffs. Similarly an increase of 5% in the cutoff rate (columns 2) yields similar findings in terms of the asymmetry in housing investment.

Since a significant number of subprime mortgages are Federally guaranteed with fixed low interest rates, one natural robustness check is to account for these mortgages as borrowers might be self-selected into their categories and therefore could bias our results. In Table B1 columns (3), we exclude mortgages from government sponsored enterprises such as the Federal Housing Administration, the Veteran’s Administration, various state housing programs, and first-time buyer programs, etc. in our regressions. Given these restrictions, about 27 percent of subprime mortgages and 19 percent of prime mortgages were backed by Federal programs. Again, our results on the asymmetry in the housing wealth are robust to excluding these Federally guaranteed loans.

---

20The government sponsored enterprises exclude Fannie Mae and Freddie Mac. However, including Fannie Mae and Freddie Mac does not change the results.
Table B1: Robustness Checks

<table>
<thead>
<tr>
<th></th>
<th>Subprime Borrowers</th>
<th>Prime Borrowers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>1998</td>
<td>0.017***</td>
<td>-0.000</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>2001 Recession</td>
<td>-0.001</td>
<td>0.008</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>2004</td>
<td>0.005***</td>
<td>0.008***</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>2007</td>
<td>0.078***</td>
<td>0.057***</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>Great Recession</td>
<td>0.037***</td>
<td>0.043***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>2013</td>
<td>0.051***</td>
<td>0.047***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.006)</td>
</tr>
<tr>
<td>Observations</td>
<td>26,219</td>
<td>13,800</td>
</tr>
</tbody>
</table>

Note: Table B1 estimates the Probit regressions in Equation 1 with (1) a decrease of 5% in the cutoffs of subprime and prime borrowers, (2) an increase of 5% in the cutoffs of borrowers, and (3) the exclusion of the mortgages from government sponsored enterprises. We report the marginal effects at the means using 1995 as the base year. ***, **, and * denote the 1%, 5%, and 10% levels of significance, respectively.
C  Full Model

Patient Households:

\[ C_{h,t} + D_t = R_{t-1}D_{t-1} + w_t l_{h,t} \tag{31} \]
\[ \frac{1}{\beta_h C_{h,t} R_t} = E_t \left\{ \frac{1}{C_{h,t+1}} \right\} \tag{32} \]
\[ l_{h,t}^* = \frac{w_t}{C_{h,t}} \tag{33} \]

Prime Borrowers:

\[ C_{p,t} + q^h_{t} H_{p,t+1} = q^h_{t} H_{p,t} - \frac{Z_{p,t-1} B_{p,t-1}}{\pi_t} + B_{p,t} + w_t l_{p,t} \tag{34} \]
\[ B_{p,t} Z_{p,t} \leq m_p E_t \left\{ q^h_{t+1} H_{p,t+1} \right\} \tag{35} \]
\[ l_{p,t}^* = \frac{w_t}{C_{p,t}} \tag{36} \]
\[ E_t \frac{\beta_p \Gamma_p}{H_{p,t+1}} = E_t \left\{ \frac{\beta_p q^h_{t+1}}{C_{p,t+1}} (m_p - 1) + \frac{q^h_t}{C_{p,t}} \left( 1 - \frac{m_p q^h_{t+1}}{Z_{p,t+1}} \right) \right\} \tag{37} \]

Subprime Borrowers:

\[ Z_s = Z_p + f_t \tag{38} \]
\[ C_{s,t} + q^h_{t} H_{s,t+1} = q^h_{t} H_{s,t} - Z_{s,t-1} B_{s,t-1} + B_{s,t} + w_t l_{s,t} \tag{39} \]
\[ B_{s,t} Z_{s,t} \leq m_s E_t \left\{ q^h_{t+1} H_{s,t+1} \right\} \tag{40} \]
\[ l_{s,t}^* = \frac{w_t}{C_{s,t}} \tag{41} \]
\[ E_t \frac{\beta_s \Gamma_s}{H_{s,t+1}} = E_t \left\{ \frac{q^h_t}{C_{s,t}} + (m_s - 1) \frac{\beta_s q^h_{t+1}}{C_{s,t+1}} - \frac{m_s q^h_{t+1}}{Z_{s,t+1} C_{s,t}} \right\} \tag{42} \]

Entrepreneurs:

\[ Y_t = A_t K_t^{\alpha} H_{e,t}^{\kappa} (L_{e,t})^{(1-\alpha-\kappa)} \tag{43} \]
\[ C_{e,t} + q^h_{t} H_{e,t+1} + \frac{Z_{e,t-1} B_{e,t-1}}{\pi_t} = \frac{Y_t}{X_t} + q^h_{t} H_{e,t} - w_t L_{e,t} - q_t I_t + B_{e,t} + F_t \tag{44} \]
\[ L_{e,t} = \nu (\varrho L_{p,t} + (1 - \varrho)L_{s,t}) + (1 - \nu) L_{h,t} \tag{45} \]
\[ B_{e,t} \leq m_e E_t \left\{ \left( q^h_{t+1} H_{e,t+1} + q_{t+1} K_{t+1} \right) \frac{\pi_{t+1}}{Z_{e,t}} \right\} \tag{46} \]
\[ E_t \frac{\beta_e q^h_{t+1}}{C_{e,t+1}} \left( \frac{\alpha Y_{t+1}}{q_{t+1} K_{t+1}} + (1 - \delta) - m_e \right) = \frac{1}{C_{e,t}} \left( q_t - E_t \frac{m_e q^h_{t+1}}{Z_{e,t}} \right) \tag{47} \]
$$E_t \beta q_{t+1}^h \left( \frac{\kappa Y_{t+1}}{q_{t+1}^h H_{e,t+1}} + (1 - m_e) \right) = \frac{1}{C_{e,t}} \left( q_t^h - E_t \frac{m_{c,t+1}^h}{\pi_{t+1}} \right)$$  \hspace{0.5cm} (48)$$

$$(1 - \alpha - \kappa) \frac{Y_t}{L_{e,t}} = w_t$$  \hspace{0.5cm} (49)$$

Retailers:

$$Y_t = \left( \int_0^1 Y_t(z)^{(\epsilon - 1)/\epsilon} \frac{dz}{z^\epsilon} \right)^{\epsilon/(\epsilon - 1)}$$  \hspace{0.5cm} (50)$$

$$\pi_t = \left[ (1 - \theta) (\pi_t^e)^{1-\epsilon} + \theta \right]^{\frac{1}{1-\epsilon}}$$  \hspace{0.5cm} (51)$$

$$F_t = \left( 1 - \frac{1}{X_t} \right) Y_t$$  \hspace{0.5cm} (52)$$

Capital Producers:

$$E_t \left\{ q_t x_t^i - 1 - \chi \left( \frac{I_t}{K_t} - \delta \right) \right\} = 0$$  \hspace{0.5cm} (53)$$

$$x_t^i I_t = K_{t+1} - (1 - \delta) K_t$$  \hspace{0.5cm} (54)$$

House Producers:

$$x_t^h \Delta H_t = H_{t+1} - H_t$$  \hspace{0.5cm} (55)$$

$$H_t = H_{p,t} + H_{s,t} + H_{e,t}$$  \hspace{0.5cm} (56)$$

$$E_t \left\{ q_t^h x_t^h - 1 - \chi_h \left( \frac{\Delta H_t}{H_t} \right) \right\} = 0$$  \hspace{0.5cm} (57)$$

Monetary Policy:

$$R_t = \bar{R} \left( \left[ \frac{Y_t}{Y} \right]^{b_1} \left[ \frac{1 + \pi_t}{1 + \pi} \right]^{b_2} \right) \epsilon_t^R$$  \hspace{0.5cm} (58)$$

$$R_t - 1 \geq 0$$  \hspace{0.5cm} (59)$$

Market Clearing Conditions:

$$Y_t = C_t + I_t + \Delta H_t$$  \hspace{0.5cm} (60)$$

$$D_t = B_{p,t} + B_{s,t} + B_{e,t}$$  \hspace{0.5cm} (61)$$

$$L_{e,t} = l_{h,t} + l_{s,t} + l_{p,t}$$  \hspace{0.5cm} (62)$$

Shock Processes:

$$\log \beta_{h,t} = (1 - \rho_{\beta_h}) \beta_h + \rho_{\beta_h} \log \beta_{h,t-1} + \varepsilon_{t}^{\beta_h}$$  \hspace{0.5cm} (63)$$

$$f_t = (1 - \rho_f) f + \rho_{f} f_{t-1} + \varepsilon_{t}^{f}$$  \hspace{0.5cm} (64)$$

$$\log A_t = \rho_{A} \log A_{t-1} + \varepsilon_{t}^{A}$$  \hspace{0.5cm} (65)$$

$$\log x_t^i = \rho_{x_t^i} \log x_{t-1}^i + \varepsilon_{t}^{x_t^i}$$  \hspace{0.5cm} (66)$$
\[
\log x_t^h = \rho x_t^h \log x_{t-1}^h + \varepsilon_t^h \quad (67)
\]
\[
\log (\epsilon_t^R) = \rho_e \log (\epsilon_{t-1}^R) + \varepsilon_t^R \quad (68)
\]
D Estimation Appendix

We estimate the model to fit the following five series: real output growth (GDPC96), bank prime loan rate (MPRIME), growth rate of private residential investment (PRFI), the growth rate of house prices (MSPUS), and real consumption growth (PCECC96), in which the codes in the brackets denote the corresponding codes from the St. Louis’s FRED database. Data from 1984:Q1 to 2016:Q2 are retrieved from the St. Louis’s FRED database, are in quarterly frequency, seasonally adjusted, and filtered using the Hodrick-Prescott filter. Here we abstract from periods with high volatility before the Great Moderation by focusing on post-1984 data only. We define a set of auxiliary variables in the model and then transform the data accordingly. In particular, we use the following four quantities

\[ g_Y = \frac{Y' - Y}{Y}; \quad g_C = \frac{C' - C}{C}; \quad g_{PRFI} = \frac{PRFI' - PRFI}{PRFI}; \quad g_{PH} = \frac{P_{PH}' - P_{PH}}{P_{PH}} \]

where \( P_{PH} \) denotes the series “Median Sales Price of Houses Sold for the United States (MSPUS)” from the U.S. Bureau of the Census. To match with the growth rate of real house prices in the model, we deflate the variables using a common GDP deflator as in the case for output and consumption. For the growth rate of house prices and the borrowing rates for primers, we match the net rates with the ones obtained from the St. Louis’s FRED.

Robustness of the Bayesian Estimation Here we verify the robustness of the model’s estimation by running several alternative specifications. Table D1 presents the estimation results of the main extended model by removing or adding a number of parameters.
Table D1: Estimation using Alternative Specifications

<table>
<thead>
<tr>
<th>Par.</th>
<th>Prior</th>
<th>Posterior</th>
<th>90% HPD interval</th>
<th>Prior</th>
<th>Post. Std.</th>
<th>Prior</th>
<th>Posterior</th>
<th>90% HPD interval</th>
<th>Prior</th>
<th>Post. Std.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_H$</td>
<td>0.99</td>
<td>0.9884</td>
<td>0.9816 0.9957</td>
<td>beta</td>
<td>0.005</td>
<td>0.99</td>
<td>0.9879 0.9798</td>
<td>beta</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>$\beta_S$</td>
<td>0.950</td>
<td>0.9507</td>
<td>0.9432 0.9581</td>
<td>beta</td>
<td>0.005</td>
<td>0.950</td>
<td>0.9508 0.9434</td>
<td>beta</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>$\beta_P$</td>
<td>0.97</td>
<td>0.9699</td>
<td>0.9617 0.9771</td>
<td>beta</td>
<td>0.005</td>
<td>0.970</td>
<td>0.9692 0.9607</td>
<td>beta</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>$\beta_e$</td>
<td>0.98</td>
<td>0.9794</td>
<td>0.973 0.9889</td>
<td>beta</td>
<td>0.005</td>
<td>0.98</td>
<td>0.9804 0.9725</td>
<td>beta</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>$\rho_A$</td>
<td>0.90</td>
<td>0.9016</td>
<td>0.8704 0.9317</td>
<td>beta</td>
<td>0.02</td>
<td>0.90</td>
<td>0.8981 0.8636</td>
<td>beta</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>$\chi_K$</td>
<td>0.59</td>
<td>0.59</td>
<td>0.5848 0.5946</td>
<td>beta</td>
<td>0.003</td>
<td>0.59</td>
<td>0.5897 0.585</td>
<td>beta</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>$\chi_H$</td>
<td>0.1</td>
<td>0.1</td>
<td>0.0956 0.1051</td>
<td>beta</td>
<td>0.003</td>
<td>0.10</td>
<td>0.0996 0.0939</td>
<td>beta</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>$m_o$</td>
<td>0.80</td>
<td>0.7995</td>
<td>0.7583 0.8574</td>
<td>norm</td>
<td>0.03</td>
<td>0.80</td>
<td>0.7995 0.7583</td>
<td>norm</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>$m_s$</td>
<td>0.80</td>
<td>0.796</td>
<td>0.751 0.8556</td>
<td>norm</td>
<td>0.03</td>
<td>0.80</td>
<td>0.796 0.751</td>
<td>norm</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>$m_p$</td>
<td>0.80</td>
<td>0.8015</td>
<td>0.7594 0.8509</td>
<td>norm</td>
<td>0.03</td>
<td>0.80</td>
<td>0.8015 0.7594</td>
<td>norm</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>$\theta$</td>
<td>0.75</td>
<td>0.7456</td>
<td>0.7159 0.7775</td>
<td>norm</td>
<td>0.02</td>
<td>0.75</td>
<td>0.7478 0.7129</td>
<td>norm</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>$\bar{f}$</td>
<td>0.05</td>
<td>0.0502</td>
<td>0.0451 0.0543</td>
<td>norm</td>
<td>0.003</td>
<td>-</td>
<td>-     -</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$e$</td>
<td>0.6</td>
<td>0.5999</td>
<td>0.5411 0.657</td>
<td>norm</td>
<td>0.03</td>
<td>-</td>
<td>-     -</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$s$</td>
<td>0.4</td>
<td>0.3994</td>
<td>0.3477 0.437</td>
<td>norm</td>
<td>0.03</td>
<td>-</td>
<td>-     -</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$p$</td>
<td>2.5</td>
<td>2.5015</td>
<td>2.4565 2.557</td>
<td>norm</td>
<td>0.03</td>
<td>-</td>
<td>-     -</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\rho_f$</td>
<td>0.5</td>
<td>0.5066</td>
<td>0.3495 0.6608</td>
<td>beta</td>
<td>0.1</td>
<td>0.5</td>
<td>0.4856 0.3297</td>
<td>beta</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>$\rho_X$</td>
<td>0.5</td>
<td>0.5135</td>
<td>0.3824 0.6329</td>
<td>beta</td>
<td>0.1</td>
<td>0.5</td>
<td>0.5259 0.4035</td>
<td>beta</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>$\rho_{XI}$</td>
<td>0.5</td>
<td>0.5415</td>
<td>0.4201 0.6498</td>
<td>beta</td>
<td>0.1</td>
<td>0.5</td>
<td>0.4826 0.3077</td>
<td>beta</td>
<td>0.1</td>
<td></td>
</tr>
</tbody>
</table>

Standard Deviation of Shocks

<table>
<thead>
<tr>
<th>Shocks</th>
<th>Prior</th>
<th>Posterior</th>
<th>90% HPD interval</th>
<th>Prior</th>
<th>Post. Std.</th>
<th>Prior</th>
<th>Posterior</th>
<th>90% HPD interval</th>
<th>Prior</th>
<th>Post. Std.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\varepsilon_A$</td>
<td>0.01</td>
<td>0.0343</td>
<td>0.032 0.0365</td>
<td>invg</td>
<td>Inf</td>
<td>0.01</td>
<td>0.0357 0.0344</td>
<td>invg</td>
<td>Inf</td>
<td></td>
</tr>
<tr>
<td>$\varepsilon_e$</td>
<td>0.01</td>
<td>0.0409</td>
<td>0.0376 0.0444</td>
<td>invg</td>
<td>Inf</td>
<td>0.01</td>
<td>0.0431 0.0401</td>
<td>invg</td>
<td>Inf</td>
<td></td>
</tr>
<tr>
<td>$\varepsilon_f$</td>
<td>0.02</td>
<td>0.0075</td>
<td>0.0046 0.0105</td>
<td>invg</td>
<td>Inf</td>
<td>0.02</td>
<td>0.0087 0.0042</td>
<td>invg</td>
<td>Inf</td>
<td></td>
</tr>
<tr>
<td>$\varepsilon_X$</td>
<td>0.01</td>
<td>0.0378</td>
<td>0.0355 0.0396</td>
<td>invg</td>
<td>Inf</td>
<td>0.01</td>
<td>0.0378 0.034</td>
<td>invg</td>
<td>Inf</td>
<td></td>
</tr>
<tr>
<td>$\varepsilon_{XI}$</td>
<td>0.01</td>
<td>0.0283</td>
<td>0.0265 0.0313</td>
<td>invg</td>
<td>Inf</td>
<td>0.01</td>
<td>0.0282 0.0266</td>
<td>invg</td>
<td>Inf</td>
<td></td>
</tr>
<tr>
<td>$\varepsilon_P$</td>
<td>0.01</td>
<td>0.0093</td>
<td>0.0085 0.0103</td>
<td>invg</td>
<td>Inf</td>
<td>0.01</td>
<td>0.0094 0.0083</td>
<td>invg</td>
<td>Inf</td>
<td></td>
</tr>
</tbody>
</table>

Note: We estimate the model to fit five series: real output growth (GDPC96), bank prime loan rate (MPRIME), growth rate of the private residential investment (PRFI), the growth rate of house prices (MSPUS), and real consumption growth (PCECC96). Data are all seasonally adjusted, HP filtered, and transformed in a way such that the variable definitions match ours in the model. Here re-estimate our baseline extended model estimation with different sets of parameters.