Macroeconomic Dynamics, **26**, 2022, 1775–1805. Printed in the United States of America.
doi:10.1017/S1365100521000055

HOUSING WEALTH REALLOCATION BETWEEN SUBPRIME AND PRIME BORROWERS DURING RECESSIONS

AYSE SAPCI
Utah State University

NAM T. VU
Miami University

The Survey of Consumer Finances (SCF) indicates that, unlike subprime borrowers, prime borrowers are more likely to own investment homes during recessions than during recoveries. Drawing on this empirical fact, we present and estimate a dynamic stochastic general equilibrium (DSGE) model that distinguishes between borrowers through their credit access. We find that the relative ease of credit access among borrowers explains the divergence in investment homeownership seen in the data. This divergence is amplified when subprime borrowers are subject to lax credit conditions prior to a financial shock or when the nominal interest rate is constrained at the zero lower bound (ZLB). An expansionary monetary policy helps bridge this gap across borrowers.

Keywords: Housing Investment, Credit Access, Subprime Borrowers, Prime Borrowers

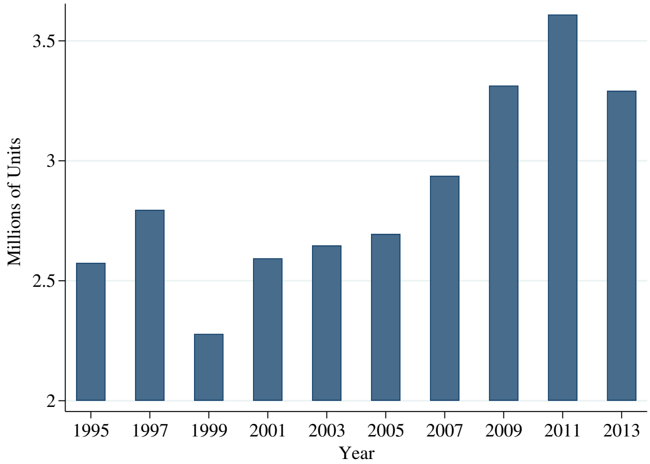
1. INTRODUCTION

The Great Recession reminded us how integrated the housing market and the rest of the economy are. As the US slipped into the worst recession since World War II, both the financial and housing markets collapsed. This wave of defaults, combined with massive fire sales from banks and other homeowners, put significant downward pressure on house prices. Despite considerable losses in the overall housing wealth, lower 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.

Our motivation follows Figure 1, which plots the total number of units whose residence is elsewhere between 1995 and 2013 from the American Housing

We are particularly grateful for comments from Kimberly Berg, Mario J. Crucini, Matthew Jaremski, Kevin Huang, Seth Neumuller, Yang Song, Harald Uhlig, Jonathan Wolff, and participants of the seminars and conferences in Miami University, Colgate University, Fordham University, Lafayette College, Vanderbilt University, Utah State University, Federal Reserve Bank of Dallas, Federal Reserve Board, Fall 2016 Midwest Macroeconomic Meetings, and 2016 Southern Economic Association Conference. Address correspondence to: Ayse Sapci, Department of Economics and Finance, Utah State University, 3565 Old Main Hill, Logan, UT 84322-3565, USA. email: ayse.sapci@usu.edu. Phone: 435 797 2332.

 1469-8056/21



Note: This figure plots the total number of "units whose residence is elsewhere" (URE) (in millions). Data are from the American Housing Survey by the US Census. Since the survey is conducted on the unit basis (not by the owner), this number includes all homes owned for purposes other than being the primary residence of the owner(s) which includes properties that are seasonally vacant.

FIGURE 1. Housing units whose residence is elsewhere (1995–2013).

Survey. The key observation here is that the total number of these units increases significantly during the two most recent recessions. Given the massive collapse of the housing market during the Great Recession, the increase in the number of investment home units is unexpected. However, Figure 1 suggests that some borrowers, particularly those who still have good credit access, were able to take advantage of low house prices during the Great Recession, increasing housing wealth inequality across borrowers.

We confirm this observation using micro-level data from the Survey of Consumer Finances (SCF). We find that prime borrowers are more likely to own investment homes during recessions than during recoveries, in contrast to the subprime borrowers who are less likely to do so. This asymmetry in investment homeownership is robust to various demographic and financial characteristics of the borrowers, the types of mortgages in use, and different classifications of the borrower groups. We, thus, conclude that this increase in inequality across wealth distribution is solely attributable to credit access differences among borrowers as we control for other factors that may cause such inequality in the first place. What is more striking in our findings is that the inequality actually increases during recessions. Therefore, recessions not only have direct negative aggregate effects on the economy, but they also change the structure of the economy by making the prime borrowers better off and subprime borrowers worse off, expanding the wealth gap between them.

To provide a mechanism for the asymmetry observed in the data, we present a tractable dynamic stochastic general equilibrium (DSGE) model featuring collateral constraints, debt accumulation, and an occasionally binding zero lower bound (ZLB, thereafter). Similar to our empirical analysis, we divide borrowers into subprime and prime categories based on their loan rates. Since housing is used as collateral, the ability of borrowers to obtain loans is constrained by the expected value of their housing investment. We next estimate the model to match important features of the data from 1984:Q1 to 2016:Q2 using Bayesian methods. Our results suggest that an adverse financial shock makes borrowing disproportionately more costly for subprime borrowers who have higher risk premia. Since prime borrowers can sustain easier access to credit than subprime borrowers during recessions, they are better positioned to capitalize on the declining house prices, resulting in the observed inequality in housing wealth distribution. We also explore the extent to which the wealth reallocation channel is dependent on the *ex ante* state of the housing market. We find that a negative financial shock creates a larger wedge between prime and subprime borrowers when house prices are low compared to when they are high, making the inequality in wealth distribution more prominent.

While borrowing elements from Iacoviello (2005) and Justiniano et al. (2016), our model complements the literature along multiple dimensions. First, we introduce heterogeneity in credit access to account for differences among borrowers in a tractable way. Second, since our model features construction, housing supply varies over time. In particular, the fixed housing supply assumption could automatically create an asymmetry in the model as any decrease in the housing demand of subprime borrowers would be offset by the same amount of increase in those of their prime counterparts. However, with the presence of housing construction in our model, it is possible (and more likely) to have all agents increase or decrease their demand simultaneously given the changes in house prices. The asymmetry in housing wealth distribution, therefore, arises from the heterogeneity in credit access among borrowers, rather than from the fixed housing supply assumption. Third, we allow entrepreneurs to borrow subject to collateral holdings of not only their commercial real estate but also their physical capital. Lastly, we consider a Taylor-style monetary policy with an occasionally binding ZLB to replicate the near-zero interest rate environment of the Great Recession.

Our model highlights the importance of credit access in explaining housing wealth reallocation during recessions and how differences in credit access contribute to the unequal wealth distribution across prime and subprime borrowers. In particular, we demonstrate that the asymmetry in housing wealth across subprime and prime borrowers becomes more significant when an adverse financial shock follows a period in which the subprime borrowers are subject to lax credit conditions, as was the case during the Great Recession. We also find that the ZLB amplifies the negative effects of financial shocks on aggregate housing demand while increasing the asymmetry in the housing wealth distribution. Moreover, an expansionary monetary policy ameliorates the negative effects of financial frictions, and therefore mitigates the investment homeownership gap across borrowers during recessions.

Our paper belongs to a vast literature focusing on the interactions of financial frictions, the housing market, and macroeconomic aggregates. In particular, this literature highlights the importance of house prices and collateral constraints in amplifying recessions (see, e.g., Iacoviello (2005), Iacoviello and Pavan (2013), Favilukis et al. (2013), Liu et al. (2013), Mian et al. (2013), Kaplan et al. (2016), and Lambie-Hanson et al. (2019), among others). We complement this literature by studying the contrasting responses in investment homeownership across prime and subprime borrowers during recessions. To the best of our knowledge, our paper is the first to reconcile the asymmetry seen in the data with an estimated DSGE model.

The heterogeneity of borrowers incorporated in our model plays an important yet underappreciated role in understanding macroeconomic fluctuations in the literature (see, e.g., Philippon and Midrigan (2011), Mian and Sufi (2009, 2016), Krueger et al. (2016), and Guerrieri and Lorenzoni (2017), among others). Similar to this paper, Huo and Rios-Rull (2016) argue that when lower housing prices are combined with the reduction in access to credit, consumption decreases more dramatically, particularly for the more constrained agents. Justiniano et al. (2016) further show that a drop in interest rates helps subprime borrowers afford larger mortgages. As subprime borrowers ramp up their demand for housing and accumulate debt, they cause larger increases in house prices. In this paper, we emphasize the role of credit access heterogeneity across borrowers in creating housing wealth reallocation during recessions. We find that as subprime borrowers gain easier 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 across prime and subprime borrowers using the US data from the SCF. Drawing on this empirical finding, Section 3 introduces a DSGE model to explain how a financial shock can lead to an asymmetry in housing investment decisions across borrowers. Section 4 estimates the model to US data using Bayesian methods. Section 5 discusses the implications of our model and highlights the importance of credit access in creating the asymmetry in housing investment across prime and subprime borrowers both in the model and data. Section 6 examines the role of collateral constraints, and finally, Section 7 concludes the paper.

2. EMPIRICAL EVIDENCE

We examine the extent to which housing wealth reallocation changes across prime and subprime borrowers using repeated cross-sectional data from the SCF. The SCF consists of a triennial set of detailed questions about family income, real estate assets, and financial and demographic characteristics of the respondents from 1995 to 2013.[1]

We use the borrowers' current loan rates on their primary home mortgages to differentiate between prime and subprime borrowers. Specifically, we define prime borrowers as borrowers whose current loan rates on their primary home mortgages are less than the prime rate in the corresponding year and subprime borrowers as those whose current mortgage loan rates belong to the highest one-third of the loan rate distribution in a given survey year.[2]

The most common method to separate prime and subprime borrowers is to use credit scores (e.g., Mian and Sufi (2009), Justiniano et al. (2016), Foote et al. (2016), and Albanesi et al. (2017)). Credit scores, however, cannot contain any demographic or public assistance information under the Consumer Credit Protection Act. Along this dimension, our paper complements the literature by exploiting the rich set of demographic and financial characteristics from the SCF to study the asymmetry in housing wealth between prime and subprime borrowers during recessions.[3]

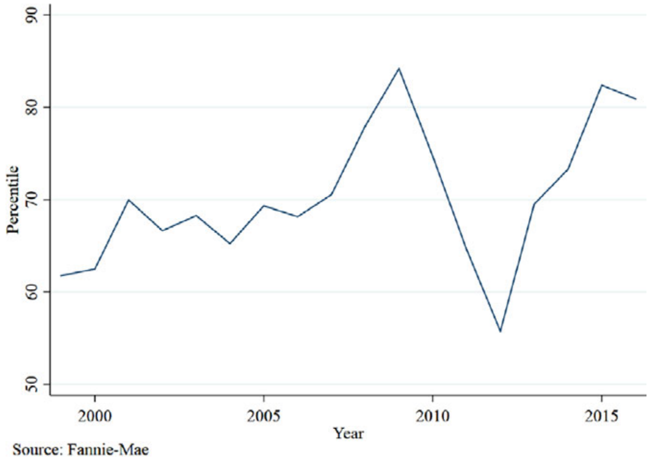
As Segal et al. (1998), Charles and Hurst (2002), and Chambers et al. (2009) show, demographic characteristics are very important in explaining the homeownership gap. For instance, Segal et al. (1998) find that households who have high education, are married, have more members, and are white are more likely to be homeowners. They further show that the changes in homeownership in the 80s and early 90s were entirely attributable to shifts in demographic characteristics, such as the decline in the fraction of married household heads. In particular, they find that 40% of the difference between homeownership rates of black and white households can be explained by demographic differences. Using the SCF, we find that while only 30% of whites are credit rejected, 64% of blacks are credit rejected at least once in their lives, showing the importance of controlling demographic characteristics.

While the SCF allows us to control demographic characteristics that affect the differences in homeownership rates across borrowers, it does not contain any geographical location information in the public database. Even though markets respond differently to house price fluctuations over time, we have to abstract from all spatial dimension implications for technical reasons.

Our choice of cutoffs to separate prime and subprime borrowers is consistent with the micro-level data from the Single Family Loan-Level Dataset by Freddie Mac.[4] The dataset shows that, on average, subprime borrowers correspond to the top third of the loan rate distribution for our time period (Figure 2). Moreover, using the same dataset, we find that borrowing rates and credit scores have a strong negative correlation of about -0.89 (Figure 3).

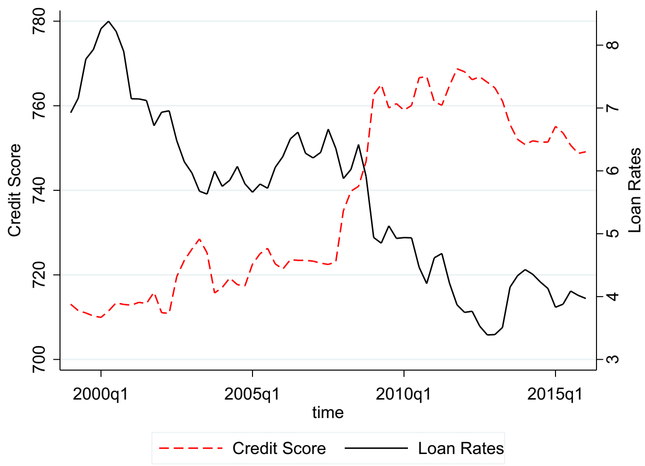
Turning to more details, we estimate the following Probit regression separately for prime and subprime borrowers using the SCF.[5]

$$\begin{aligned}
&\textit{Investment Homeownership}_{i,t} \\
&\quad = \beta_0 + \beta_{1,t}\,\textit{Survey Year}_t + \beta_{2,t}\,\textit{Survey Year}_t \times \textit{Credit Rejected}_{i,t} \\
&\qquad + \beta_3\,\textit{Credit Rejected}_{i,t} + \beta_4\,\textit{House Value}_{i,t} \\
&\qquad + \beta_5\,\textit{Demographic Controls}_{i,t} + \nu_{i,t}, \qquad (1)
\end{aligned}$$



Note: This figure plots the average loan rate for subprime as a percentile of the whole loan rate distribution. Data are from the Single-Family Home from Fannie-Mae. Subprime borrowers are those with a credit score of 660 or lower.

FIGURE 2. Loan rate percentiles for subprime borrowers over time.



Note: This figure plots the average loan rates (in percent) and the corresponding credit scores over time using data from the Single-Family Loan-Level Dataset by Freddie Mac. Loan rates are the rates at origination for primary homes. The correlation between the two series is −0.89 and is significant at the 5% level.

FIGURE 3. Credit scores and loan rates.

in which *Investment Homeownership* is a binary variable indicating whether household i owns an investment home in year t.[6] *Credit Rejected* indicates whether the household was turned down for a credit application by a lender, and therefore is a control variable accounting for within-group heterogeneity in credit

https://doi.org/10.1017/S1365100521000055 Published online by Cambridge University Press

TABLE 1. Probit regression results: The asymmetry in homeownership rates

	Prime Borrowers	Subprime Borrowers
1998	0.010**	0.002
	(0.002)	(0.003)
2001 (Dot-com recession)	0.020***	−0.016**
	(0.002)	(0.004)
2004	0.098***	0.027***
	(0.005)	(0.002)
2007	0.072***	0.083***
	(0.001)	(0.004)
2010 (Great recession)	0.118***	0.050***
	(0.006)	(0.003)
2013	0.098***	0.056***
	(0.003)	(0.003)
Credit rejected	−0.088***	−0.032***
	(0.002)	(0.003)
1998 × Credit rejected	0.060***	0.055***
	(0.003)	(0.002)
2001 × Credit rejected	0.046**	0.073***
	(0.013)	(0.003)
2004 × Credit rejected	0.145***	0.072***
	(0.006)	(0.001)
2007 × Credit rejected	0.006	−0.062***
	(0.003)	(0.006)
2010 × Credit rejected	−0.059***	0.024***
	(0.010)	(0.003)
2013 × Credit rejected	0.072***	0.049***
	(0.004)	(0.003)
Sex	0.176***	0.108***
	(0.003)	(0.001)
Birth year	−0.007***	−0.005***
	(0.000)	(0.000)
Education of head of households	0.002***	0.002***
	(0.000)	(0.000)
Employed	0.037***	0.063***
	(0.002)	(0.003)
Expectation on the economy (5 years)	−0.001**	0.002*
	(0.000)	(0.001)
Household size	−0.007***	−0.009***
	(0.001)	(0.001)
Current residence's value (Log)	0.027***	0.012***
	(0.001)	(0.000)
Observations	25,307	18,422
F-test (Dotcom)	15.118	64.320
p-value (Dotcom)	0.018	0.001

https://doi.org/10.1017/S1365100521000055 Published online by Cambridge University Press

TABLE 1. Continued

	Prime Borrowers	Subprime Borrowers
F-test (GR)	93.250	149.926
p-value (GR)	0.001	0.000
F-test (All Recessions)	321.537	1081.904
p-value (All Recessions)	0.000	0.000

For the F-tests:

$H0: \beta^{\text{Pre-Recession Expansion}} = \beta^{\text{Recession.}}$

$HA: \beta^{\text{Pre-Recession Expansion}} \neq \beta^{\text{Recession.}}$

Note: Values in parentheses show the standard errors. 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. We estimate the following Probit regression: $\textit{Investment Homeownership}_{i,t} = \beta_0 + \beta_{1,t}\,\textit{Survey Year}_t + \beta_{2,t}\,\textit{Survey Year}_t \times \textit{Credit Rejected}_{i,t} + \beta_3\,\textit{Credit Rejected}_{i,t} + \beta_4\,\textit{House Value}_{i,t} + \beta_5\,\textit{Demographic Controls}_{i,t} + \nu_{i,t}$. Prime rate is obtained from FRED, St. Louis. The rest of the data is from the SCF.

prosperity. To control for wealth, we include *House Value*, indicating the current value (in log level of 2013 US Dollars) of the primary home owned by the household.[7] *Demographic Controls* include employment status, gender, age, education level of the household head, household size, and 5-year economic expectations of the household.[8]

Consistent with Figure 1, we also find that prime borrowers are more likely to own investment homes during recessions than during expansions using the Probit regression in equation (1).[9] For example, during the Great Recession, the change in the likelihood of being an investment homeowner increases about 64% for prime borrowers. Whereas in the dot-com recession, the change in this likelihood increases by more than double compared to the prerecession levels.[10]

As reported in Table 1, other variables take their expected signs. Households who are more educated, have a male household head, are employed, are smaller in size, are older, are less optimistic about the economy, and have higher wealth are more likely to be homeowners. Moreover, while the coefficient for *Credit Rejected* suggests that individuals whose credit applications were turned down are much less likely to own a house within their borrowing group. The interaction term of *Survey Years* and *Credit Rejected* shows that among prime borrowers those who are more credit rejected become worse off during recessions compared to those who are not credit rejected.

To examine the robustness of our cutoff rates for prime and subprime borrowers, we vary them by 5% in each direction.[11] We also control for Federally guaranteed (GSEs) mortgages to account for low interest rates that might be provided to subprime borrowers which could misclassify them.[12] Our results are consistent across these robustness exercises. Furthermore, given that the ratio of subprime borrowers may not be constant over time, we allow the fraction of subprime borrowers to be time-varying and find our results are insensitive to this exercise as well.[13] To economize on space, we leave the details of our robustness checks in the supplementary material, Appendix B.

3. MODEL

We have documented in Section 2 that prime borrowers are more likely to own investment homes during recessions than during recoveries, while subprime borrowers are less likely to do so. To understand the underlying mechanism of the asymmetry in housing the wealth distribution between prime and subprime borrowers, we present a DSGE model with collateralized borrowing and heterogeneity in credit access. The economy is populated by six types of agents: households, entrepreneurs, retailers, capital producers, house producers, and a central bank. Households are divided into patient households, prime borrowers, and subprime borrowers. Entrepreneurs are assumed to own the goods producers and the retailers. For brevity, the full model is reported in supplementary material, Appendix C.

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, similar to Iacoviello (2005). Specifically, the discount factor of the patient households is larger than that of prime and subprime 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.[14] 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 averaged about 65% since the end of the Great Recession, patient households represent the remaining 35% of the population.[15]

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 nominal deposit rate, R_t. The patient households use the following objective function to maximize their lifetime utility from consumption and leisure subject to the Walrasian budget constraint equation (2) that equates households spending and income.

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

$$C_{h,t} + D_t = \frac{R_{t-1} D_{t-1}}{\pi_t} + w_t l_{h,t}, \tag{2}$$

where w_t denotes the real wage, and $\pi_t = \frac{P_t}{P_{t-1}}$ is the gross inflation rate.

3.1.2. Prime borrowers. Represented by the subscript p, prime borrowers buy real estate, $H_{p,t+1}$, for the price of q_t^h at time t. They maximize their utility from consumption, leisure, and housing services subject to the flow of funds constraint equation (3) and the collateral constraint equation (4) as follows:

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

$$C_{p,t} + q_t^h \left(H_{p,t+1} - H_{p,t} \right) + \frac{Z_{p,t-1} B_{p,t-1}}{\pi_t} = B_{p,t} + w_t l_{p,t}, \tag{3}$$

where Γ_p governs the weight of housing services in the utility function, ${q_t}^h$ is the real house price, $Z_{p,t}$ denotes the gross lending rate for prime borrowers. Prime borrowers 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 the borrowers' assets to be collateralized, which limits their amount of available credit.[16] The borrowing constraint equation (4) shows that the repayment of household's debt cannot exceed the expected future value of the real estate bought at time t.[17] On the other hand, if borrowers do not buy a new house but instead keep their existing ones, there would be no mortgage repayment as they would not need to get any loans. As a result, the borrowing constraint would never bind in this situation, and therefore, would not have any effect on the decision-making process of either prime or subprime borrowers.

$$B_{p,t} \leq m_p E_t \left\{ q_{t+1}^h H_{p,t+1} \frac{\pi_{t+1}}{Z_{p,t}} \right\}, \tag{4}$$

where m_p is the loan-to-value (LTV) ratio.

Additionally, borrowers can have negative equity within one period when house prices decrease. Once the borrowers have negative equity, they decumulate their housing, work more to make more income, and/or decrease their consumption to stay solvent. Given that mortgage debts last one period in the model, all the solvency issues are resolved within the period.

Because of data limitations and other computational difficulties, we are assuming that debts are short-term. However, the lack of long-term debts will not alter our results. For instance, Greenwald (2018) introduces long-term mortgages by allowing borrowers to prepay their existing debt and get new debt by paying some transaction costs. Yet, he finds that only a small fraction of borrowers in good condition obtain new debt. In our model, it would have been prime borrowers who could prepay since they are subject to more favorable borrowing conditions than subprime borrowers. If the prime borrowers were to obtain new debt, then their housing would be larger than what we find in our current model. In fact, using data from the SCF, we find that prime borrowers are almost one and a half times more likely to pay their debt ahead of time compared to subprime borrowers, on average.

The first-order conditions for the labor supply and housing demand decisions of prime borrowers are as follows:

$$l_{p,t}^{\xi} = \frac{w_t}{C_{p,t}}, \tag{5}$$

$$E_t \frac{\beta_p \Gamma_p}{H_{p,t+1}} = E_t \left\{ \frac{q_t^h}{C_{p,t}} + (m_p - 1) \frac{\beta_p q_{t+1}^h}{C_{p,t+1}} - \frac{m_p q_{t+1}^h}{\frac{Z_{p,t}}{\pi_{t+1}} C_{p,t}} \right\}. \tag{6}$$

Here, equation (6) is particularly important as it shows the trade-off between consumption and housing investment, which depends on the borrower's credit conditions through the LTV ratio.

Similar to Iacoviello (2005), Philippon and Midrigan (2011), Iacoviello and Pavan (2013), Favilukis et al. (2013), Liu et al. (2013), Justiniano et al. (2015), Guerrieri and Lorenzoni (2017), Huo and Rios-Rull (2016), our model does not capture defaults due to identification problems in estimation. Given that our paper is about credit access, collateral constraints are at the heart of our model. Therefore, following this literature, our model builds on the Kiyotaki and Moore (1997) setup that allows us to introduce collateral constraints.[18] However, even if possible, adding defaults would only strengthen our results. Amromin and Paulson (2010) show that in 2007, the default rate of prime borrowers was around 5% in the first 12 months, whereas it was about 25% for subprime borrowers. Given that subprime borrowers default more, following a financial shock, we would see them decumulating more houses than what is currently captured in our current model.

3.1.3. Subprime borrowers. Similar to prime borrowers, subprime borrowers can use collateral to invest in the housing market. However, subprime borrowers are subject to higher borrowing rates. The risk premium, f_t, between the gross loan rates of prime and subprime borrowers is given by the following equation:

$$Z_{s,t} = Z_{p,t} + f_t, \tag{7}$$

where f_t is characterized by a mean-reverting process as follows:

$$f_t = (1 - \rho_f)\bar{f} + \rho_f f_{t-1} + \varepsilon_t^f. \tag{8}$$

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

Subprime borrowers optimize their consumption and leisure, subject to the budget constraint equation (9) and the borrowing constraint equation (10).

$$C_{s,t} + q_t^h \left(H_{s,t+1} - H_{s,t}\right) + \frac{Z_{s,t-1} B_{s,t-1}}{\pi_t} = B_{s,t} + w_t l_{s,t}, \tag{9}$$

$$B_{s,t} \leq m_s E_t \left\{ q_{t+1}^h H_{s,t+1} \frac{\pi_{t+1}}{Z_{s,t}} \right\}. \tag{10}$$

https://doi.org/10.1017/S1365100521000055 Published online by Cambridge University Press

3.2. Entrepreneurs

Entrepreneurs produce homogeneous intermediate goods using capital, labor, and commercial real estate through the following aggregate Cobb–Douglas production function.

$$Y_t = A_t K_t^{\alpha} H_{e,t}^{\kappa} \left(L_{e,t}\right)^{(1-\alpha-\kappa)}, \tag{11}$$

where $\alpha \geq 0$ and $\kappa \geq 0$ denote the shares of capital and commercial real estates in production, respectively. $L_{e,t} = \nu\left(\varrho L_{p,t} + (1-\varrho)L_{s,t}\right) + (1-\nu)\, L_{h,t}$ represents the total labor demand in the economy, where ν denotes the relative size of borrowers to patient households, and ϱ shows the relative mass of prime borrowers to subprime borrowers. In the production function, $H_{e,t}$ can be interpreted as land. Entrepreneurs purchase capital K_t and land $H_{e,t}$ from capital and housing producers, respectively. A_t is the total factor productivity (TFP) that follows the AR (1) process in equation (12).

$$\log A_t = \rho_A \log A_{t-1} + \varepsilon_t^A, \tag{12}$$

where ρ_A is the persistence of the TFP shock, and $E\left(\varepsilon_t^A\right) = 0$. Entrepreneurs maximize their consumption over time subject to equations (11) and (12), as well as their flow of funds in the budget constraint equation (13), and the borrowing constraint equation (14).

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

$$C_{e,t} + q_t^h H_{e,t+1} = \frac{Y_t}{X_t} + q_t^h H_{e,t} - w_t L_{e,t} - q_t I_{k,t} + B_{e,t} - \frac{Z_{e,t-1}B_{e,t-1}}{\pi_t} + F_t, \tag{13}$$

where F_t represents the lump-sum profits from retailers. X_t is the markups in period t, $I_{k,t}$ is the gross capital investment, and $q_t = Q_t/P_t$ is the real capital price. Similar to prime and subprime borrowers, entrepreneurs can only borrow up to the expected future value of their total assets, which include their physical capital as well as their commercial real estate. Following Liu et al. (2013), the borrowing constraint of the entrepreneurs is given by

$$B_{e,t} \leq m_e E_t\left\{\left(q_{t+1}^h H_{e,t+1} + q_{t+1}K_{t+1}\right)\frac{\pi_{t+1}}{Z_{e,t}}\right\}, \tag{14}$$

where m_e is the LTV for entrepreneurs.

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

$$Y_t\,(z) = \left(\frac{P_t\,(z)}{P_t}\right)^{-\varepsilon} Y_t. \tag{15}$$

https://doi.org/10.1017/S1365100521000055 Published online by Cambridge University Press

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

$$P_t = \left[\theta P_{t-1}^{1-\epsilon} + (1-\theta)\left(P_t^*\right)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}, \tag{16}$$

where $\varepsilon > 1$, and P_t^* is the symmetric optimal price that equates expected discounted marginal revenue and marginal cost. The retailers' profit, $F_t = (1 - \frac{1}{X_t})Y_t$, is distributed back to the entrepreneurs. The markup, X_t, is equal to $\frac{\varepsilon}{1-\varepsilon}$ in the steady state.

3.3. Capital Producers

Similar to Bernanke et al. (1999), Christiano et al. (2004), and Christensen and Dib (2008), capital producers produce new capital goods, which replace the depreciated capital and contribute to the capital stock. Capital producers use a fraction of the final goods purchased from retailers as investment goods, $I_{k,t}$, to produce efficient investment goods, ${x^i}_t I_{k,t}$, that are combined with the existing capital stock to produce new capital goods K_{t+1} as shown in (18). Capital producers maximize their profit subject to a quadratic capital adjustment cost, $\frac{\chi}{2}(\frac{I_{k,t}}{K_t} - \delta)^2 K_t$.

$$\max_{I_{k,t}} E_t \left\{ q_t x_t^i I_{k,t} - I_{k,t} - \frac{\chi}{2}\left(\frac{I_{k,t}}{K_t} - \delta\right)^2 K_t \right\},$$

where x_t^i is the investment-specific technology shock, which follows the autoregressive process (17) where $\varepsilon_t^{x_t^i} \sim N(0, \sigma_{x^i}^2)$.

$$\log x_t^i = \rho_{x^i} \log x_{t-1}^i + \varepsilon_t^{x^i}. \tag{17}$$

The law of capital motion is

$$x_t^i I_{k,t} = K_{t+1} - (1-\delta) K_t. \tag{18}$$

The optimization gives the standard Tobin's Q as follows:

$$E_t \left\{ q_t x_t^i - 1 - \chi\left(\frac{I_{k,t}}{K_t} - \delta\right)\right\} = 0. \tag{19}$$

3.4. House Construction

Similar to Alpanda and Zubairy (2016) and Christensen et al. (2016), our house constructors are modeled analogous to capital producers which follows the set up in Bernanke et al. (1999), Christiano et al. (2004), and Christensen and Dib (2008). In particular, prime and subprime borrowers sell their undepreciated housing to house constructors at the end of every period. House constructors then combine the existing housing stock and final goods that they purchase from retailers to produce new units of installed houses. Therefore, similar to capital, there

https://doi.org/10.1017/S1365100521000055 Published online by Cambridge University Press

is liquidation of houses at the end of each period. This ability allows house constructors to alter the new housing supply to the point where the new demand is if there is a change in the preferences of one (or both) types of borrowers.

Housing constructors maximize their own profits subject to the quadratic housing adjustment cost, $\frac{\chi_h}{2}\left(\frac{I_{h,t}}{H_t}\right)^2 H_t$, and the housing supply shock x_t^h to the marginal efficiency of housing production.[19]

$$\max_{I_{h,t}} E_t \left\{ q_t^h x_t^h I_{h,t} - I_{h,t} - \frac{\chi_h}{2}\left(\frac{I_{h,t}}{H_t}\right)^2 H_t \right\},$$

and

$$x_t^h I_{h,t} = H_{t+1} - H_t, \tag{20}$$

where $H_t = H_{p,t} + H_{s,t} + H_{e,t}$ and $I_{h,t}$ denotes the total housing investment at time t.[20] The adjustment cost governs how easy it is to convert old housing into new housing in the model. Therefore, the adjustment cost does not affect the supply by destroying available houses, instead it makes it more costly to produce housing and thus decrease the profits of construction companies, directly affecting house prices. Additionally, when a financial shock hits the economy and lowers demand, it will cause a decrease in house prices, which results in a movement along the line on the supply curve instead of a shift. Lower prices decrease households' wealth, make the collateral constraint tighter, and further decrease the profits of construction companies. The role of the housing adjustment cost, therefore, is to decrease the speed of the adjustment along the supply curve to meet the demand.

The housing supply shock follows the autoregressive process below.[21]

$$\log x_t^h = \rho_{x^h} \log x_{t-1}^h + \varepsilon_t^{x^h}. \tag{21}$$

The maximization problem of house constructors yields the following rule for house prices:

$$E_t \left\{ q_t^h x_t^h - 1 - \chi_h \left(\frac{I_{h,t}}{H_t}\right) \right\} = 0. \tag{22}$$

House prices are equal to 1 in equilibrium, however, the adjustment cost and the housing supply shock create fluctuations in prices when the economy is on an off-equilibrium path.

3.5. Monetary Policy

Monetary policy follows a Taylor rule as in equation (23), 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, respectively.[22]

$$R_t = \bar{R} \left(\left[\frac{Y_t}{\bar{Y}}\right]^{b_1} \left[\frac{1+\pi_t}{1+\bar{\pi}}\right]^{b_2} \right) e_t^R. \tag{23}$$

https://doi.org/10.1017/S1365100521000055 Published online by Cambridge University Press

The monetary policy shock, e_t^R, follows

$$\log\left(e_t^R\right) = \rho_e \log\left(e_{t-1}^R\right) + \varepsilon_t^R, \tag{24}$$

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

$$R_t - 1 \geq 0. \tag{25}$$

3.6. Market Clearing Conditions

The economy-wide resource constraint is shown below.

$$Y_t = C_t + I_{k,t} + I_{h,t}, \tag{26}$$

in which C_t represents the aggregate consumption and is the sum of households, borrowers, and entrepreneurs' consumption.

The following labor market clearing condition guarantees that the demand and supply of labor will be equal:

$$L_{e,t} = l_{h,t} + l_{s,t} + l_{p,t}. \tag{27}$$

Lastly, the loans market clears when the supply of deposits is equal to the demand for funds by subprime borrowers, prime borrowers, and entrepreneurs as follows:

$$D_t = B_{p,t} + B_{s,t} + B_{e,t}. \tag{28}$$

4. CALIBRATION AND ESTIMATION

We estimate a number of important parameters while calibrating the rest either to values that are common in the literature or to values obtained from data. Table 2 presents the set of parameters that we calibrate. 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 prime borrowers to subprime borrowers, ϱ, is set to 0.64 following Justiniano et al. (2016), and the relative size of borrowers to patient households, ν, is set to 0.65 using the homeownership data from the US Bureau of 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. We calculated the steady-state level of risk premium (2%) from the SCF using long-run mortgage rates for prime and subprime borrowers. These values generate a steady-state level of the prime rate that matches the long-run average prime interest rate (i.e., 6.3%, annualized).

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 entrepreneurs so that the entrepreneurial loan rate matches the data for our time period. Following Taylor (1993), we select neutral values for the

https://doi.org/10.1017/S1365100521000055 Published online by Cambridge University Press

TABLE 2. Calibrated parameters

Par.	Description	Value	Source
ξ	Inverse of Frisch elasticity	3	Aaronson and French (2009)
ϱ	Relative size of prime borrowers to subprime borrowers	0.64	Justiniano et al. (2016)
ν	Relative size of borrowers to patient households	0.65	US Bureau of Economic Analysis (BEA)
$\bar{f}$	Steady-state level risk premium	2% (annualized)	SCF
α	Share of capital in production	0.33	Literature
δ	Capital depreciation	0.025	Literature
b_1	Taylor rule output weight	0.5	Taylor (1993)
b_2	Taylor rule inflation weight	1.5	Taylor (1993)

weights on output (b_1) and inflation (b_2) targeting that match the US 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. 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.[23]

Table 3 presents the sets of estimated parameters, along with the posteriors and our choices of priors. We match the 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:Q1–2016:Q2) from the Federal Reserve Bank of St. Louis' FRED, where all data series are seasonally adjusted. We estimate the model using Bayesian methods with the Metropolis–Hastings algorithm and make sure the Markov Chain Monte Carlo (MCMC) converges to its ergodic distribution.

5. MODEL IMPLICATIONS

This section documents the implications of the model presented in Section 3. 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 nonfinancial shocks, such as TFP, capital, and housing supply shocks, as well as monetary policy shocks on the housing wealth distribution. As expected, the nonfinancial shocks have little effect on the asymmetry in housing wealth distribution because they tend to affect borrowers similarly.

Since the Great Recession coincided with a period of a near-zero nominal interest rate and lax credit conditions, we examine the effects of an adverse financial shock at the ZLB in Section 5.4. We show that the ZLB amplifies the negative

TABLE 3. Priors and posteriors of the estimated parameters

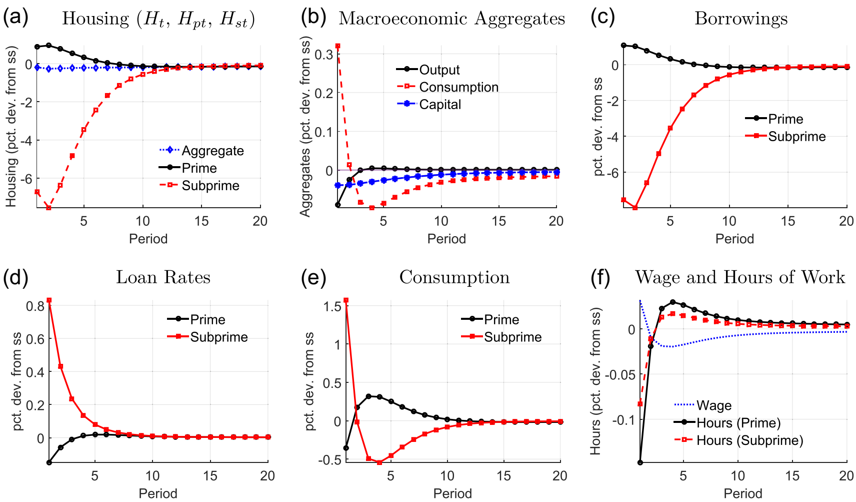
Parameters	Prior Mean	Post. Mode	Low	High	Prior	Post. Std.
β_H	0.99	0.9865	0.9798	0.9960	beta	0.005
β_S	0.95	0.9505	0.9432	0.9593	beta	0.005
β_P	0.97	0.9676	0.9624	0.9774	beta	0.005
β_e	0.98	0.9810	0.9741	0.9886	beta	0.005
ρ_A	0.90	0.8993	0.8669	0.9291	beta	0.02
χ_K	0.59	0.5901	0.5853	0.5948	beta	0.003
χ_H	0.10	0.1015	0.0948	0.1046	beta	0.003
m_e	0.80	0.8024	0.7442	0.8442	norm	0.03
m_s	0.80	0.8076	0.7525	0.8504	norm	0.03
m_p	0.80	0.7946	0.7487	0.8436	norm	0.03
θ	0.75	0.7459	0.7145	0.7805	norm	0.02
e	0.60	0.6003	0.5528	0.6516	norm	0.03
s	0.40	0.4021	0.3496	0.4514	norm	0.03
p	2.50	2.5064	2.4508	2.551	norm	0.03
ρ_f	0.50	0.5351	0.4108	0.6686	beta	0.1
ρ_X	0.50	0.5024	0.3174	0.6960	beta	0.1
ρ_{XI}	0.50	0.5232	0.3572	0.6750	beta	0.1
Standard deviation of shocks						
Shocks	Prior mean	Post. mode	Low	High	Prior	Post. Std.
ε_A	0.01	0.0362	0.0328	0.0398	invg	Inf
ε_e	0.01	0.0486	0.0383	0.045	invg	Inf
ε_f	0.02	0.0079	0.0051	0.0107	invg	Inf
ε_X	0.01	0.0383	0.0334	0.041	invg	Inf
ε_{XI}	0.01	0.0267	0.0241	0.0293	invg	Inf
ε_P	0.01	0.0095	0.0085	0.0103	invg	Inf

Note: We estimate the model to fit five series: real output growth, bank prime loan rate, the growth rate of the private residential investment, the growth rate of house prices, and real consumption growth from the Federal Reserve Bank of St. Louis database. Data are all seasonally adjusted and transformed in a way such that the variable definitions match ours in the model. Please see Appendix D in supplementary material for more details. Here e, s, and p denote the steady-state levels of commercial real estate relative to output, subprime borrowers' housing to output, and prime borrowers' housing to output, respectively. "High" and "Low" denote the upper and lower bounds for the 90% HPD interval.

effects of financial frictions on aggregate housing demand, while increasing the asymmetry in housing wealth distribution.

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 3 under the calibration presented in Section 4 and initiate a one-standard-deviation increase in the risk premium, f_t. Figure 4 presents the



Note: The figure plots the impulse responses of selected variables to a one-standard-deviation increase in the innovation of the financial friction, ε_t^f. All responses are normalized so that the units of the vertical axes represent percentage deviations from the steady state. In these responses, we do not constrain the interest rate at the ZLB. Here, the variable used for aggregate housing is H_t, for primers' housing is $H_{p,t}$, and for subprimers' housing is $H_{s,t}$.

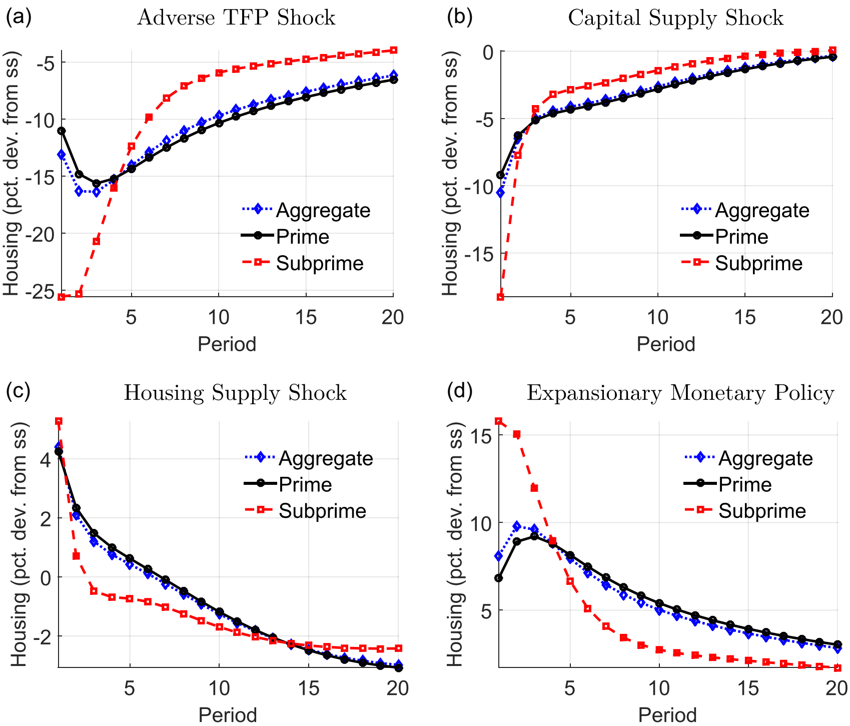
FIGURE 4. Responses to an adverse financial shock.

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 of subprime borrowers implies an increase of over 1% in the housing investment for prime borrowers and a decrease of around 7% for subprime borrowers. Intuitively, when there is an increase in the risk premium f_t, as observed during recessions, the relative cost of obtaining additional housing for the subprime borrowers increases significantly. Because subprime borrowers are subject to disproportionately higher loan rates, their collateral constraints bind faster than that of prime borrowers, leading to a larger decrease in their housing demand. This decrease in subprime borrowers' demand pushes house prices down. Since prime borrowers still have easier access to credit and more favorable loan rates, they can increase their housing investment to take advantage of lower prices.[24] It is important to point out that a negative shock to subprime borrowers does not necessarily have to generate a positive effect on prime borrowers because the housing supply is not fixed in the model.

Turning to the responses of macroeconomic aggregates, an adverse financial shock has significant ramifications on the economy. Specifically, output, consumption, and capital decrease following the shock as the overall demand for housing investment declines. While prime borrowers can 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

https://doi.org/10.1017/S1365100521000055 Published online by Cambridge University Press



Note: The figure plots the impulse responses of the housing investment to a 1% 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 prime and subprime borrowers. All responses are normalized so that the units of the vertical axes represent percentage deviations from the steady state. In these responses, we do not constrain the interest rate at the ZLB. Here, the variable used for aggregate housing is H_t, for prime borrowers' housing is $H_{p,t}$, and for subprime borrowers' housing is $H_{s,t}$.

FIGURE 5. Effects of nonfinancial shocks.

as a whole experiences a further decrease in output, consumption, and capital as a result of an increase in the risk premium for the subprime borrowers.

5.2. The Effects of Nonfinancial Shocks

The Effects of a TFP Shock: Figure 5a presents the responses of the housing market to a one-standard-deviation decrease in the TFP shock. While both borrowers are affected similarly, the steady-state level of the risk premium causes subprime borrowers to be significantly worse off in the housing market. In particular, a decrease in productivity lowers the demand for labor, depressing wages. The resulting temporary decline in income induces both borrowers to lower their debt. The extent to which these consumers decrease their debt depends largely on the contemporaneous levels of borrowing as well as their borrowing costs (i.e.,

$Z_{p,t}$ and $Z_{s,t}$). This difference in borrowing initiates the asymmetry in housing consumption as purchases of housing must be accompanied by borrowing.

The intuition behind the asymmetry between prime and subprime borrowers is similar to that of Campbell and Hercowitz (2005). In their model, they use two regimes: low- and high-equity requirements, which correspond to our prime and subprime borrowers, respectively. They show that in the low-equity-requirement regime (prime borrowers), debt responses are half in magnitude, compared to that under the high-equity-requirement regime (subprime borrowers). In our paper, such a difference follows mainly from lower repayment rates.

The Effects of Capital and Housing Supply Shocks: We next investigate the effects of negative capital (i.e., the investment-specific technology shock, x_t^i) and negative housing supply (i.e., the housing-specific technology shock, x_t^h) shocks. In particular, we initiate a one-standard-deviation decrease in the innovations of each shock, the results of which are plotted in Figure 5 (b and c). As expected, a negative shock on capital supply causes the entrepreneurs to substitute away from capital. Therefore, entrepreneurs demand more housing given this decrease in capital demand due to higher prices in the economy. On the other hand, the decreases in income and the low amount of available credit cause prime and subprime borrowers to demand less housing. As expected, the more constrained agents respond more to the changes because housing investment is financed by borrowing which is more costly for them.

A negative housing supply shock (Figure 5c) in construction lowers supply and causes a spike in house prices. Higher house prices increase the collateral value of households' real estate holdings. Therefore, relaxed collateral constraints encourage borrowers to invest in the housing market. Because this shock acts as a positive shock in terms of housing investment by relaxing the collateral constraint, allowing both borrowers to benefit from it equally, at least initially. Therefore, an adverse shock in housing construction that reduces supply (and increases price) does not generate a wealth reallocation between prime and subprime borrowers.[25]

The Effects of a Monetary Policy Shock: Figure 5d presents the responses of the housing market to a 100-basis-point decrease in the nominal interest rate. While housing investment of both prime and subprime borrowers increases significantly (more so for latter), the responses of prime borrowers are more persistent. This result supports the findings of Eickmeier and Hofmann (2013) that the monetary policy shock has a persistent effect on house prices. However, as the interest rate reverts to its *ex ante* level, the positive effects on subprime borrowers diminish. Prime borrowers, on the other hand, can sustain higher investment levels for a longer period of time. The finding that subprime borrowers initially enjoy the low interest rate more is not surprising given the findings from Justiniano et al. (2016). They show that lower interest rates encourage the more constrained agents to accumulate leverage. Our result suggests that an expansionary monetary policy can help ameliorate the asymmetry in housing wealth reallocation during recessions to some extent, especially in the first year.

TABLE 4. Variance decomposition

	Shocks				
	Financial	TFP	Monetary	Housing supply	Capital supply
B_p	1.03	75.98	17.73	2.55	2.65
B_s	24.54	56.65	15.54	0.90	2.37
ΔH_p	9.94	58.23	18.21	4.89	8.63
ΔH_s	26.27	48.94	16.81	0.47	7.63

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.

5.3. Variance Decomposition of Shocks

We next investigate the contributions of each shock to overall fluctuations of the model. To do so, we present the contribution of financial (i.e., risk premia), TFP, monetary policy, housing supply, and capital supply shocks to variations in housing investment and borrowing for prime and subprime borrowers in Table 4. The financial shock accounts for 26.27% and 9.94% of variations in housing investment for subprime and prime borrowers, respectively. For subprime borrowers, a higher fraction of variations in borrowing can be explained by the financial shock (24.54%) than by the housing supply (0.90%), the capital supply (2.37%), or the monetary policy (15.54%) shocks. For prime borrowers, on the other hand, the financial shock explains little of the variation in their borrowing, as expected. Overall, we find these simulation results to suggest the importance of the financial shock in explaining the reallocation in housing investment.

5.4. The Role of the Zero Lower Bound

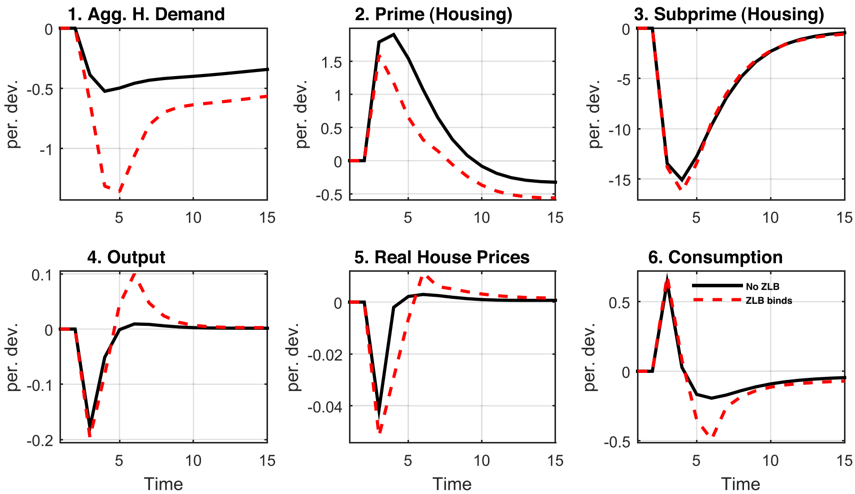
We next explore the effects of an adverse financial shock when the economy is at the ZLB. To that end, we add a mean-reverting preference shock for patient households as below, where $\varepsilon_t^{\beta_h}$ follows $N(0, \sigma^2_{\beta_h})$.

$$\log \beta_{h,t} = \left(1 - \rho_{\beta_h}\right) \log \beta_h + \rho_{\beta_h} \log \beta_{h,t-1} + \varepsilon_t^{\beta_h}. \quad \textbf{(29)}$$

We keep the risk-free interest rate R_t at the ZLB for two periods using a negative preference shock to the discount factor of patient households, $\beta_{h,t}$, and initiate a one-standard-deviation adverse financial shock to the economy.[26] We solve the model using a piecewise approximation as in Iacoviello (2015b). Figure 6 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.[27]

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

https://doi.org/10.1017/S1365100521000055 Published online by Cambridge University Press



Note: The figure plots the impulse responses of selected variables to a one-standard-deviation increase in innovation to the financial friction, ε_t^f. All responses are normalized so that the units of the vertical axes are percentage deviations from the steady-state. Aggregate housing demand shows the total demand of prime and subprime borrowers. We solve the model using a piecewise approximation, following Iacoviello (2015b).

FIGURE 6. Responses at the zero lower bound

constrained by the ZLB under an adverse financial shock, it becomes increasingly more costly to save using the risk-free bond with the presence of inflation.

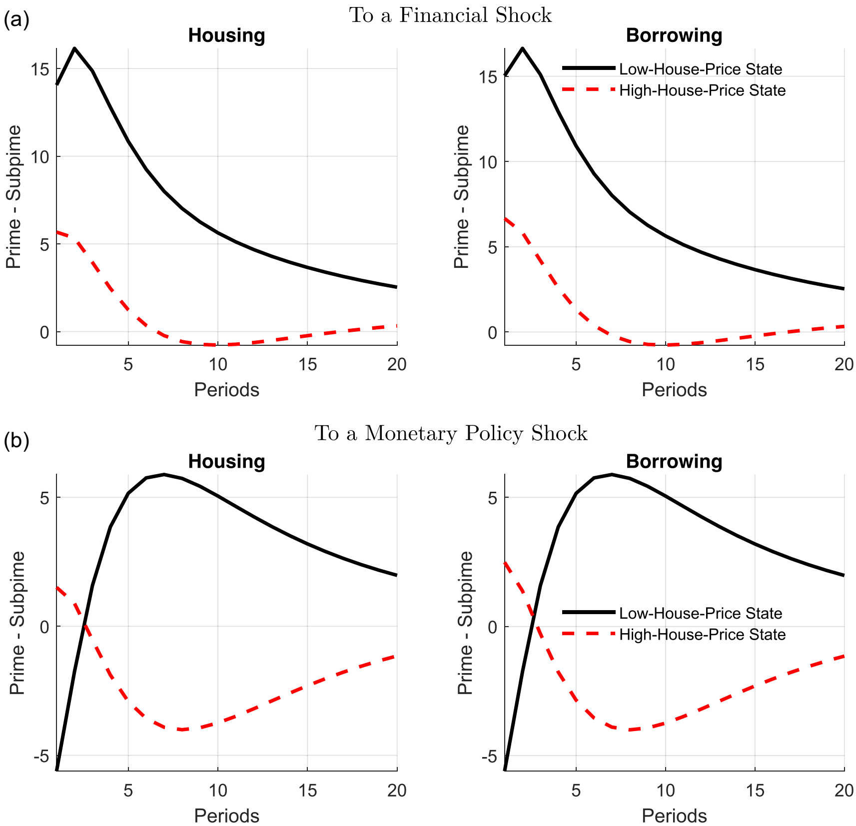
As a result, the amount of available funds in the economy decreases, making it harder to borrow for everyone, especially for subprime borrowers. This decrease depresses both housing demand and prices. Overall, the ZLB amplifies the negative effects of financial frictions on aggregate housing demand compared to the case in which the ZLB does not bind, increasing the asymmetry in housing wealth distribution by about 1%.

5.5. State-Dependent Implications of Housing Redistribution

In this section, we study the extent to which the responses of housing wealth redistribution to a negative financial shock depend on the *ex ante* state of the housing market. Intuitively, since prime borrowers are subject to lower borrowing costs, they are better positioned to take advantage of depressed house prices. We should, therefore, expect a negative financial shock to drive a larger wedge of housing wealth between prime and subprime borrowers when house prices are generally low.

We simulate the model for 10,000 periods in which all shocks are present and use this simulated (base) series to identify the state of the economy. In particular, we classify periods in which the *ex ante* house price, q_t, is lower than unity (i.e., the steady-state level) as the low-price state and periods in which it is larger

https://doi.org/10.1017/S1365100521000055 Published online by Cambridge University Press



Note: This figure plots the difference in the responses of prime and subprime borrowers to a one-standard-deviation risk premium shock and a one-standard-deviation expansionary monetary policy shock during a low house price state and during a high house price state. All responses are normalized so that the units of the vertical axes represent percentage deviations from the steady state.

FIGURE 7. State-dependent responses: Low versus High house price states.

than unity as the high-price state. In each of the two states, we then initiate a 1% increase in the risk premium process, f_t for every period. We next average out all simulated responses in each of the two states to ensure that our state-dependent responses are not affected by any particular draw of shocks within each corresponding state.

We plot the impulse responses of the differences in housing and borrowing for prime and subprime borrowers across the two *ex ante* states (low vs. high house price) to a financial shock (in Figure 7a) and to a monetary policy shock (in Figure 7b).

One key insight from Figure 7a is that the difference in housing investments between prime and subprime borrowers is amplified when house prices are low compared to when house prices are generally high *ex ante*. This finding is

https://doi.org/10.1017/S1365100521000055 Published online by Cambridge University Press

consistent with the intuition that prime borrowers are more likely to be able to take advantage of low house prices than their subprime counterparts.

We next examine the state-dependent nature of housing wealth redistribution responses to a monetary policy shock in the form of a 1% interest rate cut. As Figure 7b shows, the advantages of prime borrowers over subprime borrowers in terms of wealth redistribution are stronger when the low house price state is followed by an expansionary monetary policy shock. In the high house price state, prime borrowers are still at an advantage after an expansionary monetary policy shock, although less so compared to the low house price state.

6. THE ROLE OF COLLATERAL CONSTRAINTS AND LEVERAGE

In this section, we investigate the role of collateral constraints in generating asymmetric housing responses across prime and subprime borrowers. In particular, we study how variations in the LTV ratio of subprime borrowers can amplify the effects of an adverse financial shock on the housing wealth across borrowers.

6.1. Mechanism and Static Analysis

As previously demonstrated, the collateral constraints serve as an important channel in our model. Given that the LTV ratios directly affect the borrowing capacity of households, we next examine the role of collateral constraints using LTV ratios. In particular, decreases in LTV ratios tighten the borrowing conditions for all borrowers and limit their credit access. For instance, consider the following borrowing constraint for subprime borrowers:

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

Here, the LTV ratio for the subprime borrowers, m_s, creates a constraint on the value of assets and limits the amount that a subprime borrower can obtain using his/her housing as collateral. If LTV ratios differ across borrowers, then their housing investment decisions could vary as a result of their different borrowing conditions. To understand the mechanism, consider the following first-order condition for subprime borrowers:

$$E_t \frac{\beta_s \Gamma_s}{H_{s,t+1}} = E_t \left\{ \frac{q^h_t}{C_{s,t}} + (m_s - 1) \frac{\beta_s q^h_{t+1}}{C_{s,t+1}} - \frac{m_s q^h_{t+1}}{\frac{Z_{s,t}}{\pi_{t+1}} C_{s,t}} \right\}. \quad \mathbf{(30)}$$

Taking the partial derivatives of the consumption and housing trade-off in equation (30) with respect to the LTV ratio yields the following condition in the steady state:

$$\begin{cases} \dfrac{\partial\left(\frac{C_s}{q^h H_s}\right)}{\partial m_s} > 0 \quad \text{if} \quad Z_s > \frac{1}{\beta_s}. \\ \dfrac{\partial\left(\frac{C_s}{q^h H_s}\right)}{\partial m_s} < 0 \quad \text{if} \quad Z_s < \frac{1}{\beta_s}. \end{cases}$$

https://doi.org/10.1017/S1365100521000055 Published online by Cambridge University Press

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

To understand the role of credit access in a dynamic setting, we vary the LTV ratio for subprime borrowers, m_s, while keeping everything else in line with the baseline calibration. This analysis helps us replicate the credit conditions before the Great Recession in which subprime borrowers enjoyed lax credit constraints. 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 a standard deviation of 0.16. Using the range of values obtained from this dataset, Figure 8 plots the responses of housing demand, output, and consumption to an adverse financial shock.

Figure 8 shows that an adverse financial shock that follows a period with higher LTV ratio for subprime borrowers, or equivalently more lax credit conditions, magnifies the asymmetry in housing wealth distribution between subprime and prime borrowers. Despite this negative effect, laxer credit constraints cause a smaller decrease in consumption and output. Intuitively, when subprime borrowers are subject to easier access to credit (higher LTV ratio), 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 subprime borrowers 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).

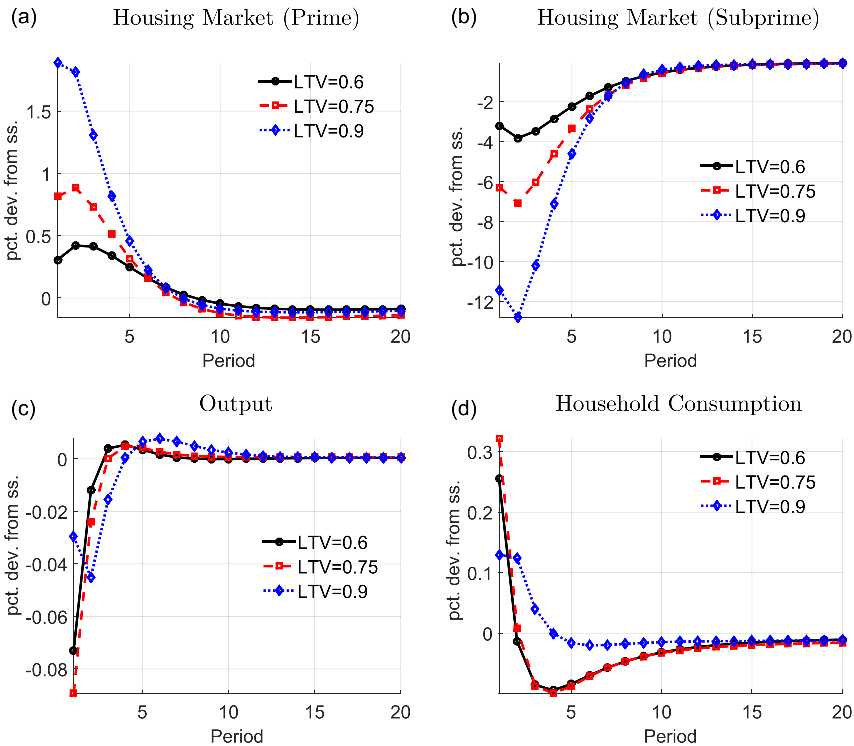
All in all, this exercise highlights the importance of credit access in amplifying the housing wealth reallocation asymmetry across agents during recessions. In particular, tighter credit constraints for subprime borrowers can dampen the asymmetry in housing wealth distribution across borrowers at the cost of larger declines in output and aggregate consumption.

6.2. Empirical Evidence on Collateral Constraints and Leverage

To understand the extent to which credit access and leverage affect risk premium in the data, we return to the SCF and regress the individual risk premia for subprime borrowers (in basis points) on 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 the time fixed effects, μ_t. In particular, we use the following specification:

$$\begin{aligned}\text{Risk Premium}_{it} = \beta_0 + \beta_1 \text{Leverage}_{it} + \beta_2 \text{Credit Rejected}_{it} \\ + \beta_3 \text{Demographic Controls}_{it} + \mu_t + \varepsilon_{it}, \qquad \textbf{(31)}\end{aligned}$$

https://doi.org/10.1017/S1365100521000055 Published online by Cambridge University Press



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, ε_t^f. All responses are normalized so that the units of the vertical axes represent percentage deviations from the steady state.

FIGURE 8. Adverse financial shock: Varying LTV ratios for subprime borrowers.

in which the leverage ratio is calculated from the data as

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

Table 5 presents the regression results for subprime borrowers using equation (31), with the same classification for borrowers as in our baseline regressions in Section 2. As Table 5 shows, leverage is positively associated with significant increases in risk premia. When subprime borrowers accumulate leverage, possibly due to previous lax credit conditions, their risk premia increase, which dovetails with the implications of Figure 8. Additionally, Table 5 highlights the importance of credit access within a group that when subprime borrowers are more credit rejected, their risk premia increase significantly.

https://doi.org/10.1017/S1365100521000055 Published online by Cambridge University Press

TABLE 5. Effects of leverage and credit access on risk premium

	Risk premium
Leverage	0.888***
	(0.152)
Credit rejected	50.919***
	(0.455)
Demographic controls	Yes
Time fixed effects	Yes
Number of observations	17,394

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. We control for time fixed effects as well as household demographics. ***, **, and * denote the 1%, 5%, and 10 % levels of significance, respectively.

7. CONCLUSION

In this paper, we investigate the effects of the heterogeneity in credit access among borrowers on the inequality of housing wealth during recessions. We first document that investment homeownership increases significantly during recessions. To differentiate and control for idiosyncratic characteristics of borrowers, we use micro-level survey data from the SCF. We classify the borrowers as prime and subprime borrowers based on their current mortgage loan rates and control for a rich set of demographic and financial characteristics. We find prime borrowers to be more likely to own investment homes during recessions compared to recoveries, whereas their subprime counterparts are more likely to invest during expansions. This result points to a dramatic difference between prime and subprime borrowers: while the latter were adversely affected by the collapse of the housing market, the former have been able to take advantage of the depressed house prices.

To explain this reallocation of housing wealth across borrowers, we present a DSGE model with heterogeneity in credit access across borrowers. Consistent with the data, subprime borrowers are subject to a risk premium in the model. A financial shock that increases this risk premium causes the more constrained agents, that is, subprime borrowers, to reduce their housing demand significantly. In stark contrast, borrowers who have easier access to credit benefit from lower house prices and thus can increase their investment home purchases.

We also find that when a financial shock follows a period in which subprime borrowers experience lax credit conditions, as in the Great Recession, the asymmetry in housing wealth distribution between prime and subprime borrowers becomes larger. Moreover, when the nominal interest rate is constrained at the ZLB, we find the negative effects of financial shock on aggregate housing demand and the asymmetry in housing wealth distribution to be amplified. An expansionary monetary policy, however, can help decrease this asymmetry in

https://doi.org/10.1017/S1365100521000055 Published online by Cambridge University Press

housing purchases, ameliorating the undesirable effects of adverse financial shocks during recessions.

SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit http://doi.org/10.1017/S1365100521000055.

NOTES

1. We exclude survey data before 1995 because the standardized survey weights are not publicly available for earlier years.
2. We have to exclude people who do not have any mortgages because we are unable to verify if the borrowers already paid their mortgages on their investment homes or if they made a cash purchase. However, as we detail in supplementary material, Appendices B.1 and B.2, we have an indirect measure to pin down the cash purchases. Tables B1 and B2 show that dropping the individuals who had cash purchases from the analysis entirely or adding them to the prime borrower category does not change any of our results.
3. We use the start of the three most recent contractions as designated by the National Bureau of Economic Research (NBER). We choose to study NBER recessions rather than periods when house prices decline because we are interested in the effects of the borrowing environment on housing investment decisions. Low house prices do not necessarily indicate an economic environment with limited credit access.
4. In supplementary material, Appendix B.3, we classify subprime borrowers based on their income and revolving balances on their loans. Our results persists with these new classifications.
5. Instead of having separate regressions for prime and subprime borrowers, we pool the data and use a recession dummy instead of year dummies in supplementary material, Appendix B.4 and still draw the same conclusions. Also in supplementary material, Appendix B.5, we bundle survey years into recessions and expansions and find that prime borrowers invest during recessions significantly more than during recoveries.
6. We also exclude investment ownership by businesses in supplementary material, Appendix B.6 to account for institutional investors. As shown in Table B6, our results are robust to this exercise.
7. Instead of using house value as a proxy for wealth, we also create a general wealth measure that includes a variety of households' assets and find that our results are robust to this measure. Please check supplementary material, Appendix B.7 and Table B7 for more details. Additionally, we control for liens information in supplementary material, Appendix B.8. As Table B8 shows, controlling for debt of households does not change any of our conclusions.
8. We restrict the sample to exclude households whose total income is below the Federal poverty level (i.e., \$19,530 in 2013 US Dollars) because these households are highly unlikely to invest in housing. Unsurprisingly, the results are stronger when including households with income under the poverty line.
9. Our results are qualitatively identical if a Linear Probability Model is used instead of Probit.
10. Ferreira and Gyourko (2015), Foote et al. (2016), Adelino et al. (2017), and Albanesi et al. (2017) document that foreclosures by prime borrowers and their debt accumulation were as important as those of subprime borrowers during the Great Recession. Our paper, however, does not address this issue due to the lack of foreclosure data in the SCF. Moreover, when examining the reasons for the credit growth before the Great Recession, Foote et al. (2016) and Albanesi et al. (2017) show that borrowing by high-income individuals was responsible for creating the bubble. The focus of our paper, however, is to study the aftermath of a housing bubble or bust, taking it as given. Foote et al. (2016) study the extensive margin where households become first-time homeowners while we focus on the investment homeownership. On the other hand, in line with our findings on the importance of credit

access, Ferreira and Gyourko (2015) show that LTV is a powerful predictor of home loss regardless of the borrower type, and Adelino et al. (2017) provide evidence that borrowers exploited the expanded credit supply and increased their demand for housing due to inflated house price expectations.

11. It is possible that there might be some misclassification of prime borrowers, particularly if a borrower fails to refinance when market rates are low. However, the SCF lacks the information on the original rate of refinanced loans which prevents us categorizing borrowers as prime or subprime when they took out the original loan. The 5% variation of the cutoff rate however should capture some of those borrowers.

12. We also check the robustness of our main regression results by controlling for whether the borrowers are subject to a fixed or an adjustable rate, income, and payment schedule, and find that our results are robust to this exercise as can be seen in Table B11.

13. We also try a narrower definition of subprime borrowers where they correspond to top 23% of the mortgage rate distribution to reflect the trend observed in the most recent periods. Our results are consistent for this cutoff as well.

14. We abstract from rents in the baseline model for simplicity. However, adding a rental market strengthens our results on the wealth redistribution among borrowers. Please refer to supplementary material, Appendix E for an extended version of the model where we introduce a rental market.

15. The homeownership rate for the USA is obtained from the US Bureau of Economic Analysis.

16. For the borrowing constraints to bind in equilibrium, discount factors of borrowers must be lower than the inverse of the gross loan rate.

17. Having *ex ante* or *ex post* collateral constraint does not change our results.

18. The literature takes a different stand on incorporating defaults by implementing Bernanke and Gertler (1989) and Bernanke et al. (1999)'s financial accelerator mechanism, for instance Aoki et al. (2004), Hobijn and Ravenna (2010), Forlati and Lambertini (2011), and Lambertini et al. (2017). Such models, however, do not feature collateral constraints.

19. The housing depreciation rate is assumed to be equal to zero to match the findings in Iacoviello (2005).

20. We follow the literature and treat the housing as a continuous asset. Therefore, the model does not distinguish between the *intensive* and *extensive* margins of home investment. We leave this topic for future research.

21. Housing is a predetermined variable. Therefore, the housing supply shock should be interpreted similarly to the investment-specific technology shock.

22. While the Taylor rule ignores rental inflation, Jeske and Liu (2013) shows that its optimal weight is small.

23. We leave additional estimation details in supplementary material, Appendix D for brevity.

24. This result is not driven because prime borrowers expect house prices to go up in the future. To confirm this intuition, we simulate a regime change in which house prices change and do not recover. For brevity, we leave the details of this exercise in supplementary material, Appendix E5.

25. The role of the adjustment cost parameter, (χ_H), is very limited here. Indeed, we find our model prediction to be consistent when this cost is half ($\chi_H = 0.05$) of the estimated value.

26. This setup is motivated by the related literature that uses models in which the nominal interest rate is constrained at the ZLB (see, e.g., Iacoviello (2015b), Miao and Ngo (2019), or Vu (2020).)

27. While we did not use a global method to solve for the policy function, the piecewise method presented by Iacoviello (2015b) provides a reasonably close approximation of the policy function to the one that is solved using global methods.

REFERENCES

Aaronson, D. and E. French (2009) The effects of progressive taxation on labor supply when hours and wages are jointly determined. *The Journal of Human Resources* 44, 386–408.

Adelino, M., A. Schoar and F. Severino (2017) Dynamics of housing debt in the recent boom and great recession. Working Paper 23502, National Bureau of Economic Research.

Albanesi, S., G. De Giorgi and J. Nosal (2017) Credit growth and the financial crisis: A new narrative. Tech. rep., National Bureau of Economic Research.

Alpanda, S. and S. Zubairy (2016) Housing and tax policy. *Journal of Money, Credit and Banking* 48, 485–512.

Amromin, G. and A. L. Paulson (2010) Default rates on prime and subprime mortgages: Differences and similarities. *Chicago Fed Research Review*.

Aoki, K., J. Proudman and G. Vlieghe (2004) House prices, consumption, and monetary policy: A financial accelerator approach. *Journal of financial intermediation* 13, 414–435.

Bernanke, B. and M. Gertler (1989) Agency costs, net worth, and business fluctuations. *American Economic Review* 79, 14–31.

Bernanke, B. S., M. Gertler and S. Gilchrist (1999) The financial accelerator in a quantitative business cycle framework. *Handbook of Macroeconomics* 1, 1341–1393.

Campbell, J. R. and Z. Hercowitz (2005) The role of collateralized household debt in macroeconomic stabilization. Tech. rep., National Bureau of Economic Research.

Chambers, M., C. Garriga and D. E. Schlagenhauf (2009) Accounting for changes in the homeownership rate. *International Economic Review* 50, 677–726.

Charles, K. K. and E. Hurst (2002) The transition to home ownership and the black-white wealth gap. *Review of Economics and Statistics* 84, 281–297.

Christensen, I., P. Corrigan, C. Mendicino and S.-I. Nishiyama (2016) Consumption, housing collateral and the Canadian business cycle. *Canadian Journal of Economics/Revue canadienne d'économique* 49, 207–236.

Christensen, I. and A. Dib (2008) The financial accelerator in an estimated new Keynesian model. *Review of Economic Dynamics* 11, 155–178.

Christiano, L. J., R. Motto and M. Rostagno (2004) The great depression and the Friedman-Schwartz hypothesis. Tech. rep., National Bureau of Economic Research.

Eickmeier, S. and B. Hofmann (2013) Monetary policy, housing booms, and financial (IM) balances. *Macroeconomic Dynamics* 17, 830.

Favilukis, J., D. Kohn, S. Ludvigson and S. G. Van Nieuwerburgh (2013) International capital flows and house prices: Theory and evidence. *Housing and the Financial Crisis*, 235–299.

Ferreira, F. and J. Gyourko (2015) A new look at the U.S. foreclosure crisis: Panel data evidence of prime and subprime borrowers from 1997 to 2012. Working Paper 21261, National Bureau of Economic Research.

Foote, C. L., L. Loewenstein and P. S. Willen (2016) Cross-sectional patterns of mortgage debt during the housing boom: Evidence and implications. *Federal Reserve Bank of Boston Working Paper*.

Forlati, C. and L. Lambertini (2011) Risky mortgages in a DSGE model. *International Journal of Central Banking*.

Greenwald, D. (2018) The Mortgage Credit Channel of Macroeconomic Transmission. *MIT Sloan Research Paper*.

Guerrieri, V. and G. Lorenzoni (2017) Credit crises, precautionary savings, and the liquidity trap. *The Quarterly Journal of Economics* 132, 1427–1467.

Hobijn, B. and F. Ravenna (2010) Loan securitization and the monetary transmission mechanism. *IMF Working Paper*.

Huo, Z. and J.-V. Rios-Rull (2016) Financial frictions, asset prices, and the great recession. *Working Paper*, 1–55.

Iacoviello, M. (2005) House prices, borrowing constraints and monetary policy in the business cycle. *American Economic Review* 95, 739–764.

Iacoviello, M. (2015a) Financial business cycles. *Review of Economic Dynamics* 18, 140–163.

Iacoviello, M. (2015b) OccBin: A toolkit for solving dynamic models with occasionally binding constraints easily. *Journal of Monetary Economics* 70, 22–38.

Iacoviello, M. and M. Pavan (2013) Housing and debt over the life cycle and over the business cycle. *Journal of Monetary Economics* 60, 221–238.

Jeske, K. and Z. Liu (2013) Should the Central Bank be concerned about housing prices? *Macroeconomic Dynamics* 17, 29–53.

Justiniano, A., G. E. Primiceri and A. Tambalotti (2015) Credit supply and the housing boom. *Chicago Fed Working Paper*.

Justiniano, A., G. E. Primiceri and A. Tambalotti (2016) A simple model of subprime borrowers and credit growth. *New York Fed Staff Report*, 1–26.

Kaplan, G., K. Mitman and G. L. Violante (2016) Non-durable consumption and housing net worth in the great recession: Evidence from easily accessible data. Working Paper 22232, National Bureau of Economic Research.

Kiyotaki, N. and J. Moore (1997) Credit cycles. *Journal of Political Economy* 105, 211–248.

Krause, M. U., D. Lopez-Salido and T. A. Lubik (2008) Inflation dynamics with search frictions: A structural econometric analysis. *Journal of Monetary Economics* 55, 892–916.

Krueger, D., K. Mitman and F. Perri (2016) Macroeconomics and household heterogeneity. *Handbook of Macroeconomics* 2, 843–921.

Lambertini, L., V. Nuguer and P. Uysal (2017) Mortgage default in an estimated model of the US housing market. *Journal of Economic Dynamics and Control* 76, 171–201.

Lambie-Hanson, L., W. Li and M. Slonkosky (2019) Leaving households behind: Institutional investors and the U.S. housing recovery. Working Papers 19-1, Federal Reserve Bank of Philadelphia.

Liu, Z., P. Wang and T. Zha (2013) Land-price dynamics and macroeconomic fluctuations. *Econometrica* 81, 1147–1184.

Mian, A., K. Rao and A. Sufi (2013) Household balance sheets, consumption, and the economic slump. *Quarterly Journal of Economics* 128, 1687–1726.

Mian, A. and A. Sufi (2009) The consequences of mortgage credit expansion: Evidence from the U.S. mortgage default crisis. *The Quarterly Journal of Economics* 124, 1449–1496.

Mian, A. and A. Sufi (2016) Who bears the cost of recessions? The role of house prices and household debt. *Handbook of Macroeconomics* 2, 255–296.

Miao, J. and P. V. Ngo (2019) Does calvo meet rotemberg at the zero lower bound? *Macroeconomic Dynamics*, 1–22.

Philippon, T. and V. Midrigan (2011) Household leverage and the recession. Working Paper 16965, National Bureau of Economic Research.

Segal, L. M., D. G. Sullivan, et al. (1998) Trends in homeownership: Race, demographics, and income. *Economic Perspectives-Federal Reserve Bank of Chicago* 22, 53–72.

Taylor, J. B. (1993) Discretion versus policy rules in practice. *Carnegie-Rochester Conference Series on Public Policy* 39, 195–214.

Vu, N. T. (2020) Price flexibility and output volatility under menu costs. *Macroeconomic Dynamics*, 1–24.

https://doi.org/10.1017/S1365100521000055 Published online by Cambridge University Press