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Abstract

In this paper we study the joint transitional dynamics of the foreclosures and house prices in a standard life-cycle incomplete markets model with housing and realistic long-term mortgage structure. We calibrate our model to match several long term features of the US housing market. Using the calibrated model, we study the effects of several unexpected and permanent shocks on the house price and the foreclosure rate both across the steady-states and along the transition between the steady-states. More specifically, we consider a risk-free interest rate shock, a minimum down payment shock, and an unemployment shock, which are all unexpected and permanent. The results reveal that along the transition, these shocks can create large unexpected movements in the house price. More importantly, the foreclosure dynamics are quite significant along the transition compared to the steady-state changes. Lastly, we study the effect of two policies on the transitional dynamics of the house price and the foreclosure rate. We first analyze the effect of an ex-post monetary policy through a temporary reduction in the risk-free interest rate. We observe that this monetary policy can be effective in the movements of the house price temporarily, but it has very limited effect on the foreclosure dynamics. As a second policy, we study the effect of an ex-ante macroprudential policy which restricts the minimum down payment requirement at a higher threshold. We find that while macroprudential policy has limited effect on the house price, its effect on the foreclosure rate is quite significant.

Keywords: Housing, house price, interest rate, mortgage contract, mortgage default, home equity

JEL Classifications: D91, E21, G01, R21

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1 Introduction

In this paper we study the joint transitional dynamics of the foreclosures and house prices in a standard life-cycle incomplete markets model with housing and realistic long-term mortgage structure. In particular, we analyze how the house price and the foreclosure rate in our model respond to several unexpected and permanent shocks. We particularly focus on the effect of an increase in the risk-free interest rate, an increase in the minimum down payment requirement to purchase a house, and an increase in the unemployment shock. One distinguishing feature of our framework is that foreclosure choice and the house price are endogenous in our model so that we can analyze the feedback between them.

In a nut shell, we find that the response of the house price and foreclosure to the shocks can be quantitatively large. In our calibrated model, one percent increase in the risk-free rate together with a 20 percent increase in the minimum down payment requirement and 1.5 percent increase in the unemployment rate can result a 28 percent decrease in the house price and more than 10 percent increase in the foreclosure rate. We also study the effects of two policies in mitigating the consequences of these adverse shocks. In particular, we show that when monetary policy achieves low interest rates for a predetermined time it is effective in increasing the house price temporarily. On the other hand the monetary policy has almost no effect on the dynamics of the foreclosure rate. Finally, we study how our model economy would behave if there were a macroprudential policy (20 percent minimum down payment requirement) in effect before the shocks. We find that such policy would make the economy (especially the foreclosures) more stable.

The model that we study is a standard life-cycle model with incomplete markets and idiosyncratic labor income uncertainty. The distinguishing feature of our model is the incorporation of the housing and a realistic mortgage structure into the model. We explicitly model the housing tenure choice. Households are born as renters. Every period, renters decide whether or not to purchase a house. There is a continuum of risk-free lenders who offer mortgage contracts to prospective home buyers. A mortgage contract consists of a mortgage interest rate, loan amount, mortgage repayment schedule and maturity. Mortgages are fully amortizing, that is, homeowners have to pay the mortgage back in full until the end of the mortgage contract, as specified by the maturity. However, homeowners also have the option to sell their houses or default on the mortgage and return to the rental market. Selling a house is different from defaulting, because a seller has to pay back the outstanding mortgage balance to the lender whereas a defaulter has no obligation. Therefore, default occurs in equilibrium as long as the selling price is lower than the outstanding mortgage debt. Upon default, the household becomes a renter again and is excluded from the mortgage market stochastically as a punishment. There is free entry into the credit market, so in equilibrium lenders make zero profit on each contract. Since mortgages are long-term contracts, it is essential for the lenders to infer the default probability of each household at every date and state, which depends on the characteristics of the household. We calibrate our model to match several long term features of the US housing market such as average default rate, house price to income ratio, average moving rate of homeowners, and average homeownership rate.

As our first exercise, we feed the economy with an unexpected and permanent interest rate shock where the risk-free interest rate increases from 2 to 3 percent. We show that, if we compare the first and the second steady state the house price is around 11 percent lower in the second steady state. On the other hand, the foreclosure rate declines from 1.7 percent to 0.2 percent. Higher risk-free interest rate increases the mortgage interest rate, and makes mortgages less affordable. So, the demand for houses decreases, and results a drop in the house price. Lower house price and higher average wealth due to high risk-free interest rate increases the average down payment in the economy. Hence the foreclosure rate drops.

As a second experiment, we shock the model economy only with a financial shock. More specifically, we increase in the minimum down payment requirement from 0 percent to 20 percent. Across the steady states the house price declines around 7 percent. Higher financial constraints on purchasing a house decreases the demand for the houses, and results a drop in the house price. In the new steady state, the foreclosure rate is zero due to high minimum down payment requirement and lower house price.

As our third experiment, we only increase the unemployment rate from 5 percent to 6.5 percent, which makes income more riskier and expected income lower. The unemployment shock decreases the demand for a rigid asset (housing), and results a decrease in the house price around 6 percent. Higher income risk increases the default probability of households, and forces lenders to increase the mortgage premium. So, average down payment ratio increases from 25.5 percent to 27.5 percent. Lower house price and higher average down payment result a decrease in the foreclosure rate from 1.7 percent to 1.2 percent despite the higher income risk making households more likely to default. As our fourth experiment, we study the economy with all the three shocks together. As expected, the house price declines even further, around 17 percent. Again, 20 percent minimum down payment requirement decreases the foreclosure rate to zero percent.

The comparison of the steady states reveal that fundamental shocks, as long as they are unexpected and permanent, can create sizable movements in the house price. However, their effect on the foreclosure rate is counterfactual. Although we consider adverse shocks, they decrease the foreclosure rate. However, the transitional dynamics differ considerably from the steady state comparisons. The analysis of the same shocks along the transition show that the drop in the house price can be quite larger (around 28 percent), and the foreclosure rate can increase to significant levels (around 12 percent).

We first show that on the impact of the interest rate shock, the house price declines around 15 percent, and the foreclosure rate jumps to around 3.7 percent. Hence, studying the transitional dynamics reveals that a very important determinant of the foreclosure activity is the movement in the house price, not the level of house price. Another point that emerges from the exercise is that declining house prices induces more foreclosure due to negative home equity and more foreclosures put downside pressure on the housing price. We next study the transitional dynamics in our second experiment: an increase in the minimum down payment requirement. In response to this shock, on impact, the house price declines around 11 percent, and the foreclosure rate increases to around 3 percent. As the foreclosure rate declines over time, the effect of foreclosures on the house price declines and the house price appreciates around 5 percent before reaching to its new steady-state level. In the long run the model converges to the new steady state where the house price is around 7 percent lower than the initial steady state. In the second steady state the foreclosure rate is zero thanks to the higher down payment requirement.

The transitional dynamics in the case of only unemployment shock (an increase from 5 percent to 6.5 percent) show that, on impact of the shock, the house price declines around 8 percent, the foreclosure rate increases to around 3.5 percent, and then gradually converges to its new steady state level of 1.2 percent. When we study the transitional dynamics in our fourth experiment where all the shocks are realized together, as expected, we find that the responses are larger. On impact, the house prices drops by around 28 percent and the foreclosure rate increases to the levels around 12 percent.

We go further and study the effect of the monetary policy in this framework, and question how the transition would look like in the presence of the monetary policy. In particular we analyze the effect of lowering the risk-free interest rate for a specified period of time. We assume that, after the initial decline in the house price, the monetary authority decreases the risk-free interest rate to 0.5 percent for several periods (we study 3 years and 6 years separately). We find that temporary low interest rates have temporary effects. In general, these policies have only temporary effects on the house price. They especially are quite effective on the house price if the economy receives the interest rate shock or the unemployment shock. However, the effect of the policies on the house price is quite limited if the shock is the financial (minimum down payment) shock since it dramatically limits the affordability of the houses. More importantly, in all of the four experiments, the monetary policy is almost ineffective on the dynamics of the foreclosure rate.

Lastly we question the implications of a macroprudential policy tool: higher minimum down payment requirement. In particular, we study how the model would react to the same interest rate shock and unemployment shock if the minimum down payment requirement of 20 percent has been always in place. In the benchmark calibration we use 0 percent minimum down payment requirement. We find that with higher minimum down payment requirement the decline of the house price is around 16 percent instead of 21 percent in the benchmark economy. More importantly, the increase in the foreclosure rate is significantly lower in the presence of the macroprudential policy (0.6 percent instead of 8 percent without the policy). These results show us the importance of the macroprudential policies in mitigating the effect of the shocks on the house price and foreclosures.

2 Related Literature

The run up of the housing prices prior to 2006 and the collapse afterwards induced an increase in interest in the housing markets. The earlier studies were generally motivated to understand the increase in the house price. After the collapse, both understanding the decline in the house price and the increase in the foreclosure rate have become the main interest of research. Foote et al (2012) outlines the facts about the housing and mortgage market, and compares the success of different theories in explaining these facts. Their main finding, consistent with ours, is that the unexpected decline in the house prices is the main driving force behind the increase in the foreclosure rates. Our quantitative model produces results consistent with their finding.[1]

The model of this paper is based on the model developed in Guler (2011) where he studies the implications of the improvement in information technologies. One innovation of his paper is the modeling of the mortgage contract in detail for each individual. This extension enables us to study the mortgage default decision realistically.

Our paper is most closely related to work by Chatterjee and Eyigungor (2011). Like us, they also study the collapse of the house price and rising mortgage defaults in a standard incomplete market model. Different from our model, they assume that mortgage holders pay only the interest on their loans. Consequently, all homeowners have the same equity which is the down payment amount. In our model, consumers pay out their loans before they retire, hence consumers have heterogeneous levels of home equity. We believe this is a crucial difference between our model and Chatterjee and Eyigungor (2011) since home equity levels are found to be an important determinant of the foreclosure decision (see Foote et al (2008) and Mian and Sufi (2011)). In addition, we analyze the implications of some policies such as monetary and financial (or macro prudential) policies in mitigating the effects of adverse shocks.

Our paper differs from the related articles by Corbae and Quintin (2011) and Campbell and Cocco (2011). These papers also study the mortgage defaults in the housing market. A key difference we think is that they consider house prices as an exogenous process. With this modeling assumption they cannot study the feedback between house prices and foreclosures which has the potential to be significant. However, we model house prices and foreclosures

[1]Similar findings can be found in Foote et al (2008), Gerardi et al (2009), Mayer et al (2009) and Bajari et al (2010)

endogenously, hence are able to study the joint dynamics.

Another related study to ours is a recent study by Hatchondo et al. (2011). Similar to our study, they also study a life-cycle standard incomplete markets model with housing. They show that a calibrated version of the model matches the non targeted moments such as the distribution of the down payments hence a plausible borrowing behavior. They also study the implications of minimum down payment requirement and income garnishment on the defaults. One key point that we depart from their study is that, in their model they assume that house prices follow a stochastic process. In our model we assume that house prices are constant in the steady state and change only when an aggregate interest rate shock hits the economy. We find this difference important since to study the feedback mechanism between house prices and default, both of them should be endogenous. Another point we differ is the policies we analyze.

The empirical literature generally found significant impacts of some macro variables such as interest rates on housing prices (see Himmelberg et al. (2005)). On the other hand the quantitative macro literature studying the housing market found that in a business cycle model it is difficult to generate significant volatility in house prices (see Heathcote and Davis (2005)). However, Arslan (2008) finds that the rigidities in the housing market together with mortgage contracts imply both large house price volatility and comovement of house prices and transaction volume. Sommer et al. (2011) build a stochastic life cycle Aiyagari-Bewley-Huggett economy with exogenous down payment requirements and interest rates, and endogenous house prices and rents. They find that, fundamentals (i.e. downpayments and interest rates) can explain about half of the run up in the house price-rent ratio. In a related article Garriga et al. (2012) show that interest rates and down payment requirements generate volatilities in house prices comparable to the data. Hence, it is no surprise that in our model we also have significant response of house prices to fundamentals which is necessary to have significant movements in foreclosures as well.

3 Model

We begin by describing the environment agents face in the economy. We then specify the decision problems of households and lenders. We finally define the equilibrium.

3.1 Environment

The economy is populated by overlapping generations of J period lived households and a continuum of lenders. Each generation has a continuum of households. Time is discrete and households live for a finite horizon. There is no aggregate uncertainty but households face idiosyncratic shocks to labor income and to their house value, and markets are incomplete so that these shocks are not fully insurable. There is mandatory retirement at the age J_r. Retirement income is constant and depends on the income of the household at age J_r and the average income in the economy. Households can save at an exogenously given interest rate r but they are not allowed to make unsecured borrowing.

Households live in houses, which they can either rent or own. At the beginning of each period, a household is in one of the four housing statuses: *inactive renter*, *active renter*, *homeowner*, or *mover*. Inactive renters are the renters with default flag in their credit history whereas active renters are the renters without any default flag in their credit history.[2] In any period, active renters are always allowed to purchase a house, whereas inactive renters are not allowed to buy, and forced to stay as renters for that period. Homeowners are the households who start the period by owning a house. Lastly, movers are the owners who are forced to move from their current houses due to exogenous reasons, like a job-offer or family size change. The size of the house is fixed, i.e. there is no upgrading or downgrading the house size. However, since houses are big and expensive, their purchase can be financed through mortgages, which is also the only source of borrowing in the economy. A mortgage contract is a combination of interest rate and loan amount, specified by the down payment fraction and house value. Maturity of the mortgages is assumed to be the remaining life time of the household until retirement.[3] Lenders only offer fixed-payment mortgages, so the payment is constant throughout the life of the mortgage.[4] There is no mortgage refinancing or home-equity line of credit.

Homeowners may leave their houses for four reasons: 1) due to the income shocks, they may be liquidity constrained, and cannot make the mortgage payments, 2) due to house price shocks they might have negative equity and might find it optimal to sell/default,[5] 3) some homeowners may choose to sell/default their houses before retirement due to consumption smoothing arguments, and 4) for exogenous reasons which are not explicitly modeled here.[6] Homeowners can leave their houses by two means. They can either sell their houses, or they can default on the mortgage. Selling a house is subject to capital gains/losses, and these gains/losses are assumed to be i.i.d and only realized after the household sells the house, i.e.

[2] This is to mimic the fact that default stays in the credit history of the individuals for a certain time, and makes it hard for her to find credit.

[3] Although the maturity of the contract is set exogenously in the origination of the contract, it becomes endogenous due to prepayment and principal reduction options mortgage holders have.

[4] Since we assume constant interest rate, traditional fixed rate mortgages and adjustable rate mortgages would have fixed payments throughout the life of the mortgage and they both fall into this category. These mortgages are not necessarily optimal contracts. A more convenient formulation should also include the mortgage payment as part of the contract and be determined in equilibrium. However, for simplicity we abstract from that and focus on the fixed payment mortgage contracts which are the dominant type of mortgages in the U.S. history.

[5] It is important to note that not all households will find it optimal to sell/default once they are in negative equity. There are some future costs associated with each of these options which might outweigh the benefit of selling/defaulting.

[6] Like relocation due to job or family related reasons

upon observing the shock, the household cannot withdraw the house from the market. In the case of default, households become inactive renters, and they can become an active renter in the next period with probability δ.[7] The supply of rental and owner-occupied units is constant and targeted to match the average ownership rate in the US. Rental price is normalized to 0 and purchase price is solved endogenously given the fixed supply of owner-occupied units. The details of the model are explained below.

3.1.1 Households

Households derive utility from consumption and housing services. Preferences are represented by

$$E_0\left[\sum_{j=1}^{J_r}\beta^{j-1}u_k\left(c_j\right)+\beta^{J_r+1}W\left(w_{J_r},y_{J_r}\right)\right]$$

where $\beta<1$ is the discount factor, c is the consumption and k is the housing status: renter or homeowner. W represents the value function of the household at retirement given wealth w_{J_r} and income y_{J_r}.[8] The house size is fixed and the utility from housing services is summarized as two different utility functions: one for the renter, u_r and one for the homeowner, u_h. A homeowner receives a higher utility than a renter from the same consumption: $u_h(c)>u_r(c)$.[9]

The log of the income before retirement is a combination of a deterministic and a stochastic component whereas after retirement, it is λ fraction of the income at age J_r plus η fraction of the average income in the economy, $\bar{y}$:

$$\begin{aligned} y\left(j,z_j\right) &= \left\{\begin{matrix} \exp\left(f\left(j\right)+z_j\right) & \text{if } j\leq J_r \text{ and employed} \\ \bar{y}_u & \text{if } j\leq J_r \text{ and unemployed} \\ \lambda y_{J_r}\left(J_r,z_{J_r}\right)+\eta\bar{y} & \text{if } j>J_r \end{matrix}\right\} \\ z_j &= \rho z_{j-1}+e_j \end{aligned}$$

where y_j is the income at age j, $f\left(j\right)$ is the age-dependent deterministic component of the log income, and finally z_j is the stochastic component of the log income. The stochastic component is modeled as an $AR(1)$ process with ρ as the persistency level. The innovation to the stochastic component, e_t, is assumed to be i.i.d and normally distributed with mean 0 and variance σ_e^2. We also assume that in any period, the household is subject to an exogenous

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[7] We have this assumption to mimic the fact that in reality default stays in the credit history of the households for a certain time period. Moreover it makes default costly for the individuals. This is also the reason we have the inactive renters as a different housing status.

[8] Since there is no housing tenure choice and uncertainty after retirement, household's problem is trivial and can be calculated analytically.

[9] Note that the size of the houses is fixed, that's why having separate utility functions for renter and homeowners imply that they get different housing services from the same house. This specification is also identical to a Cobb-Douglas specification between housing consumption and nondurable consumption.

unemployment shock, u. The unemployment income is assumed to be constant and equal to $\bar{y}_u$.[10] Households can save to smooth their consumption at the constant risk-free interest rate r, but there is no unsecured borrowing.

Households start the economy as active renters, and can purchase a house and become an owner at any period in time. However, an inactive renter is only allowed to purchase a house with probability δ. With $(1-\delta)$ probability, she is forced to live as a renter. Since houses are expensive items, their purchases can be done through securitized borrowing: mortgages. A purchaser chooses among a menu of feasible mortgage contracts, each specified with a loan amount and interest rate.[11] Since the mortgages are fixed-payment mortgages, the contract together with the maturity, remaining time to retirement, determine the periodic mortgage payments. As long as the household stays in the house, she has to make at least these payments. However, a mortgage holder is always allowed to make additional payments to reduce the principal amount. The homeowner has also the option to sell the house at any time period. However, selling the house is costly. Firstly, upon deciding to sell, the individual receives an i.i.d house price shock, ϵ_h, drawn from a distribution $F_h(\epsilon_h)$. This idiosyncratic shock changes the value of the house up or down.[12] Additionally, there are some other costs (transaction costs including real-estate costs and maintenance costs) associated with selling the house. These costs are assume to be proportional, φ_h, of the house price. Moreover, a seller has to pay the outstanding mortgage debt back to the lender.

There is another option for the household to quit ownership. She can default on the mortgage. A defaulter has no obligation to the lender. Upon default, the lender seizes the house, sells it and pays back, if any, to the defaulter the amount net of outstanding mortgage debt and costs associated to selling the house. The lender's cost of selling the house is $\varphi_l \geq \varphi_h$ fraction of the house price. What makes default appealing for the household is the fact that a defaulter has no obligation to the lender whereas a seller has to pay back the debt in full. The same fact puts a risk of loss on the lender. The lender incurs a loss if the net value of the house is smaller than the outstanding debt upon default.

Default is not without any cost to the household. A defaulter becomes an inactive renter and can only enter to the housing market with probability δ. Since default is costly and the selling price of the house to the homeowner is at least the selling price to the lender, the homeowner who decides to leave the house only defaults if the outstanding mortgage balance

[10] We assume away the endogenous choice of unemployment. So, given a low realization of income shock, households cannot choose to become unemployed. This assumption can be justified by a perfect monitoring technology for the unemployed.

[11] Not every combination of mortgage interest rate and loan amount is feasible for the household. Lenders' inference about the type of the household and competition among lenders restrict the contracts offered to the household in the equilibrium.

[12] We can think of this shock as a local shock. We need this feature of the model to create realistic mortgage default rates in steady-state. Since house prices are fixed in the steady-state, without these local shocks, the incentive to default becomes very small.

is strictly higher than the selling price. Otherwise it is always optimal to sell the house rather than defaulting.

In addition, we assume that in each period homeowners receive exogenous moving shock with probability ψ, and they are forced to quit to the rental market. These shocks represent the reasons households move other than the ones modeled here, like job mobility, family reasons, etc. Movers again have two choices, either sell the house or default on the current mortgage.

3.1.2 Lenders

There is a continuum of lenders and financial markets are perfectly competitive, and there is no cost to entry. Lenders are risk-neutral.[13] The economy is assumed to be an open economy and the risk-free interest rate, r, is set exogenously. Mortgage contracts are long-term contracts and the maturity of the contract is directly determined by the time to retirement, which is assumed to be certain and observable. Lenders have full commitment to the contract and renegotiation is not allowed.

Each contract is characterized by a loan amount, d, and interest rate, r_m. Since households can default on the mortgage at any time, and transaction and further costs make the loan not fully securitized, lenders face a risk of loss on mortgage loans.

3.1.3 Timing

The timing of the events is the following: Households are born as active renters. For any other period, the household starts the period either as a homeowner, a mover, an active renter or an inactive renter. At the beginning of each period, households realize their income shock including unemployment shock, and decide about their housing statuses for the current period.

An active renter has two choices: continue to rent or purchase a house. If she decides to continue to rent, she pays the rental price, makes her consumption and saving choices, and reaches to the next period as an active renter. If she decides to buy a house, she goes to a lender. The lender offers a menu of mortgage contracts depending on the characteristics of the household. The household chooses the mortgage contract that maximizes her utility. However, the buyer is also allowed to pay the whole house price upon purchase in which case she will have no mortgage to pay. Upon deciding about the mortgage choice, she pays the down payment and periodic mortgage payment implied by the mortgage contract, makes her consumption choice, and reaches to the next period as a homeowner with $(1 - \psi)$ probability and mover with ψ probability. We do not allow owners to save once they do have a mortgage

[13] Securitization of mortgages helped lenders to diversify the risk they face and liquidate their asset holding. Risk-neutrality assumption corresponds to perfect securitization.

obligation. We also do not allow for refinancing, but owners with mortgage can always prepay the mortgage. This prepayment will reduce the outstanding mortgage balance, but it will have no effect on the mortgage interest rate.

A homeowner has three choices: stay, sell or default; whereas a mover has two choices: sell or default. If she decides to stay in the current house, she makes her consumption and mortgage payment choice, which has to be at least the amount dictated by an amortizing fixed rate mortgage, and starts the next period again as a homeowner or a mover depending on the moving shock. If she decides to sell the house, she receives the idiosyncratic house price shock, pays the outstanding mortgage debt back to the lender, makes her consumption and saving choices and begins the next period as an active renter. If she decides to default, she receives any positive remaining balance - the selling price of the house to the lender minus the outstanding mortgage debt - from the lender, makes her consumption and saving choices, and starts the next period as an active renter with δ probability and inactive renter with $(1-\delta)$ probability.

An inactive renter has no housing tenure choice. She is forced to live as a renter. So, she pays the rental price, and only makes her consumption and saving choices and starts the next period as an active renter with δ probability and inactive renter with $(1-\delta)$ probability.

3.2 Decision Problems

We now turn to the recursive formulation of the household's and lender's problem. Note that since the mortgages are long-term contracts, the lender's problem also has dynamic structure. The lender has to calculate the default risk of the household through the life of the mortgage. Here, we first start with the recursive formulation of the household's problem, then we set up the lender's dynamic programming problem which is also closely related to the household's problem.

3.2.1 Household's Problem

We only focus on household's problem before retirement. The value function at the time of retirement can be calculated analytically given the utility specification. At the beginning of each period, the household is in one of the four housing positions: inactive renter, active renter, homeowner, or mover. After the realization of the income shock, the active renter and the homeowner make their housing tenure choices for the current period and start the next period with their new housing statuses. Let's denote V^r as the value function for an active renter after the realization of the income shock and just before the housing choice. Similarly, let V^h be the value function for a homeowner, V^m be the value function for a mover, and let V^e be the value function for an inactive renter. Note that in the current period inactive renters and movers have no housing tenure choice.

Inactive Renter. We start with the problem of an inactive renter. An inactive renter's problem is simple. She does not have any housing tenure choice, she is forced to be a renter in the current period. The only decisions she has to make are the consumption and saving allocations. She starts the next period as an active renter with probability δ and an inactive renter with probability $(1-\delta)$. Denoting the value function of an inactive renter with age j, period beginning saving a and income z as $V^e(a,z,j)$, the inactive renter's problem is given by:[14]

$$V^e(a,z,j) = \max_{c,a'\geq 0} \left\{u_r(c) + \beta E\left[\delta V^r\left(a',z',j+1\right) + (1-\delta)V^e\left(a',z',j+1\right)\right]\right\} \tag{1}$$

subject to

$$c + a' + p_r = y(j,z) + a(1+r)$$

where c is the consumption, a' is the next period saving, and p_r is the exogenous rental price . Note that the inactive renter derives utility from consumption and renting a house.

Active Renter. Different from an inactive renter, an active renter has to make housing tenure choice. After the realization of the income shock, an active renter has to decide whether to continue to stay as a renter or purchase a house in the current period. This means we need to define two additional value functions for the active renter. Define V^{rr} as the value function for an active renter who decides to stay as a renter and name such a household as *renter*. Her problem is very similar to the inactive renter's problem apart from the fact that she starts the next period as an active renter for sure. Given all these facts, we can write down the problem of the renter as:

$$V^{rr}(a,z,j) = \max_{c,a'\geq 0} \left\{u_r(c) + \beta E V^r\left(a',z',j+1\right)\right\} \tag{2}$$

subject to

$$c + a' + p_r = y(j,z) + a(1+r)$$

The second possible choice of an active renter is to purchase a house. Define the value function for an active renter who decides to purchase a house as V^{rh} and name such a household as *purchaser*. Housing purchase is done through a mortgage contract. The purchaser, additional to the usual consumption choice, has to choose a mortgage contract. Lenders design the mortgage contracts depending on the observable of the household. Due to the perfect competition in the financial market, lenders have to make zero-profit on these mortgage contracts. So, only the contracts which make zero-profit are feasible and offered to the

[14] One can argue that unemployment should be another state in the recursive formulation. We basically stack unemployment state as another state to the income variable z to avoid another state variable.

household. We denote the set of feasible contracts for a household with observable θ as $\Upsilon(\theta)$ where $\theta \equiv (a, z, j)$. A mortgage contract is specified with a loan amount d and interest rate, r_m. So, a typical element of the feasible contract set is $(d, r_m) \equiv \ell \in \Upsilon(\theta)$. We leave the construction of $\Upsilon(\theta)$ to the section we define the lender's problem. Since mortgages are due by retirement, which is deterministic, household's age captures the maturity of the mortgage contract. Moreover, since we only focus on fixed payment mortgages, the choice of the loan amount and interest rate, together with the age of the household, determine the amount of mortgage payments, m. The calculation of these payments is shown in the lender's problem. Out of the total financial wealth, net of the mortgage payment and the down payment fraction, the household consumes the rest, and starts the next period as a homeowner. So, we can formulate the problem of the purchaser in the following way:

$$V^{rh}(a, z, j) = \max_{c,(d,r_m)\in\Upsilon(\theta)} \left\{ u_h(c) + \beta \left[(1-\psi) EV^h\left(z', j+1; d', r_m\right) + \psi EV^m\left(d', z', j+1\right) \right] \right\} \tag{3}$$

subject to

$$\begin{aligned} c + m(d, r_m, j) + p_h - d &= y(j, z) + a(1+r) \\ d' &= (d - m(d, r_m, j))(1 + r_m) \end{aligned} \tag{4}$$

where p_h is the house price. The household makes the down payment immediately upon the purchase of the house, and mortgage payments are due by the beginning of each period. Outstanding mortgage debt decumulates according to equation (4). It says that next period outstanding mortgage debt, d', is the current period outstanding mortgage debt reduced by the mortgage payment, net of interest payment. Note that since the purchaser becomes a homeowner in the current period, she derives utility from both consumption and being a homeowner. Lastly, notice that purchaser starts the next period as a mover with ψ probability and as a homeowner with $(1-\psi)$ probability.

The value function for the renter together with the value function for the purchaser characterize the value function for the active renter:

$$V^r = \max\left\{V^{rr}, V^{rh}\right\} \tag{5}$$

Homeowner. A homeowner has three housing choices: stay in the current house, sell the house, or default on the mortgage. This requires us to define three additional value functions. Let V_i^{hh} be the value of a homeowner who decides to stay in the current house and name such a household as *stayer*. The stayer has to make at least the periodic mortgage payment, but also can prefer to make additional payments to reduce the outstanding mortgage debt. However, this will not effect the interest rate on the mortgage, Apart from the usual state variables (z, j), a stayer is also defined by her outstanding mortgage debt, d, and interest rate on the mortgage, r_m. The outstanding mortgage debt decumulates according to the same equation we defined in the purchaser's problem. In recursive formulation, the problem of the stayer becomes the following:

$$V^{hh}(d, z, j; r_m) = \max_{c,d'} \left\{ u_h(c) + \beta \left[(1-\psi) EV^h \left(d', z', j+1; r_m\right) + \psi EV^m \left(d', z', j+1\right) \right] \right\} \tag{6}$$

subject to

$$\begin{aligned} c + d &= y(j, z) + d'/(1 + r^m) \\ d' &\leq (d - m(d, r_m, j))(1 + r_m) \end{aligned}$$

Again, notice that a stayer starts the next period as a mover with ψ probability and as a homeowner with $(1 - \psi)$ probability.

The second possible choice for a homeowner is to sell the house and become a renter, and name such a household as *seller*. The selling price of the house is exogenously set to $(1 - \varphi_h)$ fraction of the purchase price p_h. This feature tries to capture the possible transaction costs, maintenance costs etc. Additional to this transaction cost, sellers also incur an i.i.d capital loss/gain, ϵ_h. Moreover, a seller has to pay the outstanding mortgage debt, d, in full to the lender. Denoting V_i^{hr} as the value function for a seller, the recursive formulation of her problem is the following:

$$V^{hr}(z, j; d, r_m) = \max_{a' \geq 0} \left\{ Eu_r(c) + \beta EV_{j+1}^r \left(a', z', j+1\right) \right\} \tag{7}$$

subject to

$$c + a' + p_r = y(j, z) + p_h(1 - \varphi_h)(1 + \epsilon_h) - d$$

where the expectation operator before the utility function is for the i.i.d. house prices. Again, since the seller becomes a renter in the current period, she pays the rental price and enjoys the utility of a renter.

The third and the last possible choice for a homeowner is to default on the mortgage. Name such a household as *defaulter*. A defaulter has no obligation to the lender. The lender seizes the house, sells it in the market and pays any positive amount net of the outstanding mortgage debt and selling costs back to the defaulter. For the lender, selling price of the house is assumed to be $(1 - \varphi_l) p_h$. So, the defaulter receives $\max\{(1 - \varphi_l) p_h, 0\}$ from the lender. Defaulter starts the next period as an active renter with probability δ. With $(1 - \delta)$ probability she becomes an inactive renter. Denoting V^d as the value function for a defaulter, her problem becomes the following:

$$V^d(z,j) = \max_{c,a'\geq 0} \left\{ u_r(c) + \beta E\left[\delta V^r\left(a',z',j+1\right) + (1-\delta) V^e\left(a',z',j+1\right)\right]\right\} \tag{8}$$

subject to

$$c + a' + p_r = y(j,z) + \max\left\{(1-\varphi_l)\, p_h - d, 0\right\}$$

Since the defaulter is a renter in the current period, she pays the rental price and enjoys the utility of a renter.

So, we can characterize homeowner's value function, which is the maximum of the above three value functions as:

$$V^h = \max\left\{V^{hh}, V^{hr}, V^d\right\} \tag{9}$$

Mover. A mover's problem is very similar to the homeowner's problem apart from the staying option. A mover can either choose to sell the house or default on the mortgage. So, we can characterize the value function of the mover as:

$$V^m = \max\left\{V^{hr}, V^d\right\} \tag{10}$$

3.2.2 Lender's Problem

Since the mortgages are long-term contracts, the lender's problem is also a dynamic problem. The lender has to design a menu of contracts, $\Upsilon(\theta)$, depending on the observable, θ of the purchaser. As we mentioned above, a mortgage contract is a combination of a loan amount and an interest rate: $(d, r_m) \in \Upsilon(\theta)$. Note that we do not include mortgage payment, m and maturity as parts of the mortgage contract, because maturity is directly determined through the age of the household, which is observable, and mortgage payment is assumed to be fixed and becomes a function of the loan amount, interest rate and household's age.

Present Value Condition. We first show how the mortgage payments are computed. Since the mortgages are fixed-payment mortgages, the payments are constant through the life of the mortgage. They are directly computed from the *present value condition* for the contract. This condition says that given the loan amount and the mortgage interest rate, the present discounted value of the mortgage payments should be equal to the loan amount. Since the lender has full commitment on the contract, he calculates the payments as if the contract ends by the maturity. Assuming the interest rate on the mortgage is r_m and current age of the household is j, this gives me the following formulation for the per-period payments of a mortgage loan with outstanding debt d:

$$\begin{aligned} d &= m + \frac{m}{1+r_m} + \frac{m}{(1+r_m)^2} + ... + \frac{m}{(1+r_m)^{J_r - j}} \\ m(d, r_m, j) &= \frac{1-\alpha}{1-\alpha^{J_r - j+1}} d, \text{ where } \alpha = \frac{1}{1+r_m} \end{aligned} \tag{11}$$

No-Arbitrage Condition. Next, given the mortgage payments and loan amount, the lender has to determine the mortgage interest rate. This rate is pinned down by the *no-arbitrage condition*. It says that given the expected mortgage payments, the lender should be indifferent between investing in the risk-free market, which is the only outside investment option for the lender, and creating the mortgage loan. Note that the expected payments are not necessarily the above calculated mortgage payments. If the household defaults when the outstanding mortgage debt is d, the lender receives $\min\{(1-\varphi_l) p_h, d\}$[15].

Before formulating the no-arbitrage condition, let us denote the value of a mortgage contract with outstanding debt d and interest rate r_m, offered to a household with current period characteristics (z, j) as $V^\ell(z, j; d, r^m)$[16]. Note that this function does not only represent the value of the contract at the origination, but also represents the continuation value of the contract at any time period through the mortgage life. Depending on the homeowner's tenure choices, the realized payments may change. If the household stays in the current house, the lender receives the calculated mortgage payment and the continuation value from the contract with the updated characteristics of the household and the loan amount. If the household defaults, then the lender receives $\min\{(1-\varphi_l) p_h, d\}$. If the household sells the house, the lender receives the outstanding loan amount, d.

Given that the opportunity cost of the contract is the risk-free interest rate, r, plus the per period transaction cost, τ, and the lender is risk-neutral, the value function for the lender becomes the following:

$$V_i^\ell(z, j; d, r_m) = \left\{ \begin{array}{ll} d - \frac{d'}{1+r_m} + \frac{1}{1+r+\tau} EV_i^\ell(z', j+1; d', r_m) & \text{if hh stays} \\ \min\{p_h(1-\varphi_l), d\} & \text{if hh defaults} \\ d & \text{if hh sells} \end{array} \right\} \tag{12}$$

where d' is the policy function to problems (3) and (6) and finally $m(d, r_m, j)$ is defined by

[15]Since default is costly, as long as $p_h(1-\varphi_h) \geq d$, the household sells the house rather than defaulting. This means, in equilibrium, when the household defaults, the lender receives $p_h(1-\varphi_l) \leq p_h(1-\varphi_h) < d$ and incurs some loss.

[16]Notice that asset level, a, is not part of the state variable for the lender. This is because we do not allow mortgage holders to save.

equation (11).

Now, we are ready to formulate the no-arbitrage condition. At the time of the origination of the contract, the lender observes all the characteristics of the household. This actually means that mortgage contracts are individualized and independent from all the other households in the economy. The lender can solve the household's problem and obtain the necessary policy functions (mortgage payment choice and housing choice) to evaluate the value of the contract at the origination. So, the no-arbitrage condition for a mortgage contract offered to a household with characteristics (z, j) becomes:

$$V^{\ell}(z, j; d, r_m) = d \tag{13}$$

Note that initial loan amount d is determined by the down payment fraction: $d = (1 - \phi)\, p_h$.

3.3 Equilibrium

Define the set of state variables for the household as Ω with a typical element (a, z, j) [17],and let $\theta \in \Theta \subseteq \Omega$ be the observable characteristics of the household by the lender.

Definition 1 ***Equilibrium:*** *An equilibrium to the economy is a set of policy functions* $\{c^*, a^*, d'^*, \ell^*, i^*\}$ *and a contract set* Υ *such that*

(i) *given the feasible contract set* Υ*,* $c^* : \Omega \times \Upsilon \to \Re$*,* $d'^* : \Omega \times \Upsilon \to \Re$*, and* $\ell^* : \Omega \times \Upsilon \to \Re^2$ *solve equations* $(1) - (3)$ *and* $(6) - (8)$*,* i_s^* *is a policy indicator function which solves equations* (5) *and* (10)*,*

(ii) *given the policy functions each contract* $\ell \in \Omega \times \Upsilon$ *solves equation* (13) *and*

(iii) *no lender finds it profitable to offer another contract, which is not in the contract set,* $\Omega \times \Upsilon$*, i.e.* $\nexists (d, r_m)$ *such that* $V^{\ell}(\theta; d, r_m) > d$ *for* $\forall \theta \in \Theta$*, with* V^{ℓ} *defined as in equation* (12)*.*

4 Calibration

A set of the parameters is directly taken from the literature. For the rest of the parameters, we calibrate the economy to match some relevant data moments for the 2002-2006 period. In particular, we calibrate the utility advantage of homeownership, γ_h, discount factor β and exogenous moving probability, ψ, to match the homeownership rate, mortgage default rate, and moving rate of households in the pre-2004 period. Table **??** presents the results of the calibration.

[17] The only relevant household for the lender is the purchaser, since contracts are only offered to them. And the state variable for a purchaser is, as mentioned earlier, (a, z, j)

Parameter	Explanation	Value
σ	risk aversion	2
ρ	persistence of income	0.84
σ_ε	std of innovation to AR(1)	0.34
φ_h	selling cost for a household	10%
r	risk-free interest rate - initial	2%
δ	prob. of being an active renter	0.14
u	unemployment shock	0.05
β	discount factor	0.95
φ_l	selling cost for a lender	10.7%
γ_h/γ_r	utility advantage of ownership	1.37
ψ	moving probability	4%

External Calibration A model period is 1 year and households live for 70 periods. So, we assume households start the economy at the age 20, and live till the age of 90. The mandatory retirement period is 25, corresponding to the age of 65. Utility function for the households is the standard CRRA utility function with a slight modification to account for the benefit of homeownership: $u_k(c) = \frac{(\gamma_k c)^{1-\sigma}}{1-\sigma}$, $k \in \{r, h\}$ and γ_k is the utility advantage of being a renter ($k = r$) or homeowner ($k = h$).[18] We normalize $\gamma_r = 1$, and calibrate γ_h internally. We set the risk-aversion parameter, σ, to 2.

For the income process before retirement, we take the parameters to be consistent with the findings of Hubbard, Skinner and Zeldes (1994), Carroll and Samwick (1997) and Storesletten, Telmer and Yaron (2004). Using their income process, we simulate an economy for a sufficiently long time and estimate the resulting income profile as an AR(1) process. This gives us the income persistency, ρ, as 0.84 and standard deviation of the innovation to the AR(1) process, σ_ε, as 0.34. We approximate this income process with a 7-states first-order Markov process using the discretization method outlined in Tauchen (1986). For the retirement income, we assume $\lambda = 0.35$ and $\eta = 0.2$, meaning the retiree receives 35% of the income at the time of retirement plus 20% of the mean income in the economy. For the unemployment income, we set it as the minimum income households earn when employed before retirement. This corresponds to around 25% of the average income of the household before retirement.[19]

The probability of becoming an active renter, while the household is an inactive renter, is set to 0.14, to capture the fact that the bad credit flag stays, on average, 7 years in the

[18] Given this utility specification, since there is no housing tenure choice and uncertainty after retirement, we can solve the value function at the time of retirement analytically: $W(w_r, y_r) = u_r(\bar{c}) \frac{1-\varkappa^{J-J_r+1}}{1-\varkappa}$, where w_r is the total wealth, including real estate, at the of retirement and y_r is the retirement income level, $\bar{c} = \frac{\alpha_1 y_r}{\alpha_2} + \frac{w_r}{\alpha_2}$, $\alpha_1 = \frac{1-\omega_1^{J-J_r+1}}{1-\omega_1}$, $\alpha_2 = \frac{1-\omega_2^{J-J_r+1}}{1-\omega_2}$, $\omega_1 = \frac{(\beta(1+r))^{1/\sigma}}{1+r}$, $\omega_2 = \frac{1}{1+r}$, and $\varkappa = \beta(\beta(1+r))^{\frac{1-\sigma}{\sigma}}$.

[19] This assumption also makes sure that employment is always preferred to unemployment.

credit history of the household. The loss in the selling price of the house for the household is set to $\varphi_h = 10\%$.[20] The initial distribution of the income is assumed to be the stationary distribution, and initial wealth of individuals is set to 0.

The annual risk-free interest rate in the first steady-state is set to $r = 2\%$. The same rate is 3% in the second steady-state. Rental price is normalized to 0 in both steady states, and we solve for the house price which equalizes the fixed supply of owner-occupied units in both steady-states. We set the initial house price to 3.0 of the annual average income of a household. Lastly, following Garriga and Schlagenhauf (2009), we set the i.i.d house price shock to take seven values: $\varepsilon_h \in \{0.80, 0.903, 0.987, 1.059, 1.122, 1.179, 1.230\}$ with corresponding probabilities $\pi_{e_h} = \{0.0388, 0.2046, 0.4917, 0.1437, 0.0670, 0.0347, 0.0195\}$.

Internal Calibration The remaining parameters of the model are calibrated internally to jointly match some of the key moments of the data. We use the initial steady-state in which the risk-free interest rate set to 2 percent to calibrate the parameters. These parameters are the utility advantage of owning a house, γ_h, discount factor, β, selling cost for a lender, φ_l, and moving probability, ψ. We internally calibrate these parameters to jointly match the following data moments: homeownership rate of 68.8 percent, foreclosure rate of 1.7 percent, average wealth-to-income ratio of 4, and homeowners' moving rate of 6.5 percent.

5 Initial Steady State Analysis

Table 1 shows the success of the model in matching some aspects of the data. Clearly, the model matches the homeownership rate, wealth-income ratio, foreclosure rate and moving rate of the homeowners very well since the parameters are chosen to deliver these results. However, the model also matches the data quite well along several other untargeted dimensions. The average down payment in the model is 25.5 percent, which is similar to the average down payment of 21.1 percent in the data during the 2001-2005 period. Loan-to-value ratio in the model is 53.3 percent, again very close to its data counterpart, 58.4 percent.

Given the success of the model in matching the data, we now turn into the workings of the model. The individuals in the model make three important choices regarding the housing market. When to buy the house, how much loan to obtain to buy the house, and when and how to exit from homeownership. Figure 1(a) displays renting vs owning choice as a function of wealth and income. Keeping household income constant, as wealth increases the household becomes more likely to choose owning over renting. Similarly, keeping the wealth constant as

[20] Gruber and Martin (2003) estimates this cost for the homeowner as 7% using CEX data. Note that we abstract from various other sources of selling the house like house price change, unemployment shock, medical expense shock and we also exclude the depreciation on the houses. So, we think 10% is a reasonable estimate of the transaction cost for selling the house.

Table 1: **Initial Steady-State Results**

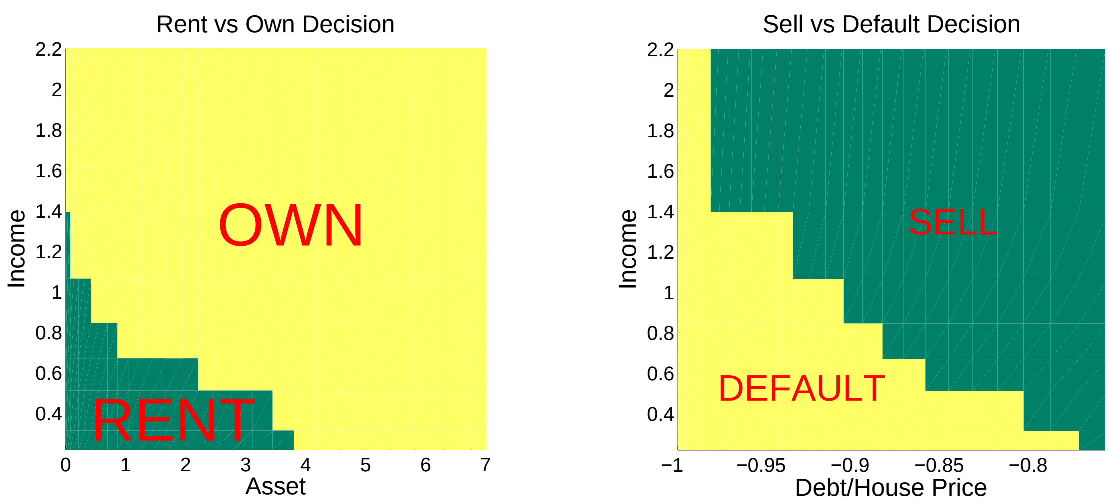
Statistic[a]	**Data**	**Model: r=2%**
Homeownership rate	68.8%	68.8%
Wealth-income ratio	4	4.1
Moving rate-owners	6.5%	6.3%
Foreclosure rate	1.7%	1.7%
Prices to income ratio	3.0	3.0
Average down payment ratio	21.1	25.5%
Loan-to-Value ratio	58.4	53.3%

[a]Homeownership rate, foreclosure rate, moving rate, and wealth-income ratio are matched to the data. Homeownership and moving data are from Census, foreclosure rate is from Mortgage Bankers Association, average down payment is from the Monthly Interest Rate Survey of FHFA, and loan-to-value ratio is from Flow of Funds Account.

the income increases the household becomes more likely to own a house instead of renting. The presence of exogenously set positive utility premium attached to owning a house makes ownership more appealing compared to renting. However, since houses are expensive, not every household can buy a house whenever they want. Households need to accumulate some wealth to partially cover the cost of buying a house. We set the minimum down payment requirement to 0 percent in the initial steady-state, meaning households can buy a house by borrowing the whole purchase price from a lender. However, since the terms of the mortgage loans are determined endogenously depending on the characteristics of the households, higher leverage will imply higher risk of default. This, in turn, will be reflected as a higher premium on the loan. Since mortgage loans are long-term contracts, the benefit of waiting for several periods and accumulating enough wealth to reduce the mortgage premium might outweigh the cost of waiting, which is the loss of the utility advantage of ownership.

Whenever a homeowner with a mortgage chooses to rent in the next period, she has two options: sell or default on the mortgage. In case of selling the household receives the selling price net of capital gain/loss and transaction costs. However she has to pay the outstanding mortgage debt back to the lender. Given that the transaction cost is positive and there is a chance of capital loss, it is possible that the household has negative equity in the house. As a result she might choose defaulting over selling. This is exactly what we see in Figure 1(b) which displays selling vs defaulting choice as a function of income and mortgage debt. First of all for sufficiently small amount of debt, the household never defaults. This is because in this region the household has always positive equity in her house. As debt increases it is more likely that the household has negative equity which triggers default. Notice that even the household is in negative equity she might not choose to default, because default is costly due to exclusion from housing market. As a result there are some states of the world in which the household sells the house although she is under water, and pays the difference through her wealth. However as income decreases this option becomes less likely. Thus as income decreases household becomes more likely to default.

At this point, it is important to emphasize that in the steady-state the only trigger factors for foreclosures are the income and the moving shocks since there is no aggregate house price movements. Remember that the minimum down payment in the initial steady-state is 0 percent. Moreover, selling a house requires to pay some transaction costs (10 percent in the current calibration). So, it is possible that households with mortgage loans higher than 90 percent of the house price are effectively underwater if we think the house price as the net amount households receive after the transaction costs. However, without income or moving shocks, these households never choose to default on their mortgages. As they receive an income shock, they might not afford the periodic mortgages, and should decide to default on the mortgage. Or if they receive moving shock, they are forced to quit the homeownership, and in that case they might find it optimal to default rather than sell the house at a loss. While income and moving shocks are the only trigger events for foreclosures in the steady-state, as we see later, if the economy is hit by an unexpected shock, and the house price drops, then the change in the house price becomes the main force behind the foreclosures.



(a) Rent vs Own

(b) Sell vs Default

Figure 1: Tenure Decisions as a Function of Income and Wealth: The figure shows the choice of tenure for a renter and a mover as a function of income and asset. The choices are depicted for an individual at the age of 30.

Figure 2 shows the homeownership rate over the life cycle for different income levels. It is clear from this picture that early in the life-cycle a few households have enough asset to purchase a house, mainly high-income, high-wealth households. Over time, as households accumulate enough wealth they buy their houses. It is also seen that unemployed are less likely to own a house. There are two reasons behind it. First, even if an unemployed owns a house the default probability (hence defaults) is larger. Second, if she does not have a house she needs to wait to find a job since the liquid assets may be needed.

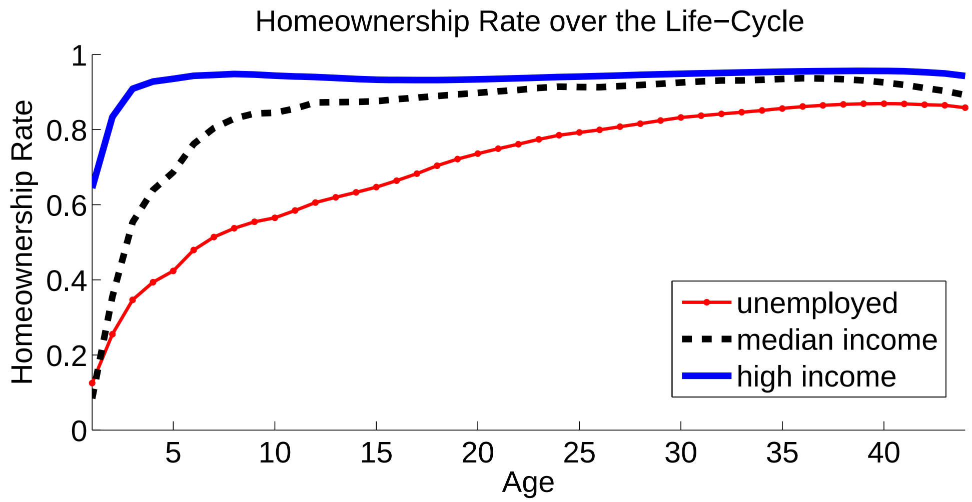


Figure 2: Homeownership Rate over the Life-Cycle: Homeownership rate among different income deciles over the life cycle

In the steady state the main source of the foreclosures is the unemployed (Figure 3). At the early periods of the life only the wealthy people buy a house. Otherwise they would have to pay large risk premia. As a consequence the foreclosure rate is small during the early life. Once consumers accumulate some amount of wealth for down payment they buy a house. But if they get unemployed and if they receive a negative idiosyncratic house value shock they become more likely to default. Otherwise, they will have to pay mortgage which will cause a sharp decline in consumption. So, we observe that foreclosures are common among the lower income households and early in the life-cycle.

Figure 4 shows how the mortgage premium responds to the down payment fraction for different income levels. As the down payment fraction decreases, loan-to-value ratio increases, meaning the amount of mortgage debt the household receives increases. Since higher mortgage debt results a higher likelihood of default on the mortgage, lenders incorporate this increase in the default probability into the mortgage premium. Notice that households only default when house value net of transaction costs is smaller than the mortgage debt, and this happens due to the transaction costs involved in selling the house and the idiosyncratic house price shocks sellers receive during their transactions in the steady-state. In the case of default, the lender seizes the house, and sells the house in the market. Since the lender faces at least the same costs the household faces in the housing transaction, the lender will incur some loss at the time house selling. This loss will be reflected as a default premium into

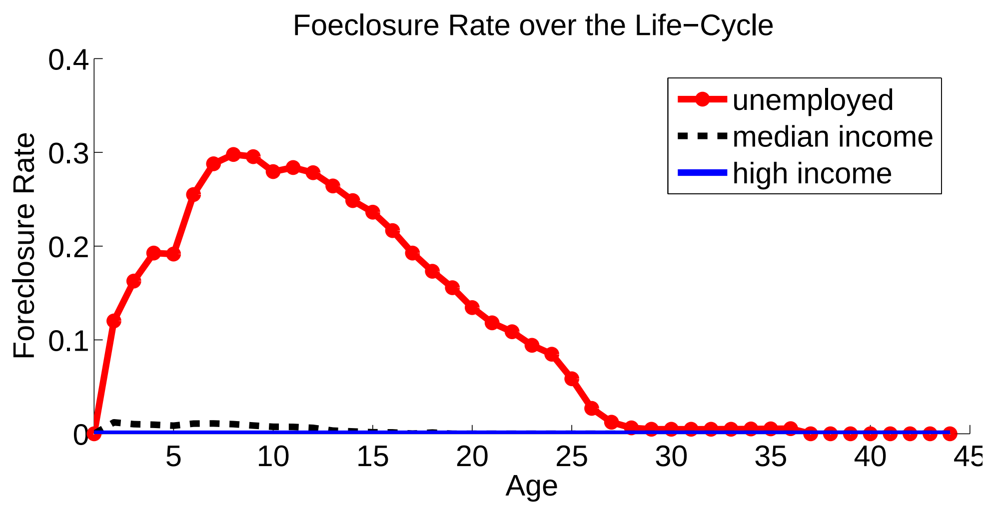


Figure 3: Foreclosure Rate over the Life-Cycle: Foreclosure rate among different income deciles over the life cycle

the mortgage interest rate. In Figure 4, we see that for every income level as down payment fraction increases mortgage interest rate decreases. Moreover as the down payment fraction exceeds a certain threshold, which is around 10 percent given the current parametrization, the loan effectively becomes riskless, and the mortgage interest rate equalizes to the risk-free interest rate. Another observation we can derive from Figure 4 is the effect of income on the premium. As we know from Figure 1(a), higher income implies less likelihood of default for the same amount of mortgage debt. Thus, we expect the premium to decrease as the income increases. This is what we see from Figure 4.

6 Steady State Comparisons

We assume that the economy has been in the steady-state initially at the risk-free interest rate set to 2 percent, the unemployment rate set to 5 percent, and the minimum down payment set to 0 percent. We consider four scenarios. In each case the shock is permanent and unexpected. In the first scenario the economy is hit by an interest rate shock (the risk-free interest rate increases from 2 percent to 3 percent). In the second scenario we shock the economy with a financial shock; the minimum down payment requirement increases from 0 to 20 percent. In the third scenario the unemployment rate increases from 5 to 6.5 percent. Finally, as the last scenario we study a case where all the three shocks are realized together. We assume that in all steady-states homeownership rate is fixed at 68.8 percent, and we solve for the house prices endogenously.

Table 2 presents the comparison of the steady-states along several important dimensions.

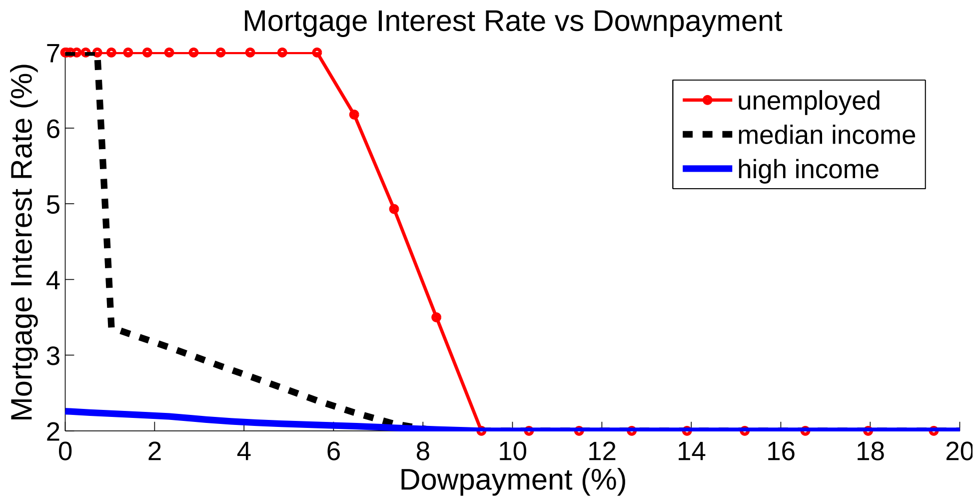


Figure 4: Mortgage Interest Rate: The figure shows equilibrium mortgage interest rate charged by the lenders to an individual with different income levels at the age 30 as a function of the down payment.

In the table, the second column (SS1) shows the results for the initial steady-state. In the third column (SS2), we see the results when the economy is hit by only the risk-free interest rate shock. In this case, the house price declines by around 11 percent. The increase in the risk-free interest rate increases the cost of financing a house through mortgages since it also increases the mortgage interest rate. The increase in the cost of mortgages decreases the demand for houses. Since we fix the homeownership rate to 68.8 percent, meaning owner-occupied housing supply is fixed, this requires a decrease in the house price.

However, in the new steady state, although the house price is lower, the mortgage default rate is also lower. It declines to 0.2 percent. As the economy moves from the low interest rate state to the high interest rate state, mortgage payments become larger for a given loan amount (due to higher risk-free interest rate). This pushes the foreclosure rate up. However, there is also an opposing effect. In the high interest rate regime, lenders require a larger mortgage premium for a given loan amount to compensate the increase in the default probability. This makes lower down payment loans less affordable. As a result, households put larger down payments (average down payment increases from 25.5 percent to 33 percent) to avoid the higher cost of borrowing (due to higher interest rates). Moreover, thanks to the high risk-free interest rate, households are also wealthier (wealth-income ratio increases from 4.1 to 4.6). This, in turn, means households have lower leverage levels, which decreases the likelihood of default. The current calibration of the model suggests that the second effect dominates, and we observe a lower foreclosure rate in the second steady-state.

In the third steady state (SS3), the risk-free interest rate stays at 2 percent, the unemployment rate stays at 5 percent, but the minimum down payment rate increases from 0 to

Table 2: **Steady-State Comparisons**

Statistic[a]	SS1 **r=2% λ=0% u=5%**	SS2 **r=3% λ=0% u=5%**	SS3 **r=2% λ=20% u=5%**	SS4 **r=2%** λ=0% **u=6.5%**	SS5 **r=3% λ=20% u=6.5%**
Homeownership rate	68.8%	68.8%	68.8%	68.8%	68.8%
Price to income ratio	3.0	2.68	2.80	2.82	2.51
Foreclosure rate	1.7%	0.2%	0%	1.2%	0%
Down payment ratio	25.5%	33%	33%	27.5%	35.4%
Mortgage Premium	0.1%	0.001%	0%	0.03%	0%

[a]This Table compares the steady-states for different risk-free interest rate, minimum down payment requirement and unemployment shock. SS1 shows the results for the benchmark economy. SS2 shows the results when the risk-free interest rate increases to 3%. SS3 shows the results when the minimum down payment requirement increases to 20%. SS4 shows the results when the unemployment increases to 6.5%. Finally SS4 shows the results when all these changes happen simultaneously.

20 percent. The decline in the house price in this steady state is smaller compared to the interest rate shock (around 7 percent in SS3 as opposed to 11 percent in SS2). The foreclosure rate is almost zero, since with 20 percent down payment it is unlikely to have negative home equity even in the presence of transaction costs, which are around 10 percent, and idiosyncratic house price shocks. Notice that with higher minimum down payment requirement, the average down payment in the economy is 33 percent. So, households never choose to default on their mortgages, and mortgages essentially become risk-free.

In the fourth steady state (SS4), the economy moves from 5 percent unemployment rate to 6.5 percent unemployment state.[21] All the other parameters are assumed to stay the same as in SS1. As the income becomes riskier and permanently lower, the demand for a rigid asset (housing) declines, and as a consequence, the price of a house declines by 6 percent (from 3 to 2.82). Again due to the increased risk, lenders require higher mortgage premium, and this makes larger loans less affordable. So, again, the average down payment ratio increases from 25.5 percent to 27.5 percent. On the other hand, the increase in the unemployment rate makes households more riskier, and more likely to default. However, with the current calibration , the effect of a decrease in the house price together with an increase in the average down payment dominates and the foreclosure rate decreases to 1.2 percent in the new steady state.

[21]This exercise not only captures a riskier income profile but also includes a decrease in the expected income. We calibrate the unemployment rate so that it results a drop of 5 percent of the average income as we observe in the data. This gives us 6.5 percent unemployment rate. We also repeated this exercise by fixing the average expected income while making the income more riskier through high unemployment rate. Then, the house price drops to **2.9** instead of **2.82**. And the dynamics during the transition are similar but quantitatively smaller in magnitude. The results are available from the authors upon request.

Lastly, when we apply all the shocks together, the house price declines around 17 percent from 3.0 to 2.51. As the minimum down payment is 20 percent in this new economy, the foreclosure rate is zero percent and the average down payment is 35.4 percent (as the ones with smaller than 20 percent are not allowed any more). The higher response is through the combination of all channels discussed above. Higher interest rate and higher minimum down payment make mortgages less affordable. Higher income risk makes households more riskier, and forces the lenders to increases the mortgage premium, which, again, decreases the demand for mortgages. These forces decreases the demand for houses, which, in turn, results a decrease in the house price. However, the foreclosure rate is 0 percent thanks to the 20 percent minimum down payment requirement which makes mortgages risk-free for the lenders.

6.1 The Effect of Long-Term Mortgages and Default

The rate of the response of the house price to movements in the interest rate is significant, and it is larger than most of the models studied in the literature. The existence of long term mortgage contracts, the option of default, and the transaction costs in the housing market are key ingredients in the model that generate large house price movements. As housing is rigid in the model, and the mortgages are long-term contracts with fixed rates, once an agent buys a house the effect of a change in the interest rate goes beyond one period. Moreover, the option of default can potentially decrease the effective demand for houses. To check for the importance of long-term mortgages and the option of default, Table 3 compares the performance of the model by relaxing each of these assumptions one at a time. In each case, we calibrate the ownership premium to match the homeownership rate of 68.8 percent.

When we assume one-period mortgage instead of long-term mortgages, the change in the interest rate does not create any significant impact on the house price. One of the main reasons for this small effect is the compositional effect long-term mortgages have on the house price. Without long-term mortgages, every household in the economy should respond immediately to the change in the environment by changing their mortgage portfolio. This means high-income, high-wealth households will also effect the demand for houses together with the low-income, low-wealth households. However, the housing demand of high-income and high-wealth households is less sensitive to the shocks compared to the low-income, low-wealth households (see Figure 1(a)). However, with long-term mortgages, the households who change their housing portfolio once the shock is realized is a selected group of households; mainly low-income and low-wealth households. So, their housing demand can potentially respond more to the change in the environment. This makes the house price more sensitive to the shocks compared to a case with one-period mortgages. Moreover, in the presence of one period mortgage, the model requires an ownership premium of 3.6 instead of 1.37 we

Table 3: **Model Robustness**

	Benchmark		One period Mortgage		No Default	
Statistic[a]	SS1	SS2	SS1	SS2	SS1	SS2
Homeownership rate	68.8%	68.8%	68.8%	68.8%	68.8%	68.8%
Price to income ratio	3.00	2.68	3.00	2.99	3.00	2.85
Foreclosure rate	1.7%	0.2%	0.6%	0.3%	0%	0%
Down payment ratio	25.5%	33%	47%	51%	33%	34%
Mortgage Premium	0.1%	0.001%	0.002%	0.001%	0%	0%

[a]This table compares the change between the initial and final steady states in response to an increase in the risk-free interest rate with different modeling assumptions. The second and the third columns show the results for the benchmark economy. The fourth and the fifth columns show the results when we assume one-period mortgage instead of long-term mortgages. The sixth and the seventh columns show the results when we do not allow default option for the mortgages. In each model, homeownership premium is calibrated to match the homeownership rate of 68.8%.

calibrate for the benchmark economy. This means ownership should give 260% higher utility from the same consumption compared to renting.

Similarly, we check the performance of the model once we shut down the default channel. This requires the ownership premium to be 1.41, similar to the original calibration. However, now the response of the house price to the change in the interest rate is less than one half of the change in the benchmark case. The presence of default option forces also the lenders to react to the shocks. As the economy moves to a high risk-free interest regime, default becomes more likely for a same size of loan. This increases the premium on mortgages, and in turn decreases the demand for houses.

These two experiments could explain the smaller responses of the house price to the risk-free interest rate found in Garriga etal (2012) and Glaeser etal (2010), both of which assume away the effect of long-term mortgage contracts and foreclosure.

7 Transition

Comparing just the steady states masks important dynamics during the transition. To better understand the dynamic implications of different kinds of shocks, we also analyze the transition between the two steady-states. The main difference between the steady-state dynamics and the transitional dynamics comes from the fact that in the steady-state each household and lender make their housing and mortgage plans according to the new environment. However, in the transitional exercise, we can see the response of some households who made their housing and mortgage plans with the assumption of the initial steady-state expectations, but after the shocks are realized they need to revise their expectations, and react to the new environment. The nature of the exercise is the following. We first assume that the economy is in the initial steady-state as in the benchmark economy described above. However, at time 1, the economy is hit by an unexpected and permanent shock. Then, we solve the transition of the economy from the initial steady-state to the final steady-state with perfect foresight about the house prices. As in the steady state analysis, we assume that during the transition, the homeownership rate is fixed at 68.8 percent.[22]

In the following transition exercises, we separately study the transition in response to an increase in the risk-free interest rate, an increase in the minimum down payment requirement, and an increase in the unemployment rate. All three shocks are permanent and unexpected. Since, it is more likely that all these shocks happened together during the latest financial crisis, we also study a scenario where all the three shocks affect the economy together. In the first transition exercise we provide extra information about various variables. For the other transition exercises we only depict prices and foreclosures (our key variables of interest for this study) since the dynamics of other variables look similar for different exercises.[23]

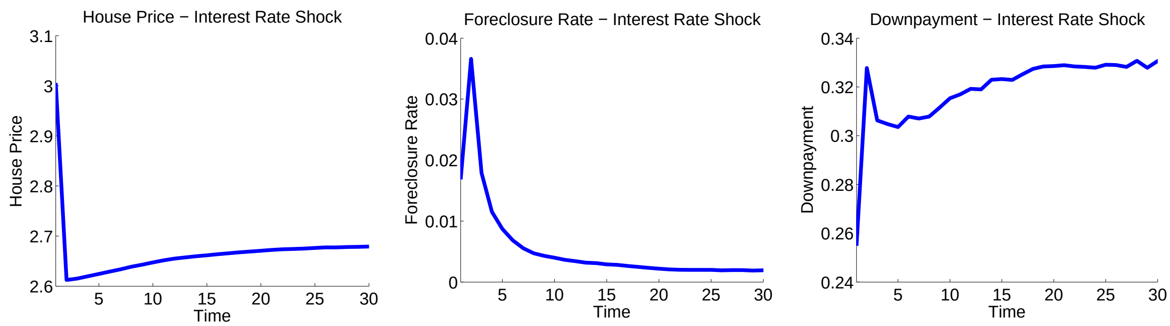
Transition with only interest rate shock: In response to a permanent and unexpected rise in the risk-free interest rate (from 2 percent to 3 percent), the demand for homeownership decreases as the cost of mortgages increases. This decreases the demand for houses, and decreases the house price. Different than the steady-state dynamics, now, some households are caught up with larger mortgage debt which were acquired with the assumption of initial steady-state house price. Some of these underwater households default on their mortgages, which increases the effective supply of houses. Moreover, since defaulters are excluded from the mortgage market for a while, the effective demand also decreases. Thus, the house price needs to decline sharply to the levels below the second steady state to achieve the homeownership rate of 68.8 percent. After the first fall, the house price increases gradually to the second steady state level as the effective supply decreases and effective demand increases as fewer households default.

At this point we should note that there is a feedback mechanism from the house prices to the foreclosure rate and from the foreclosure rate to the house prices. A fall in the house price initiates an increase in the foreclosure rate since some homeowners who end up having negative equity in their houses choose defaulting. This increases the effective house supply.

[22] So, the numbers reported here can be interpreted as upper bounds for the effect of the shocks on house prices and foreclosures. A complete analysis should simultaneously endogenize ownership rate and house prices, which requires a model with endogenously determined rental and owner-occupied housing supply.

[23] One drawback of the below transition exercises is the omission of the response of the lenders to the shocks on impact. In the initial steady-state lenders originate the mortgage loans to make zero-profit. However, with the realization of the unexpected shock, lenders make losses on these loans, and since we do not model the lender balance sheet we do not carefully treat how the lenders respond to these shocks. We basically assume that these lenders are the international investors, and they cover their losses with their additional wealth. If we further assume these investors face no financing constraint and they are risk-neutral, then the reduction in their wealth should have no effect on the newly generated mortgage loans.

That extra supply pushes the house price even lower, which, in turn, increases the incentives to foreclose due to more people ending up with negative equity. Moreover, households who choose to foreclose are stochastically excluded from the market. This fact decreases the effective demand for houses, which in turn decreases the house price even further. As a consequence of these feedback mechanisms the house price falls sharply after the interest rate shock. When the house price dips, it starts gradually to appreciate to its new steady state value. As the house price starts to appreciate the foreclosure rate starts to decline.



(a) House Price (b) Foreclosure (c) Down payment

Figure 5: Transition in Response to Interest Rate Shock: The Figures show the evolution of the house price, foreclosure rate and average down payment in response to an unexpected and permanent increase in the risk-free interest rate from 2 percent to 3 percent.

Figure 5(a) shows the evolution of the house price during the transition. Remember that the house price drops by 11 percent (from 3 to 2.68) from the initial steady-state to the final steady state when hit by the assumed risk-free interest rate shock. However, with the transition exercise, we see that on impact the house price drops even further (from 3 to 2.61, a 13 percent drop).

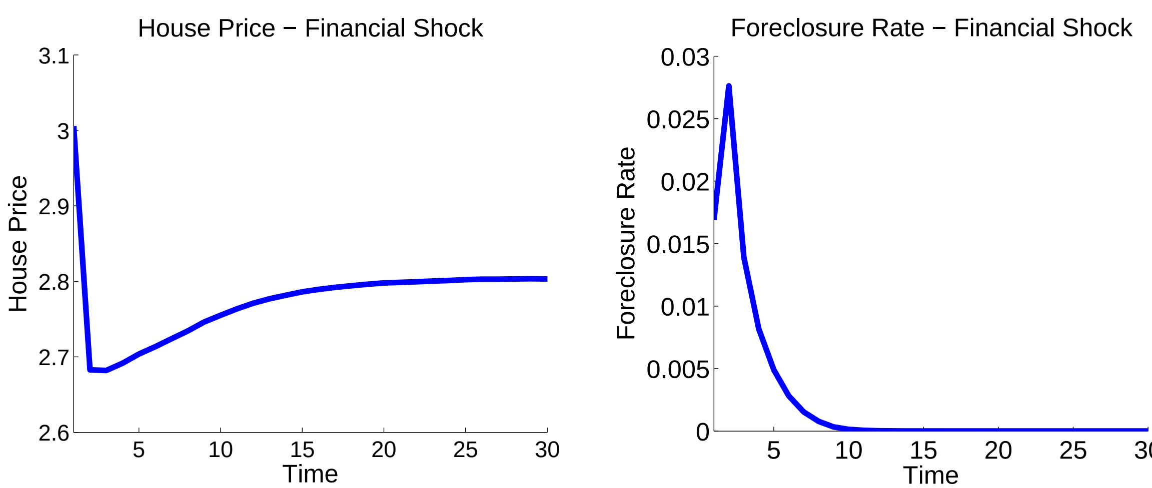
An important difference between the steady states and the dynamics during the transition arises when we analyze the foreclosure rates. As we mentioned earlier the foreclosure rate drops from 1.7 percent to 0.2 percent from the initial steady-state to the final steady-state. However, as shown in Figure 5(b), during the transition, at its peak, the foreclosure rate increases sharply compared to the initial steady state level (from 1.7 percent to 3.7 percent). The results from the steady state and the transition analysis reveal that what matters for the foreclosure rate is the change in the house price, not the levels. The house price is around 11% lower in the final state compared to the initial steady state. Despite the significant difference in the house price levels between the two steady states, the average foreclosure rate is significantly lower in the second steady state. The reason is that at the final steady state, since lenders and households respond to the changes in the environment, equilibrium mortgage contracts change, and the percentage of homeowners who have negative equity is significantly lower than the initial steady-state. Whereas during the transition, households with low levels of home equity go to negative equity with the significant and unexpected drop in the house price. With more homeowners who have negative home equity, the foreclosure rate increases on impact. However, the households adjust their portfolio during the transition, and after a while, the foreclosure rate reaches its new steady-state level.

The initial spike in the foreclosure rate is due to the households who find themselves in negative home equity, and strategically choose to default. However, the higher foreclosure rate after the first period compared to the final steady-state is due to two reasons. On the one hand, it is due to the longer-term mortgages. Not every household adjusts her mortgage portfolio on impact. Other than the negative equity incentive, the main reason for default is the income and moving shocks households receive. Although some households might be financially not constrained at the time of the interest rate shock, they might be financially constrained or forced to choose between selling versus defaulting when they receive the income and moving shocks. However, since the house price is still lower than the final steady-state level, these households have higher incentives to default compared to their incentives in the final steady-state. Hence, it takes some time for the foreclosure rate to achieve its final steady-state level of 0.2 percent.

One merit of our modeling strategy is that we optimally solve for the endogenous down payment ratios and mortgage interest rates jointly in the equilibrium. Consequently, we are able to study the dynamics of the down payment ratio as well. In Figure 5(c) we plot the average down payment requirement during the transition. The average down payment in the model increases from 26 percent to 33 percent initially. After the first jump, the down payment declines to 30.5 percent and then slowly increases to its new steady-state level of 33 percent. The initial spike is the compositional affect. Since the low income households are the ones who default, they are excluded from purchasing the house once they default. So, the new home buyers at the time of the shock are mostly high income and high wealth households compared to the final steady-state. But then as the defaulters start to buy houses they decrease the average down payment since they can afford lower down payment. However, the further increase in the down payment comes from the fact that since the house price is expected to increase during the transition, initial home buyers are subject to lower risk of default since they are less likely to end up with negative home equity. So, the initial mortgage premium is lower, and this makes lower down payment affordable initially. However, over time the expected increase in the house price drops, and the mortgage premium returns to its final steady-state level. This makes lower down payment less affordable.

Transition with only financial shock: In our model, the lender is a risk neutral agent and has unlimited financing opportunities at the given risk-free interest rate. However, with the crisis, lenders had difficult times in financing themselves. There are several mechanisms, such as decline in collateral values, increase in haircuts which made the borrowing difficult for financial companies to raise funds to give loans. Besides, there was an urgency to deleverage which required selling assets on their book without issuing sizable loans. In addition, the uncertainty about the financial health of the lenders made things even worse. These mechanisms do not exist in our model. To simulate the effects of financial turmoil we exogenously force lenders in our model to require a 20 percent minimum down payment unexpectedly and permanently.

Figures 6(a) and 6(b) show how house prices and foreclosures are affected from this shock. First of all, comparison of the steady-states reveals that the house price drops by 7 percent (from 3 to 2.8), and foreclosures decrease from 1.7 percent to 0 percent. However, during the transition the dynamics are quite different. A 20 percent permanent and unexpected increase in down payment requirement causes around 11 percent decline in the house price on impact. The main reason is that a higher minimum down payment requirement imposes a limit on the affordability of the houses through mortgages for the potential home buyers. Consequently, once the shock is realized the number of potential buyers declines, and the demand for houses declines. Over time people accumulate more assets and overcome the constraint. But as the young agents cannot easily accumulate that much asset the house price does not recover to the initial level even in the long run. Foreclosures sharply rise to around 3 percent on impact and then declines to very low levels around zero. Very low levels of foreclosures in the second steady state is due to the larger down payment requirement, which makes the probability of experiencing negative home equity zero and makes mortgages essentially risk-free.



(a) House Price (b) Foreclosure

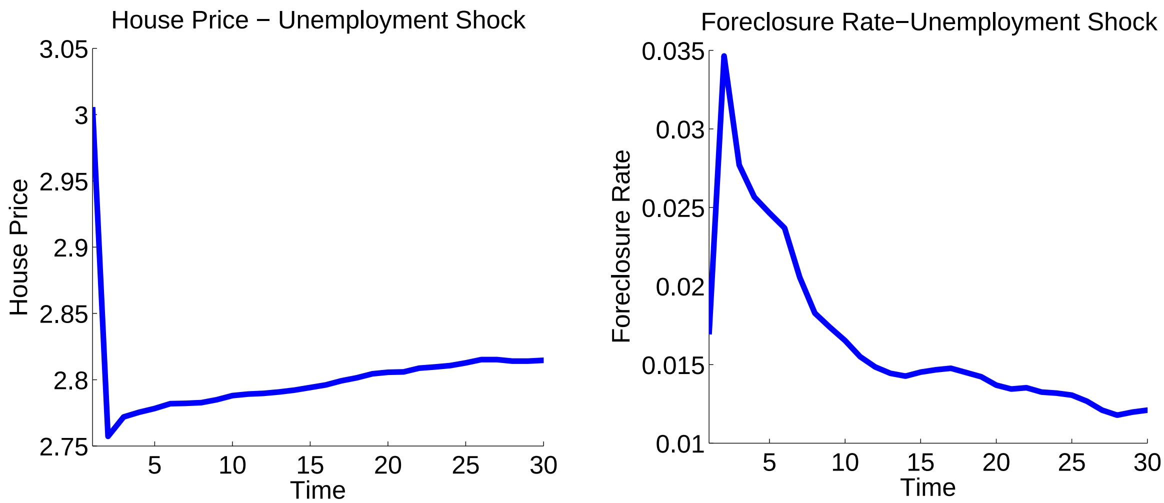
Figure 6: Transition in Response to Financial Shock: The Figures show the evolution of the house price and the foreclosure rate in response to an unexpected and permanent increase in the minimum down payment requirement to purchase a house from 0 percent to 20 percent.

Transition with only unemployment shock: During the financial crisis the U.S. economy has experienced a deep recession and shrank around 5 percent. Despite the size of the recession it can be thought that it should potentially have a small affect on the house price and the foreclosure rate since estimated income elasticity of housing is small (see Carliner (1973)). One critical point, we believe, is that not every household is effected in the same way. While some incurred only small losses in their income, some got unemployed, which is a small probability but a very costly event. Hence, it is likely that a rise in unemployment can have quantitatively large and significant effects on house prices and foreclosures.

To understand the effect of unemployment and income risk, we run the following experiment. We assume that when the economy is in its initial steady-state, it is hit by an unexpected unemployment shock, and the unemployment rate increases from 5 percent to 6.5 percent immediately and permanently. From the steady-state comparisons, we know that this shock decreases the house price by 6 percent (from 3 to 2.82). However, on impact, thanks to the unexpected nature of the shock and the feedback mechanism between foreclosures and the house price, the effect is bigger: the house price drops by 8 percent (from 3 to 2.76, see Figure 7(a)). Although the foreclosure drops from 1.7 percent to 1.2 percent between the steady-states, during the transition it spikes to the levels around 3.5 percent (see Figure 7(b)). Remember that households either default strategically due to the house price movements or they default due to some trigger events, like income or moving shocks. The increase in the unemployment shock increases the probability of receiving the income shock, and forces households to default more frequently. But as the economy converges to a high unemployment steady state, lenders respond to the increase in the unemployment shock by increasing the mortgage premium and by making mortgages less affordable and less available to the household. This response of the lenders increases the average down payment in the economy and gradually decreases the foreclosure rate to its final steady-state levels.

Transition with all three shocks together: In the previous simulations we studied the effects of an interest rate shock, an unemployment shock, and a financial shock separately. However, in reality all of them happened together during the crisis. In particular we study the transition where the interest rate increases from 2 percent to 3 percent, the minimum down payment households are required to put during the purchase of the house increases from 0 percent to 20 percent, and the unemployment rate increases from 5 percent to 6.5 percent.

Figure 8(a) plots the path of the house price, and Figure 8(b) plots the path of the foreclosure rate when all shocks hit the economy together. As would be predicted the response of both house prices and foreclosures are larger. The house price declines around 28 percent on impact (from 3 to 2.15). The second steady state of the house price is around 17 percent lower than the first steady state (from 3 to 2.51). The foreclosure rate initially jumps to



(a) House Price

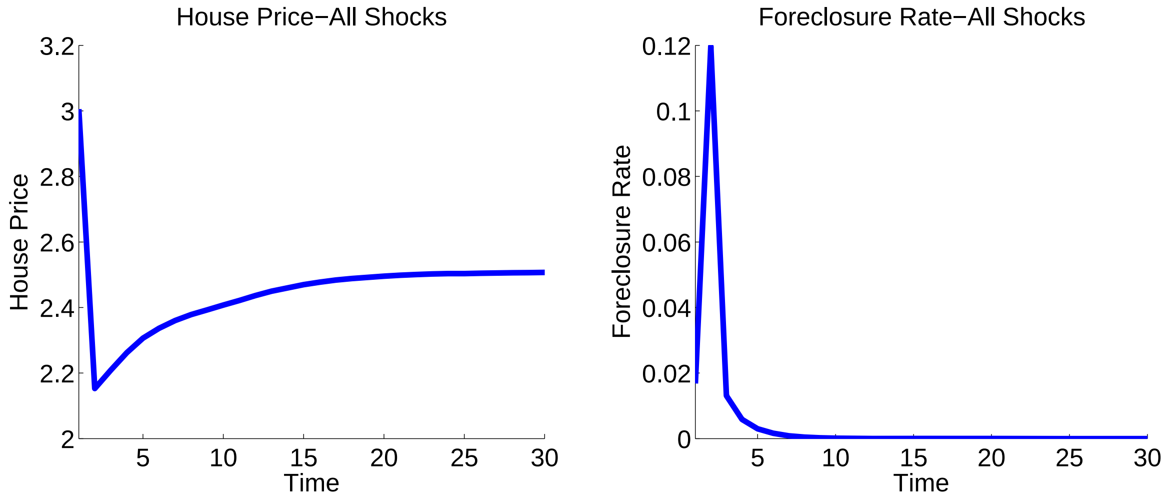
(b) Foreclosure

Figure 7: Transition in Response to Unemployment Shock: The Figures show the evolution of the house price and the foreclosure rate in response to an unexpected and permanent increase in the unemployment rate from 5 percent to 6.5 percent.

the levels around 12 percent and immediately declines to the levels even smaller than the initial steady state, and quickly reaches to the levels of the final steady-state, 0 percent. Our results show that, these three shocks all together can bring a relevant explanation to the large responses of house prices and foreclosures during the latest financial crisis.

Taking Stock: Figure 9(a) shows a comparison of the transitions in response to the above defined shocks. As it is clear from the graph, the shock which is responsible for the largest decline in the house price is the interest rate shock. However, the nonlinear dynamics in the model results a larger impact of the combination of the three shocks. With all three shocks in place, the mortgages become less affordable. Higher risk-free interest rate increases the mortgage interest rate making mortgage payments larger, and high unemployment rate increases the mortgage premium due to higher income risk of the households, and they both make mortgages less affordable. High minimum down payment requirement leaves low-wealth, low-income households out of the housing market. The combination of these three factors makes many households not afford to purchase a house. As a result, the demand for houses decreases sharply, and the house price drops by 28 percent on impact.

Figure 9(b) shows the same comparison for the foreclosure rate. Here the message is the same as in the house price case. In steady-state the main triggers for foreclosures are the income and the moving shocks. When a mortgage holder is hit by an income shock, she might not afford the mortgage payments, find it optimal to quit homeownership. In that case, if the house price net of selling costs (10 percent in the benchmark calibration) and



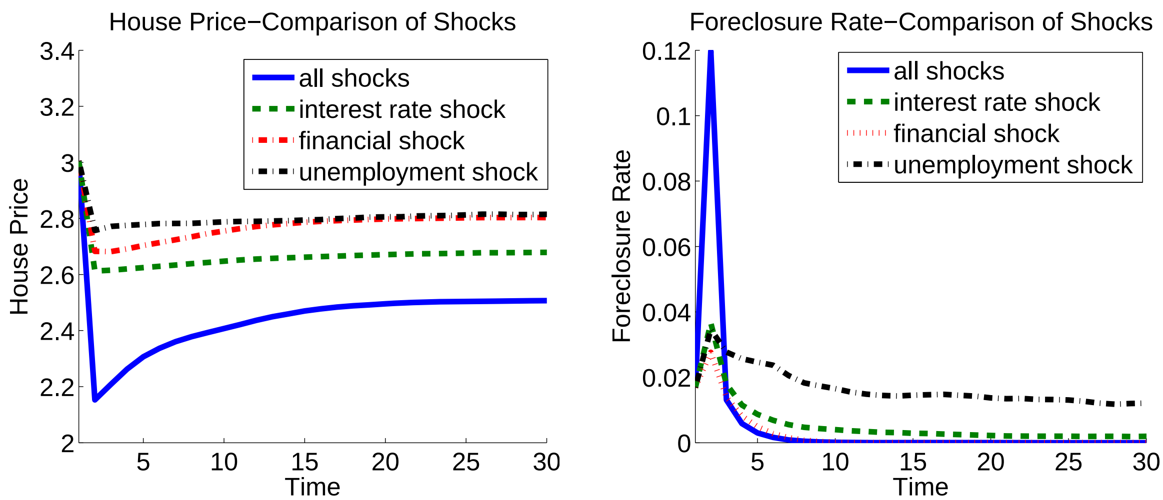
(a) House Price

(b) Foreclosure

Figure 8: Transition in Response to All Three Shocks: The Figures show the evolution of the house price and the foreclosure rate in response to an unexpected and permanent increase in the risk-free rate from 2 percent to 3 percent, an increase in the minimum down payment requirement from 0 percent to 20 percent and an increase in the unemployment rate from 5 percent to 6.5 percent.

i.i.d. house price shocks is lower than the mortgage balance, the household might find it optimal to default instead of selling the house. The same mechanism also applies to the case when the household receives moving shock. In either case, the necessary element for default is the negative home-equity position of the mortgage holder. However, in the steady-state, the homeowner never finds it optimal to default without receiving the income or the moving shock.

When the economy is hit by the above defined unexpected shocks, the house price unexpectedly drops significantly. This drop in the house price leaves many mortgage holders with negative home-equity. Since these households purchased their houses when the house price was higher, they might strategically find it optimal to default on their existing mortgages, and purchase another house at the lower price when their default flag is cleared. Moreover, whenever the household receives either the income or the moving shock, with the lower house price, the incentive to default on the mortgage is higher compared to the initial steady-state when the house price was higher. So, as the drop in the house price becomes larger, the incentive to default increases, and we observe an increase in the foreclosure rate. This is exactly what we see in Figure 9(b). The drop in the house price is the largest (28 percent on impact) when all shocks hit at the same time, and in this case the foreclosure rate increases to very high levels (12 percent on impact).



(a) House Price

(b) Foreclosure

Figure 9: Comparison of Transitions in Response to Different Shocks: The Figures show the evolution of the house price and the foreclosure rate in response to different unexpected and permanent shocks: an increase in the risk-free interest rate from 2 percent to 3 percent, an increase in the minimum down payment requirement from 0 percent to 20 percent, and an increase in the unemployment rate from 5 percent to 6.5 percent.

8 Policy Experiments

In the remaining parts of the paper we study how two specific policies would affect the transition dynamics. In particular, we study an ex-post monetary policy and an ex-ante macroprudential policy. As a monetary policy, we consider the FED's low interest rate policy. As a macroprudential policy, we consider imposing a higher minimum down payment requirement. We study how the model dynamics would change during the transition in response to these two policies.

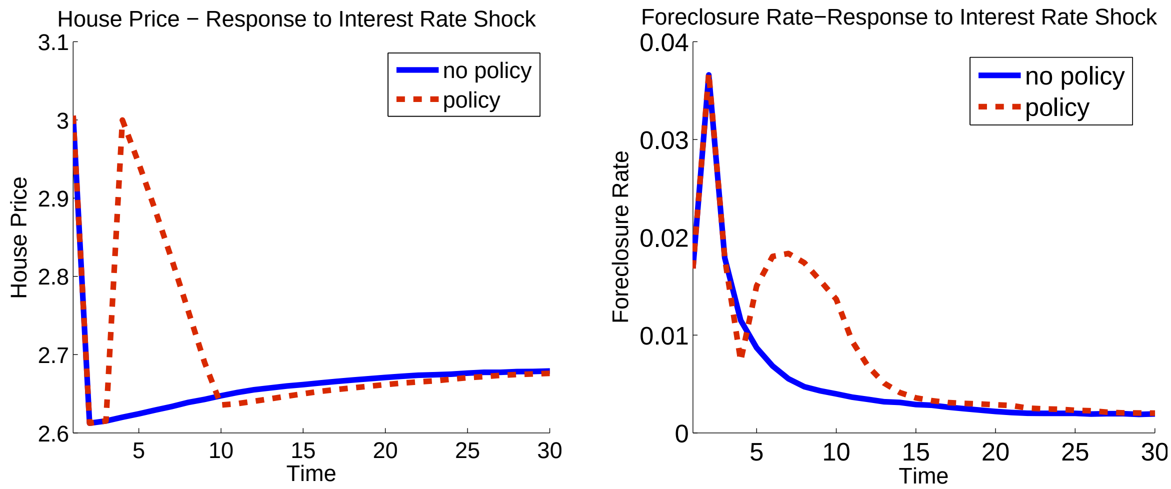
8.1 Monetary Policy

As a response to the financial crisis, the FED decreased the funding rate. In addition to that policy, the FED also stated that the policy rates will stay low for a prolonged period of time. As of now, in the policy statements it is mentioned that the policy rates will be low until mid 2015. In this part of the paper we analyze the potential implications of this policy. In particular, we study the transitional dynamics of our model in response to the FED's monetary policy in the presence of the above studied permanent, unexpected shocks. More specifically, we assume that in response to the shocks, the FED lowers the risk-free interest rate to 0.5 percent, and commits to this policy for a predetermined period of time. Consequently, agents in our economy know that low interest rate policy of the FED will be transitory. We also study how the length and the timing of the FED's low interest rate policy affects the transition. In particular, we first assume that the policy takes place 2 periods after the shocks are realized and continue either for 3 and 6 periods (which corresponds to a year).[24] We also analyze the timing of the policy by assuming the policy takes place as soon as the shocks are realized. In all these experiments, we analyze the effectiveness of the monetary policy in 4 different shock scenarios: interest rate, unemployment, financial (higher down payment requirement) shocks, and all the shocks combined.

Interest rate shock: In Figures 10(a) and 10(b) we plot the response of the house price and the foreclosure rate during the transition when the FED implements the above described policy in response to a higher interest shock only (an increase from 2 percent to 3 percent). We assume that economy stays in the high interest rate state for 2 periods. In the third period the FED lowers the risk-free interest rate to 0.5 percent, and commits to this policy for 6 periods. As a response to the FED's announcement, the house price appreciates rapidly and significantly and then declines to the low levels as policy end date becomes closer. As shown previously, without the policy the foreclosure rate increases sharply with the fall in the house price but then stabilizes. In the case with the FED policy, the foreclosure rate does not stabilize as rapidly as the case without the FED policy. Hence, it takes more time for the foreclosures to converge to its low steady state levels. The reason for the significant response of the house price to the FED's policy, even though it is temporary, is that the FED's policy just reverses the effects of the original shock. The house price drops initially due to high interest rates which make mortgages less affordable. However, when the FED implements its policy after 2 periods, mortgages become more affordable, and this increases the demand for houses. Notice that the house price only increases to the levels of the initial steady-state when the risk-free interest rate was 2 percent. A risk-free interest rate of 0.05 percent in this economy implies a house price of 3.68 in the steady-state. The house price with the FED policy does not increase to those levels since households know the house price will be lower in the near future due to the temporary nature of the policy, and delay their house purchases. The large but short swing in the house due to the FED policy creates a small temporary increase (around 1 percent) in the foreclosure rate. It is important to notice here that although households perfectly foresee the path of the interest rate, on a temporary basis, it creates sizable house price and foreclosure movement.

Financial shock: Next we study the potential effects of the FED policy in response to a financial shock. Here, as a short cut, we again model the financial shock as a permanent increase in the minimum down payment requirement from 0 percent to 20 percent. We

[24] We compare 3 and 6 period policies when we study the scenario where all the shocks hit together. For individual shocks we only study the 6 period case.



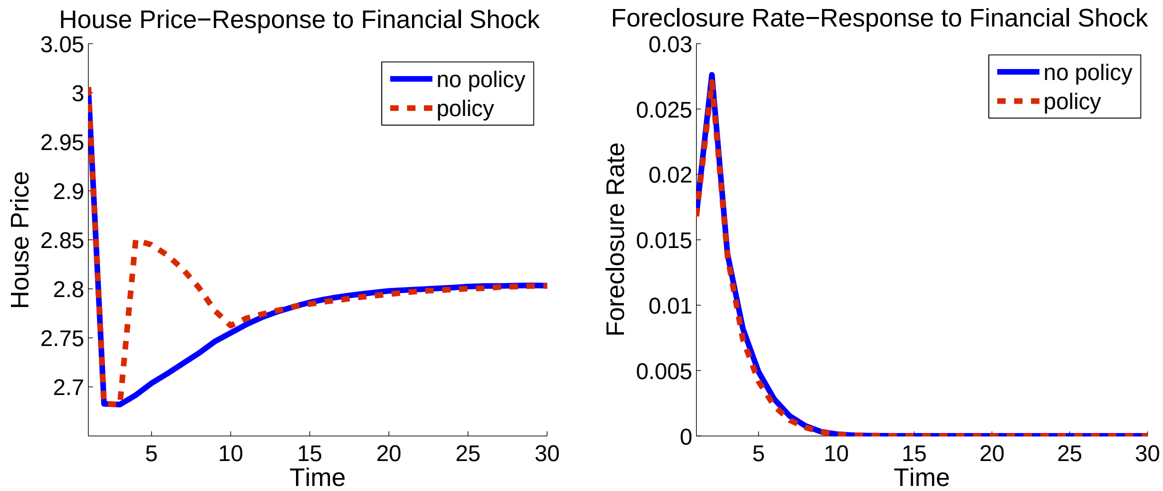
(a) House Price

(b) Foreclosure

Figure 10: The Effect of FED Policy in Response to Interest Rate Shock: The Figures show the evolution of the house price and the foreclosure rate in response to an unexpected and permanent increase in the risk-free interest rate from 2 percent to 3 percent together with a FED intervention after 2 periods of the shock. The FED decreases the risk-free interest rate to 0.5 percent and commits to this policy for 6 periods.

assume that other than the FED policy periods interest rate is fixed to 2 percent. In Figures 11(a) and 11(b) we plot the house price and the foreclosure rate during the transition when there is the FED policy in response to the financial shock. The interest rate policy of the FED seems much less effective in this case compared to the previous interest rate shock case. The policy causes only a small appreciation in the house price even if it is kept low for 6 periods. Similarly, the policy does not have significant effects on the foreclosure rate. The main reason behind the small house price appreciation is that, even if the interest rates are very low, since people are constrained by the minimum down payment requirement, they cannot borrow and then the monetary transmission channel is hampered. So, the monetary policy becomes ineffective. As for the foreclosure, since the effect of the monetary policy on the house price is limited, and moreover, since most of the increase in the foreclosure rate happens in the first period, the policy does not have any significant effect on the foreclosure rate. By the time the monetary policy takes place, the foreclosure rate is below 1 percent even in the absence of the policy.

Unemployment shock: If there was only the unemployment shock, the FED's policies have somewhat larger effects compared to the case of the financial shock. When the policy takes place the house price temporarily increases to the levels even higher than the initial steady-state house price (from 2.76 to 3.04, an increase of 10 percent, see Figure 12(a)). The

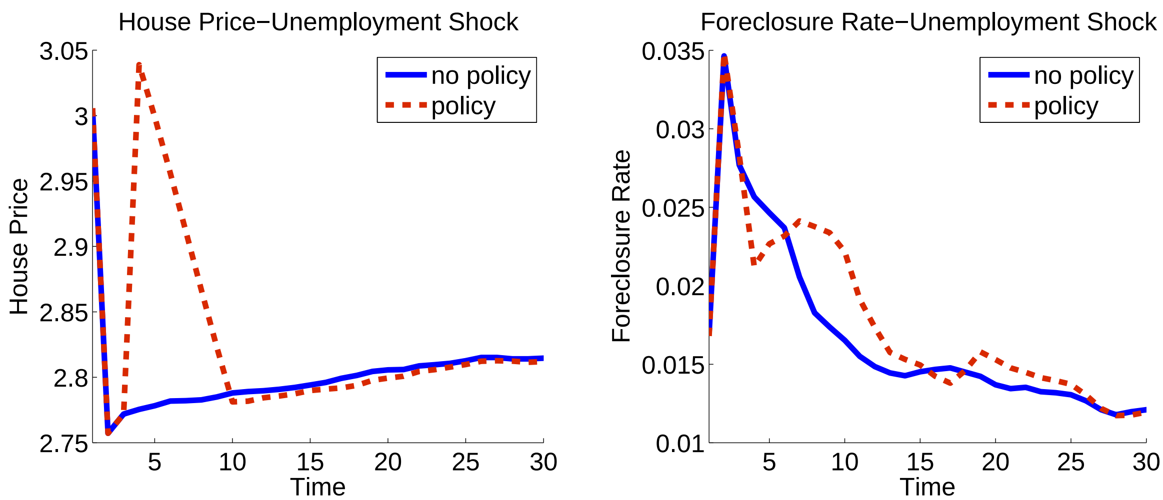


(a) House Price (b) Foreclosure

Figure 11: The Effect of FED Policy in Response to Financial Shock: The Figures show the evolution of the house price and the foreclosure rate in response to an unexpected and permanent increase in the minimum down payment requirement from 0 percent to 20 percent together with a FED intervention after 2 periods of the shock. The FED decreases the risk-free interest rate to 0.5 percent and commits to this policy for 6 periods.

policy here is somewhat effective on the house price, because with lower interest rate and zero minimum down payment requirement, households find mortgages affordable, and this pushes up the demand for houses temporarily. With the unemployment shock, even though the FED policy makes mortgages more affordable, some households still cannot afford them due to two reasons. First, the higher income risk increases the default risk of the households and increases the mortgage premium, which in turn makes mortgages less affordable. More importantly, with higher unemployment rate, the expected income is lower, hence households are less likely to become homeowners. Hence, even with the FED policy, the house price does not increase to the levels it should be in a steady state with 0.5 percent interest rate and 6.5 percent unemployment rate, which implies a house price of 3.48.

When we look at the effect of the FED policy on the foreclosure rate (see Figure 12(b)), we see a similar picture as in the interest shock case. Even though the FED policy has some impact on the house price, the effect on the foreclosure rate is much muted. Again, the main reason for the ineffectiveness of the policy is the temporary nature of the policy and the timing of the policy. When the FED policy takes place (two periods after the shock), the foreclosure rate is very close to its final steady-state levels. Nevertheless, since the FED policy causes the house price to jump by 10 percent temporarily, it helps the foreclosure rate to decrease from 2.6 percent to 2.1 percent as soon as the the policy becomes active. However, as in the interest rate shock case, the FED policy creates large house price swings for a short period



(a) House Price (b) Foreclosure

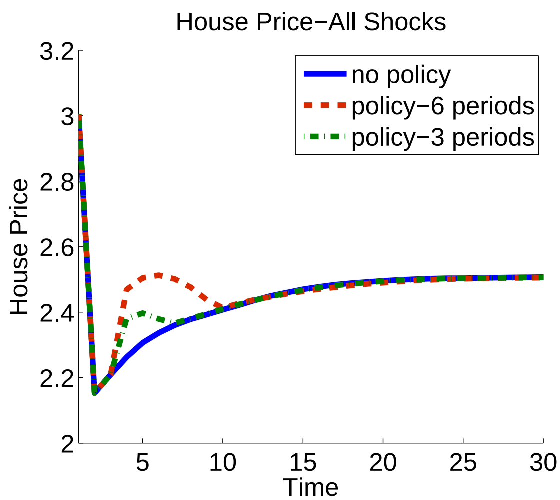
Figure 12: The Effect of FED Policy in Response to Unemployment Shock: The Figures show the evolution of the house price and the foreclosure rate in response to an unexpected and permanent increase in the unemployment rate from 5 percent to 6.5 percent together with a FED intervention after 2 periods of the shock. The FED decreases the risk-free interest rate to 0.5 percent and commits to this policy for 6 periods.

of time. Although this price movement is perfectly foreseen by the households, it creates a slight increase in the foreclosure rate in the next few periods.

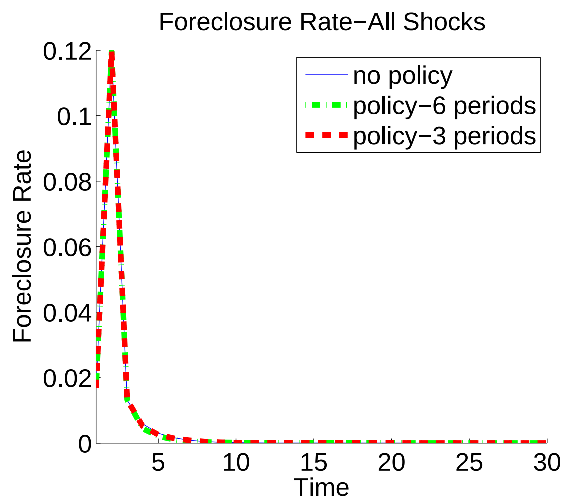
All shocks combined Figures 13(a) and 13(b) show the effect of the FED policy in the presence of all the three shocks analyzed above. We observe that the effect of the FED policy is less effective both for the house price and the foreclosure rate in this case. The main reason is that even the risk free interest rate is lowered to 0.5 percent temporarily, the presence of high minimum down payment requirement and high unemployment risk makes mortgages and houses less affordable. So, the households cannot respond much to the policy in this case. Again, due to the timing of the FED policy and lower response of the house price, the foreclosure rate essentially does not change.

We also experiment on the length of the FED policy. In Figures 13(a) and 13(b), we can also see the effect of the policy if the FED commits to this policy for only 3 periods instead of 6 periods. Not surprisingly, in this case, the FED policy becomes even less effective on both the house price and the foreclosure rate.

In addition, we also analyze the effect of the timing for the FED policy. In Figures 14(b) and 14(b), we see the effect of the FED policy with two different timing assumptions. In the Figures the solid line is the benchmark case with no FED policy. The line with the label “policy in 2 periods” shows the effect of the FED policy once it takes place two periods after



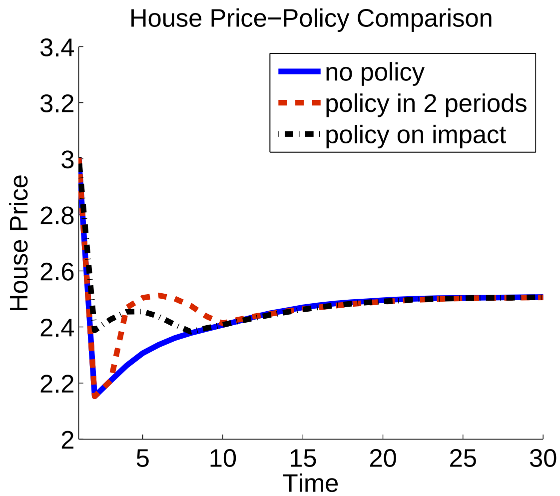
(a) House Price



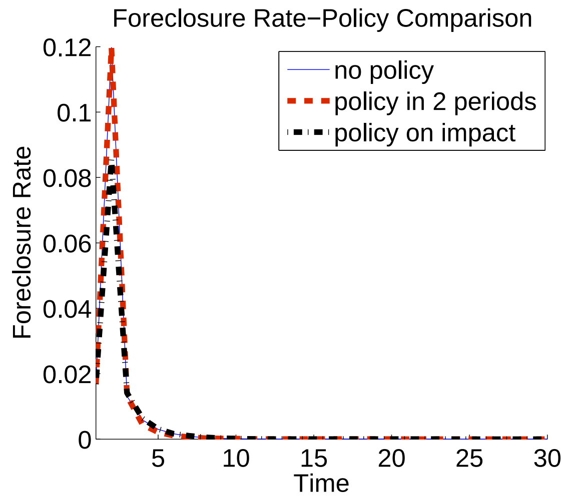
(b) Foreclosure

Figure 13: The Effect of FED Policy in Response to All Three Shocks: The Figures show the evolution of the house price and the foreclosure rate in response to an unexpected and permanent increase in the risk-free rate from 2 percent to 3 percent, increase in the minimum down payment requirement from 0 percent to 20 percent, and an increase in the unemployment rate from 5 percent to 6.5 percent together with a FED intervention after 2 periods of the shock. The FED decreases the risk-free interest rate to 0.5 percent and commits to this policy for a specific amount of time. We both analyze the commitment for 3 and 6 periods.

the shocks are realized. Lastly, the line with the label "policy on impact" shows the effect of the FED policy if it takes place as soon as the shocks are realized. In this case, the drop in the house price and the increase in the foreclosure rate are lower. However, again the effect is not significant due to the presence of high down payment requirement and high unemployment risk.



(a) House Price

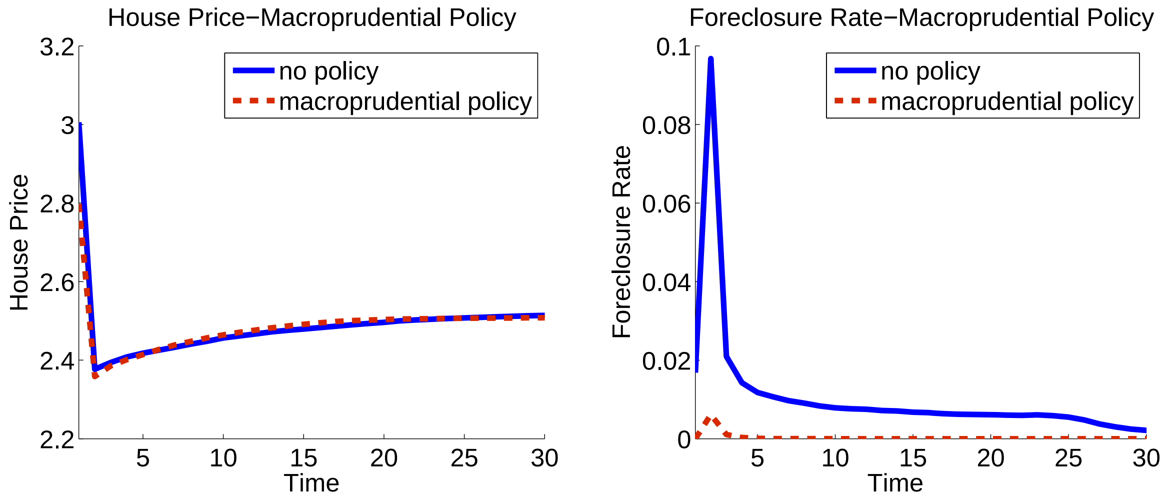


(b) Foreclosure

Figure 14: The Effect of FED Policy in Response to All Three Shocks: The Figures show the evolution of the house price and the foreclosure rate in response to an unexpected and permanent increase in the risk-free rate from 2 percent to 3 percent, increase in the minimum down payment requirement from 0 percent to 20 percent, and an increase in the unemployment rate from 5 percent to 6.5 percent together with a FED intervention. We analyze the case when the FED intervenes to the market by decreasing the risk-free interest rate to 0.5 percent both as soon as the unexpected shocks are realized, and 2 periods after the shocks are realized. In both cases, the FED commits to its policy for the next 6 periods.

8.2 Macroprudential Policy

In the previous section we showed that a policy similar to the FED's interest rate policy has small effects on our main variables of interest. Another possible policy is an ex ante macroprudential policy. The regularity authority can easily enforce a minimum down payment requirement. In the following figures we depict our analysis of how the transition would look like if there has been a 20 percent minimum down payment requirement even before the shocks. In the following analysis we assume that the risk-free interest rate increases from 2 percent to 3 percent, and the unemployment rate increases from 5 percent to 6.5 percent. In order to isolate the effect of the macroprudential policy, we assume that in the benchmark case the minimum down payment requirement does not change and stays at 0 percent. However, with the macroprudential policy in place, we assume that the minimum down payment is 20 percent all along.



(a) House Price

(b) Foreclosure

Figure 15: The Effect of Macroprudential Policy in Response to Shocks: The Figures show the evolution of the house price and the foreclosure rate in response to an unexpected and permanent increase in the risk-free rate from 2 percent to 3 percent, and an increase in the unemployment rate from 5 percent to 6.5 percent together with and without ex-ante macroprudential policy. The ex-ante macroprudential policy we consider here is a 20 percent minimum down payment requirement to purchase a house.

Our results show that both the decline in the house price and the increase in the foreclosure rate are much smaller with the macroprudential policy. Without the policy, the house price drops by 21 percent, whereas with the ex-ante macroprudential policy the house price drops by 16 percent. The house price still drops significantly in the presence of the macroprudential policy because with the higher interest rate and higher unemployment risk, mortgages become less affordable, and the demand for houses decreases. This is the same mechanism working in the case without policy. As can be seen from Figure 15(b), the increase in the foreclosure rate is significantly lower in the case with ex-ante macroprudential policy (0.6 percent versus 9.7 percent on impact). So, the feedback mechanism between the foreclosures and house prices is muted. This results a lower house price drop in the case of ex-ante macroprudential policy. The lower increase in the foreclosure rate with ex-ante macroprudential policy is due to the higher minimum down payment requirement. Thanks to the ex-ante macroprudential policy, when the economy is hit with the shocks, households have higher home equity compared to the case without the policy. As a result, the effect of a drop in the house price on the foreclosure rate is not very effective once the ex-ante macroprudential policy is in place.

We should mention that even though the cost of the shocks to the economy is smaller it does not mean that the welfare is higher with this policy. On the other hand, due to the effect of price movements in on foreclosures it is potentially possible to obtain welfare improving macro prudential policies. The mechanism behind this reasoning is that as individual consumers are price takers they do not internalize how their housing decisions affect house prices. But a social planner can internalize it and implement some policies to improve welfare. This is a topic for future research.

9 Conclusion

The causes of the recent financial crisis and policies to mitigate the effects of the crisis have become an important area of research for the economics. In this paper, we too, deal with these questions. We do this by utilizing an incomplete market life cycle model with housing where we model mortgage contracts in detail. We believe both life cycle structure and the detailed mortgage contracts that we model are crucial for this sort of analysis. It is imperative for the analysis of the mortgage default to know the specifics of the mortgage contract, savings and the income of the mortgage holders. Our model can deal with such complexities.

We follow three steps to perform our analysis. After calibrating the model the US data we study several steady state properties of the data to provide some insights of the workings of the model. Next we identify three shocks which have been potentially effective during the crisis. These shocks are: interest rate increases from 2 percent to 3 percent, minimum down payment ratio increases from 0 to 20 percent, and unemployment rate increases from 5 percent to 6.5 percent. With these three shocks (both separately and together) we study how the model economy responds to them. First we analyzed the steady states, and then the transitions.

One of the main findings from this paper is that transition can be quite different from the steady state. During the transitions, for all the shocks, the response of house prices and foreclosures have been much higher. Most importantly, foreclosures have been very low (around 0) at the steady states, but for all shocks they have been very large especially after the initial realization of the shocks. The main reason behind is that price dynamics but not the levels are important for the default decision.

Lastly we use the model to try to understand the implications of some policies. As the first policy we study a case where interest rates become low temporarily for a specified period of time. By this we intend to mimic the FED's monetary policy. The results show that the FED's monetary policy has some effect if the shock is an interest rate shock. For the other shocks it causes a temporary increase in house prices but only have a very small effect on the foreclosure rate. As the second policy we study a macroprudential policy. For this policy exercise we ask how our model economy would behave if a minimum down payment requirement of 20 percent was effective. We find that the house price would decline less and especially the foreclosure rate would increase much less with this policy.

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