Mortgage Defaults and Prudential Regulations in a Standard Incomplete Markets Model*

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Abstract

A model of mortgage defaults is built into the standard incomplete markets model. Households face income and house-price shocks and purchase houses using long-term mortgages. The model accounts for the demand for housing and mortgages and mortgage defaults in U.S. data. The model is used to study policies that could prevent mortgage defaults. The mortgage default rate, housing demand, households' ability to self-insure, and welfare are hump-shaped in the degree of recourse (the level of defaulters' wealth that can be garnished). Loan-to-value (LTV) limits for new mortgages lower mortgage defaults with negligible negative effects on housing demand and, therefore, welfare. The combination of recourse mortgages and LTV limits reduces the default rate while boosting housing demand. Furthermore, the combination of recourse mortgages and LTV limits prevents an increase in mortgage defaults after a large decline in house prices.
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1 Introduction

This paper extends a life-cycle standard incomplete markets (SIM) model to study the effect of policies that could mitigate mortgage defaults. Mortgage defaults are seen as costly, putting the stability of mortgage markets at the center of policy debates (Campbell, 2012; FED, 2012). This view became even more widespread after the increase in U.S. mortgage defaults observed since 2006, which invigorated academic and policy debates about prudential policies that could prevent mortgage defaults.[1] Two prudential policies have received widespread consideration: recourse mortgages, which allow lenders to garnish defaulters' assets, and loan-to-value (LTV) limits on new mortgages.[2] We evaluate these policies in the light of a SIM model that incorporates housing, house-price risk, and mortgages.

Our life-cycle SIM model features idiosyncratic shocks to labor earnings and the value of houses. Households can consume housing services by renting or owning the house they live in and they can buy houses of different sizes. A household can borrow to buy a house using a long-term collateralized defaultable mortgage. A defaulting household must move out of the house used as collateral and is excluded from the mortgage market for a stochastic number of periods. A default also entails social costs (the inefficient liquidation of houses in foreclosure is captured by an ad hoc exogenous decline in their values). Households can also refinance their mortgage loans (with a cost) and save using a risk-free asset. Since households decide sequentially and markets are incomplete, there is room for policy intervention.

We first show that our model generates plausible predictions for households' demand for housing, demand for mortgages, and mortgage default decisions. We parameterize the income and house-price stochastic processes using previous studies' estimations obtained with micro data for the U.S. We then calibrate the model to match four targets: the homeownership rate,

[1] Concerns about mortgage defaults motivated the Obama administration's programs to modify mortgage terms for borrowers with negative home equity (Treasury, 2009).

[2] IMF (2011) discusses the widespread use of these policies across countries. It is often argued that recent house-price declines had a much larger effect on mortgage defaults in the U.S. than in Europe in part because of soft U.S. recourse policies (IMF, 2011; Feldstein, 2008). Wong et al. (2011) present empirical evidence that, for a given fall in house prices, the incidence of mortgage default is higher for countries without a LTV limit than for countries with a LTV limit. Several studies document the important effects of LTV at origination on the probability of a mortgage defaults (Mayer et al., 2009; Schwartz and Torous, 2003).

the median house price, non-housing savings, and the median down payment. We show that the model also generates plausible implications for other indicators of the demand for housing (the life-cycle profiles of ownership and house prices), the use of mortgages (the share of owners with mortgages, mortgage payments, and the distribution of mortgage down payments), and the mortgage default rate. The overall match between the model predictions and the data makes the model a good laboratory for the quantitative evaluation of policies.

We next simulate the benchmark model but including recourse mortgages. We compute economies with different degrees of recourse, defined as the level of defaulters' wealth that can be garnished. We find that the mortgage default rate, housing demand, households' ability to self-insure, and the ex-ante welfare from being born in each of these economies are hump-shaped in the degree of recourse.

Two opposite forces explain why the effect of recourse on the default rate is non-monotonic. On the one hand, a harsher recourse policy increases the LTV chosen by households and, therefore it may increase the default rate. On the other hand, given the LTV on a mortgage, a harsher recourse policy makes defaults more costly, reducing the probability of a default on that mortgage. We find that the second effect becomes dominant (decreasing the default rate) only for sufficiently harsh recourse rules. This non-monotonicity may explain why the evidence on the effect of recourse on mortgage defaults is mixed.[3]

The effect of recourse on the demand for housing is hump-shaped because (i) recourse mortgages allow households to buy houses with higher LTVs while paying a lower mortgage interest rate (for any given LTV), thereby boosting the demand for housing; but (ii) for recourse policies that make defaults very harsh, households choose to lower the LTV enough to eliminate mortgage defaults from the simulations. The latter situation occurs at the expense of reducing the demand for housing (compare with milder recourse policies).

The relationship between recourse and households' ability to self-insure (measured with the insurance coefficients used by Blundell et al., 2008, and Kaplan and Violante, 2010) follows the hump shape of the relationship between recourse and the default frequency. In particular,

[3] See Clauretie (1987), Ghent and Kudlyak (2011), and the references therein.

recourse rules that reduce the default frequency significantly also damage the households' ability to self-insure.

The relationship between recourse and welfare follows the one between recourse and the demand for housing. In particular, among the levels of recourse considered here, welfare is maximized by the recourse rule that maximizes the homeownership rate and the size of houses. In our model, households' ability to default implies endogenous borrowing constraints. Recourse mortgages may relax these constraints, boosting the demand for housing and, therefore, producing welfare gains (default decisions are not optimal from an ex ante perspective). The recourse rule that maximizes the demand for housing and welfare also displays a very low default rate (10 percent of the rate in the benchmark) and weakens households' ability of self-insure. This indicates that the relaxation of borrowing constraints that boosts housing consumption more than compensate (in welfare terms) the negative effect of recourse on non-housing consumption volatility.

The previous findings indicate that while recourse policies have great potential for mitigating mortgage defaults, the implementation of these policies may present difficulties. On the one hand, a recourse policy that is too mild may increase default. On the other hand, a recourse policy that is too harsh may reduce the boost to housing consumption implied by recourse mortgages and may also damage households' ability to self-insure.[4] Since the increase in default implied by mild recourse policies is the result of low LTVs at origination, this problem could be mitigated by imposing LTV limits for new mortgages. We first study the effect of introducing LTV limits and later the effects of combining LTV limits with recourse mortgages.

We find that LTV limits may lower the default rate with mild effects on the demand for housing and welfare.[5] For instance, comparing simulations for the benchmark economy with those

[4]Of course, in the U.S., bankruptcy laws could also prevent the implementation of very harsh recourse policies. As pointed out by Campbell (2012), the main stated goal of much U.S. housing policy is to increase the homeownership rate.

[5]Our measure of welfare gains from policies that reduce the mortgage default rate (as LTV limits and recourse mortgages do) should be interpreted as a lower bound. The mild negative effect of LTV limits on welfare in our model could easily be overcome by benefits from LTV limits that we do not model. In our model, a majority of households expect to buy more housing and find it costly to save for higher down payments. Therefore, these households are worse off with LTV limits. However, our model does not feature a positive feedback from a lower

for a model economy with an 85 percent LTV limit shows negligible differences in homeownership and the type of houses owned by households, while the LTV-limit economy shows a default rate 64 percent lower than the one in the benchmark.

These results shed light on important policy debates. For instance, in the U.S., qualified residential mortgage rules proposed by regulators make higher down payments necessary to allow originators to fully securitize and sell the mortgage, which in turn would result in lower interest rates for borrowers. Critics argue that these rules could have significant negative effects on housing demand (see, for example, MBA, 2011). Our results cast doubt on these arguments.

We also show there may be important complementarities between recourse mortgages and LTV limits. For instance, we show that compared with the no-recourse, no-LTV-limit benchmark, an economy with a relatively mild recourse policy features higher homeownership at the expense of a higher default rate. In contrast, the economy with an 80 percent LTV limit features a lower default rate at the expense of a lower homeownership rate. The economy with both the mild recourse policy and the 80 percent LTV limit features a higher ownership rate with a lower default rate than the benchmark, thus achieving the two most cited goals of mortgage policies (promoting homeownership and containing default). Furthermore, we show that mild recourse rules combined with LTV limits may reduce the mortgage default rate without damaging households' ability to self-insure.

We also study the effect of default-prevention policies after large declines in house prices. We find that the combination of mild recourse policies and LTV limits would be successful in preventing a rise in defaults.

1.1 Related literature

We follow closely the SIM model and calibration presented by Kaplan and Violante (2010) but we incorporate into their model housing, house-price risk, and mortgages. SIM models are also

default rate to the banking sector or house prices. Campbell (2012) discusses the importance of mortgages in the banking sector and during the recent financial crisis, and externalities from mortgage defaults (see also Campbell et al., 2011, and the references therein).

studied by, for instance, Carroll (1997), Huggett (1993, 1996), Krusell and Smith (2006), and Ríos-Rull (1995).

Our modeling of mortgages extends the equilibrium default model that has been used in quantitative studies of credit card debt (Athreya, 2005; Chatterjee et al., 2007). Some studies of credit card debt focus on the effects of changes in the severity of bankruptcy penalties or income garnishment, which is comparable to our discussion on the effects of recourse (Athreya, 2008; Athreya et al., 2011; Chatterjee and Gordon, 2012; Li and Sarte, 2006; and Livshits et al., 2007). We depart from these studies by focusing on collateralized long-term debt (mortgages) and shocks to the price of the collateral. Studying collateralized debt allows us to look at LTV limits as an alternative default-prevention policy and discuss important complementarities between recourse mortgages and LTV limits.

Some recent studies discuss the effects of recourse mortgages. Quintin (2012) shows that recourse mortgages may increase mortgage defaults by changing the pool of borrowers in a model economy with asymmetric information. We also find hump-shaped relationship between the degree of recourse and mortgage default. However, the mechanism through which a harsher recourse policy increases the default frequency in our environment is completely different from the one presented by Quintin (2012). Moreover, while Quintin (2012) presents a theoretical discussion of the effects of recourse, we show that it is possible that recourse increases mortgage defaults in a quantitative model that matches several features of the data.

Corbae and Quintin (2010) present a quantitative study of mortgage defaults. The main focus of their study is on the role of the introduction of mortgage contracts with low down payments and delayed amortization in accounting for the recent rise in U.S. mortgage defaults. As we do, they assume that the benchmark economy does not have recourse mortgages. They also present an exercise with the effects of introducing recourse mortgages on the model predictions.

Mitman (2012) presents a quantitative study of the interactions between mortgage defaults and bankruptcy across U.S. states. He finds small effect of recourse mortgages on mortgage default for U.S. recourse rules. This is consistent with using a benchmark model without recourse mortgages to study the U.S. economy as done, for instance, by Corbae and Quintin (2010) and in this paper.[6] Mitman (2012) also performs an exercise on the optimal degree of recourse and finds that non-recourse is the optimal policy. This is in sharp contrast with the gains from introducing recourse mortgages that we discuss in this paper.

While we are not aware of studies using theoretical models to evaluate the effects of LTV limits for new mortgages, Campbell and Cocco (2012) present comparative statics on their model with respect to exogenous LTV at origination. They show that higher LTV at origination are related with higher probabilities of mortgage defaults. Our model features endogenous LTVs and we show that the distribution of LTVs generated by the model is consistent with the one in the data. Thus, our model is better suited to study the effects of LTV limits (because these limits do not change the LTV chosen by all households in the model economy). For instance, our model allows to discuss the effects of LTV limits on homeownership, a key element of policy debates.

Our main objective—presenting a quantitative evaluation of prudential regulations for mortgage defaults, including the effects of these regulations after large declines in house prices—lead us to study a set of prudential policies richer than the ones study by Corbae and Quintin (2010), Mitman (2012), and Quintin (2012). Thus, we study several recourse rules, several LTV rules, and combinations of these rules. Our objective also leads us to chose assumptions that contrast with those made by Campbell and Cocco (2012), Corbae and Quintin (2010), and Mitman (2012) (the high computation cost implied by some of our assumptions justify abandoning them when they do not seem important for the issues under study). We next discuss the assumptions that differentiate our work.

First, we assume that house-price shocks affect both the household's wealth and the price of housing services but do not affect the services the household obtains from its house. Our approach contrasts with the one followed by Corbae and Quintin (2010) and Mitman (2012) and other previous studies. They model shocks to the house value as depreciation shocks that affect the services a household obtains from its house without affecting the price of housing.

[6] Chatterjee and Eyigungor (2009), Garriga and Schlagenhauf (2010), Guler (2008), and Jeske et al. (2010) present other recent quantitative studies of mortgage defaults but do not discuss policies that could mitigate defaults.

Depreciation shocks are likely to overstate the cost of a decline in the price of a house by implying that the household receives less services from its house and cannot buy housing cheaper. Thus, depreciation shocks are likely to underestimate the benefits from a recourse mortgages, which limit households' ability to transfer resources to state with low house prices (or states where households suffer a depreciation shock). This may explain in part why the evaluation of a recourse policies in this paper differs from the one presented by Mitman (2012).

Furthermore, depreciation shocks are likely to distort the relationship between house-price shocks and mortgage default. For example, depreciation shocks may be more likely to trigger a mortgage default than shocks to the price of housing because the former shocks may lead the household that suffers it to move to a different house. And moving to a different house is an important cost of mortgage defaults. These distortions could be particularly important for our goal of studying mortgage defaults after large shocks to the price of housing (which could hardly be interpreted as depreciation shocks). Instances of large declines in the price of housing are a central part of policy debates on prudential regulations that could mitigate mortgage defaults.

Previous studies calibrate depreciation shocks to match their default rate target. Consequently, these studies do not have a distribution of home equity, which is key to understand mortgage defaults.[7] Attempting to better model the relationship between house-price declines and mortgage defaults, we calibrate house-price risk using estimations obtained with micro data. We show how our model produces plausible default rates although many more households have negative home equity. The careful modeling of the relationship between house-price declines and defaults could be particularly important for our goal of studying prudential policies.

The duration of mortgages is endogenous in our model—because we allow for refinancing—and we show that the model generates plausible levels of mortgages payments. This contrasts with the one-period mortgages that is commonly assumed by previous studies. Assuming long-term mortgage contracts also allows us to better capture the relationship between house-price changes and mortgage defaults. First, with long-term contracts, mortgage payment obligations

[7]Empirical studies document the importance of home equity for default decisions. See, for example, Bajari et al. (2008),Campbell and Dietrich (1983), Deng et al. (2000), Foote et al. (2008) Mayer et al. (2009), and Schwartz and Torous (2003).

are independent from the house price. Thus, long-term debt contracts provide insurance to households by eliminating the obligation to refinance after a decline in the house price. In contrast, with one-period mortgages, the household asks for a new mortgage every period. Thus, after a house-price decline, since the borrowing cost increases, if the household chooses to repay he has less resources available for non-housing consumption. Therefore, the household's obligation to refinance could trigger a default after a relatively mild house price decline.

Furthermore, the assumed duration of mortgages could play an important role in the evaluation of recourse policies. As explained by Mitman (2012), he finds that in his one-period-mortgage model, non-recourse mortgages are optimal in part because rich households that could be affected by recourse always have low LTV mortgages and, therefore, do not default. In contrast, with long-term mortgages, relatively rich households could default after a sequence of realistic mild house price declines (while in one-period-mortgage models these households would choose high LTVs every period). Since default by rich households are not desirable ex ante, this could also play a role in explaining the difference between our evaluation of recourse policies and the one presented by Mitman (2012).

Our model also differs from the one presented in the few other studies with long-term mortgages (Corbae and Quintin, 2010; Campbell and Cocco, 2012) because we allow for refinancing. Refinancing is important for the evaluation of recourse and LTV policies because it allows mortgage holders to benefit from the lower rates implied by the imposition of these policies. Refinancing is also essential for generating a plausible distribution of the age of mortgages, which is key determinant of defaults (as older mortgages have lower LTVs; see, for instance Schwartz and Torous, 2003). Furthermore, the possibility of refinancing affects the trade-off between accumulating housing and non-housing wealth, and is essential for generating the increase in mortgage payments over the life cycle observed in the data and replicated by our model.[8] Previous studies assumed that the size of the down-payment is exogenous in one (Campbell and Cocco, 2012) or two values (Corbae and Quintin, 2010). In our model households choose the level of down-payment and the interest rate associated with that level of down-payment is determined in equilibrium. This is essential for evaluating recourse policies, which we find affect equilibrium

[8] Chen et al. (2012) discuss the important role of mortgage refinancing in consumption smoothing.

down payments greatly. This is also important to give refinancing a meaningful role.

Compared with previous studies (Corbae and Quintin, 2010; Mitman, 2012), we also present a richer model of the life cycle, income shocks, and house sizes. We show that there are significant variations in housing consumption and mortgage financing over the life cycle, and that our model can account for these variations. Allowing for a richer set of house sizes allows us to capture the increase in housing consumption over the life cycle while generating households that change houses, which has been argued could be important for evaluating recourse policies. Using an estimated income process in a yearly model males risk-sharing quantitatively meaningful, as shown by the fact that the insurance coefficients are similar to those in Kaplan and Violante (2010).

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 discuss our calibration. Section 4 presents the results. Section 5 concludes.

2 The model

We study a life-cycle SIM model close to the one presented by Kaplan and Violante (2010). As they do, we model the choices of a household that lives up to T periods and works until age $W \leq T$. In contrast with their study, we assume that (i) in addition to consuming non-durable goods, the household consumes housing; (ii) in addition to earning shocks, the household faces house-price shocks; and (iii) borrowing options are endogenously given by lenders' zero-profit conditions on mortgages contracts.

At the beginning of the period, the household observes the realization of its earning and house-price shocks. After observing its shocks, the household makes its housing and financial decisions. We let β denote the subjective discount factor, and $\zeta_{t,t+s}$ denote the probability of being alive at age $t+s$ conditional on being alive at age t.

2.1 Housing

We present a stylized model of housing that follows closely the one presented by Campbell and Cocco (2003). As in Campbell and Cocco (2003), we assume that the household must live in a house and that, in any given period, the household may own up to one house.

We depart from Campbell and Cocco (2003) by allowing the household to choose whether to own or rent the house it lives in and by incorporating houses of different size. We assume that if the household owns a house, he must live in the house he owns. For simplicity, we also assume the household does not need to pay rent if he chooses to be a renter. This assumption guarantees that the household is always able to afford housing. In our stylized model of homeownership, the only cost of renting is that it forces the household to live in a smaller house. We calibrate the size of the rental house, h^R, targeting the homeownership rate.

Incorporating houses of different sizes allows us to account for the increasing life-cycle profile of the mean house-price observed in the data. We assume there are four sizes of houses the household can buy, which are evenly distributed between 2 and 10. We will show that this is sufficient for reproducing the life cycle profile of the average house price. As Chatterjee and Eyigungor (2009), we assume that the utility derived from consumption c and from living in a house of size $h \in \left\{h^R, h_1, ..., h_M\right\}$ is specified by

$$u(c,h) = \frac{\left(c^{\alpha} h^{1-\alpha}\right)^{1-\gamma}}{1-\gamma} - 1,$$

where γ denotes the curvature parameter, and α determines the demand for housing.

The price of housing is given by p_t. This price changes stochastically over time. The cost of buying a house of size h is $\xi_B h p_t$, and the cost of selling a house of size h is $\xi_S h p_t$.

2.2 Earning and house price stochastic processes

We allow for correlation between earnings and house prices. As it is standard in the housing literature, we explicitly allow for predictability in house prices (see Corradin et al., 2010; Nagaraja et al., 2009, and references therein). In particular, following Nagaraja et al. (2009), the log of the housing price is assumed to follow an AR(1) process:

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

where $\bar{p}$ is the mean price. We assume $\log(\bar{p}) = 1.5$.

Each period, the household receives income y_t. Before retirement, income has a fixed effect, a persistent component, a life cycle component, and an i.i.d component, as in Kaplan and Violante (2010):

$$\log(y_t) = f + l_t + z_t + \varepsilon_t,$$

where f denotes the fixed effect, l_t denote the life cycle component,

$$z_t = \rho_z z_{t-1} + e_t,$$

ε is normally distributed with variance σ_ε^2, and e and ν are jointly normally distributed with correlation $\rho_{e,\nu}$ and variances σ_e^2 and σ_ν^2. After retirement, the household's receives a percentage of the last realization of the persistent component of its working-age income.

2.3 Mortgage contracts and savings

Financial intermediaries are risk-neutral and make zero profits in expectation. Their opportunity cost of lending is given by the interest rate r. The household can save using one-period annuities and can finance housing consumption with mortgages.

Mortgage loans are the only loans available to the household and he may have up to one mortgage. The household cannot ask for a mortgage loan that implies a negative down payment. There is a fixed cost ξ_M of signing a mortgage contract.

A mortgage for a household of age t is a promise to make payments for the next $T-t$ years or to prepay its debt in any period before T. Payments promised in a mortgage decay at rate δ. This allows us to account for the decline in the real value of mortgage payments due to inflation. In order to prepay its mortgage the household has to pay the fee ξ_P plus the value of the remaining payment obligations discounted at the rate r. That is, a household of age t may cancel its mortgage by paying, $\xi_P + q^*(n)b$, where b denotes the current-period mortgage payment,

$$q^*(n) = 1 + \frac{1-\delta}{1+r} + ... + \left(\frac{1-\delta}{1+r}\right)^n = \frac{1-\left(\frac{1-\delta}{1+r}\right)^{n+1}}{1-\frac{1-\delta}{1+r}} \text{ for } n \geq 1,$$

and $n = T - t$. Note that since we allow borrowers to prepay their mortgage and ask for a new one every period, they can choose a decreasing or increasing pattern of mortgage payments and change the effective duration of their mortgage.

The household can default on its mortgage. If the household chooses to default he hands in its house to its lender who sells it with a discount at $p_t(1-\overline{\xi}_S)$, with $0 \leq \overline{\xi}_S \leq 1$. The household must rent in the period in which he defaults. After that period, the household regains the option of becoming a homeowner with probability ψ, and stays in default and must rent with probability $1-\psi$.

As is standard in models with mortality risk, wealth is annuitized. Thus, in this model, we have to annuitized both financial and housing wealth. Each period, a household with assets receives a transfer equal to its discounted expected next-period wealth. A household with financial assets receives a transfer equal to its discounted expected next-period financial assets multiplied by the probability of its death. Thus, a household that wants financial savings for a' next period needs to save

$$\frac{a'(1-\chi_n)}{1+r},$$

where χ_n denotes the probability of being alive next period, at age $T-n$. In the same way, a homeowner with positive expected home equity receives a transfer ϵ equal to its discounted expected next-period home equity position (net of the cost of selling the house) multiplied by the probability of its death:

$$\epsilon(h', b', p, n) = \max\left\{0, \frac{1-\chi_n}{1+r}\left[h'\mathbb{E}[p'|p](1-\xi_S) - q^*(n-1)b'\right]\right\}.$$

If the homeowner dies, the financial intermediary who contracted with him receives the house. After paying the selling cost, the financial intermediary sells the house and uses the proceeds to pay to the mortgage lender the minimum between the mortgage prepayment amount and the proceeds from the house sale.

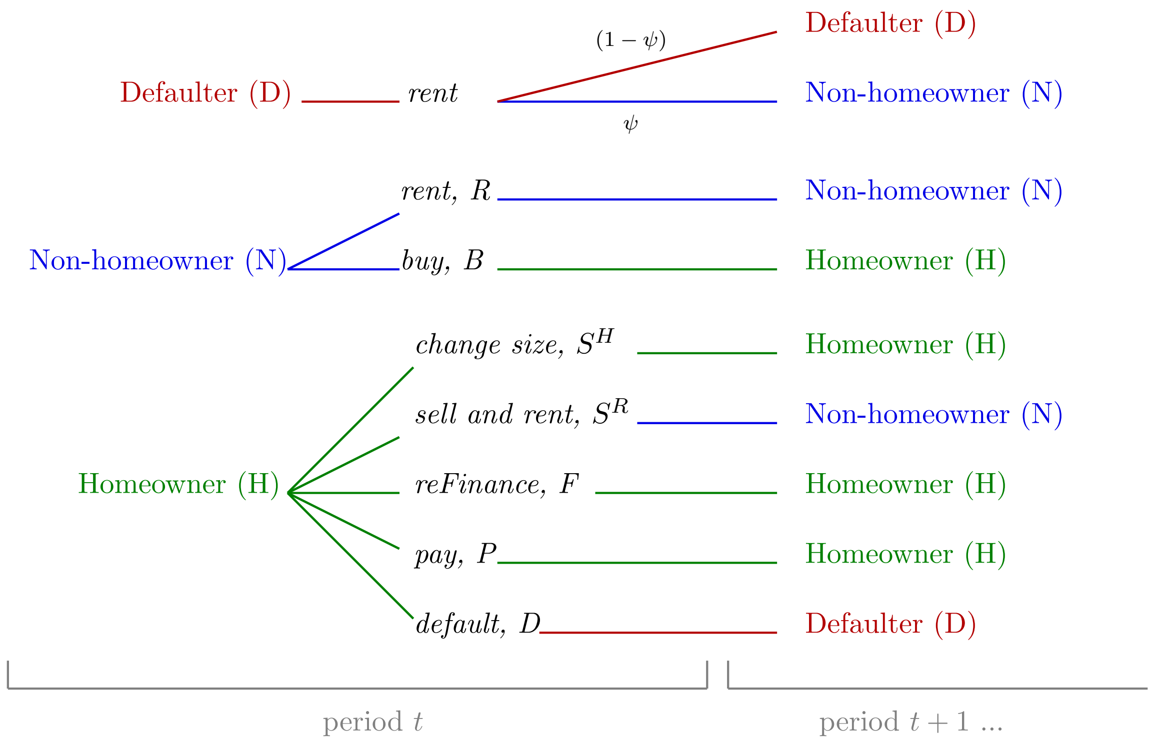

Figure 1: Households' choices.

3 Recursive formulation

The household can enter each period either as (i) a defaulter (who defaulted in a previous period and still does not have the choice to buy a house), (ii) a non-homeowner with a clean credit that can choose whether to buy a house, and (iii) a homeowner. Figure 1 presents households' choices in each of these three situations and the corresponding value functions.

3.1 Non-homeowner

If the household does not own a house it has to choose whether to stay as a renter or buy a house. Thus, the lifetime utility of a household that enters the period not owning a house is given by

$$N(w, z, p, n) = \max\{R(w, z, p, n), B(w, z, p, n)\}, \tag{2}$$

where $w = \exp(f + l_n + z + \varepsilon) + a \geq 0$ denotes the household's cash-on-hand wealth (labor income plus savings) at the beginning of the period, R denotes the lifetime utility of a not-owner who decides to stay as a renter during the period, and B denotes the lifetime utility of a household that buys a house in the period.

3.1.1 Renter

A household that enters the period not owning a house and chooses to continue renting, can only choose its next-period savings $a' \geq 0$. Thus, the value of $R(w, z, p, n)$ is determined as follows:

$$R(w,z,p,n) = \max_{a' \geq 0} \left\{ u\left(c, h^R\right) + \beta \chi_n \mathbb{E}\left[N(w', z', p', n-1)|z) \mid z, p\right] \right\}, \tag{3}$$

$$s.t. \qquad c = w - \frac{\chi_n}{1+r} a'$$

$$w' = \exp(f + l_{n-1} + z' + \varepsilon') + a'.$$

3.2 Mortgages

Let q denote the secondary market value of a mortgage loan, where

$$q(h', b', a', z, p, n) = \left[\frac{\chi_n(q_{\text{pay}} + q_{\text{prepay}} + q_{\text{default}}) + (1 - \chi_n) q_{\text{die}}}{1+r}\right]$$

and

$$\begin{aligned}
q_{\text{pay}} &= \mathbb{E}\left[I_{\text{pay}}(h', b', w', z', p', n-1)\left(1 + (1-\delta)\, q\left(h', b'\left(1-\delta\right), a'', z', p', n-1\right)\right)|z, p\right], \\
q_{\text{prepay}} &= \mathbb{E}\left[I_{\text{prepay}}(h', b', w', z', p', n-1) q^*(n-1)|z, p\right], \\
q_{\text{default}} &= \mathbb{E}\left[\frac{I_{\text{default}}\left(h', b', w', z', p', n-1\right) p' h' (1 - \overline{\xi}_S)}{b'}|z, p\right], \\
q_{\text{die}} &= \mathbb{E}\left[\frac{min\left\{q^*(n-1)b', p'h'(1-\xi_S)\right\}}{b'}|p\right].
\end{aligned}$$

In the expressions above, b' denotes the next-period mortgage payment; $a'' = \hat{a}^P(h, b', w', z', p', n-1)$ denotes the next-period optimal saving choice of a household that pays its mortgage next period (i.e., the solution of problem (7) below); I_{pay} is an indicator function that is equal to one (zero) if the optimal choice of an household is to make (to not make) its current-period mortgage payment; I_{prepay} is equal to one (zero) if its optimal choice is (is not) to prepay its mortgage (which the household does when it refinances or when it sells the house); I_{default} is equal to one (zero) if its optimal choice is (is not) to default. Note then than if the household asks for a mortgage promising to pay b' next period, the amount he borrows is given by $b'q(h', b', a', z, p, n)$.

3.3 Buyer

A household that decides to buy a house must choose the size of the house (h'), its savings (a') and the amount it borrows. The latter is determined by how much the household promises to pay next period (b'), and is given by $b'q(b', a', z, p, h', n)$. Thus, the expected discounted lifetime utility of a renter that buys a house satisfies

$$B(w, z, p, n) = \max_{\{b' \geq 0, a' \geq 0, h'\}} \{u(c, h') + \beta \chi_n \mathbb{E}[H(h', b', w', z', p', n-1) \mid z, p]\} \tag{4}$$

$$\begin{aligned}
s.t. \quad & c = w + b'q(h', b', a', z, p, n) - I_{b'>0}\xi_M - \frac{\chi_n}{1+r}a' - (1+\xi_B)ph' + \epsilon(h', b', p, n), \\
& w' = \exp(f + l_{n-1} + z' + \varepsilon') + a', \\
& b'q(h', b', a', z, p, n) \leq ph', \qquad (5) \\
& h' \in \{h_1, ..., h_M\},
\end{aligned}$$

where the indicator $I_{b'>0}$ takes a value of 1 if the individual buys the house with a mortgage and zero otherwise, and H denotes the expected discounted lifetime utility of a household that enters the period as a homeowner. Equation (5) prevents the household from asking for a mortgage with a negative down payment (i.e., this equation imposes a 100 percent LTV limit).

3.4 Homeowner

A household that enters the period as a homeowner can: (i) pay its current mortgage (if any), (ii) refinance its mortgage (or ask for a mortgage if it does not have one), (iii) default on its mortgage, and (iv) sell its house (and buy another house or rent). Thus, the value function

H is given by the maximum of the values of these four options denoted by P, F, D, and S, respectively:

$$H(h,b,w,z,p,n) = \max\{P(\cdot), F(\cdot), D(\cdot), S(\cdot)\}. \tag{6}$$

3.5 Mortgage payer

If the household makes the current-period mortgage payment, its only remaining choice is a'. Then, the value of making the mortgage payment is given by

$$P(h,b,w,z,p,n) = \underset{a'\geq 0}{Max}\left\{u\left(c,h\right) + \beta\chi_n \mathbb{E}\left[H(b\left(1-\delta\right), w', z', p', h, n-1) \mid z, p\right]\right\} \tag{7}$$

$$s.t. \quad c = w - b - \frac{\chi_n}{1+r}a' + \epsilon(h', b', p, n),$$

$$w' = \exp(f + l_{n-1} + z' + \varepsilon') + a',$$

3.6 Mortgage refinancer

In order to refinance, the household must pay its mortgage and choose a new next-period payment of its new mortgage $b' \geq 0$ (the household can choose to not have a mortgage, $b' = 0$). The household is also free to adjust its financial wealth. Thus the value of refinancing is given by

$$F(h,b,w,z,p,n) = \max_{b'\geq 0, a'\geq 0}\left\{u\left(c,h\right) + \beta\chi_n \mathbb{E}\left[H(h, b', w', z', p', n-1) \mid z, p\right]\right\} \tag{8}$$

$$s.t. \quad c = y - q^*(n)b + q(h', b', a', z, p, n)b' - \xi_P - I_{b'>0}\xi_M + \epsilon(h', b', p, n) - \frac{\chi_n}{1+r}a',$$

$$w' = \exp(f + l_{n-1} + z' + \varepsilon') + a',$$

$$b'q(h', b', a', z, p, n) \leq ph.$$

3.7 Mortgage defaulter

If the household defaults its becomes a renter and cannot own a house for a stochastic number of periods. The household is still free to adjust its financial wealth. Thus, the value of defaulting is given by

$$
\begin{aligned}
& D(w,z,p,n) = \underset{a'\geq 0}{Max}\left\{u\left(c,h^R\right)\right. \\
& \left.+\beta\chi_n\mathbb{E}\left[\psi N(w',z',p',n-1)+(1-\psi)D(w',z',p',n-1)\mid z,p\right]\right\} \\
s.t. \quad & c = y - \frac{\chi_n}{1+r}a', \\
& w' = \exp(f+l_{n-1}+z'+\varepsilon')+a'.
\end{aligned}
$$

3.8 Seller

If the household sells its house it can become a renter or it can buy another house. Thus, the value of selling the house is given by

$$
S(h,b,w,z,p,n) = \max\left\{S^R(h,b,w,z,p,n), S^H(h,b,w,z,p,n)\right\},
$$

where S^R denotes the expected discounted lifetime utility of selling the house and becoming a renter, and S^H denotes the expected discounted lifetime utility of selling the house and buying another house.

If the seller chooses to become a renter, it can only adjust its financial wealth. Thus, its lifetime utility is given by

$$
\begin{aligned}
& S^R(h,b,w,z,p,n) = \max_{a'\geq 0}\left\{u\left(c,h^R\right)+\beta\chi_n\mathbb{E}\left[N(w',z',p',n-1)\mid z,p\right]\right\} \qquad (9) \\
s.t. \quad & c = w - q^*(n)b + ph\left(1-\xi_S\right) - \frac{\chi_n}{1+r}a', \\
& w' = \exp(f+l_{n-1}+z'+\varepsilon')+a'.
\end{aligned}
$$

If the seller buys another house, it must also choose the size of its new house and its new mortgage. Thus, its lifetime utility is given by:

$$S^H(h,b,w,z,p,n) = \max_{\{b'\geq 0, a'\geq 0, h'\}} \left\{ u\left(c,h'\right) + \beta\chi_n \mathbb{E}\left[H(h',b',w',z',p',n-1) \mid z,p\right]\right\} \quad (10)$$

$$\begin{aligned}
s.t. \quad & c = w - q^*(n)b - \xi_P \\
& + ph\left(1-\xi_S\right) + b'q(h',b',a',z,p,n) - I_{b'>0}\xi_M - (1+\xi_B)ph' + \epsilon(h',b',p,n) - \frac{\chi_n}{1+r}a', \\
& w' = \exp(f + l_{n-1} + z' + \varepsilon') + a', \\
& b'q(h',b',a',z,p,n) \leq ph', \qquad (11) \\
& h' \in \left\{h_1, ..., h_M\right\}.
\end{aligned}$$

4 Calibration

We calibrate the model using data for the U.S. Most parameter values are taken from previous studies. Whenever possible, we use as a reference the 2001 Survey of Consumer Finances (SCF).[9] Table 1 presents the value of all parameters in the model.

As in Kaplan and Violante (2010), a period in the model refers to a year; households enter the model at age 25, retire at age 60, and die no later than at age 82. Survival rates are obtained from Kaplan and Violante (2010). With a retirement income replacement ratio of 75 percent, we replicate the mean income after retirement in the data. A household's initial asset position is 65 percent of its initial income, which allows us to match the mean net asset position at age 25 in the SCF.

Our strategy is to feed into the model stochastic processes for income and prices estimated using micro data. We pin down the variance of house price innovations σ_ν^2 and the correlation of income and house price innovations ($\rho_{e,\nu}$) to match the standard deviation of house-price growth and the correlation between house-price growth and income growth estimated by Campbell and Cocco (2003), 0.115 and 0.027, respectively. We use the estimate of the persistence of house prices (ρ_p) by Nagaraja et al. (2009).

[9] We use households between 25 and 60 years of age that are not in the top 5 percentile of the wealth distribution. The choice of the year 2001 is because this is before the large swings in average house prices in the U.S. and we calibrate our model without changes in the aggregate house prices (we study such changes in Subsection 5.5).

Parameter	Value	Definition	Basis
b_0	$0.65y_0$	Initial wealth	SCF
σ^2_ν	0.302	Variance of ν	Campbell and Cocco (2003)
$\rho_{e,\nu}$	0.115	Correlation e and ν	Campbell and Cocco (2003)
ρ_p	0.970	Persistence in p	Nagaraja et al. (2009)
l	–	Income life-cycle component	Kaplan and Violante (2010)
σ^2_ε	0.0630	Variance of ε	Kaplan and Violante (2010)
σ^2_e	0.0166	Variance of e	Kaplan and Violante (2010)
ρ_z	0.990	Persistence in z	Kaplan and Violante (2010)
f	$+-0.459$	Income fixed effects	Storesletten et al. (2004)
r	0.020	Risk-free rate	Kocherlakota and Pistaferri (2009)
γ	2.00	Risk aversion	Standard RBC
ξ_B	0.025	Cost of buying, hhds	Gruber and Martin (2003)
ξ_S	0.070	Cost of selling, hhds	Gruber and Martin (2003)
$\bar{\xi}_S$	0.220	Cost of selling, bank	Pennington-Cross (2006)
ξ_M	0.15	Cost of signing mortgage	Federal Reserve
ξ_P	0.070	Cost of prepaying mortgage	Federal Reserve
δ	0.02	Payments decay	Average inflation

Table 1: Parameter values.

The parameters $\sigma_e, \sigma_\varepsilon$ and ρ_z, and the life-cycle component of the income process are calibrated following Kaplan and Violante (2010). As in Storesletten et al. (2004), the fixed effect takes two values, -0.459 and 0.459.

We set $\gamma = 2$, which is within the range of accepted values in studies of real business cycles. Following Kocherlakota and Pistaferri (2009), we set $r = 2\%$. We set the cost of buying and selling a house using estimates in Gruber and Martin (2003) and Pennington-Cross (2006). The costs of signing and prepaying a mortgage are the average costs reported by the U.S. Federal Reserve. The depreciation of mortgage installments is set considering an inflation rate of 2 percent.

We calibrate the remaining four parameter values (the size of the house available for rent, the discount factor, the housing utility parameter α, and the probability of regaining access to the mortgage market after a default) to match four data targets. The size of the house available for rent is the key parameter to match homeownership (SCF). The discount factor is the key parameter that allows us to match the median (non-housing) savings-to-income ratio (SCF). The housing utility parameter α is the key parameter to match the median house price to median income ratio (SCF). The probability of regaining access to the mortgage market is the key parameter that allows us to match the median down payment (Paniza Bontas, 2010).[10] Table 2 presents the fit of the targets we obtain with our benchmark calibration and the implied parameter values.

5 Results

This Section is organized as follows. First, we discuss the ability of our benchmark model to match features of the demand for housing and mortgages, and the rate of mortgage defaults in

[10]The probability of regaining access to the mortgage market determines the cost of defaulting in our model. Thus, this probability determines how much households can borrow and is useful to match the median down payment. There is controversy about the extent to which a mortgage default prevents a household from obtaining a new mortgage or increases the defaulter's borrowing cost. It is certainly the case that some defaulting households can quickly obtain new loans, specially with significant down payments. Instead of trying to calibrate the controversial cost of defaulting, we choose to target the more easily measured level of down payments (which in the model is closely related to the cost of defaulting).

Variables	Data	Model
Homeownership rate	0.66	0.66
Median Price/ Median income	2.80	2.91
Median (saving/income)	0.85	0.77
Median down payment	0.18	0.17
Parameter	Value	Definition
h^R	1.43	Size rental house
α	0.9	Housing utility
β	0.946	Discount factor
ψ	0.667	Probability default ends

Table 2: Targets and Fit.

the data. Second, we compare model economies with different recourse rules, LTV limits, and combinations of these policies. Third, we discuss welfare gains generated by these policies.

5.1 Benchmark

In this Subsection, we describe model predictions not targeted in the calibration regarding the demand for housing, the demand for mortgage loans, and mortgage defaults. Regarding the demand for housing, our calibration targets (and matches reasonably well) the homeownership rate and the median house price. Figure 2 shows that the model also captures changes in the demand for housing over the life-cycle (SCF). Homeownership increases over the life cycle, since older households tend to be richer and thus are more likely to be able to afford ownership. Furthermore, the mean house price also increases over the life cycle as older households tend to be able to afford larger (or in the data, better) houses.

Regarding the use of mortgages, Table 3 shows that the proportion of homeowners with mortgages in the simulations is almost identical to the one in the data. The model also matches very well the proportion of house values that is financed with mortgages: Figure 3 shows that the

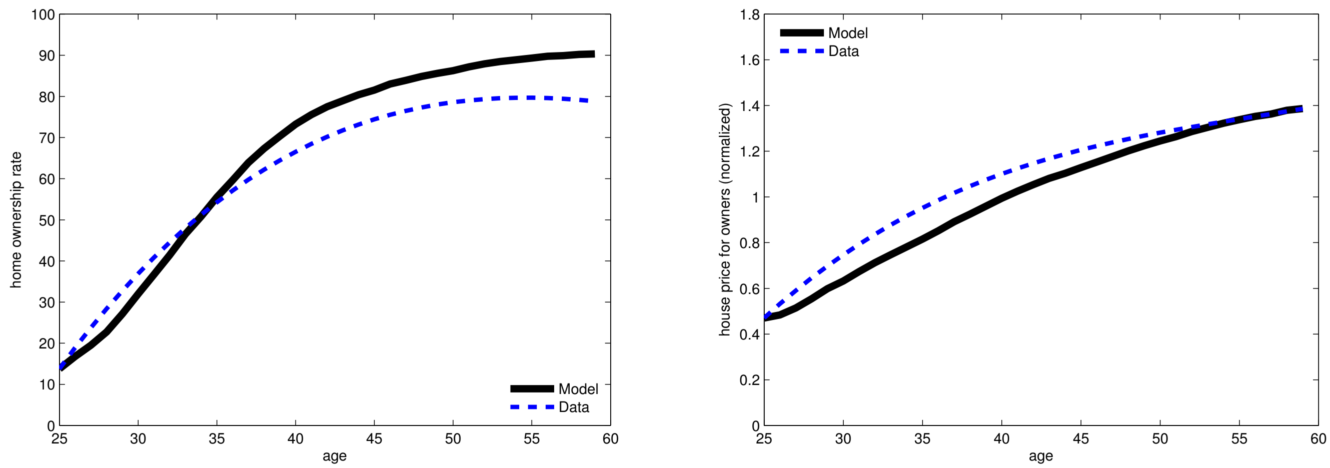

Figure 2: Demand for housing over the life cycle (non-targeted). The left (right) panel presents the homeownership rate (average price of houses).

model produces plausible implications for the distribution of mortgage down payments.[11] Table 3 also shows that mortgage payments in the data are higher than those in the model simulations. Notice, however, that mortgages payments in the data overstate the financial cost of mortgages because of the tax deductibility of interest payments (which is not a feature of our model).

The model also generates a plausible default rate. In particular, the default rate generated by the model is close to the 0.5 percent targeted by Jeske et al. (2010) and Mitman (2012). They explain that the quarterly foreclosure rate was 0.4 percent between 2000 and 2006 and that the ratio of mortgages in foreclosure that eventually end in liquidation was 25 percent in 2005. They argue that since a default in their model (as in ours) implies that the household hands in its house to the bank, the default rate in the simulations should be compared to the liquidation rate in the data. They also argue that since the default rate in the data is for a period of strong appreciation of house prices, they should target a higher default rate.[12]

[11] Down payment data is not available in the SCF. We constructed the empirical distribution of down payments using data on combined loan-to-value ratios at origination for the 2000-2009 period presented by Paniza Bontas (2010). We focus on the distribution of down payments because, to the best of our knowledge, it is not clear which data one could use for the distribution of home equity. For instance, the level of equity in the SCF is significantly higher than the one in other data sources (e.g., Corelogic).

[12] Later, in Figure 7, we illustrate how our model generates a lower default rate during a period of strong appreciation of house prices.

Variables	Data	Model
Homeowners with mortgages	0.82	0.83
Median payment / Median Income	0.15	0.12
Default rate (%)	0.50	0.59

Table 3: Demand for mortgages and default. The homeowners with mortgages and payments data is from the SCF; the default rate data is the calibration target presented by Jeske et al. (2010) and Mitman (2012).

In addition, Table 4 shows that our model has plausible predictions about the circumstances that trigger a mortgage default. Households only default when they have sufficiently negative equity.[13] Furthermore, defaulters income is significantly lower than the income of other households.

Group	Mean equity/price	Mean income
Defaulters	-0.26	0.88
Payers	0.32	1.44
Sellers	0.31	1.91
Refinancers	0.44	1.83

Table 4: Equity and income for defaulters and other households.

Overall, the results presented above indicate that our framework is a reasonable quantitative model of the demand for housing and mortgages, and mortgage defaults. Thus, our framework could be a useful laboratory for the study of policies that could mitigate mortgage defaults. We next study the effects of such policies.

[13] In our simulations, consistently with empirical evidence (Foote et al., 2008), most households with negative equity do not default.

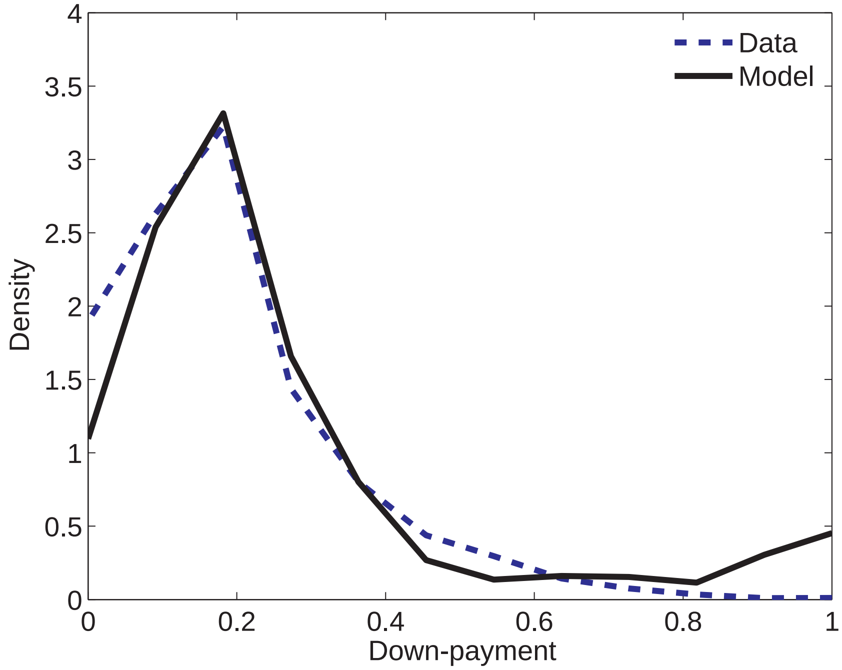

Figure 3: Distribution of down payments. The empirical distribution is constructed using data presented by Paniza Bontas (2010).

5.2 Recourse mortgages

In this Subsection, we study model economies with recourse mortgages.[14] That is, we use the baseline model parametrization but we assume that a defaulting household must use all its financial wealth above a threshold $\phi\tilde{w}$ for deficiency payments, transferring to the lender

$$\Phi(b, w, p, h) = \max\{\min\{w - \phi\tilde{w}, q^*(n)b - ph(1 - \overline{\xi}_S)\}, 0\},$$

where $\tilde{w}$ represents the median income in the benchmark economy.[15] Thus, a defaulting households must use all its financial wealth w in excess of the threshold $\phi\tilde{w}$ to pay any amount of its

[14]Note that since we do not model the decision to supply labor, we cannot study the effect of recourse mortgages on this decision. Results in previous studies indicate, however, that this effect is negligible (Chatterjee and Gordon, 2012; Chen, 2011; Li and Han, 2007). This is in part because people would choose to default for asset and income levels lowers than the ones that make recourse operative.

[15]This formulation resembles means testing features often present in debt relief legislation (see, for instance, the U.S. Bankruptcy Abuse Prevention and Consumer Protection Act of 2005).

	Benchmark	Recourse, $\phi =$ 4	2	1	0.5	0.1	0.05	0.025	0.01
Homeownership rate	0.66	0.67	0.70	0.73	0.78	0.80	0.78	0.76	0.74
Mean house size (owners)	1.00	1.02	1.02	1.02	1.03	1.08	1.08	1.07	1.06
Median down payment	0.17	0.15	0.12	0.04	0.00	0.00	0.00	0.00	0.00
Default rate (%)	0.59	0.75	0.77	0.79	0.58	0.06	0.02	0.00	0.00
Median payment / Median Inc.	0.12	0.14	0.15	0.16	0.17	0.19	0.18	0.17	0.16
Median (equity/price), mortgagees.	0.23	0.17	0.10	0.04	0.02	0.00	0.00	0.01	0.03

Table 5: Effects of recourse mortgages. House sizes are normalized to 1 in the benchmark.

mortgage debt $q^*(n)b$ that was not covered by the sell of the house at $ph(1 - \overline{\xi}_S)$.

Table 5 shows that augmenting the degree of recourse (lowering the level of non-garnishable financial wealth ϕ) boosts the demand for housing significantly, which is reflected in a higher homeownership rate and larger houses. Figure 4 illustrates how recourse increases the demand for housing because it allows households to buy houses with higher LTVs while paying a lower mortgage interest rate.

In addition, Table 5 shows that the increase in the demand for housing (as represented by ownership and house sizes) implied by recourse is hump-shaped with respect to the degree of recourse. The demand for housing increases with recourse because it lowers the mortgage interest rate households pay (Figure 4) and, in particular, allows them to choose higher LTVs. However, for the harsher recourse rules in Table 5, households choose LTVs lower than the ones they choose for softer recourse rules. This is because for the harsher rules, defaulting becomes so onerous that households want to eliminate the possibility of defaulting (the default frequency is zero in the simulations).

Somehow surprisingly, Table 5 shows that among relatively mild recourse policies, harsher recourse lead to a higher, not lower, default rate. Among harsher rules, increasing recourse has the opposite effect; i.e., it reduces mortgage defaults. On the one hand, given the LTV, a harsher recourse policy increases the cost of defaulting and, therefore, it reduces the probability of default. On the other hand, a harsher recourse policy increases the LTV chosen by households

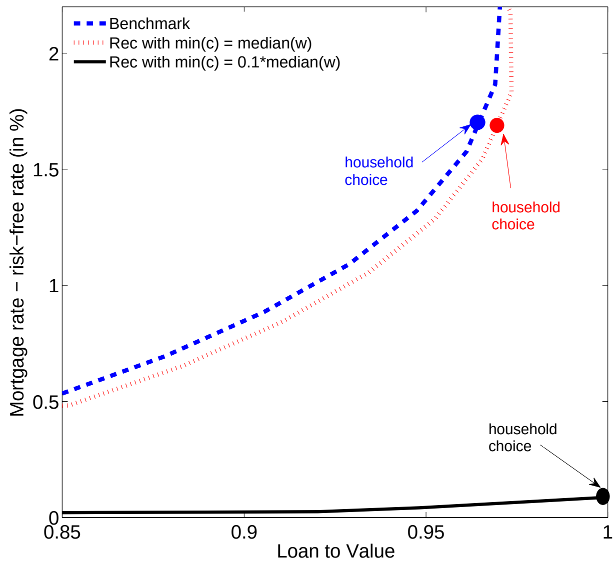

Figure 4: Mortgage spread with and without recourse

and it may increase it enough to increase the default frequency.

To understand the hump-shaped relationship between the degree of recourse and default, it is useful to think about how a household chooses the default risk on its mortgage. A household trades off the desire to consume more housing sooner using higher LTV mortgages with the cost of exposing itself to costly defaults—which it dislikes because of the associated costs of defaulting (including, for instance, the cost of moving to a different house) and because future default decisions are not optimal from an ex ante perspective.

On the one hand, a harsher recourse policy may increase a household's benefit from assuming default risk. First, with a harsher recourse policy, for a given increase in default risk, the household can lower more the mortgage LTV. This is illustrated by the flatter mortgage spread curve with recourse in Figure 4. This flattening of the spread curve occurs because a harsher recourse policy reduces the relative importance of the LTV (compared with income) in the default decision.

Second, households dislike default risk less when default is more likely to be triggered by income shocks. Very negative income shocks that could trigger a mortgage default are something households would like to insure against (and mortgage defaults provide this insurance). In contrast, declines in the price of housing that could also trigger a mortgage default may have small negative welfare effects for households that do not plan to adjust their consumption of housing and may even increase welfare for homeowners who expect to buy larger houses in the future (see Subsection 5.7). Thus, households may like less contracts that transfer resources to states with negative shocks to the price of housing (as defaultable mortgages do more when the recourse rule is softer). Overall, a harsher recourse policy may make households more willing to choose default risk in equilibrium. In particular, households that choose to rent without recourse choose to become homeowners with high default risk when recourse is introduced.

On the other hand, if the recourse policy is very harsh, households choose to decrease their exposure to default risk, which leads to a decrease in the default frequency. As mentioned before, if defaulting is sufficiently painful, households choose to eliminate the possibility of default, even at the expense of reducing housing consumption.

Our results indicate that while recourse policies have great potential for mitigating mortgage defaults, the implementation of these policies present difficulties. On the one hand, a recourse policy that is too mild may increase default risk. On the other hand, a recourse policy that is too harsh may reduce the boost to housing consumption implied by recourse mortgages. Since the increase in default risk implied by mild recourse policies is the result of low LTVs at origination, this problem could be mitigated by imposing LTV limits for new mortgages. We next study the effect of introducing LTV limits with non-recourse mortgages and later the effects of combining LTV limits with recourse mortgages.

5.3 LTV limits

In this Subsection, we study model economies with LTV limits for new mortgages. That is, we solve the benchmark model but changing only the LTV limit in constraints (5) and (11) of the household's problem. We now allow the household to borrow only a fraction of the value of the house it buys (the LTV limit), instead of 100 percent as in the benchmark. All other parameter values are as in the benchmark.

	Benchmark	LTV limit at 90%	85%	80%
Homeownership rate	0.66	0.66	0.66	0.64
Mean house size (owners)	1.00	1.00	1.00	1.00
Median down payment	0.17	0.16	0.16	0.20
Default rate (%)	0.59	0.39	0.21	0.10
Median payment / Median Income	0.12	0.12	0.11	0.10
Median (equity/price), mortgagees	0.23	0.23	0.24	0.27

Table 6: Effects of LTV limits. House sizes are normalized to 1 in the benchmark.

Table 6 shows that an economy with a LTV limit features a significantly lower mortgage default rate. This occurs because households are less likely to have equity negative enough to trigger a default.

That table also shows that economies with a LTV limit feature a lower homeownership rate but the decline in ownership is not significant for limits higher than 80 percent. Similarly, LTV limits do not have a significant impact on house sizes.

Our findings shed light on current policy debates. For instance, in the U.S., Qualified Residential Mortgage (QRM) rules would imply an increase in the interest rate that mortgage borrowers paying a down payment lower than 20 percent of the house price would have to pay. Thus, these rules could be interpreted as a soft version of the LTV limits we study: while our LTV limits make it impossible (or prohibitively expensive) to borrow above the limit, QRM implies an increase in the cost of borrowing with an LTV above 80 percent. Critics argue that QRM rules could have a significant negative effect on homeownership (see, for example, MBA, 2011). We find that eliminating mortgages with a LTV lower than 80 percent would only reduce ownership by 2 percentage points and would have a negligible effect on house sizes. Thus, our results cast doubts on the aforementioned criticisms.

We identify two reasons why LTV limits may have negligible effects on housing demand in our simulations. First, LTV limits only have a small effect on the demand for housing because in economies with LTV limits households save more in order to afford higher down payments. Thus, in general, LTV limits do not prevent households from buying the house they want. Second, LTV limits lower the interest rate households pay on their mortgage, making housing consumption more attractive. Mortgage interest rate are higher when the default probability is higher. LTV limits make it harder for a household that defaulted to buy a new house and, therefore, lowers the default probability and the mortgage interest rate. However, we find that the second reason is not quantitatively important in our simulations.

5.4 Combining recourse mortgages and LTV limits

Could the combination of recourse mortgages and LTV limits mitigate mortgage defaults and at the same time boost housing consumption? Previous subsections show that recourse mortgages could relax households' borrowing constraints and thus increasing housing consumption but at the expense of increasing the rate of mortgage defaults. In contrast, LTV limits would lower the default rate but at the expense of worsening households' borrowing constraints and thus decreasing housing consumption. In this Subsection, we study the effects of combining these policies.

Table 7 shows that there may be important complementarities between recourse mortgages and LTV limits. For instance, the Table shows that compared with the benchmark, the economy with the median-income recourse policy ($\phi = 1$) features higher ownership at the expense of a higher default rate. In contrast, the economy with an 80 percent LTV limit features a lower default rate at the expense of a lower ownership rate. The economy with both the median-income recourse policy and the 80 percent LTV limits features a higher ownership rate with a lower default rate, indicating that the combination of these two tools could succeed in the two most often cited goals of mortgage policies (promoting ownership and containing the risk of default). Furthermore, the economy with both policies features a default rate even lower than the one in the economy with the 80 percent LTV only. This shows that recourse policies that would lead to higher default rates in the no-LTV-limit benchmark, may lead to a lower default rate in economies with LTV limits.

Variable	Benchmark	$\phi = 2$ & $LTV = 90\%$	$\phi = 1$ & $LTV = 80\%$
Homeownership rate	0.66	0.69	0.68
Mean house size (owners)	1.00	1.02	1.00
Median down payment	0.17	0.12	0.20
Default rate (%)	0.59	0.36	0.04
Median payment / Median Income	0.12	0.13	0.12
Median (equity/price), mortgagees	0.23	0.22	0.17

Table 7: Combining recourse mortgages and LTV limits. House sizes are normalized to 1 in the benchmark.

As discussed before, the default rate may be higher in an economy with recourse mortgages because the level of home equity is lower with recourse mortgages. Figure 5 shows that this effect is mitigated in an economy with LTV limits. For all ages, equity is significantly lower in the economy with the median-income recourse policy than in the benchmark, which implies a higher default rate in the economy with recourse mortgages. In contrast, in the economy with the median-income recourse policy and the 80 percent LTV limit, equity is higher than in the benchmark for all ages.

Figure 6 shows how the economy with both the median-income recourse mortgages and the 80 percent LTV limit also features a stronger demand for housing than the benchmark economy. The homeownership rate is higher in the economy with the prudential policies, except for households under 27 years of age, for which the rate is only slightly lower. Furthermore, houses are on average larger in the economy with default prevention policies than in the benchmark, as indicated by a higher mean house price.

5.5 Large swings in the average price of housing

In previous Subsections, we compare the mortgage default rate across model economies with different prudential policies. In those economies, households face idiosyncratic shocks to the price of housing, but the aggregate price of housing $\bar{p}$ remains constant. In this Subsection, we

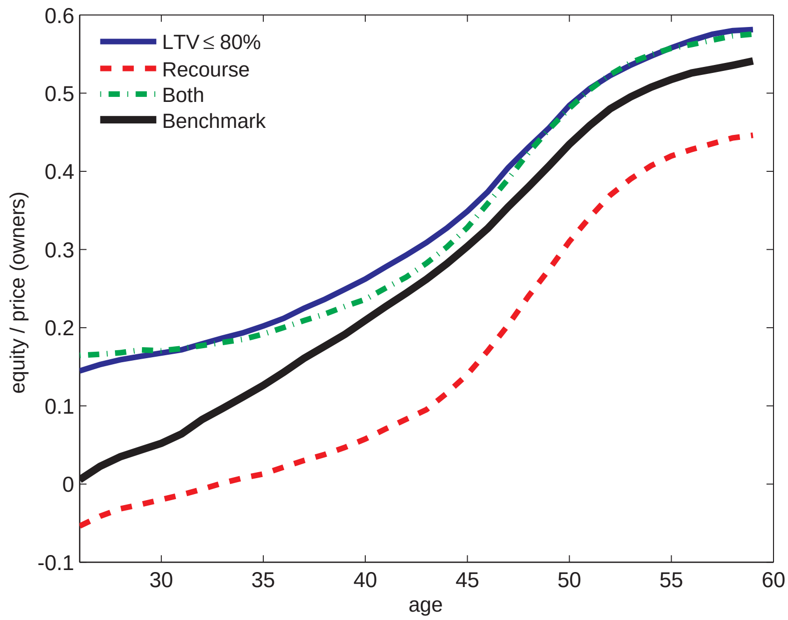

Figure 5: Equity in economies with different policies. Recourse allows for garnishment of all defaulters' wealth above the median income.

present the evolution of the mortgage default rate during large swings in the aggregate price of housing $\bar{p}$, for economies with different prudential policies. Figure 7 presents the evolution of the mortgage default rate after an increase of the average price of housing of 15 percent over two years, and then a decline of 15 percent in one year. More specifically, we assume unanticipated changes in the price of housing such that the aggregate price of housing $\bar{p}_t$ in year t of the experiment is equal to: $\bar{p}_2 = 1.07\bar{p}$, $\bar{p}_3 = 1.15\bar{p}$, $\bar{p}_t = \bar{p}$ for all $t \geq 4$.

We consider the benchmark economy (with non-recourse mortgages and without LTV limits), an economy with an 80 percent LTV limit, an economy with recourse mortgages that allow for garnishment of all defaulters' financial wealth above the median income level ($\phi = 1$), and an economy that combines these LTV and recourse rules. Previous Subsections show that the model economy with the combination of these prudential policies would feature a default rate significantly lower than the one in the benchmark. In this Subsection we test whether in the economy with these prudential policies the default rate would remain low after the proposed

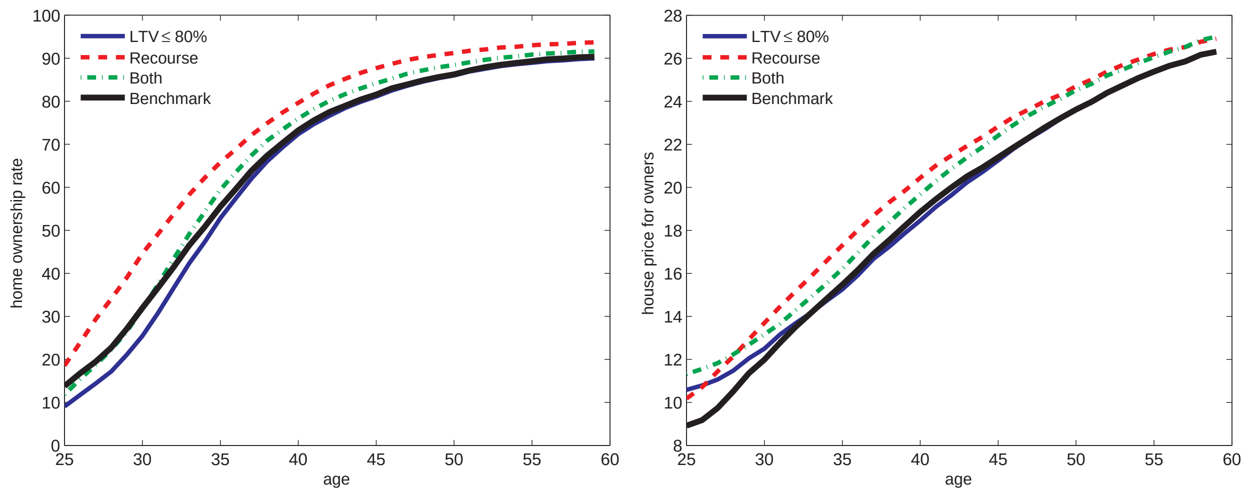

Figure 6: Housing demand in economies with different policies. The left (right) panel presents the homeownership rate (mean house price for home owners). Recourse allows for garnishment of all defaulters' wealth above the median income.

swings in house prices.[16]

Figure 7 shows that the economy with the lowest default rate after the house-price swings is the one with recourse mortgages and the LTV limit. In this economy, the default rate in year 4 of the experiment remains at its very low year-1 value. In the economy with recourse mortgages but without LTV limit, the default rate grow less than in the benchmark but from a higher initial value, resulting in a higher year-4 rate (1.1 instead of 1 percent).

The gains from combining recourse mortgages and LTV limits are confirmed in a similar exercise. Now, we simulate a decline in the average house price of 22 percent over three years that does not follow an aggregate house-price increase ($\bar{p}_2 = 0.93\bar{p}$, $\bar{p}_3 = 0.85\bar{p}$, $\bar{p}_4 = 0.78\bar{p}$). In the benchmark economy the mortgage default rate increases to 6.13 percent in year 4! In the economies with the 80 percent LTV limit or the median-income recourse mortgages alone, the year-4 default rate is lower but still very high: 3.63 and 4.23, respectively. Combining 80 percent

[16] The median-income recourse rule is the kind of soft recourse rule that could be easier to implement. For instance, the U.S. Bankruptcy Abuse Prevention and Consumer Protection Act of 2005 establishes that if a debtor's income is above the median income amount of the debtor's state, the debtor is subject to a means test that could force the debtor to file under Chapter 13 (under which a percentage of debts must be paid over a period of 35 years) as opposed to Chapter 7 (under which debts are paid only out of existing assets).

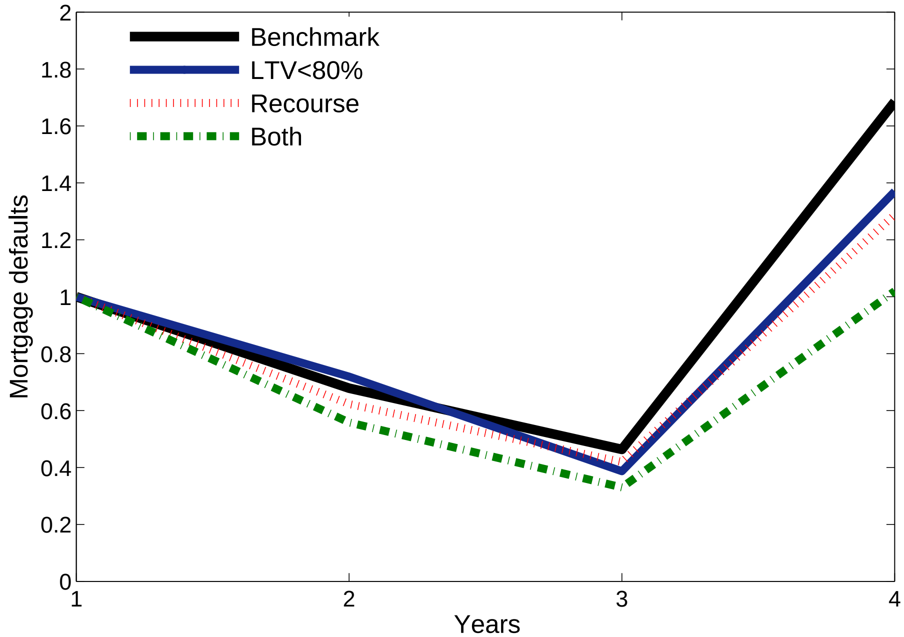

Figure 7: Default rate after a large decline in house prices that follows a housing boom.

LTV limits and recourse at the median wealth level, the year-4 default rate is much lower, only 1.18 percent.

5.6 Ex ante welfare gains from recourse mortgages

Throughout, we measure welfare gains as the implied permanent consumption increase. In this Subsection, we discuss the ex ante welfare gains from being born in economies with different recourse rules instead of being born in the no-recourse benchmark. Table 8 shows that a household benefits from being born in an economy with recourse mortgages.

Table 8 also shows that gains from recourse mortgages are hump-shaped with respect to the degree of recourse. In particular, welfare gains across recourse rules follow the same pattern of the homeownership rate (Table 5), and are maximized by the rule that maximizes ownership. Recourse mortgages are beneficial because they expand the household's borrowing opportunities, as illustrated in Figure 4. However, as discussed before, when recourse becomes very harsh

	Recourse, $\phi =$							
	4	2	1	0.5	0.1	0.05	0.025	0.01
Welfare Gains (%, CE)	0.04	0.17	0.32	0.62	0.94	0.56	0.32	0.16

Table 8: Ex ante welfare gains from recourse mortgages.

		Recourse, $\phi =$							
	Benchmark	4	2	1	0.5	0.1	0.05	0.025	0.01
House-price shock (%)	0.80	0.81	0.82	0.83	0.82	0.75	0.73	0.72	0.72
Persistent shock (%)	0.29	0.29	0.31	0.33	0.36	0.36	0.32	0.29	0.27
Transitory shock (%)	0.69	0.69	0.70	0.70	0.69	0.71	0.72	0.71	0.71

Table 9: Insurance coefficients with recourse mortgages.

households dislike the possibility of defaulting so much that they may choose to not buy a house.

A large literature (in law, history, and economics) emphasizes that facilitating defaults can be welfare enhancing because the ability to repudiate debts can play an important role in helping households fend against adverse shocks (see Athreya et al., 2011; Bolton and Jeanne, 2005; Grochulski, 2010, and references therein). In order to discuss the quantitative merits of these arguments for mortgage defaults, Table 9 presents the value of insurance coefficients in the simulations. As in Blundell et al. (2008) and Kaplan and Violante (2010), we define the insurance coefficient for shock x_{it} as

$$\mu^x = 1 - \frac{cov(\Delta log(c_{it}), x_{it})}{var(x_{it})},$$

where the variance and covariance are taken cross-sectionally over the entire population.[17] The insurance coefficient is interpreted as the share of the variance of shock x that does not translate into consumption growth.

Table 9 shows that share of the variance of the house-price shock that translates into con-

[17] Also as in Blundell et al. (2008) and Kaplan and Violante (2010), when computing insurance coefficients, log consumption and log earnings are defined as residuals from an age profile.

sumption growth is significantly smaller than the one for income shocks (even more so when compared with the one for the more significant persistent income shock). Households that do not expect to adjust their housing consumption will not adjust significantly their non-housing consumption after a house-price shock, as they expect the housing price will revert to its mean. This is consistent with the evidence presented by Sinai and Souleles (2005) who show that the risk of owning a house declines with the time the household's expects to stay in its house.

For households that expect to adjust their housing consumption there are two possible effects of a negative house-price shock. On the one hand, a negative house-price shock may has a negative effect on homeowners' wealth and, therefore, it may have a negative effect on non-housing consumption. On the other hand, a negative house-price shock lowers the cost of housing consumption and, therefore, leaves more resources available for non-housing consumption.[18] Thus, households that expect to buy (sell) housing in the future typically benefit (are hurt) from a negative house-price shock and choose higher (lower) non-housing consumption.

Figure 8 and Table 10 illustrate the effects described in the previous paragraph. The Figure and the Table present welfare gains from a 5 percent decline in house prices.[19] Figure 8 illustrates how house-price declines tend to hurt the old, who are likely to be net sellers of housing, but benefit the young, who are likely to be net buyers of housing. The Figure also show that, as expected, welfare gains are larger when households expect current low prices to be temporary (and thus expect to gain from a future price increase).[20]

Table 10 shows that welfare gains are indeed concentrated in those who are likely to be net buyers of housing. In particular, welfare gains are larger for renters than for homeowners, and even renters who are old (older than 50) experience welfare gains (on average). The Table also shows that among renters, those who are more likely to be able to afford buying a house (i.e., those with higher cash-on-hand or expected future income) experience larger gains from the decline in house prices.

[18]In theory, households could still choose to lower non-housing consumption if the substitution effect dominates the income effect.

[19]Welfare gains do not include lenders' capital losses, which we discuss in Subsection 5.8.

[20]This resembles the findings presented by Glover et al. (2012) for asset prices declines during the Great Recession.

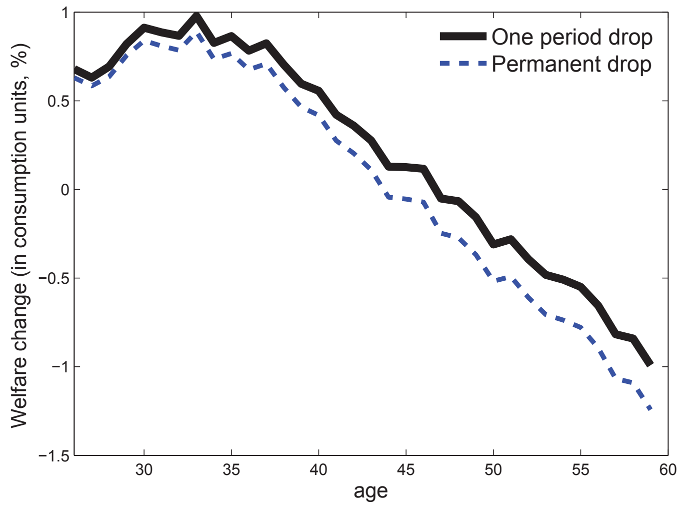

Figure 8: Welfare gains from a permanent 5 percent fall in home prices.

Table 9 also shows that the effects of introducing recourse mortgages on households' ability to self-insure is hump-shaped with respect to the degree of recourse. The hump-shape of the insurance coefficient for the house-price shock follow the hump-shape of the equilibrium default frequency, peaking with the $\phi = 1$ recourse rule. Moreover, there is a large decline in the house-price insurance coefficient when increasing the severity of the recourse rule from $\phi = 0.5$ to $\phi = 0.1$, precisely the change in the recourse rule that triggers a large decline in the default rate (Table 5). Thus, our findings indicate that recourse rules that are successful in lowering significantly the default rate may harm households' ability to self-insure. In the next Subsection we show that this is not the case when recourse mortgages are combined with LTV limits.

5.7 Ex ante welfare gains from LTV limits

Table 11 shows that a household would prefer being born in an economy with higher LTV limit. Recall that in our model endogenous borrowing constraints prevent households from consuming more housing. LTV limits are likely to make these constraint stricter. Table 11 also shows that about half of the welfare losses from being born in the 80-percent-LTV-limit could be compensated with a recourse rule that relaxes the household's borrowing constraint. Recall also

Group	Young	Old
All	0.52	-0.84
Homeowners	0.75	-1.03
Renters	0.26	0.25
- Low cash-on-hand	0.26	0.23
- High cash-on-hand	0.65	0.62
- Low permanent component	0.20	0.18
- High permanent component	0.39	0.42
- Low persistent component	0.26	0.25
- High persistent component	0.58	0.51

Table 10: Welfare gain from a 5 percent fall in house prices. Households with less than 50 years of age are "young."

	LTV limit at				
	90%	85%	80%	90% & $\phi = 2$	80% & $\phi = 1$
Welfare Gains (%, in CE)	-0.06	-0.16	-0.24	0.02	-0.12

Table 11: Ex ante welfare gains from LTV limits.

that, since our model does not feature a negative feedback from a higher default rate to the banking sector or house prices (Campbell, 2012; Campbell et al., 2011), our measure of welfare gains from introducing LTV limits (or recourse mortgages) that reduce the mortgage default rate should be interpreted as a lower bound.

Table 12 shows that combinations of recourse mortgages and LTV limits that are successful in reducing the frequency of mortgage defaults while increasing homeownership do not present significant changes in households' ability to self insure when compared to the benchmark. Since economies with LTV limits have more home equity (Table 6 and Figure 5), they necessitate a softer recourse rule to lower the default rate. Such a softer rule is still consistent with defaults

	Benchmark	LTV limit at 90%	85%	80%	90% & $\phi = 2$	80% & $\phi = 1$
House-price shock (%)	0.80	0.80	0.79	0.79	0.80	0.79
Persistent shock (%)	0.29	0.30	0.29	0.27	0.30	0.29
Transitory shock (%)	0.69	0.69	0.69	0.70	0.69	0.71

Table 12: Insurance coefficients with LTV limits.

by households that would require a large adjustment in non-housing consumption to pay their mortgage.

5.8 Welfare gains from introducing prudential regulations

In previous Subsections we discussed welfare gains from being born in economies with different mortgage default prevention policies. In contrast, in this Subsection we discuss welfare gains from introducing different policies for all households living in the benchmark economy. As in previous subsections, we focus on the relatively mild median-income recourse policy ($\phi = 1$) and the commonly used 80 percent LTV limit. Table 13 presents the distribution of these welfare gains. Welfare gains in the table are computed without including lenders' gains (losses) from the introduction of policies that lower (increase) the default probability.

Table 13 shows that recourse mortgages produce welfare gains for about half the households. As explained before, households benefit from the improved borrowing conditions implied by recourse mortgages. However, mortgage debtors that anticipate a significant probability of defaulting in the future, dislike the sudden increase in the cost of defaulting implied by recourse mortgages (while this benefits lenders). Debtors' losses from the change of their mortgages from non-recourse to recourse could be eliminated by imposing recourse only on new mortgages. We do not do this exercise because it would imply introducing an additional endogenous state variable.

Table 13 also shows that LTV limits reduce welfare for a majority of households. Most households are worse off because LTV limits make their borrowing constraint stricter. A small share of households expect to be able to afford higher down payments and benefit from the lower

Welfare gains	LTV $\leq$ 80	Recourse	Both
5^{th} percentile, CE %	-0.232	-1.280	-1.373
10^{th} percentile, CE %	-0.143	-0.770	-0.901
25^{th} percentile, CE %	-0.059	-0.186	-0.354
50^{th} percentile, CE %	-0.018	-0.003	-0.053
75^{th} percentile, CE %	-0.003	0.145	-0.001
90^{th} percentile, CE %	-0.000	0.655	0.035
95^{th} percentile, CE %	0.002	1.210	0.182

Table 13: Distribution of welfare gains from implementing different policies in the benchmark economy. Recourse allows for garnishment of all defaulters' wealth above the median income.

mortgage rate implied by LTV limits. Again, since our model does not feature a positive feedback from a lower default rate to the banking sector or house prices (Campbell, 2012; Campbell et al., 2011), our measure of welfare gains from LTV limits (and recourse mortgages) should be interpreted as a lower bound.

We next include in our welfare analysis the lenders' capital gains from the implementation of these policies. We find that the implementation of the median-income recourse mortgages produces an increase of 3.97 percent in the value of the lenders' mortgage holdings. In contrasts, the implementation of the 80 percent LTV limit produce a small decline in the value of mortgage holdings of 0.01 percent. Consistently, the joint implementation of both policies produces an increase of 3.89 percent in this value.

Table 14 presents the distribution of households' welfare gains after the implementation of default prevention policies when lenders' capital gains are distributed across households. The table presents results for two ways of distributing lenders' capital gains. The left panel presents welfare gains when lenders capital gains are equally distributed across households. Using the subscript $j \in \{B, P\}$ to denote equilibrium function in the benchmark (B) and with the policy (P), the secondary-market price of a mortgage at the beginning of a period is given by:

$$
\begin{aligned}
b\tilde{q}^j(h,b,w,z,p,n) \quad = \quad & I^j_{\text{pay}}(h,b,w,z,p,n)b\left[1+(1-\delta)\,q^j\left(h,b\,(1-\delta)\,,\hat{a}^{Pj}(h,b,w,z,p,n),z,p,n\right)\right] \\
& +I^j_{\text{prepay}}(h,b,w,z,p,n)q^*(n)+I^j_{\text{default}}(h,b,w,z,p,n)ph(1-\overline{\xi}_S).
\end{aligned}
$$

Let M denote the number of households in the simulations. The lump-sum transfer τ received by all household when the new policy is introduced satisfies:

$$
M\tau = \sum_{i=1}^{M}\left[b_i\tilde{q}^P(h_i,b_i,w_i+\tau,z_i,p_i,n_i) - b_i\tilde{q}^B(h_i,b_i,w_i,z_i,p_i,n_i)\right]. \tag{12}
$$

We use the maximum τ that satisfies equation (12).

The right panel of Table 14 assumes that each household receives from its lender the transfer τ_i, which is equal to the increase in the value of the household's mortgage. Thus, τ_i satisfies:

$$
\tau_i = b\tilde{q}^P(h,b,w+\tau_i,z,p,n) - b\tilde{q}^B(h,b,w,z,p,n). \tag{13}
$$

We use the maximum τ_i that satisfies equation (13).

Comparing Tables 13 and 14 shows that including the lenders' capital gains in the welfare calculations changes the number of winners and losers from default prevention policies significantly. For instance, the share of households that looses from the introduction of the median-income recourse policy is reduced from 50 percent to 20 percent.

The greater household losses from the introduction of this recourse policy are mostly mitigated with individualized transfers. For example, the 5 percent of households that suffer the larger welfare losses with the introduction of recourse mortgages experience losses above 1.3 percent without transfers, above 0.8 percent with constant transfers, and above only 0.1 percent with individualized transfers. Recall that transforming existing mortgages into recourse mortgages hurts households that are more likely to default. Introducing recourse lowers the most the default probability for these households' mortgages. Thus, the market price of these households' mortgages increases the most with recourse. This explains why these households receive the largest individualized transfers.

Welfare gains	Lump-sum transfers LTV $\leq$ 80	Recourse	Both	Individualized transfers LTV $\leq$ 80	Recourse	Both
5^{th} percentile, CE %	-0.234	-0.810	-0.913	-0.146	-0.125	-0.175
10^{th} percentile, CE %	-0.145	-0.335	-0.469	-0.086	-0.068	-0.102
25^{th} percentile, CE %	-0.061	0.068	-0.002	-0.028	-0.002	-0.017
50^{th} percentile, CE %	-0.020	0.376	0.267	-0.003	0.000	0.000
75^{th} percentile, CE %	-0.005	0.898	0.568	0.000	0.320	0.086
90^{th} percentile, CE %	-0.001	1.490	1.009	0.000	0.884	0.494
95^{th} percentile, CE %	0.000	2.327	1.756	0.001	1.372	0.938

Table 14: Welfare gains when lenders' capital gains are distributed across households. The left panel presents welfare gains when capital gains are equally distributed across households. The right panel assumes that each household receives from its lender a transfer equal the increase in the value of the household's mortgage.

6 Conclusions

We incorporated house-price risk and mortgages into a SIM model and showed that the model produces plausible implications for the demand for housing, mortgage borrowing, and default. We studied two policies often discussed as prudential regulations to mitigate mortgage defaults: recourse mortgages and LTV limits. We found that there may be important complementarities between these two policies.

We first showed that recourse mortgages have great potential for lowering the frequency of defaults while boosting housing consumption and thus producing welfare gains. However, a recourse policy that is too mild may increase default risk, while a recourse policy that is too harsh may reduce the boost to housing consumption implied by recourse mortgages and households' ability to self-insure.

We also found that these concerns about undesirable effects of recourse policies could be mitigated by combining a relatively mild recourse rule with LTV limits. We first showed that the negative effect of LTV limits on housing consumption may be small but LTV limits still reduce welfare for prospective home buyers. We then showed that an economy that combines recourse mortgages with LTV limits displays a lower default rate and a stronger demand for housing without diminishing households' ability to self-insure. Furthermore, we showed that this combination of recourse mortgages and LTV limits prevent high default rates after sharp declines in the price of housing.

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