Macroeconomic effects of the mortgage refinance and the home equity lines of credit

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Abstract

I examine how the mortgage refinance and the home equity lines of credit (HELOC) impact the increase in pre-crisis mortgage debt and post-crisis mortgage defaults. Financially constrained homeowners can cash out funds through refinancing mortgages or extract home equity through the HELOC. My quantitative exercise shows that prevalent usage of refinancing increases pre-crisis mortgage debt, which amplifies the post-crisis foreclosure rate. The HELOC also contributes to an increase in mortgage defaults, though it negligibly impacts pre-crisis mortgage debt.

JEL classification: E21, E44, G01, G21, R21

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1 Introduction

There are several ways of extracting home equity through mortgage finance. Among them, this paper focuses on the mortgage refinance and the line of credit secured by home equity, which is called the home equity lines of credit (HELOC). During the housing boom, a significant number of households refinanced their loans and used the HELOC, which could possibly have increased the mortgage debt before the crash and deepened the foreclosure crisis. In this paper, I quantitatively examine how refinancing and the HELOC impact the increase in pre-crisis mortgage debt and post-crisis mortgage defaults. I then analyze effective mortgage finance directions to mitigate mortgage defaults after the crisis.

The HELOC is a secured junior loan where lenders agree to lend a maximum amount within an agreed period, collateralized by the borrower's home equity. It works like a credit card loan where households can use the line of credit to borrow funds. The HELOC has two phases: the draw period and the repayment period. During the draw period, which usually lasts for 10 years, homeowners can freely accumulate or decumulate loans by repaying only interests. After the draw period, the loan enters repayment, where the household cannot borrow additional funds and must repay both the principal and interest. The repayment period typically lasts for 20 years. Unlike the conventional (first) mortgage that is mainly used for buying homes, the HELOC is widely used to borrow relatively small amounts to be repaid quickly for the purpose of home improvements and maintenance, living expenses, and personal loans (See Section 3 for more details).[1]

[1]In the real world, financially troubled households can also use the home equity loan. Similar to the HELOC, the home equity loan is a second mortgage. However, the home equity loan users usually take out the lump sum amount of debt, face (relatively large) closing costs, and repay fixed periodic payments over

Instead of using the HELOC, financially constrained households can relax their budget tightness by refinancing the loan. Through refinancing, households can replace the original mortgage contract with a new one and cash out additional funds. Since the refinanced mortgage is the first loan, the borrowing interest rate is generally lower than the HELOC. However, a significant origination cost is incurred.

In this paper, I examine roles of refinancing and the HELOC in improving households' liquidity, accumulating household debt during the housing boom, and amplifying mortgage defaults during the financial crisis. To analyze this, I introduce a quantitative model and calibrate model parameters to match the US economy before and after the crisis. I then consider a counter-factual economy where the costs of refinancing or using the HELOC increase. By comparing the benchmark transition with the experiment economy, I can examine the impacts of these mortgage finance tools on households' optimal behavior.

A household can purchase a home by taking out a long-term conventional mortgage. While maintaining homeownership, the household might face adverse income shocks, which makes it difficult to repay the periodic mortgage as contracted. If the household has positive home equity – the difference between the home value and the remaining mortgage balance – it is eligible to access the HELOC. Unlike the conventional mortgage, the HELOC is a second mortgage where the lender has the subordinate right to recover losses when the borrower defaults. In other words, when the household defaults on loans, the HELOC lender can receive proceeds from liquidating the foreclosed house only after the first mortgage lender

next several years. Since the home equity loan and the HELOC are substitutable, it would be important to consider both loans. However, as reported in Section 3, the size of the HELOC is significant. Also, for computational simplicity, this paper mainly focuses on the HELOC.

is fully paid off. Because of the difference in the lien priority, the interest rate for the HELOC is usually higher than that for the conventional mortgage, which reflects the higher likelihood of incurring losses. Though the cost of borrowing the HELOC is high, financially constrained homeowners have an incentive to take it out to smooth consumption and to meet the periodic mortgage payment burden. This implies that the HELOC helps reduce the likelihood of mortgage defaults. On the contrary, households tend to save less financial assets by leaning on the HELOC and thus are vulnerable to adverse house price shocks. In addition, since households under the repayment phase cannot roll over the HELOC, their simultaneous repayment of both loans can be burdensome, leading to an increase in the default probability.

Instead of using the HELOC, financially constrained households can also access liquidity and avoid defaults through refinancing loans. Though they incur both the fixed and variable costs to refinance loans, households that are not eligible to use the HELOC can refinance their mortgages. By cashing out additional funds through refinancing, households can avoid mortgage defaults, which leads to a decrease in mortgage interest rates. On the other hand, this tends to increase loans that take advantage of low borrowing costs and decrease savings. In turn, improved accessibility to refinancing can possibly increase mortgage defaults.

In this paper, I introduce a heterogeneous agent model where these mechanisms are embedded. When a renter decides to buy a house, (s)he chooses the house size, takes out the long-term mortgage, and moves into the owner-occupied home. If the home value is higher than the outstanding mortgage, (s)he is eligible to take out the HELOC up to home equity.

The HELOC is initially under the draw period where households can freely roll over the balance while paying interests. I model that the HELOC turns out be the repayment period with a certain probability. Once the HELOC is under the repayment period, households must reduce the HELOC balance with a given proportion, along with paying interest. When the household refinances loans, it repays the outstanding balance of loans, borrows again with new contract terms, and is allowed to switch the size of its home. The homeowner can also choose to sell the house or default on loans. When the household sells the house, it pays the remaining loan balance including the transaction cost. Mortgage defaulters cannot access the loan market and buy a new house for several periods as a default penalty. The mortgage and the HELOC interest rates are endogenously determined, reflecting the borrower's default risk and the loan seniority. Specifically, financial intermediaries observe households' optimal behavior, calculate the expected profit by making a household-by-household contract, and decide the price of loans competitively.

I calibrate the benchmark steady-state model to match the early 2000s US economy. Given the benchmark steady state, I consider the transition that reflects the pre- and post-financial crisis. In 2001, households expect that the average house price will increase year-by-year until 2007 and then remain steady. The rent-to-price ratio is also expected to change following the data path. Their ex-ante expectation, the ex-post realization of the house price, and the rent-to-price ratio all coincide during the housing boom (until 2006). At the start of 2007, unlike their original expectation, the average house price unexpectedly declines for four consecutive years, mirroring the financial crisis. Consistent with data, the rent-to-price ratio simultaneously changes after 2007. Over the transition path, I adjust the cost of refinancing loans to match the actual refinance rate. Given this benchmark transition, I consider counterfactual transitions where the costs of refinancing or accessing the HELOC increase over the transition path.

When the pre- and post-crisis cost of refinancing increases – which halves the refinance rate compared to the benchmark over the transition – the aggregate mortgage debt decreases by 6.2%p during the housing boom. This in turn leads to a smaller increase in the foreclosure rate after the financial crisis. My exercise shows that the cumulative foreclosure rate between 2007 and 2010 decreases by 1.3%p. As the cost of refinancing increases, it is costly to cash out funds secured by home equity, which incentivizes households increase their financial assets and decrease their consumption. Hence, nondurable consumption responds less elastically to the increase in the average house value than the benchmark before the crisis. However, since households under the experiment economy have accumulated more financial assets than the benchmark, post-crisis consumption under the former economy is less affected than the latter.

Next, I consider a counterfactual economy where the cost of accessing the HELOC is prohibitively high before and after the crisis. With limited access to the HELOC, financially troubled households instead refinance loans while paying closing costs. In turn, aggregate household debt under the experiment economy is almost same as the benchmark. However, households tend to accumulate more financial assets and spread out the mortgage payment burden. Hence, the foreclosure rate after the financial crisis increases less than the benchmark. The cumulative foreclosure rate in 2007-10 decreases by 1.4%p under the experiment economy. Though limited access to the HELOC makes households more likely to be liquidity-constrained, an increase in financial assets offset such effects. In turn, the response of consumption after the financial crisis reflects such mixed effects.

Last, I examine effective policy directions for reducing post-crisis mortgage defaults by adjusting accessibility to the refinance or the HELOC. Given the benchmark pre-crisis transition, I model that the post-crisis cost of the refinance or the HELOC either increases or decreases, which makes it either easier or more difficult for financially troubled households to extract home equity. When households can easily refinance loans after the crisis, they can avoid mortgage defaults and relax budget tightness. However, they tend to replace the long-term mortgage into the HELOC, which accumulates the periodic debt payment burden and contributes to an increase in the foreclosure rate. In sum, the change in the post-crisis refinance cost negligibly impacts the foreclosure rate. Similar to refinancing, improving accessibility to the HELOC cannot reduce the post-crisis foreclosure rate. In terms of reducing mortgage defaults, an increase in the HELOC cost is effective. Though limited access to the HELOC constrains financially troubled households more, it makes them to switch the HELOC into the long-term mortgages. In turn, they are less vulnerable to consecutive decreases in the house price.[2]

This paper is organized as follows. Section 2 reviews related papers. Section 3 presents the outline of the refinance and the HELOC market. I introduce a quantitative model in

[2]This result is consistent with Kim (forthcoming), who examines the effective policy direction for mitigating both the mortgage and the unsecured loan defaults. According to his analysis, restricting accessibility to the unsecured credit can mitigate the foreclosure rate.

Section 4 and present the calibration in Section 5. I analyze the benchmark steady state in Section 6. Subsequently, in Section 7, I present the main quantitative results. Section 8 concludes the paper.

2 Related literature

This paper complements empirical and theoretical research analyzing the mortgage default and dynamics of household debt before and after the financial crisis. The most relevant paper is Chen et al. (2013) who examine the response of household debt and consumption as macroeconomic conditions change that mirror the financial crisis. Consistent with my paper, they model the long-term mortgage along with the (short-term) HELOC and refinancing, which allows liquidity-constrained households to share income risk. Both papers can successfully generate the increase in household debt and consumption prior to the crisis and the subsequent collapse.[3]

My paper is also related to Kaplan et al. (forthcoming) who examined the main driver of movements in macroeconomic variables during the housing boom and bust. Similar to my paper, they also explicitly model the long-term mortgage, refinancing, and the HELOC. However, unlike Chen et al. (2013) and Kaplan et al. (forthcoming), I explicitly model the mortgage finance market, where both the mortgage and the HELOC prices are endogenously determined to reflect households' default risk. I also consider the seniority of the conventional mortgage and the HELOC, which are not modeled in these papers. The HELOC in this

[3]Empirical studies show that household consumption responds elastically to home values before and after the financial crisis (Mian et al. (2013) and Mian & Sufi (2014)). Consistent with these findings, my

paper reflects actual operational details that include both the draw and repayment phases. In addition, I mainly analyze the macroeconomic impacts of the refinance and the HELOC, which is not their main focus.

Besides these papers, Agarwal et al. (2017) and Wong (2019) examined the macroeconomic implications of refinancing mortgages. The former focuses on the performance of the government-driven mortgage refinance program (Home Affordable Refinance Program) after the crisis. Specifically, they empirically and theoretically study how a reduction in refinance costs impact consumption, foreclosure rate, house prices, and welfare. The latter studies the transmission mechanism of an expansionary monetary policy on the consumption of different age groups through the refinancing channel. However, I consider counterfactual exercises where costs to access the refinance or the HELOC change before and after the financial crisis, compare it with the benchmark transition, and examine impacts on macroeconomic and household finance moments.

This paper also complements the literature on how additional liquidity impacts households' behavior and macroeconomic variables. In my model, financially troubled households can access liquidity more easily and relax their tightened budget through the refinancing or the HELOC. Though they do not explicitly consider the impact of these mortgage finance tools, Kaplan & Violante (2014) and Gorea & Midrigan (2018) examined the impact of liquidity on home equity extraction, consumption, and liquid asset holdings. They analyze how the injection of additional liquidity impacts the optimal behavior of budget-constrained households, especially the "hand-to-mouth" households. Households can relax their budgets

benchmark model which mimics the pre- and post-financial crisis can generate such consumption path.

through the refinance in Gorea & Midrigan (2018) and the adjustment of illiquid assets in Kaplan & Violante (2014), while households in my model can do so through mortgage finance tools.

In terms of the general model structure, this paper is related to the quantitative analysis of mortgage defaults (Jeske et al. (2013), Mitman (2016), Corbae & Quintin (2015), Chatterjee & Eyigungor (2015), Guler (2015), Hatchondo et al. (2015), Arslan et al. (2015), and Gete & Zecchetto (2018)). Specifically, households in this paper can access two types of loans, conventional mortgages and the HELOC, which is in line with Mitman (2016). However, he modeled that households can take out either the mortgage or the unsecured loan and examined the heterogeneity of default behavior across state-level bankruptcy and foreclosure guidelines. Though I do not explicitly model the unsecured credit, financially troubled households can relax their budget tightness and share income risk through either refinancing or by using the HELOC.[4]

3 Empirical motivation

The residential mortgage debt in the US significantly increased during the housing boom. As presented in Figure 1a, total outstanding mortgage debt increased by 85% from 2000 to 2007. This was not limited to only the standard residential mortgages – the HELOC debt also dramatically increased, as its balance almost quadrupled from 2000 to 2007. Even after the beginning of the financial crisis, its amount still increased. The outstanding HELOC

[4]Similar to Mitman (2016), Kim (2015) and Kim (forthcoming) also considered two types of loans – the mortgage and the unsecured loan – and examined the efficacy of the mortgage modification program and

Figure 1: Size and usage patterns of the mortgage and the HELOC

(a) Size of US mortgage and HELOC loans **(b)** HELOC and refinance usage patterns

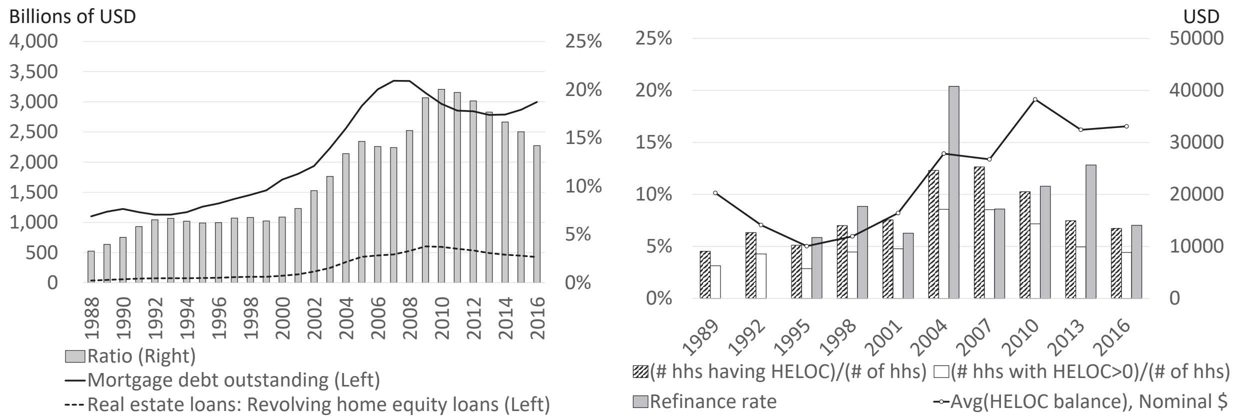


Figure 1a: The data source of two types of debts is the FRED. Mortgage debt is defined by the sum of one-to-four family and multifamily residence mortgages issued by depository institutions and life insurance companies. I exclude mortgages for non-residences and farms. Figure 1b: The data source is the SCF. The refinance rate is defined by the ratio of the number of households that refinance loans at a certain time to the number of households that live in an owner-occupied house. The numerator of the ratio is measured by the number of households that refinance or rollover earlier loans, borrow additional money secured by home equity, or both. By using the SCF in year t, I count the number of such households that refinance loans at year t or $t-1$. The SCF surveyed refinance information after 1995.

balance was 6.8% of residential mortgages in 2000, and the ratio increased to 14% in 2007 and peaked 20% in 2010. Since debt increased in such a fast manner during the housing boom, the HELOC could possibly contribute to the increase in residential mortgages and the subsequent increase in mortgage defaults.

Micro-level data also shows the size and the prevalent usage of the HELOC, just as in macro-level data. Figure 1b presents the fraction of households that have the HELOC account with a positive balance. During the housing boom, especially in 2004, a significant portion of households had a HELOC account with a balance. At the same time, their average balance also increased. Though the fraction of households with a HELOC balance (extensive margin) decreased in 2010, the average dollar amount of positive HELOC balances (intensive margin) notably increased. That is why the total outstanding HELOC balance did not decrease, even after the start of the financial crisis.

Figure 1b also presents the refinance rate, which is defined by the ratio of the number of households that refinance loans to the number of households that stay in owner-occupied homes.[5] The Survey of Consumer Finances (SCF) shows that the refinance rate peaked in 2004. At the start of the financial crisis in 2007, the refinance rate decreases to 8.6%. One possible reason for the increase in the refinance rate after 2007 might be the Home Affordable Refinance Program initiated in 2009. The US government introduced several programs to prevent mortgage defaults right after the crisis. HARP is one such program which promotes mortgage refinancing and aims to prevent defaults.

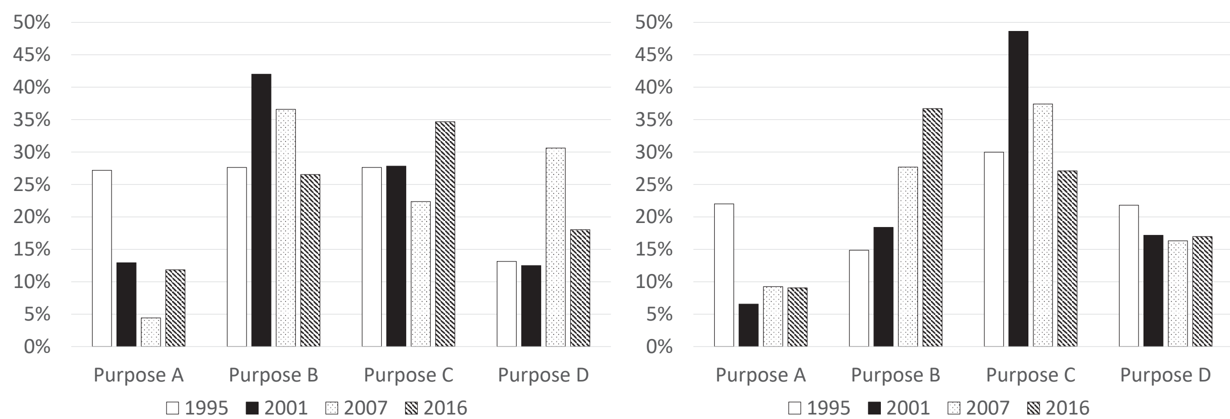
Figure 2 presents the purposes for refinancing and using the HELOC. The reported number in the figure is the ratio of the unpaid loan balance used in a specific category to the total outstanding (refinanced or HELOC) loans in each survey year. In 1995, a quarter of households used either a refinance or the HELOC to buy or construct houses. However, such proportions have since decreased. Households usually refinance loans or use the HELOC to maintain their homes or use them as vehicles for personal investment. Thirty percent of refinanced loans before the beginning of the crisis or 18% of the HELOC loans were

effective unsecured credit policy directions for mitigating mortgage defaults.

[5] See more details about the definition of the refinance rate in the note of Figure 1b. The reason I define the refinance rate in this manner is to make it consistent with the literature (Chen et al. (2013) and Gorea & Midrigan (2018)). That is, when I calculate the ratio based on this criteria, the refinance rate in 2001 or 1998 is 8%.

Figure 2: Purpose of using the refinance and the HELOC

(a) Refinance **(b)** HELOC



"Purpose A" includes (main and second) home purchase and construction. "Purpose B" includes home improvements, repairs, and maintenance. "Purpose C" includes business and asset (stocks, bonds, IRA, gold, farmland, and other real estate) investment and holding cash reserves. "Purpose D" includes tax and insurance expenses, personal and living expenses, gifts, debt consolidation, and loans to other people.

used to subsidize living expenses. Hence, the refinance or the HELOC were mainly used to supplement the shortage of household income, to improve access to liquidity, or to increase consumption, and not simply to buy new homes.

4 Model

Time is discrete and infinite and indexed by $t = 0, 1, 2, ...$ There are three market participants: households, conventional mortgage lenders, and HELOC lenders. Households maximize their lifetime utility given by

$$E_0 \sum_{t=0}^{\infty} \beta^t u\left(c_t, h_t\right)$$

where c_t is consumption and h_t is the housing service (or house size). The household's periodic utility is defined by $u(c_t, h_t) = ln(c_t) + ln(h_t)$.[6]

Households can choose whether to stay in an owner-occupied house or a rental house. If the household decides to be a homeowner, it can endogenously choose the size of the housing service $h \in \{h_S, h_L\}$ where $h_L > h_S$. Renters can stay only in a small-sized home h_S, however. Hence, homeowners have more options for their housing sizes and can be better off by staying in a large home.[7]

Each household is endowed with the stochastic income stream e and makes the savings

[6]Following Corbae & Quintin (2015), I use the log utility function where (log) consumption and (log) housing service are additively separable. Unlike their paper, I do not include the extra utility gain from staying in an owner-occupied house to save a free parameter.

[7]Corbae & Quintin (2015) also modeled that homeowners can choose a large-sized home, while renters cannot.

decision $a(\geq 0)$ with the risk-free rate r_f. The log income follows the AR(1) process.

$$log(e_t) = (1-\rho_e)log(\bar{e}) + \rho_e log(e_{t-1}) + \varepsilon_t$$

where $\bar{e}$ is the median income and $\varepsilon_t \sim i.i.d.N(0, \sigma_e^2)$.

Each household faces idiosyncratic unit house price shocks, which also follow the AR(1) process.

$$log(p_t) = (1-\rho_p)log(\bar{p}) + \rho_p log(p_{t-1}) + \nu_t$$

where $\bar{p}$ is the median house value and $\nu_t \sim i.i.d.N(0, \sigma_p^2)$. If the household decides to stay in a rental house, it pays the periodic unit rent z. I model that the periodic rent is proportional to the house value: $z(p) = \kappa p$.

Households can access two types of debt backed by home equity: the long-term conventional mortgage (the first mortgage) and the HELOC (the second mortgage). When a renter buys an owner-occupied house at time t, it can take out the mortgage m with the price of q_m. Then, the total outstanding mortgage is given by mq_m. At the same time, the household must pay two types of origination fee: the fixed cost ξ_1 and the variable cost ξ_2 that is proportional to the initial mortgage balance. Once the household takes out the mortgage, it repays m at time $t+1$, δm at time $t+2$, $\delta^2 m$ at time $t+3$, and so on, where $\delta \in [0,1]$. The repayment stream $\{m, \delta m, \delta^2 m, \delta^3 m, ...\}$ decreases geometrically. This declining repayment can be interpreted as the amortization scheme or the mortgage contract length.[8]

[8] Suppose the household signs a mortgage contract at time t. Then, we can interpret that the contract terminates at time $t+1$ with a probability of $(1-\delta)$, at time $t+2$ with a probability of $\delta(1-\delta)$, and so on. Given this, the expected mortgage contract length can be derived by $\sum_{t=0}^{\infty}(1-\delta)\delta^t(t+1) = 1/(1-\delta)$.

Homeowners who have positive home equity are eligible to take out the HELOC. The HELOC has two phases: the draw period and the repayment period. Households with positive home equity can freely borrow $b (\geq 0)$ with the price of q_b during the draw period. The draw period will persist in the next period with the probability of ϕ. Then, the household that took out the HELOC bq_b in the last period repays b if it does not default and is eligible to borrow again if it has positive home equity. However, the HELOC enters the repayment period with the probability of $1-\phi$. Then, the household that has the loan balance b cannot roll over the HELOC even if it has positive home equity, and therefore must reduce the balance gradually. The balance of the HELOC decreases with the rate of η, where $\eta \in [0, 1]$. That is, the household repays the interest and principal of the remaining HELOC balance to make it geometrically decrease as follows: $\{b, \eta b, \eta^2 b, ...\}$. For computational simplicity, the interest rate on the HELOC is given by the sum of the risk-free rate r_f and the HELOC cost θ_b.[9]

As will be clear later, the mortgage price q_m and the HELOC price q_b are endogenously determined, reflecting the default risk premium and the origination fee. In turn, loan rates are higher than the risk-free rate. Hence, it is never optimal to simultaneously hold positive balances of the HELOC and financial assets.[10] That is, $ab = 0$.

An eligible renter decides to either buy an owner-occupied house by taking out the mortgage or stay in a rental house. If the household buys a house, it has to pay the transaction cost, which is a fraction χ_B of the house value. The household is eligible to take out the

[9]To make the model more realistic, I can derive the HELOC interest rate from its bond price q_b. However, I model that the HELOC holder under the repayment period faces the interest rate of $r_f + \theta_b$ to make it computationally tractable.

[10]Chen et al. (2013) also used this model structure.

HELOC if the house value net of the mortgage balance is positive. If the renter decides to stay in a rental house, (s)he pays the periodic rent, accumulates financial assets, and postpones the homeownership decision to the next period.

Once the household becomes a homeowner, it decides whether to repay the mortgage and the HELOC as contracted, sell the house, refinance loans, or default on loans. The homeowner's available options to choose are different, depending on the realization of the HELOC phases – the repayment or draw period. Regardless of the realization of these two phases, households can freely sell the house, refinance loans, or default.

When the household sells the house, it pays the remaining debt (mortgage and HELOC) balance and the transaction cost, which is a fraction χ_S of the current house value. It then becomes a renter. The mortgage balance is the present value of the remaining mortgage burden: $\Sigma_{t=0}^{\infty} m(\delta/(1+r_f+\theta_m))^t$, where θ_m is the cost of using mortgages.[11] For notational simplicity, let $A(m)$ be the mortgage balance $\Sigma_{t=0}^{\infty} m(\delta/(1+r_f+\theta_m))^t$.

Homeowners can refinance loans by paying the refinance fee ξ_3. Households that refinance loans must repay the remaining loans and can borrow again under the new contract term. That is, the household can choose the new long-term mortgage m with the new price. If the household's home equity is positive, it is eligible to take out the new HELOC b. Homeowners that refinance loans can also switch the size of the house by paying transaction costs.

The homeowner can potentially default after receiving bad income shocks and lose its home. Once the household defaults, it cannot access the loan market and buy an owner-

[11] The (endogenously contracted) mortgage interest rate is usually higher than the risk-free rate, since the former rate reflects the default risk premium and origination fees. By discounting the future payment burden with the sum of the risk-free rate and the cost of mortgages rather than the contracted mortgage interest rate, the calculated mortgage balance is over-estimated compared to the actual loan balance (see

occupied house for several periods as a default penalty. However, the household can re-access the loan market and become eligible for owning a home with a probability of γ. After the default, financial intermediaries foreclose the house and partially recover their losses by selling the house. However, they cannot fully recover the value of the foreclosed house. The foreclosure cost, which is a fraction χ_D of the house value, is thus incurred.[12]

Mortgage and HELOC lenders are different in terms of lien priority: loans originated by the former are more senior than the latter. Once the household defaults on the loan, financial intermediaries can recover their losses via the liquidation process. Here, the mortgage lender has priority to receive all proceeds from the liquidation of the foreclosed house. The HELOC lender can recover their losses from the liquidation yield only after the mortgage lender's losses are fully paid off. Hence, the HELOC lender is more likely to face losses, which increases the default risk premium for the HELOC.

4.1 Households' problems

There are two types of households at the beginning of each period: renters and homeowners. Here, I introduce how each household makes its optimal decisions.

Renter's problem

A renter decides whether to stay in a rental house (V^{RR}) or to buy an owner-occupied

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financial intermediaries' problems for more details). However, if we discount the future payment stream with the originally contracted interest rate, we will need an additional state variable. This increases the computational burden dramatically. Chatterjee & Eyigungor (2015) also adopted this model structure.

[12] I model that mortgages are non-recourse, following Feldstein (2008). That is, financial intermediaries cannot garnish the defaulter's income or financial assets. This assumption can simplify the computational burden.

house (V^{RH}).

$$V^{R}(a,e,p)=\max\left\{V^{RR}(a,e,p)\,,\ V^{RH}(a,e,p)\right\}$$

If the renter decides to stay in a rental house, (s)he solves the following problem:

$$V^{RR}(a,e,p)=\max_{c\geq 0,a'\geq 0} u(c,h_S)+\beta E_{e',p'|e,p}V^{R}(a',e',p')$$

$$s.t.$$

$$c+\frac{a'}{1+r_f}+z(p)\,h_S=a+e.$$

Renters stay in a small-sized home h_S and pay periodic rent $z(p)h_S$. Since renters do not hold any home equity, they cannot borrow but can save financial assets.

If the renter decides to buy an owner-occupied house, (s)he solves the following problem:

$$V^{RH}(a,e,p)=\max_{\substack{c\geq 0,a'\geq 0,b'\geq 0,\\ h'\in\{h_S,h_L\},m'\geq 0}} u(c,h')+\beta E_{e',p'|e,p}\left[\begin{array}{c} I_{b'>0}\left\{\begin{array}{c}\phi V_D^H(a',b',e',h',p',m')+\\ (1-\phi)\,V_R^H(a',b',e',h',p',m')\end{array}\right\}\\ +I_{b'=0}V_D^H(a',b',e',h',p',m')\end{array}\right]$$

$$s.t.$$

$$c+\frac{a'}{1+r_f}+ph'(1+\chi_B)$$

$$=a+e-\xi_1 I_{m'>0}+(1-\xi_2)\,q_m(a',b',e,h',p,m')\,m'+q_b(a',b',e,h',p,m')\,b'$$

$$q_b(a',b',e,h',p,m')\,b'\leq\max\{ph'-q_m(a',b',e,h',p,m')\,m',0\}$$

$$a'b'=0.$$

When the renter purchases a house, (s)he chooses the size of the house h' and takes out the mortgage m' and the HELOC b'. The home purchaser can take out the mortgage in the amount of $q_m(\cdot)m'$. If the household takes out the mortgage, it has to pay origination fees ξ_1 and ξ_2. The household with positive home equity $ph - q_m(\cdot)m'(> 0)$ is eligible to take out the HELOC $q_b(\cdot)b'$ up to the amount of home equity. However, the household cannot take out the HELOC if its home equity is negative. Prices for the mortgage $q_m(\cdot)$ and the HELOC $q_b(\cdot)$ will be specified in the financial intermediaries' problems. Since it is impossible for households to save financial assets and borrow the HELOC simultaneously, we need the last condition ($a'b' = 0$).

If the home buyer does not use the HELOC, (s)he is eligible to take it out in the next period. In turn, its value is defined by $V_D^H(\cdot)$. Conditional on drawing the HELOC, the household's value is $V_D^H(\cdot)$ if the HELOC is in the draw period with the probability ϕ and $V_R^H(\cdot)$ if the HELOC is in the repayment period with the probability $1-\phi$. The value function $V_D^H(\cdot)$ is defined as follows:

$$V_D^H(a,b,e,h,p,m) = \max_{I_D} \left\{ \begin{array}{c} V_D^{HP}(a,b,e,h,p,m), V^{HS}(a,b,e,h,p,m), \\ V^{HF}(a,b,e,h,p,m), V^D(a,e,p) \end{array} \right\}$$

where each value function represents households' available options: repaying loans under the draw period (V_D^{HP}), selling the house (V^{HS}), refinancing loans (V^{HF}), and defaulting on loans (V^D). Similarly, the value function $V_R^H(\cdot)$ is defined by

$$V_R^H(a,b,e,h,p,m) = \max_{I_R} \left\{ \begin{array}{c} V_R^{HP}(a,b,e,h,p,m), V^{HS}(a,b,e,h,p,m), \\ V^{HF}(a,b,e,h,p,m), V^D(a,e,p) \end{array} \right\}$$

where V_R^{HP} is the value of the household that repays loans under the repayment period.

Homeowner's problem

If the household under the draw period decides to repay the mortgage as contracted, it solves the following problem:

$$V_D^{HP}(a,b,e,h,p,m) = \max_{c\geq 0, a'\geq 0, b'\geq 0} u(c,h) + \beta E_{e',p'|e,p} \left[\begin{array}{c} I_{b'>0} \left\{ \begin{array}{c} \phi V_D^H(a',b',e',h,p',\delta m) + \\ (1-\phi) V_R^H(a',b',e',h,p',\delta m) \end{array} \right\} \\ +I_{b'=0} V_D^H(a',b',e',h,p',\delta m) \end{array} \right]$$

$$s.t.$$

$$c + \frac{a'}{1+r_f} + m + b = a + e + q_b(a',b',e,h,p,\delta m)\, b'$$

$$q_b(a',b',e,h,p,\delta m)\, b' \leq \max\{ph - A(m), 0\}$$

$$a'b' = 0.$$

The household repays the current mortgage m and the HELOC b. In the next period, the household's mortgage payment burden reduces to δm. Since the household is eligible to draw the HELOC, it can take out the loan again if it has positive home equity $ph - A(m)(> 0)$.

If the HELOC is under the repayment phase, the household solves the following problem:

$$V_R^{HP}(a,b,e,h,p,m) = \max_{c\geq 0, a'\geq 0} u(c,h) + \beta E_{e',p'|e,p} V_R^H(a', \eta b, e', h, p', \delta m)$$

$$s.t.$$

$$c + \frac{a'}{1+r_f} + m + \frac{b(1-\eta+r_f+\theta_b)}{1+r_f+\theta_b} = a + e.$$

The household currently owes the HELOC b and must reduce its balance to ηb in the next period. To do this, it has to pay the fraction $1-\eta$ of the HELOC balance. Since the interest rate is the sum of the risk-free rate and the HELOC cost, $b(r_f+\theta_b)$ is the interest payment. To adjust timing for payments, the term $1+r_f+\theta_b$ must be divided.[13] The household also needs to pay the mortgage m, which then becomes δm in the next period.

[13] The household currently owes a balance b and starts repaying the loan from the current period. To take into account the consistent timing of repayment values, the additional term $1+r_f+\theta_b$ must be divided.

When the household decides to refinance loans, its problem is defined as follows:

$$V^{HF}\left(a,b,e,h,p,m\right)=\max_{\substack{c\geq 0,a'\geq 0,b'\geq 0,\\ h'\in\{h_S,h_L\},m'\geq 0}} u\left(c,h'\right)+\beta E_{e',p'|e,p}\left[\begin{array}{c} I_{b'>0}\left\{\begin{array}{c}\phi V_D^H\left(a',b',e',h',p',m'\right)+\\ \left(1-\phi\right)V_R^H\left(a',b',e',h',p',m'\right)\end{array}\right\}\\ +I_{b'=0}V_D^H\left(a',b',e',h',p',m'\right)\end{array}\right]$$

$$s.t.$$

$$c+\frac{a'}{1+r_f}+I_{h\neq h'}\left(-ph\left(1-\chi_S\right)+ph'\left(1+\chi_B\right)\right)+A\left(m\right)+b$$

$$=a+e-\xi_1+\left(1-\xi_2\right)q_m\left(a',b',e,h',p,m'\right)m'+q_b\left(a',b',e,h',p,m'\right)b'-\xi_3$$

$$q_b\left(a',b',e,h',p,m'\right)b'\leq\max\left\{ph'-q_m\left(a',b',e,h',p,m'\right)m',0\right\}$$

$$a'b'=0.$$

Once the household refinances, it repays the remaining loans, borrows again with the new contract, and pays origination fees. In addition, the household also pays the refinance-specific cost ξ_3.[14] The household that refinances is eligible to switch the size of the house. It then has to pay the transaction cost from selling the old house and buying the new one.

If the household decides to sell the house, it solves the following problem:

$$V^{HS}\left(a,b,e,h,p,m\right)=\max_{c\geq 0,a'\geq 0} u\left(c,h_S\right)+\beta E_{e',p'|e,p}V^R\left(a',e',p'\right)$$

$$s.t.$$

$$c+\frac{a'}{1+r_f}+z\left(p\right)h_S+A\left(m\right)+b=a+e+ph\left(1-\chi_S\right).$$

[14]As presented in Section 5, the refinance cost ξ_3 is calibrated as zero under the benchmark steady state. Hence, households that refinance loans need to pay the fixed cost ξ_1, regardless of their choice for new debts,

Once the household sells the house, it receives the value of the house net the transaction cost and moves into a rental house. In addition, the household pays the remaining mortgage balance $A(m)$ and the HELOC b.

If the household defaults on the mortgage, it solves the following problem:

$$V^D(a,e,p) = \max_{c\geq 0, a'\geq 0} u(c,h_S) + \beta E_{e',p'|e,p}\left[\gamma V^R(a',e',p') + (1-\gamma)V^D(a',e',p')\right]$$

$$s.t.$$

$$c + \frac{a'}{1+r_f} + z(p)h_S = a + e.$$

The defaulter does not need to pay the mortgage and the HELOC loans. As the default penalty, the household cannot buy an owner-occupied house and access the loan market. However, with the probability of γ, it regains the option to buy a new house (V^R). I model that even households with bad credit can save financial assets, although they cannot borrow funds from the financial market.

4.2 Financial intermediaries' problems

The financial market is competitive and the risk-free rate is exogenously given. Financial intermediaries can freely access funds at the risk-free rate. However, this incurs origination and management costs. It is impossible for households to directly access such funds with the risk-free rate even after paying these costs. Instead, households must sign contracts and borrow funds from financial intermediaries. There is no information asymmetry between

m' and b'.

borrowers and lenders, or between mortgage lenders and HELOC lenders.

Mortgage lender's problem

Let $\Pi_m(\cdot)$ be the mortgage lender's profit function at the time of the mortgage contract. The profit function is defined as follows:

$$\Pi_m\left(a',b',e,h',p,m'\right) = -q_m\left(a',b',e,h',p,m'\right)m'$$
$$+\frac{1}{1+r_f+\theta_m}E_{e',p'|e,p}\left[\begin{array}{l} I_{b'>0}\left\{\begin{array}{l} \phi I_D\left\{\text{Repay}\right\}\left\{m'+q_m\left(a''_D,b''_D,e',h',p',\delta m'\right)\delta m'\right\} \\ +\left(1-\phi\right)I_R\left\{\text{Repay}\right\}\left\{m'+\widetilde{q_m}\left(a''_R,\eta b',e',h',p',\delta m'\right)\delta m'\right\} \\ +\left[\phi I_D\left\{\text{Sell or Refin}\right\}+\left(1-\phi\right)I_R\left\{\text{Sell or Refin}\right\}\right]A\left(m'\right) \\ +\left[\phi I_D\left\{\text{Default}\right\}+\left(1-\phi\right)I_R\left\{\text{Default}\right\}\right]\min\left\{\begin{array}{c} A\left(m'\right), \\ p'h'\left(1-\chi_D\right) \end{array}\right\} \end{array}\right\} \\ +I_{b'=0}\left\{\begin{array}{l} I_D\left\{\text{Repay}\right\}\left\{m'+q_m\left(a''_D,b''_D,e',h',p',\delta m'\right)\delta m'\right\} \\ +I_D\left\{\text{Sell or Refin}\right\}A\left(m'\right) \\ +I_D\left\{\text{Default}\right\}\min\left\{A\left(m'\right),\ p'h'\left(1-\chi_D\right)\right\} \end{array}\right\} \end{array}\right].$$

Initially, the home buyer originates the mortgage in the amount of $q_m(\cdot)m'$. The mortgage lender discounts the future cash inflow at the rate of $r_f+\theta_m$, where θ_m is the cost for managing and originating mortgages. After the loan contract, the lender's cash inflow is determined by the realization of the HELOC status and the household's idiosyncratic shocks.

Let $I_D\{\text{Repay}\}$ be an indicator function that is one if the household's optimal decision under the draw period is repayment ($max\{V_D^{HP}, V^{HS}, V^{HF}, V^D\} = V_D^{HP}$) and zero otherwise. Once the household repays the loan, the lender recovers the periodic payment m'. In addition, the lender can expect to recover future cash inflow $q_m(a''_D, b''_D, e', h', p', \delta m)\delta m'$ where a''_D and b''_D are the savings and the HELOC policies for the loan payer under the draw period, respectively. That is, $a''_D = a'_{V_D^{HP}}(a', b', e', h', p', m')$ and $b''_D = b'_{V_D^{HP}}(a', b', e', h', p', m')$.

If the HELOC is taken out, the repayment phase starts with the probability $1 - \phi$. Let $I_R\{\text{Repay}\}$ be an indicator function that is one if the household under the repayment period repays ($max\ \{V_R^{HP}, V^{HS}, V^{HF}, V^D\} = V_R^{HP}$) and zero otherwise. The lender then receives the periodic payment m' and expects to recover future cash inflow $\widetilde{q_m}(a''_R, \eta b', e', h', p', \delta m)\delta m'$, where the loan price $\widetilde{q_m}(\cdot)$ is defined by $q_m(\cdot; \phi = 0, b > 0)$ and a''_R is the saving policy for the loan payer under the repayment phase ($a''_R = a'_{V_R^{HP}}(a', b', e', h', p', m')$). Once the household starts repaying the HELOC, it cannot draw the HELOC again unless it refinances the loan. That is, its future value becomes V_R^H, which contrasts with the future value for the household under the draw period. Hence, the future cash inflow is defined differently.

The household can sell the house or refinance the loan depending on the realization of income and house price shocks. Let $I_D\{\text{Sell or Refin}\}$ ($I_R\{\text{Sell or Refin}\}$) be an indicator function that is one if the household sells the house or refinance loans under the draw (repayment) phase and zero otherwise.[15] If the household either sells the house or refinances loans, the lender can recover the remaining loan balance $A(m)$.

If the household faces adverse income or house price shocks, it can default. Let $I_D\{\text{Default}\}$ ($I_R\{\text{Default}\}$) be an indicator function that is one if the household under the draw (repayment) phase defaults on the mortgage and zero otherwise.[16] When the household defaults

[15]The indicator function $I_D\{\text{Sell or Refin}\}$ is one if $max\{V_D^{HP}, V^{HS}, V^{HF}, V^D\} = \{V^S or V^{HF}\}$ and zero otherwise. The indicator function $I_R\{\text{Sell or Refin}\}$ is one if $max\{V_R^{HP}, V^{HS}, V^{HF}, V^D\} = \{V^S or V^{HF}\}$ and zero otherwise.

[16]The indicator function $I_D\{\text{Default}\}$ is one if $max\{V_D^{HP}, V^{HS}, V^{HF}, V^D\} = V^D$ and zero otherwise. The

on the mortgage, the lender liquidates the foreclosed house. Since it is the first mortgage, the lender has priority in recovering losses by collecting the collateral. If the proceeds from liquidation are greater than the loan balance, the mortgage lender can fully recover the remaining mortgage balance. However, if the loan balance is larger than the proceeds, the mortgage lender incurs losses even after foreclosing the house.

Since the financial market is competitive, the mortgage lender's profit is zero. That is, for each state variable, the loan price q_m is pinned down by the zero-profit condition.

HELOC lender's problem

Let Π_b be the HELOC lender's profit function that is defined by the following:

$$\Pi_b\left(a', b', e, h', p, m'\right) = -q_b\left(a', b', e, h', p, m'\right) b'$$

$$+\frac{1}{1+r_f+\theta_b} E_{e',p'|e,p} \begin{bmatrix} \left[\phi I_D\left\{\text{Repay, Sell, or Refin}\right\} + (1-\phi) I_R\left\{\text{Sell or Refin}\right\}\right] b' \\ + \left[\phi I_D\left\{\text{Default}\right\} + (1-\phi) I_R\left\{\text{Default}\right\}\right] \max\left\{p'h'\left(1-\chi_D\right) - A\left(m'\right), 0\right\} \\ + (1-\phi) I_R\left\{\text{Repay}\right\} \left\{\frac{b'\left(1-\eta+r_f+\theta_b\right)}{1+r_f+\theta_b} + \widetilde{q}_b\left(a''_R, \eta b', e', h', p', \delta m'\right) \eta b'\right\} \end{bmatrix}.$$

When the household takes out the HELOC $q_b(\cdot)b'$, the lender calculates the expected cash inflow. The HELOC lender discounts the future cash stream with the rate of $r_f + \theta_b$, where θ_b is the HELOC management and origination costs. If the household decides to either sell the house or refinance the loan, the HELOC lender is fully paid off. If the HELOC is under the draw phase and the household decides to repay, the lender can also fully recover the loan.

If the household defaults on the loan, the lender can claim partial yields from liquidating the foreclosed house. Since the HELOC lender has the subordinate lien on the collateral, it can recover losses only after the mortgage lender is fully paid off. When the household defaults, the mortgage lender's cash stream is either $A(m')$ or $p'h'(1-\chi_D)$, whichever is smaller. If the former is larger, the mortgage lender will take the entire yield generated from the liquidation process while incurring losses. Hence, HELOC lender cannot claim anything. If the latter is larger than the former, the mortgage lender is fully paid off, which makes it possible for the HELOC lender to recover some of its losses. In this case, the HELOC lender's recovery is the difference between the yield from the liquidation process and the mortgage lender's loan balance.

When the household under the repayment phase decides to repay the HELOC, the lender can recover the part of the loan principal and interest $b'(1-\eta+r_f+\theta_b)/(1+r_f+\theta_b)$. In addition, the household can expect to receive future cash inflow $\widetilde{q_b}(a''_R, \eta b', e', h', p', \delta m')\eta b'$. Since the HELOC user under the repayment phase cannot draw additional funds without refinancing, his/her available options are different from those under the draw period. Hence, the price function $\widetilde{q_b}(\cdot)$ reflects these options and is defined by $q_b\left(\cdot;\phi=0\right)$.

Since the HELOC market is also competitive, its lender's profit is zero. Thus, by using the zero-profit condition, we can determine HELOC prices q_b for each state variable.

Before moving to the next section, it is worthwhile to mention a particular feature of the model. If the foreclosure cost χ_D is higher than the selling cost χ_S, the following inequality holds conditional on the default: $A(m)+b-ph(1-\chi_D)>0$. That is, neither lender can fully recover their losses by liquidating the foreclosed house. Suppose the inequality does

indicator function $I_R\{\text{Default}\}$ is one if $max\{V_R^{HP}, V^{HS}, V^{HF}, V^D\} = V^D$ and zero otherwise.

not hold. We then have the following relation: $A(m) + b \leq ph(1 - \chi_D) < ph(1 - \chi_S)$. Hence, $ph(1 - \chi_S) - A(m) - b > 0$. Under this condition, selling the house is better than defaulting on the loan. This is a contradiction.[17] Since the inequality $b > ph(1 - \chi_D) - A(m)$ holds for every defaulter, the HELOC lender cannot fully recover their debt b when the household defaults on both loans.

4.3 Definition of a steady-state equilibrium

A steady-state equilibrium consists of value functions, household optimal policy functions, mortgage loan prices, HELOC prices, and an invariant distribution such that:

1. Given loan price functions q_m and q_b, each household solves its maximization problems.

2. Given a household's optimal policy functions, the mortgage price function q_m and the HELOC price function q_b are determined by each lender's zero-profit condition.

3. The cross-sectional distribution is invariant given the optimal household policy and loan price functions.

5 Calibration

I choose model parameters to match the US economy in the early 2000s. Given the benchmark steady state, I examine how the model responds to changes in home values that mirror those of the pre- and post-financial crisis periods. Subsequently, I consider the counter-

[17] The budget constraint for the seller is $c + a'/(1 + r_f) + z(p)h_S = a + e + ph(1 - \chi_S) - A(m) - b$. For the defaulter, it is $c + a'/(1 + r_f) + z(p)h_S = a + e$. The RHS of the budget constraint for the seller is higher than for the defaulter if $ph(1 - \chi_S) - A(m) - b > 0$. In addition, defaulters face the default penalty. That is, they cannot buy a house and take out mortgages. Hence, selling is the better option.

factual economy where the costs of refinancing and the HELOC change and analyze their macroeconomic implications.

In the model, a period is a year. The risk-free rate is set to 2%, following the one-year Treasury rate. Parameters for idiosyncratic shock processes are chosen exogenously. The median income $\bar{e}$ is normalized to one. Income process parameters (ρ_e, σ_e^2) are set at (0.99, 0.017), following Storesletten et al. (2004). House price process parameters (ρ_p, σ_p^2) are set at (0.97, 0.302), following Hatchondo et al. (2015). Using Tauchen (1986), I construct five grid points for the income process and three for the house price process.

I model that the periodic rent $z(p)$ is proportional to the current house price (κp). I set the parameter κ as 0.045, which reflects the ratio of annual rents to prices in the early 2000s (Davis et al. (2008)). Homeowners can choose their home sizes. I normalize the size of a small house as one.

The parameter for the mortgage amortization scheme δ can be interpreted as the mortgage contract length.[18] According to my tabulations using the 2001 SCF data, the 30-year mortgage is the most prevalent type.[19] Hence, I set the parameter δ to reflect the 30-year contract. Mortgage lenders incur management and origination costs which are given by θ_m. I normalize this cost as zero.

When the household takes out the HELOC, it can freely roll over loans while in the draw period. The parameter ϕ captures the duration of the draw period. Following the HELOC guideline of major commercial banks in the US, I model that the draw period lasts for 10

[18] Note that $1/(1-\delta)$ is the expected mortgage contract length.

[19] The median (average) mortgage contract length is 30 (24.5) years.

years ($\phi = 0.9$).[20] After the end of the draw period, the repayment period starts. In the model, the parameter η represents the repayment period. I set its value as 0.95 to reflect the 20-year of the repayment period.[21]

When the household takes out the mortgage loan, it incurs an origination cost proportional to the loan balance. Following Gorea & Midrigan (2018), I set the parameter ξ_2 as 0.01. The household that refinances loans also faces the cost ξ_3. In my benchmark steady state, I set this parameter as zero. When I analyze the pre- and post-crisis economy over the transition, the refinance cost ξ_3 will be adjusted to match the actual refinance rate.

Once the household defaults, its credit record becomes tarnished and it cannot access the loan market for several periods as the default penalty. However, the household's credit record recovers with the probability of γ. Following Chatterjee & Eyigungor (2015), the defaulting household cannot access the mortgage market for an average of four years.[22]

When the household sells or buys a house, transaction costs are incurred. Following Gruber & Martin (2003), the transaction cost is 2.5% of the house value for buying and is 7% for selling. Once the household defaults, financial intermediaries face the foreclosure cost χ_D. I set this cost as 22% of the house value (Pennington-Cross (2006)).

Then, there are five remaining free parameters: the discount factor β, the large house

[20] According to big commercial banks in the US, such as Citi and BOA, the draw period is usually 10 years. https://www.bankofamerica.com/mortgage/learn/what-is-a-home-equity-line-of-credit https://online.citi.com/US/JRS/portal/template.do?ID=mortgage_home_equity_line Though Agarwal et al. (2006) report that the typical draw period is five years, I follow the banks and choose 10 years.

[21] The HELOC balance decreases with the rate η. One can interpret the geometric decrease in the balance as follows. The contract terminate in one year with the probability $1-\eta$, in two years with the probability $\eta(1-\eta)$, in three years with the probability $\eta^2(1-\eta)$, and so on. Then, the expected repayment period is $1/(1-\eta)(=\sum_{t=1}^{\infty} t\eta^{t-1}(1-\eta))$.

[22] According to Fannie Mae (2018), borrowers after the derogatory credit event – deed-in-lieu of foreclosure, preforeclosure sale, or charge-off of mortgage account – must wait four years to be eligible to take out new

Table 1: Calibration

Parameter	Description	Value	Target / Source
Non-target parameters			
r_f	Annual risk-free rate	0.02	1-year Treasury rate
$\bar{e}$	Median income	1	Normalized to one
ρ_e	Persistence in income process	0.99	Storesletten et al. (2004)
σ_e^2	Variance of income process	0.017	Storesletten et al. (2004)
ρ_p	Persistence in house price process	0.97	Hatchondo et al. (2015)
σ_p^2	Variance of house price process	0.302	Hatchondo et al. (2015)
κ	Rent-to-price ratio	0.045	Davis et al. (2008)
h_S	Small house size	1	Normalized to one
δ	Mortgage amortization	0.967	30-year contract
θ_m	Mortgage cost	0	Normalized to zero
ϕ	HELOC draw period	0.9	10 years
η	HELOC repayment	0.95	20-year repayment periods
ξ_2	Loan origination (variable) costs	0.01	Gorea & Midrigan (2018)
ξ_3	Refinance cost	0	Normalized to zero
γ	Default penalty	0.25	Chatterjee & Eyigungor (2015)
χ_B	Transaction cost - Buying	0.025	Gruber & Martin (2003)
χ_S	Transaction cost - Selling	0.07	Gruber & Martin (2003)
χ_D	Foreclosure cost	0.22	Pennington-Cross (2006)
Target parameters			
β	Discount factor	0.890	Mortgage foreclosure rate
h_L	Large house size	1.300	Homeownership rate
$\bar{p}$	Median house price	3.247	House-value-to-annual-income ratio
θ_b	HELOC cost	0.075	% of HHs having positive HELOC
ξ_1	Loan origination (fixed) cost	0.118	Refinance rate

size h_L, the median house price $\bar{p}$, HELOC cost θ_b, and the loan origination cost ξ_1. I jointly match the annual foreclosure rate of 0.55% (Jeske et al. (2013)), the homeownership rate of 66% (the average homeownership rate in 1995-2000), the house-value-to-annual-income ratio of 2.73 (2001 SCF), the fraction of households with positive HELOC balances of 4.8% (2001 SCF), and the fraction of homeowners who refinance loans of 8% (Chen et al. (2013)).[23] Table 1 summarizes the model parameters.

loans. After the foreclosure, they have to wait seven years. In this paper, I follow the former default penalty, which is also consistent with Chatterjee & Eyigungor (2015).

[23]The foreclosure rate in the model is measured by the ratio of the number of defaulted households to the number of mortgage debt holders.

6 Analysis of the steady-state economy

In this section, I analyze the benchmark steady-state economy and the model's underlying mechanism. Table 2 presents household finance moments generated by the benchmark economy and the data. Through the calibration, I matched five moments.

Though I did not directly target them, the model can successfully reflect several moments. The mortgage-payment-to-annual-income ratio is 11.8% in the data and 9.6% in the model.[24] The proportion of households with both the mortgage and the HELOC is 3.5% in data and 4.5% in the model. Conditional on having a positive HELOC balance, the HELOC-balance-to-annual-income ratio is 0.24 in data and 0.16 in the model. In the benchmark model, most households refinance loans for the purpose of taking out larger loans (cash out refinance). According to Chen et al. (2013), the ratio of the cash out refinance to the refinanced loan is 0.12. My model generates 0.13.[25]

Data shows that households with either the mortgage or the HELOC have higher income than the average population, which is consistent with the moments generated by the model. Though low-income households would like to take out (larger) loans, their credit application is rationed by financial intermediaries' endogenous credit limits. As reported later, low-income households face high loan interest rates (or low bond prices), which reflects their high default risk premium. This makes it difficult for them to borrow loans. The homeownership

[24] In data, the mortgage payment is measured by the annual payment for the first mortgage secured by the primary residence. Correspondingly, the mortgage payment in the model is measured by m, not including the HELOC. When I include all mortgage payments secured by the primary residence and exclude the payment for the HELOC, the payment-to-income ratio in the data is 12.4%. The source of the data in Table 2 is the 2001 SCF unless otherwise noted.

[25] In the model, the cash out refinance is measured by $q_m m' + q_b b' - A(m) - b$, conditional on $q_m m' + q_b b' - A(m) - b > 0$. The denominator of the ratio is the refinanced loan: $(q_m m' + q_b b')$.

rate for high-income households is higher than that for low-income households, both in the data and the model. By owning a house, households can better share idiosyncratic income risk through the HELOC or refinancing loans and have the option to stay in a large-sized house, which motivates high-income households to own their houses.

Table 2: Steady state

	Data	Benchmark
Targeted statistics		
Homeownership rate	66.0%	66.1%
Annual foreclosure rate	0.55%	0.56%
Refinance rate	8.0%	8.0%
House-value-to-annual-income ratio	2.73	2.73
% of households having positive balance of the HELOC	4.8%	4.6%
Non-targeted statistics		
Annual-mortgage-payment-to-annual-income ratio	11.8%	9.6%
% of households having both mortgage and HELOC	3.5%	4.5%
Avg(HELOC balance)/Avg(Income) for hhs with HELOC>0	0.24	0.16
Avg(Cash out)/Avg(Refinanced loan)	0.12	0.13
Avg(Income for hhs with HELOC>0)/Avg(Population income)	1.62	1.24
Avg(Income for hhs with mortgage>0)/Avg(Population income)	1.38	1.08
Homeownership rate for hhs with income≤50%	52.3%	61.0%
Homeownership rate for hhs with income>50%	84.1%	74.4%
Avg(Income for homeowners)/Avg(Income for renters)	2.67	1.30

To better understand how the model works, I present financial intermediaries' bond price schedules. Financial intermediaries observe households' optimal decisions – repayment, refinance, selling, or default – and offer loan prices that satisfy the zero-profit condition (see Appendix A for more details about households' discrete decisions). If financial intermediaries expect that they will likely incur losses by contracting with a certain type of household, they charge low loan prices (or high interest rates), reflecting the high default risk premium.

Figure 3 presents mortgage price (q_m) schedules. As the household holds more financial assets, the mortgage price increases, reflecting a decrease in the default probability.[26] Since

[26] Note that the mortgage bond price and the interest rate are negatively correlated. Following Hatchondo et al. (2014), the mortgage interest rate can be derived from the mortgage price as follows: $q_m =$

Figure 3: Mortgage price schedules

(a) Mortgage price schedules by financial assets, house sizes, and income

(b) Mortgage price schedules by mortgage payments, house prices, and HELOC balances

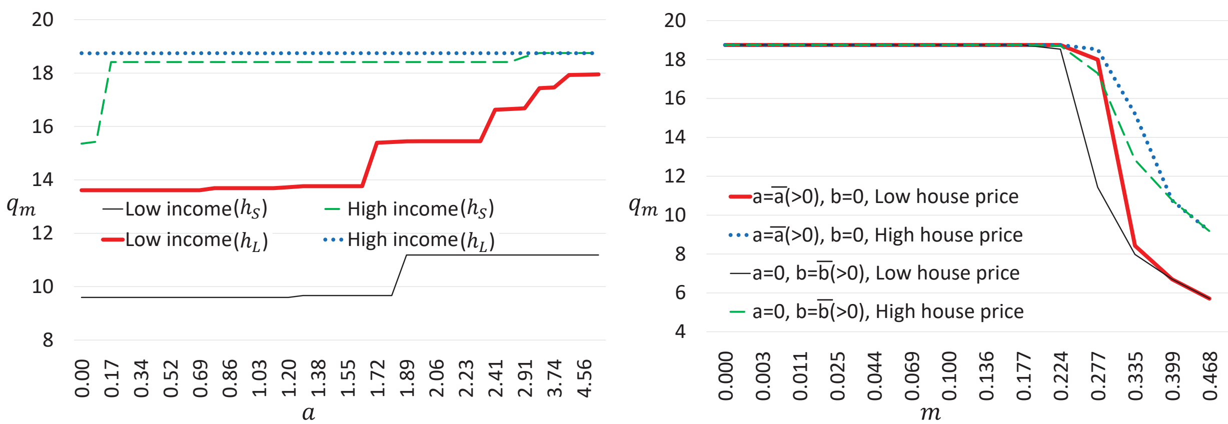
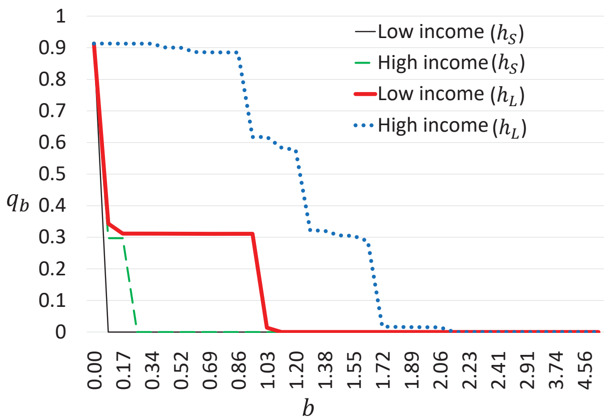


Figure 3a: The house price is used as the median value $\bar{p}$ and the mortgage payment m is used as the average value under the steady state. Low (high) income is the lowest (highest) income among the five income grid points. Figure 3b: Income is used as the median value $\bar{e}$ and the house size is h_L. The average value of the HELOC under the steady state is $\bar{b}$. The low (high) house price is the lowest (highest) house price among the three grid points.

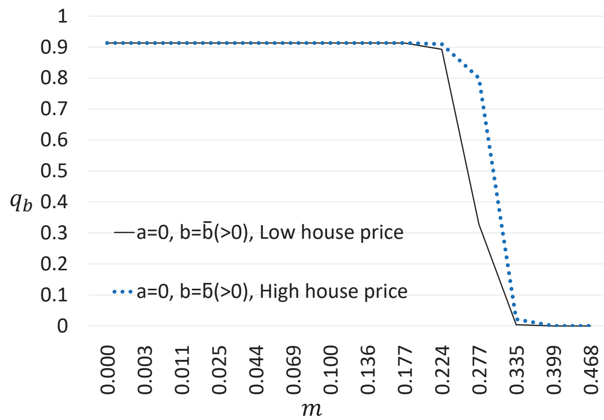
income and house prices are highly persistent, households facing high income and high house prices are less likely to default on their loans, leading to an increase in the mortgage bond price. Households staying in a big-sized home are less likely to default on their loans. By staying in a big house, households can better share income risks through the HELOC and enjoy higher utility. On the contrary, when households live in a small-sized home, they are highly likely to either refinance loans and switch the size of their home or to default. In turn, almost every homeowner stays in a big-sized home in the benchmark steady state. If households take out a large amount of the mortgage m or the HELOC b, the mortgage bond price decreases, reflecting the high default probability.

Figure 4 presents HELOC price schedules. When the household holds financial assets,

Figure 4: HELOC price schedules



(a) HELOC price schedules by HELOC balances, house sizes, and income



(b) HELOC price schedules by mortgage payments and house prices

See the note in Figure 3

it cannot hold the HELOC simultaneously. Hence, the HELOC price cannot be defined for households with positive financial assets. Similar to mortgage price schedules, the HELOC price decreases as households hold higher HELOC or mortgage balances, have lower income or house prices, and stay in small-sized houses.

7 Short-run macroeconomic effects of the refinance and the HELOC

In this section, I analyze macroeconomic impacts of the refinance and the HELOC before and after the financial crisis. First, I consider how household-finance variables respond to exogenous changes in home and rent prices. To implement this, I generate the benchmark

$\sum_{t=1}^{\infty} \delta^{t-1}/(1+r_m)^t$, where r_m is the mortgage interest rate. That is, $r_m = 1/q_m - 1 + \delta$.

transition where the median house price $\bar{p}$ and the rent-to-house-price ratio κ exogenously change, mirroring the pre- and post-crisis periods in the US data. I also model that the refinance cost ξ_3 is adjusted to match the actual refinance rate over the transition. Second, I adjust costs to refinance and access the HELOC and examine how these mortgage finance tools impact household debt and default patterns. Third, I analyze the effective policy direction for reducing the post-crisis foreclosure rate by either relaxing or tightening access to refinancing or the HELOC.

7.1 Benchmark transition

In this subsection, I examine the performance of the benchmark transition. I consider a transition where households expect the increase in the median house price $\bar{p}$ for several years, followed by a sudden decrease. The timing of the benchmark transition is as follows. The steady-state economy presented in Table 2 represents the US economy in 2001. At the end of 2001, every market participant suddenly becomes optimistic about the future housing market, as in Foote et al. (2012) and Burnside et al. (2016). They realize that the average house price will increase by 5.1% per year until 2007 and then remain constant.[27] Starting from 2002, the actual average house price increases, consistent with households' initial expectation. At the start of 2007, unlike their initial expectation, the average house price unexpectedly decreases by 3.0%, following the US house price index.[28] Market participants

[27] According to the US house price index, the average nominal house price increased by 7.7% per year from 2000 to 2006. At the same time, the annual consumer price index increased by 2.6%. Hence, the average annual real house price increased by 5.1%. I use the house price index from the "All-Transactions House Price Index for the United States" and the CPI from the "CPI-All Urban Consumers" from the FRED.

[28] At the start of 2007, households originally expected the average house price to increase by 5.1% during 2007 and then remain constant. It is also possible to model that households at the end of 2001 expected

expect that this is a one-time permanent decrease. At the start of 2008, 2009, and 2010, the average house price unexpectedly and permanently decreases by 5.2%, 8.2%, and 5.6%, respectively, consistent with data.[29] Figure C3 in the appendix graphically presents the expectation and the realization of the median house value over the transition.

Along with changes in house prices, I also model that the rent-to-price ratio κ changes, following the actual data. Davis et al. (2008) report that the rent-to-price ratio decreases from 4.5% in 2001 to 3.5% in 2006. I model that the value of κ equally decreases by 0.2%p from 2001 to 2006. At the end of 2001, every market participant rationally expects such changes in the ratio.[30] Their expectation and the realization of the ratio are consistent until the end of 2006. When the house price unexpectedly decreases starting in 2007, the rent-to-price ratio also unexpectedly increases. That is, the ratio increases to 3.83% in 2007, 4.17% in 2008, and 4.5% in 2009 and 2010, which is consistent with data.[31] Figure C4 in the appendix presents the expectation and the realization of the rent-to-price ratio for each year.

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the average house price to increase until 2006 and then remain constant. That is, the discrepancy between households' expectations and the realization of house prices is narrowed compared to the benchmark transition. Then, I cannot successfully match some data moments. For example, since households in 2006 expected that the average house price would not increase any more, many of them sell houses in advance to realize the capital gain.

[29] According to the speech by Duke (2013), homeowners did not expect the sudden and severe decrease in house prices after the crisis. Based on Thomson Reuters/University of Michigan Surveys of Consumers, households in 2007 expected that their home values would slightly increase during the next 12 months. Even in 2008-2010, they did not expect the severe drop. Hence, the assumption of an unexpected drop in house prices is not unrealistic.

[30] When I compute the model, market participants at the end of 2001 expect that the rent-to-price ratio will decrease until 2007, consistent with the decrease in house prices. That is, the rent-to-price ratio is expected to be 3.3% in 2007.

[31] When I calculate the rent-to-price ratio after the crisis, I use both the house price index and the rent price index. Given the 2006 rent-to-price ratio of 3.5%, I consider changes in those two indices and extrapolate the ratio. I use the rent price index from the "Consumer Price Index for All Urban Consumers: Rent of primary residence" from the FRED.

Given exogenous changes in the house price and the rent-to-price index, I also adjust the refinance cost ξ_3 to match the actual refinance rate over the transition.[32] The refinance rate before and after the financial crisis is calculated based on the 2004, 2007, and 2010 SCF. Since the SCF is released once per three years, it is difficult to calculate the refinance rate on an annual basis. I instead calculate the refinance rate in 2004, 2007, and 2010 and linearly interpolate the ratio for non-surveyed years.

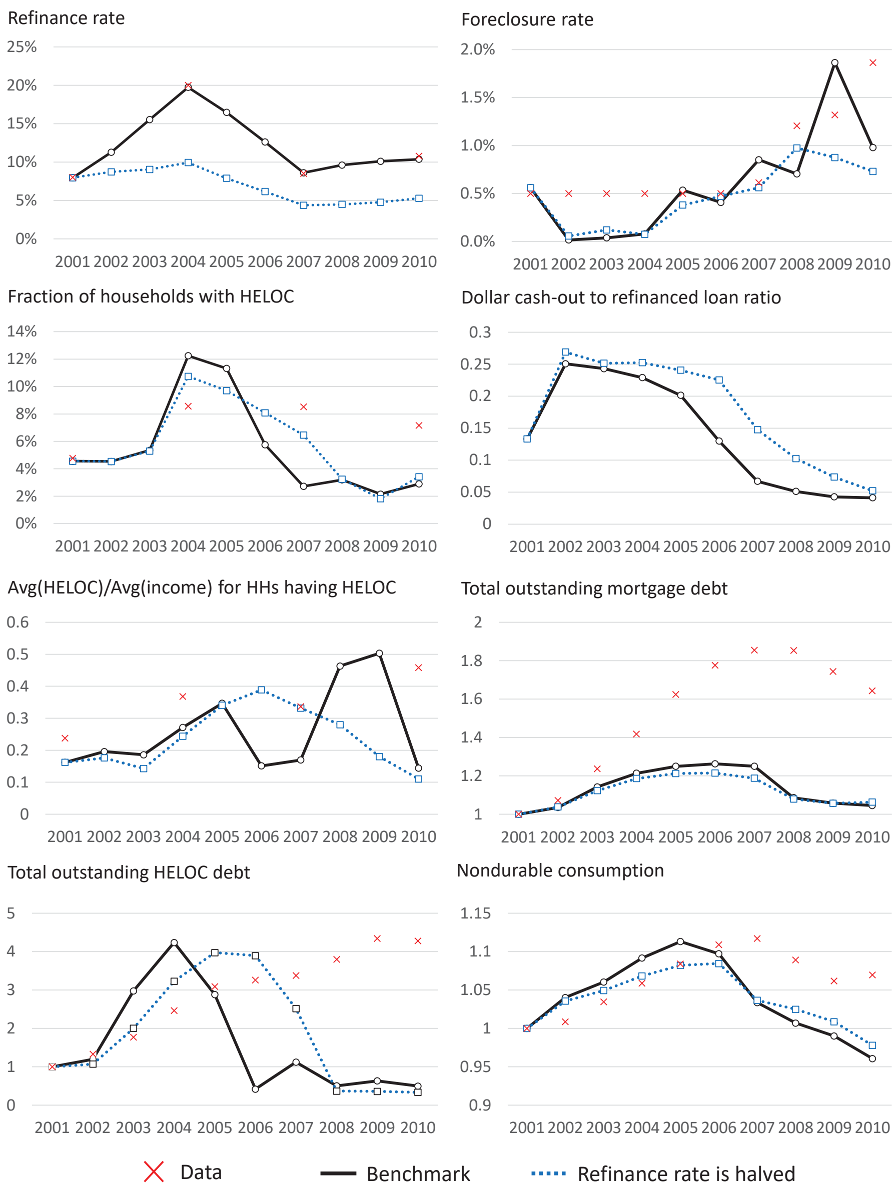
The black solid line in Figure 5 presents the model-generated benchmark transition from 2001 to 2010. The red x-dot is data. As a result of calibration, the refinance rate in the model exactly matches the actual moment. The model-generated foreclosure rate decreases during the housing boom and increases up to 1.9% in 2009.[33] Before the financial crisis, households expect that the average house price will increase, which prevents them from defaulting on their loans. However, as the house price permanently decreases from 2007, financially troubled households start giving up on repaying their debt, leading to an increase in the foreclosure rate.

During the housing boom, households increase their HELOC usage in both the data and the model. As the house price increases, there is more room to take out the HELOC. Given the increase in the credit limit for the HELOC, financially troubled households can better share income risks and smooth consumption by extracting their home equity. Since households during the housing boom expect that the average house price will increase until

[32]Households rationally expect the changes in the refinance cost before the crisis. After the crisis, the cost unexpectedly and consecutively changes to match the data.

[33]The post-crisis foreclosure rate is from the OCC Mortgage Metrics Report. The mortgage foreclosure rate is defined by the ratio of the number of completed foreclosures to the number of outstanding loans. Since the OCC Mortgage Metrics Report reports the number foreclosures only after the financial crisis, I simply set the pre-crisis (data) foreclosure rate as constant (or 0.55%).

Figure 5: Transition analysis: Impacts of the refinance



2007 and then remain constant after, they voluntarily de-leverage the balance of the HELOC in 2006. The relaxed borrowing constraints combined with an increase in household

[34] I set non-durable consumption in the data as the "Real personal consumption expenditures per capita:

wealth leads to an increase in nondurable consumption, consistent with Mian & Sufi (2014).[34] Specifically, homeowners, rather than renters, can cash out funds either by refinancing or through the HELOC and thus increase their consumption during the housing boom.[35]

After the start of the financial crisis, households' wealth and their borrowing limits decrease as the average house value decreases. In turn, households in the model tend to reduce their usage of the HELOC and decrease their consumption.[36] However, the data shows that many households still access the HELOC, which leads to an increase in the HELOC balance. In addition, the nondurable consumption in the data decreases less than in the model-generated moment. Unlike the model structure where the market interest rate (r_f) does not change, even after the crisis, the interest rate in the data decreased significantly as the US adopted the expansionary monetary policy. This might explain the difference in the HELOC balances in the model and the data. This can also prevent the sudden decrease in consumption after the financial crisis, as in Di Maggio et al. (2017) and Agarwal et al. (2017).

Households refinance more to cash out funds during the housing boom and reduce the borrowing during the bust period. In turn, my model generates the increase in total mortgage debt by 26% during the housing boom and the decrease since the financial crisis. Unlike the model, total mortgage debt in the data increased by 85% during the boom and then gradually decreased after. Since I do not explicitly model all of the important contributors

Nondurable goods" from the FRED.

[35] See Figure C5 in the appendix.

[36] As presented in Figure C5, homeowners reduce their consumption significantly after the crisis starts. However, renters' consumption increases, especially in 2008. In my model, the proportion of home sellers with positive home equity increases after facing a consecutive decrease in home values in 2008. After selling the house and becoming renters, they temporarily increase consumption by decumulating their capital gain.

of the increase in household debt before the financial crisis, such as subprime or unconventional mortgages, securitization, poor underwriting, and relaxed credit constraints, it is not unnatural that the model underestimates the increase in household debt (Demyanyk & Van Hemert (2009), Mian & Sufi (2009), Purnanandam (2010), Landvoigt (2017), Kaplan et al. (forthcoming), and more). That is, the difference in mortgage debt between the model and the data can be explained by such unmodeled components.[37]

7.2 Analysis of the refinance

In this subsection, I examine the impacts of refinancing access on the accumulation of pre-crisis household debt and the increase in the post-crisis mortgage default rate. When households can easily refinance loans, they can cash out funds elastically as the house price changes. In turn, this can contribute to an increase in household debt, which leads them more financially vulnerable to an unexpected drop in house prices. Here, I consider a counterfactual transition where the refinance rate is halved relative to the benchmark over the transition. Specifically, I increase the refinance cost ξ_3 to match the experiment rate.

The blue dotted line in Figure 5 presents the experiment transition. When I restrict refinance accessibility, households are more likely to be financially troubled from adverse income shocks, which leads to an increase in the foreclosure rate. Since financial intermediaries understand the increase in households' default probability, they reduce the bond prices

[37] If I model that the house price is endogenously determined, the mortgage debt might respond more elastically to the change in the house price. With an optimistic belief in the house value, households can increase the leverage and buy more houses. This in turn increases the house value and the debt, as in Kiyotaki & Moore (1997) and Bernanke et al. (1999). If the model includes such an amplification channel, I expect that it can match data moments more closely.

(or increase the interest rate). As the borrowing cost increases, households tend to reduce the balance of mortgages and the HELOC. Though a decrease in household debt reduces the default probability, a deterioration in risk sharing via limited access to the refinance can increase mortgage defaults. During the pre-crisis period, these two effects almost cancel out, which leads to a negligible difference in the foreclosure rate between the benchmark and the experiment economy. When the refinance cost increases, only households that are severely credit-constrained replace their old loan contracts into new ones to avoid the default. Since the frequent refinancing is costly, households that refinance loans tend to cash out a large amount of funds compared to the benchmark.

When refinancing becomes costly, households tend to accumulate more financial assets to share income risk. In addition, households have more difficulty cashing out funds from their home equity. In turn, consumption during the housing boom decreases compared to the benchmark.

Once the average house price unexpectedly decreases, the mortgage foreclosure rate suddenly increases. However, the increase in the foreclosure rate is lower than the benchmark's. The cumulative foreclosure rate under the experiment economy between 2007 and 2010 is 1.3%p lower (4.4% in the benchmark and 3.1% in the experiment). Households under the counter-factual economy have accumulated less household debt during the housing boom. In addition, when the refinance cost increases, households tend to save more financial assets to avoid mortgage defaults. These in turn make them less vulnerable to unexpected house

[38] Consistent with results in Khandani et al. (2013), my model can also generate that the refinance contributes to an increase in pre-crisis household debt and post-crisis mortgage defaults, though analysis methodologies are different.

price shocks.[38] Since households can decumulate their financial assets, households under the experiment economy reduce their consumption less than the benchmark.

7.3 Analysis of the HELOC

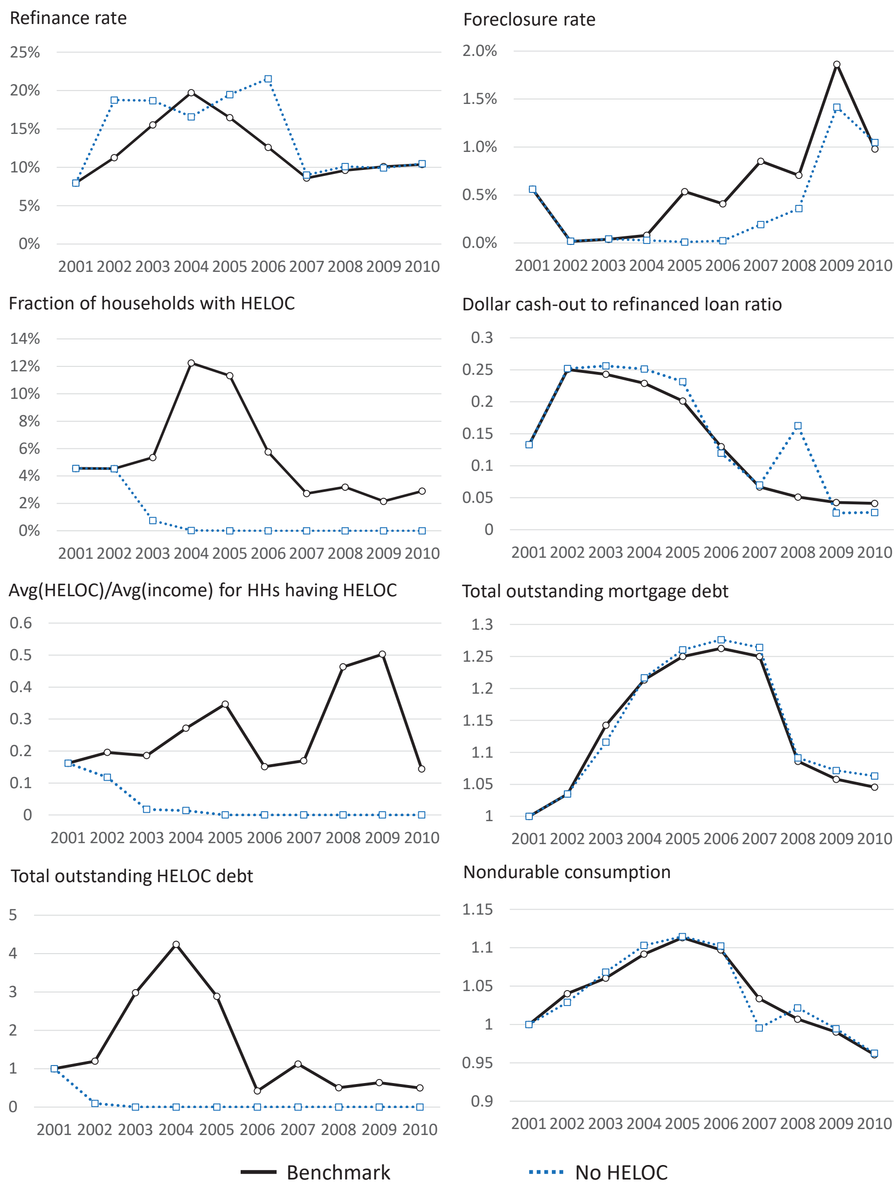
Next, I analyze how access to the HELOC impacts the run up in the pre-crisis household debt and the post-crisis foreclosure rate. To analyze this, I consider a counterfactual economy where households cannot access the HELOC ($\theta_b = \infty$) after 2002. The timing and model parameters are the same as in the benchmark, except for the HELOC cost.

The blue dotted line in Figure 6 presents the experiment transition. As households cannot access the HELOC, the fraction of households that have the HELOC and the total HELOC balance gradually decreases to zero. Since some households that are in the repayment period keep repaying their debt as contracted, the HELOC balance does not decrease to zero immediately after the increase in the cost.

Since the HELOC is not available in this economy, financially troubled households instead refinance loans to relax budget tightness. Hence, the amount of cash-out through refinancing is higher than the benchmark. In turn, total mortgage debts under both economies are almost the same. Since households cannot freely cash out funds through the HELOC, they save more financial assets as a precautionary motive, leading to a decrease in the pre-crisis foreclosure rate.

Given the accumulated financial assets and the long-term payment burden, the post-crisis foreclosure rate responds mildly compared to the benchmark. My quantitative exercise

Figure 6: Transition analysis: Impacts of the HELOC



shows that the cumulative foreclosure rate under the experiment economy between 2007 and 2010 is 1.4%p lower than the benchmark. Without the HELOC, households that can only refinance might be more vulnerable to adverse income or house price shocks. However, given a consecutive decrease in the average house price, households do not have room to take out the HELOC, even if they are allowed to access it. In addition, they have accumulated more financial assets, which prevents a sudden increase in the foreclosure rate.

7.4 Effective policies for reducing the post-crisis foreclosure rate

After the financial crisis, the US government initiated several foreclosure prevention programs, such as the Home Affordable Refinance Program (HARP) and the Home Affordable Modification Programs (HAMP).[39] In this subsection, I consider how improved access to refinancing or the HELOC market can reduce post-crisis mortgage defaults. As households can access these mortgage finance markets more easily, they can cash out more funds with low costs secured by home equity. To analyze this, I consider counterfactual transitions where the refinance or the HELOC costs decrease after the start of the financial crisis. Similarly, I also consider experiment economies where access to the refinance or the HELOC deteriorates and examine their impacts on the post-crisis foreclosure rate.

The timing of the transition is as follows. The counterfactual transition path is the same as the benchmark until 2006. After starting the financial crisis in 2007, I reduce (increase) the refinance cost ξ_3 to increase (reduce) the refinance rate by 1%p compared to the benchmark. To analyze the impacts of the HELOC, the HELOC cost θ_b either increases or decreases by 50% after 2007. By comparing the benchmark with these experiment transitions, I can analyze the effective policy direction for reducing the post-crisis foreclosure rate.

[39] See Robinson (2009) and Gerardi & Li (2010) for more details about foreclosure prevention programs.

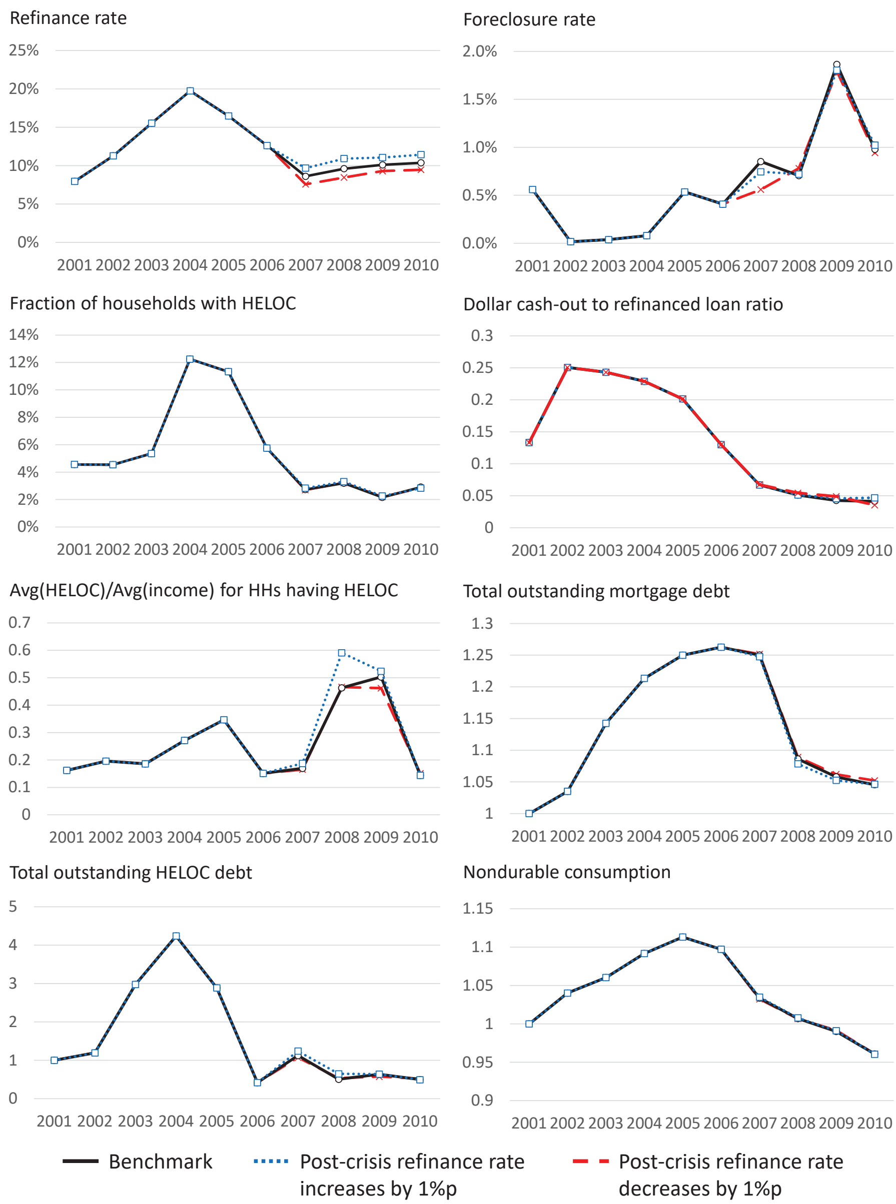
The blue dotted (red dashed) line in Figure 7 presents the experiment economy where the cost of refinancing decreases (increases) after 2007. Improved or deteriorated access to the refinance cannot significantly reduce the mortgage foreclosure rate. As households can easily refinance loans, they can avoid defaults by cashing out their home equity. However, as the crisis deepens, households that refinance significant amounts of debt cannot roll over their loans and choose defaults. These opposite forces simultaneously influence mortgage defaults when the refinance cost decreases, leading to negligible impacts on post-crisis mortgage defaults.[40]

When the accessibility of refinancing improves, along with the sudden decrease in house prices, financially troubled households refinance and increase the balance of the HELOC while reducing the long-term mortgage. Since the balance of the HELOC can be flexibly adjusted only if it is under the draw period, they prefer not to take the long-term burden by increasing their mortgages. Hence, the total mortgage debt under the experiment economy is almost the same as in the benchmark.

In Figure 8, I consider counterfactual economies where the HELOC cost θ_b either increases or decreases by 50% and increases to infinite after the start of the financial crisis. My quantitative exercise shows that improving access to the HELOC cannot mitigate mortgage defaults. When the HELOC cost decreases, financially troubled households replace their mortgage into the HELOC with refinancing, which in turn leads to a decrease in the aggregate mortgage debt. However, as the average house price sequentially and unexpectedly decreases, indebted households that cannot roll over their HELOC decide to give up repaying their

[40]When the refinance cost increases, the direction for these forces is reversed. In turn, the foreclosure rate

Figure 7: Transition analysis: Changes in post-crisis refinance costs

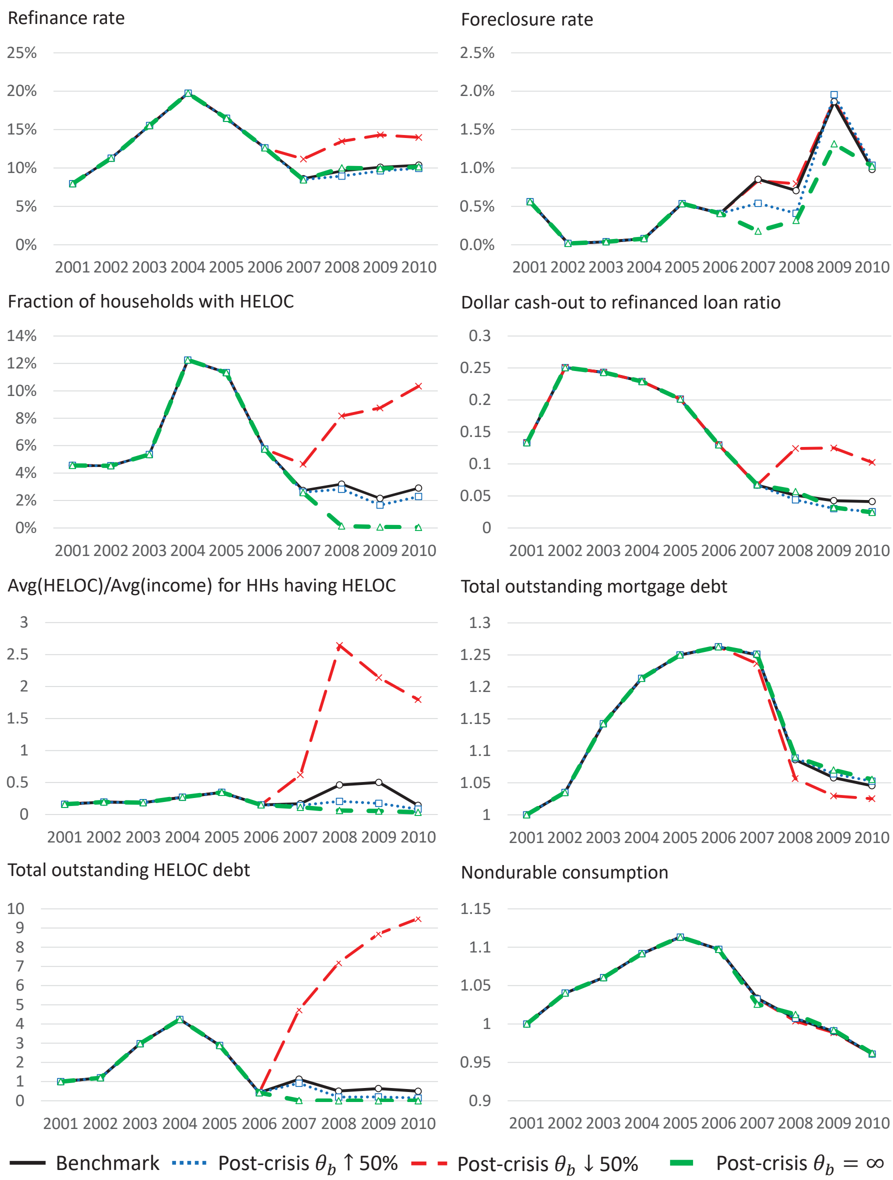


debts.

When the HELOC cost increases, it is difficult for households to access the HELOC.

negligibly changes.

Figure 8: Transition analysis: Changes in post-crisis HELOC costs



Financially constrained households refinance the mortgage for relatively cheap. Since the mortgage is a long-term contract, the households' payment burden can be spread out. This in turn prevents a sudden increase in defaults, even after facing consecutive decreases in house prices. Therefore, restricting access to the HELOC market after the start of the crisis could have been an effective policy direction for mitigating the mortgage defaults.

8 Conclusion

In this paper, I introduce a quantitative model where households can access both the conventional mortgage and the HELOC and are allowed to refinance both. The HELOC is the second mortgage where the lender can (partly) recover losses only when the first lender has been fully paid off. Because of the difference in loan seniority and origination costs, borrowing costs for the HELOC are usually higher than the mortgage. Financially troubled households can also refinance loans and cash out additional funds. Each mortgage finance has pros and cons. Though the interest rate is high, households can freely take out the HELOC and relax their tightened budget if their home equity is positive and the contract is under the draw period. Households that refinance loans can replace the old loan contract with the new one, though this is accompanied by significant one-time fixed and variable costs. Households take these costs and benefits into account for each mortgage finance tool and make their decisions optimally.

I then analyze how refinancing and the HELOC contribute to an increase in the pre-crisis household debt and the post-crisis mortgage foreclosure rate. My quantitative analysis shows that a reduction in the refinance rate in 2000s could have been effective in mitigating mortgage defaults after the financial crisis. Numerically, decreasing the refinance rate by half could have reduced the cumulative household debt by 6.2%p during the housing boom and the foreclosure rate by 1.3%p between 2007 and 2010. Though the HELOC negligibly contributes to the increase in pre-crisis household debt, elimination of the HELOC can be effective in mitigating the foreclosure rate.

Lastly, I consider effective policy measures for reducing mortgage defaults after the financial crisis. I consider scenarios where the costs of refinancing and the HELOC either increase or decrease after the start of the financial crisis. My numerical exercises show that limited access to the HELOC after the financial crisis could have been effective in reducing the severity of mortgage defaults.

References

Agarwal, S., Ambrose, B. W., Chomsisengphet, S., & Liu, C. (2006). An empirical analysis of home equity loan and line performance. *Journal of Financial Intermediation*, 15(4), 444 – 469.

Agarwal, S., Amromin, G., Chomsisengphet, S., Landvoigt, T., Piskorski, T., Seru, A., & Yao, V. (2017). Mortgage Refinancing, Consumer Spending, and Competition: Evidence from the Home Affordable Refinancing Program. *NBER Working Paper*, 21512.

Arslan, Y., Taskin, T., & Guler, B. (2015). Joint dynamics of house prices and foreclosures. *Journal of Money, Credit and Banking*, 47, 133–169.

Bernanke, B. S., Gertler, M., & Gilchrist, S. (1999). The financial accelerator in a quantitative business cycle framework. In J. B. Taylor & M. Woodford (Eds.), *Handbook of Macroeconomics* (pp. 1341–1393). North Holland.

Burnside, C., Eichenbaum, M., & Rebelo, S. (2016). Understanding booms and busts in housing markets. *Journal of Political Economy*, 124(4), 1088–1147.

Chatterjee, S. & Eyigungor, B. (2015). A quantitative analysis of the US housing and mortgage markets and the foreclosure crisis. *Review of Economic Dynamics*, 18(2), 165–184.

Chen, H., Michaux, M., & Roussanov, N. L. (2013). Houses as ATMs? Mortgage refinancing and macroeconomic uncertainty. *NBER Working Paper*, 19421.

Corbae, D. & Quintin, E. (2015). Leverage and the foreclosure crisis. *The Jounal of Political Economy*, 123(1), 1–65.

Davis, A. M., Lehnert, A., & Martin, R. F. (2008). The rent-price ratio for the aggregate stock of owner-occupied housing. *Review of Income and Wealth*, 54(2), 279–284.

Demyanyk, Y. & Van Hemert, O. (2009). Understanding the Subprime Mortgage Crisis. *The Review of Financial Studies*, 24(6), 1848–1880.

Di Maggio, M., Kermani, A., Keys, B. J., Piskorski, T., Ramcharan, R., Seru, A., & Yao, V. (2017). Interest rate pass-through: Mortgage rates, household consumption, and voluntary deleveraging. *American Economic Review*, 107(11), 3550–88.

Duke, E. A. (2013). A view from the federal reserve board: The mortgage market and housing conditions. mimeo.

Fannie Mae (2018). *Selling Guide: Fannie Mae Single Family*. Fannie Mae.

Feldstein, M. (2008). How to help people whose home values are underwater. *The Wall Street Journal*.

Foote, C. L., Gerardi, K. S., & Willen, P. S. (2012). Why did so many people make so many ex post bad decisions? The causes of the foreclosure crisis. *NBER Working Paper*, 18082.

Gerardi, K. & Li, W. (2010). Mortgage foreclosure prevention efforts. *Federal Reserve Bank of Atlanta Economic Review*, 95(2), 1–13.

Gete, P. & Zecchetto, F. (2018). Mortgage Design and Slow Recoveries: The Role of Recourse and Default. *mimeo*.

Gorea, D. & Midrigan, V. (2018). Liquidity constraints in the U.S. housing market. *NBER Working Paper*, 23345.

Gruber, J. W. & Martin, R. F. (2003). Precautionary savings and the wealth distribution with illiquid durables. *International Finance Discussion Paper*, 773.

Guler, B. (2015). Innovations in information technology and the mortgage market. *Review of Economic Dynamics*, 18(3), 456–483.

Hatchondo, J. C., Martinez, L., & Padilla, C. S. (2014). Voluntary sovereign debt exchanges. *Journal of Monetary Economics*, 61, 32–50.

Hatchondo, J. C., Martinez, L., & Sánchez, J. M. (2015). Mortgage defaults. *Journal of Monetary Economics*, 76, 173–190.

Jeske, K., Krueger, D., & Mitman, K. (2013). Housing, mortgage bailout guarantees and the macro economy. *Journal of Monetary Economics*, 60(8), 917–935.

Kaplan, G., Mitman, K., & Violante, G. L. (forthcoming). The Housing Boom and Bust: Model Meets Evidence. *Journal of Political Economy*.

Kaplan, G. & Violante, G. L. (2014). A model of the consumption response to fiscal stimulus payments. *Econometrica*, 82(4), 1199–1239.

Khandani, A. E., Lo, A. W., & Merton, R. C. (2013). Systemic risk and the refinancing ratchet effect. *Journal of Financial Economics*, 108(1), 29 – 45.

Kim, J. (2015). Household's optimal mortgage and unsecured loan default decision. *Journal of Macroeconomics*, 45, 222–244.

Kim, J. (forthcoming). How Unsecured Credit Policies Influence Mortgage and Unsecured Loan Defaults. *Journal of Money, Credit and Banking.*

Kiyotaki, N. & Moore, J. (1997). Credit cycles. *Journal of Political Economy*, 105(2), 211–248.

Landvoigt, T. (2017). Housing Demand During the Boom: The Role of Expectations and Credit Constraints. *The Review of Financial Studies*, 30(6), 1865–1902.

Mian, A., Rao, K., & Sufi, A. (2013). Household balance sheets, consumption, and the economic slump. *Quarterly Journal of Economics*, 128(4), 1687–1726.

Mian, A. & Sufi, A. (2009). The Consequences of Mortgage Credit Expansion: Evidence from the U.S. Mortgage Default Crisis. *The Quarterly Journal of Economics*, 124(4), 1449–1496.

Mian, A. & Sufi, A. (2014). House price gains and U.S. household spending from 2002 to 2006. *NBER Working Paper*, 20152.

Mitman, K. (2016). Macroeconomic effects of bankruptcy and foreclosure policies. *American Economic Review*, 106(8), 2219–55.

Pennington-Cross, A. (2006). The value of foreclosed property. *Journal of Real Estate Research*, 28(2), 193–214.

Purnanandam, A. (2010). Originate-to-distribute Model and the Subprime Mortgage Crisis. *The Review of Financial Studies*, 24(6), 1881–1915.

Robinson, B. (2009). An overview of the home affordable modification program. *Consumer Compliance Outlook*, Third Quarter.

Storesletten, K., Telmer, C. I., & Yaron, A. (2004). Consumption and risk sharing over the life cycle. *Journal of Monetary Economics*, 51(3), 609–633.

Tauchen, G. (1986). Finite state Markov-chain approximations to univariate and vector autoregressions. *Economics letters*, 20(2), 177–181.

Wong, A. (2019). Refinancing and The Transmission of Monetary Policy to Consumption. *mimeo*.

Appendix

A Households' optimal discrete decisions

In this section, I present households' optimal discrete decisions – repayment, selling, refinancing, and default – depending on the realization of idiosyncratic shocks and the household's saving and borrowing policies. Figure A1 presents households' discrete choices as the financial asset a and the mortgage payment m changes for given income, house price, and house size h_L. Since the household with positive financial assets cannot hold the HELOC simultaneously, I do not consider the balance of the HELOC (or $b = 0$). Figure A2 presents similar discrete choices, as the household's HELOC balance b changes along with zero financial asset ($a = 0$). The first column shows the household's optimal choices when it is eligible to draw the HELOC, while the second column is under the repayment phase.[41]

When the small-asset household has low income and low house prices along with a large mortgage payment burden, it chooses to default on the mortgage to relieve their budget tightness. However, when they have relatively smaller mortgage payment burden, refinancing the loan is their optimal decision. Otherwise, they chooses to repay the mortgage. High-income households are less likely to default on their loans. Also, households with high house prices tend to default less. When households face favorable idiosyncratic shocks, they can avoid costly defaults by repaying or refinancing loans. Since high-income households can replace loans with low interest rates compared to low-income households, those with less

[41] In the first column, households face the following optimal problem: $max\{V_D^{HP}, V^{HS}, V^{HF}, V^D\}$. They solve following optimal decisions in the second column: $max\{V_R^{HP}, V^{HS}, V^{HF}, V^D\}$.

assets are more likely to refinance loans. Low-income households facing high house prices are more likely to sell the house to relieve their financial constraints.

When I compare the first and second columns, households in the repayment period are more likely to refinance if they have low financial assets and default if they have a high mortgage burden. Even though households in Figure A1 do not hold the HELOC, households that are allowed to access the HELOC (or the draw period) can better share income risks and relax budget tightness. In turn, low-asset households in the draw period are less likely to refinance loans that ensue significant costs. They instead draw the HELOC. In a similar vein, highly mortgage-indebted households in the draw period can more easily access liquidity, which makes them less likely to default.

In Figure A2, households have a positive HELOC balance and do not hold financial assets. Comparing Figure A1 with Figure A2, households are more likely to default on their loans, ceteris paribus, as their net financial assets ($=a-b$) decrease. Similar to Figure A1, households are more likely to default if they face lower income or lower house prices. The mortgage-indebted household sells the house, reaps the capital gain, and relieves the budget tightness if it faces the high house price shock. When households have positive HELOC balance, they are highly likely to be financially constrained, which incentivizes them to further refinance. Without financial assets, the region for the loan repayment is much smaller than that in Figure A1.

B Long-run analysis of the refinance and the HELOC

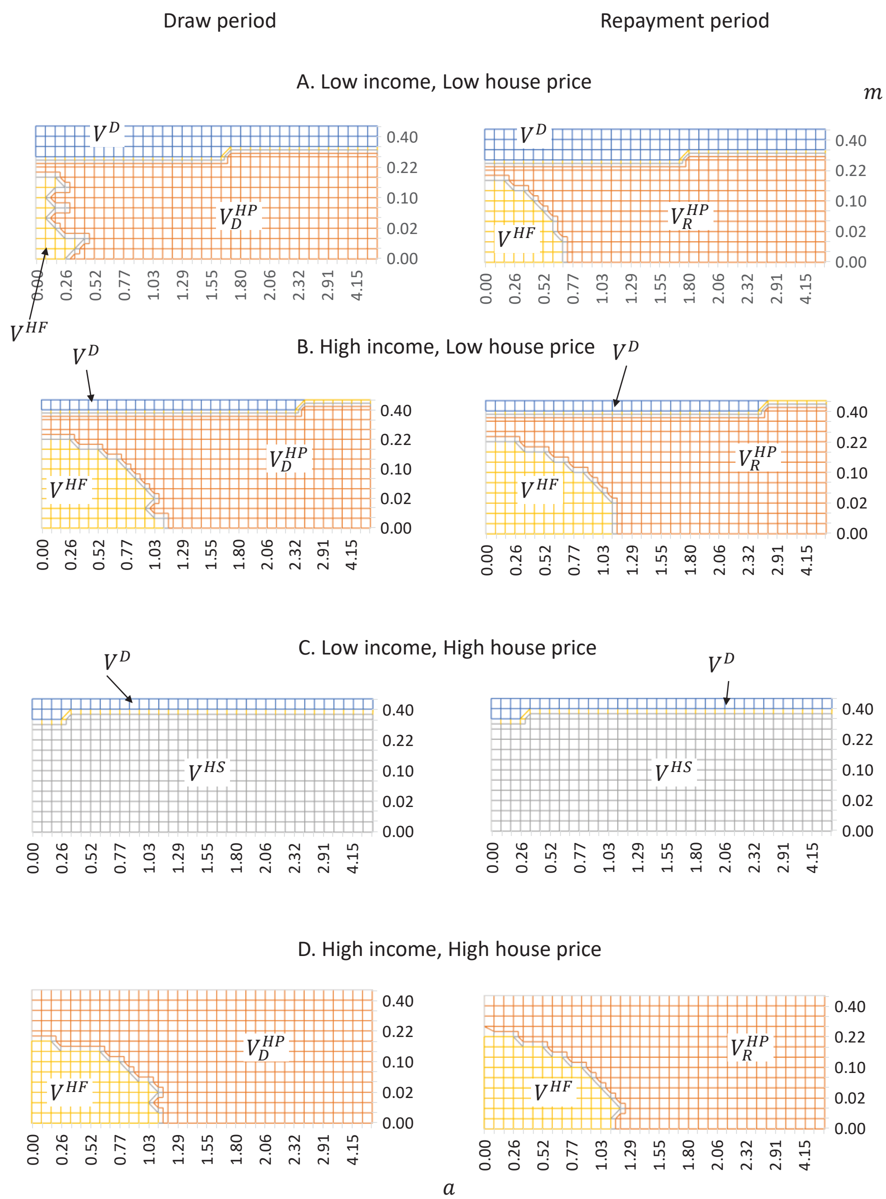
In this section, I consider the long-run impacts of refinancing and the HELOC. The second column in Table B1 presents the steady-state economy where the cost of refinance is prohibitively high ($\xi_3 = \infty$). When households cannot refinance loans, it is difficult for them to access liquidity secured by home equity and to share income and house price risks. This in turn leads to a decrease in the mortgage and HELOC bond prices (or an increase in borrowing interest rates). Given high borrowing costs, the homeownership rate decreases. When households buy homes, they tend to take out larger loans and spread out the payment burden, leading to an increase in the annual payment burden. Without the option to refinance, households tend to accumulate more financial assets and reduce HELOC usage, and are thus less likely to default on their loans. Though households' annual payment burden increases, a decrease in the number of indebted households (or a decrease in the homeownership rate) leads to a decrease in the total mortgage debt by 7% and the HELOC by 38%, compared to the benchmark. Given the low amount of debt under the restricted refinance, households' consumption increases by 3%. However, consumption volatility increases by 10%.

In the third column, I consider a counterfactual scenario where the HELOC is not available ($\theta_b = \infty$). Without the HELOC, financially troubled households have only one option – refinancing – to relax their budget tightness, which leads to an increase in the refinance rate. Since households cannot easily access liquidity through home equity, they tend to save more financial assets, especially for renters. This in turn makes renters more likely to buy their houses, leading to an increase in the homeownership rate. Since most households own their homes by taking out mortgages, the total outstanding mortgages is 4% higher than the benchmark. Though an increase in the mortgage borrowing makes households more likely to default on their loans, an increase in financial assets offsets the effect. Since the latter dominates the former, the mortgage foreclosure rate is lower than the benchmark. Though limited access to the HELOC can make households more vulnerable to adverse shocks and in turn lead to an increase in consumption volatility, an increase in financial assets offsets such effects. In turn, consumption volatility decreases by 5%.

When I eliminate households' options to use the HELOC and the refinance simultaneously, the foreclosure rate decreases by 0.48%p, compared to the benchmark. However, other moments are quite similar to those under the economy where the refinance is not allowed. Hence, the availability of the refinance strongly impacts household finance moments in the long run relative to that of the HELOC.

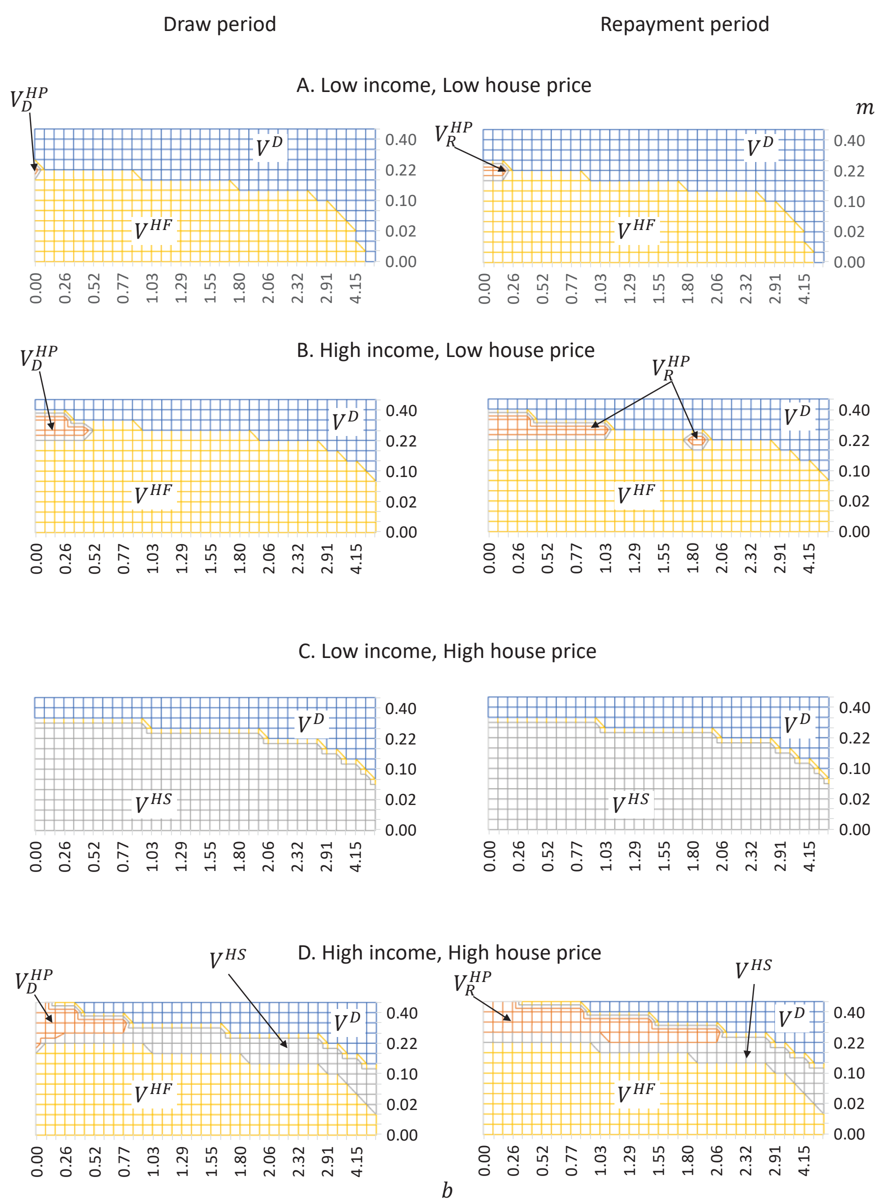
C Additional figures

Figure A1: Households' optimal discrete choices by financial assets



Under the draw (repayment) phase, households' available options are repayment (V_D^{HP} if in the draw period and V_R^{HP} if in the repayment period), selling (V^{HS}), refinancing (V^{HF}), and default (V^D). The figure presents the optimal discrete choices conditional on state variables. The x-axis is financial assets. The y-axis is the mortgage payment. Low (high) income is the lowest (highest) income among the five income grid points. Low (high) house price is the lowest (highest) house price among the three grid points. The house size is given by h_L.

Figure A2: Households' optimal discrete choices by the HELOC balance



The x-axis is the HELOC balance. The y-axis is the mortgage payment. Other conditions are the same as in the note presented in Figure A1.

Table B1: Long-run analysis of the refinance and the HELOC

	Benchmark	No refinance	No HELOC	No refinance & HELOC
Homeownership rate	66.1%	64.5%	68.5%	64.6%
Annual foreclosure rate	0.56%	0.10%	0.11%	0.08%
Refinance rate	8.0%	0.0%	9.3%	0.0%
House-value-to-annual-income ratio	2.73	2.75	2.75	2.75
% of households having positive balance of the HELOC	4.6%	8.0%	0.0%	0.0%
Annual-mortgage-payment-to-annual-income ratio	9.6%	15.1%	9.2%	15.1%
% of households having both mortgage and HELOC	4.5%	8.0%	0.0%	0.0%
Avg(HELOC balance)/Avg(Income) for hhs with HELOC>0	0.16	0.08	N/A	N/A
Avg(Cash out)/Avg(Refinanced loan)	0.13	N/A	0.15	N/A
Homeownership rate for hhs with income≤50%	61.0%	62.2%	62.6%	62.3%
Homeownership rate for hhs with income>50%	74.4%	68.1%	77.9%	68.2%
Avg(Income for hhs with HELOC>0)/Avg(Population income)	1.24	0.98	N/A	N/A
Avg(Income for hhs with mortgage>0)/Avg(Population income)	1.08	1.04	1.09	1.04
Avg(Income for homeowners)/Avg(Income for renters)	1.30	1.12	1.37	1.12
Total mortgage debt outstanding	1	0.93	1.04	0.93
Total HELOC debt outstanding	1	0.62	0.0	0.0
Nondurable consumption	1	1.03	1.00	1.03
Coefficient of variation for nondurable consumption	1	1.10	0.95	1.10

Figure C3: Belief and realization of the median house value

(a) Belief of the median house value over time **(b)** Realization of the median house value over time

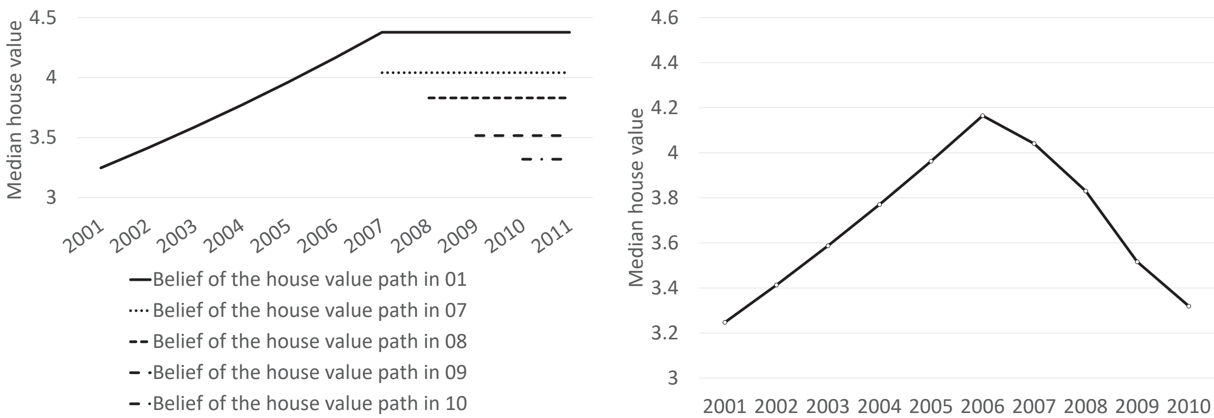


Figure C4: Belief and realization of the rent-to-price ratio

(a) Belief of the rent-to-price ratio over time **(b)** Realization of the rent-to-price ratio over time

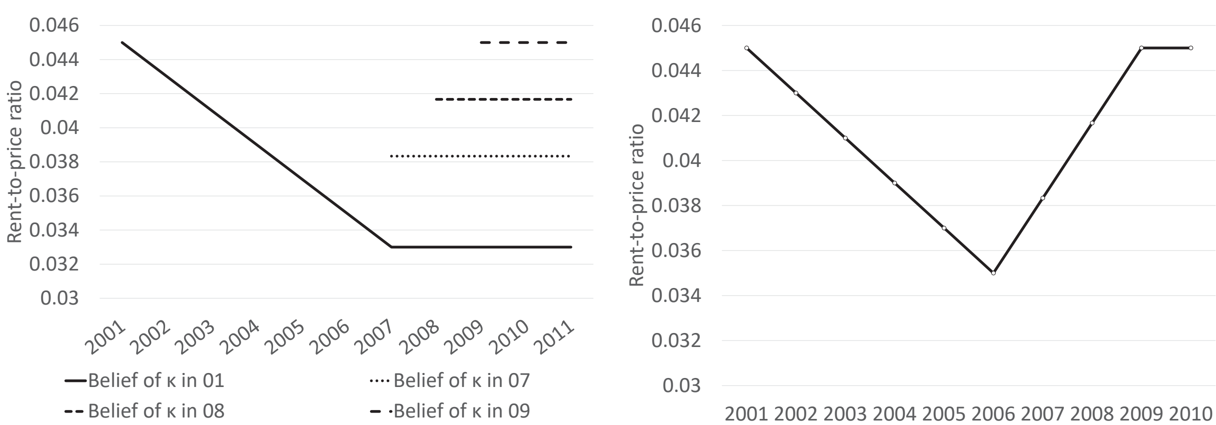


Figure C5: Changes in consumption under the benchmark transition: Homeowners and renters