FEDERAL RESERVE BANK of ST. LOUIS

RESEARCH DIVISION

Working Paper Series

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Working Paper 2011-019D
https://doi.org/10.20955/wp.2011.019

July 2014

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July 17, 2015

Abstract

We present a model in which households facing income and housing-price shocks use long-term mortgages to purchase houses. Interest rates on mortgages reflect the risk of default. The model accounts for observed patterns of housing consumption, mortgage borrowing, and defaults. We use the model as a laboratory to evaluate default-prevention policies. While recourse mortgages make the penalty for default harsher and thus may lower the default rate, they also lower equity and increase payments and thus may increase the default rate. Introducing loan-to-value (LTV) limits for new mortgages increases equity and thus lowers the default rate, with negligible negative effects on housing demand. The combination of recourse mortgages and LTV limits reduces the default rate while boosting housing demand. Recourse mortgages with LTV limits are also necessary to prevent large increases in the mortgage default rate after large declines in the aggregate price of housing.

JEL classification: D60, E21, E44.
Keywords: mortgage, default, life cycle, recourse, LTV, housing price

*For comments and suggestions, we thank seminar participants at ASU, Georgetown U., Indiana U., McMaster U., SUNY at Stony Brook, U. of Toronto, York U., the FRB of Richmond and St. Louis, the IMF, the 2008 and 2009 Wegmans conference, the 2010 and 2014 SED conference, the 2010 and 2013 HULM Conference, the 2011 North America Summer Meeting of the Econometric Society, the 2011 SAET conference, the 2011 Philadelphia Fed Conference on Consumer Credit, the 2013 NBER Summer Institute, and the 2013 Macro-Finance Workshop at NYU. We thank S. Henly, C. Liborio, J. Tompkins, T. Hursey, and E. Yurdagul for excellent research assistance. We thank Jennifer Paniza Bontas for sharing her data with us. We thank M. Michaux, M. Nakajima, and D. Schlagenhauf for useful discussions. Remaining mistakes are our own. The views expressed herein are those of the authors and should not be attributed to the IMF, its Executive Board, or its management, the FRB of St. Louis, or the Federal Reserve System.

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1 Introduction

We study the effects of policies that could mitigate mortgage defaults. The increase in U.S. mortgage defaults observed since 2006 moved the stability of mortgage markets to the center of policy debates (Campbell, 2012; FED, 2012; Treasury, 2009), invigorating academic and policy discussions about prudential policies that could prevent defaults. Two prudential policies have received widespread consideration: recourse mortgages, which allow lenders to collect from debtors after a default, and loan-to-value (LTV) limits on new mortgages.[1]

We evaluate recourse mortgages and LTV limits in the light of a life cycle model with housing and non-durable consumption, idiosyncratic shocks to labor earnings and the price of housing, and mortgages. Households can consume housing services by renting or owning the house they live in, and they can buy houses of different sizes. They 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. There is a deadweight cost of liquidating houses in foreclosure. Households can also refinance their mortgage loans and save using a risk-free asset. There is room for policy interventions because households have limited commitment and markets are incomplete.

We first show that our model generates plausible predictions for the households' demand for housing, demand for mortgages, and mortgage default decisions. We parameterize idiosyncratic income and housing-price stochastic processes using previous estimations obtained with U.S. data. We then calibrate four parameters to match four targets: the homeownership rate, the median house price, the median ratio of financial assets to income, 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 (home equity, 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

[1] IMF (2011) discusses the widespread use of these policies across countries. It is often argued that recent housing-price declines had a much larger effect on mortgage defaults in the United States than in Europe in part because of soft U.S. recourse policies (Hatchondo, Martinez, and Sánchez, 2013; IMF, 2011; Feldstein, 2008). Wong, Fong, Li, and Choi (2011) present empirical evidence that, for a given fall in house prices, the incidence of mortgage default is higher for countries without an LTV limit than for countries with an LTV limit. Several studies document the important effects of the origination LTV on the probability of mortgage defaults (Mayer, Pence, and Sherlund, 2009; Schwartz and Torous, 2003).

good laboratory for the quantitative evaluation of policies.

We next introduce recourse mortgages. We assume that lenders can garnish some of the cash-in-hand wealth (income and financial assets) of a household that defaults. We present results for 15 different recourse policies that differ in three dimensions: the level of cash-in-hand wealth exempt from attachment, the maximum percentage of cash-in-hand wealth subject to attachment, and the (expected) duration of the attachment period.

We find it may be difficult to reduce the rate of mortgage defaults significantly with recourse mortgages. Furthermore, an implementable recourse policy (mild enough to be consistent with bankruptcy law) may fail to prevent a sharp increase in the mortgage default rate after a large aggregate decline in the price of housing and may even exacerbate the increase in the default rate.

The effect of recourse on the equilibrium default rate is nonmonotonic.[2] On the one hand, a harsher recourse policy makes defaults more costly, reducing the probability of a default in any mortgage. On the other hand, in our model with endogenous choice of down payment and equilibrium pricing of mortgage interest rates, a harsher recourse policy may increase the LTV chosen by households and, therefore may increase the default rate.

The effect of recourse on the demand for housing is also nonmonotonic. This effect follows the effect of recourse on LTVs, as higher (lower) LTVs allow for more (less) housing consumption. On the one hand, a harsher recourse policy lowers the cost of high-LTV mortgages and thus may lead households to choose higher LTVs. On the other hand, a harsher recourse policy may force households with adverse income shocks to reduce their consumption in order to stay current on their mortgages payments and avoid a default. This may lead households to choose mortgages with lower LTVs to prevent these costly adjustments. The latter effect dominates for very harsh recourse policies, dampening the demand for housing.

The relationship between recourse and welfare follows the one between recourse and the demand for housing. In our model, the households' ability to default implies endogenous borrowing constraints. Recourse mortgages may relax these constraints, producing welfare gains (default

[2]This nonmonotonicity may account for the mixed evidence on the effect of recourse on mortgage defaults. See Clauretie (1987), Ghent and Kudlyak (2011), and the references therein.

decisions need not be optimal from an ex-ante perspective).

The findings described above indicate that the implementation of recourse mortgages may present difficulties. A recourse policy that is not harsh enough would increase default and a recourse policy that is harsh enough to significantly lower the default rate may end up reducing the boost to housing consumption implied by recourse mortgages (as pointed out by Campbell, 2012, the main stated goal of much U.S. housing policy is to increase the homeownership rate). Furthermore, bankruptcy laws could prevent the implementation of very harsh recourse policies.

Since the difficulty of using recourse mortgages to reduce the default rate is the result of low origination LTVs, this problem could be mitigated by imposing LTV limits. We first study the effect of introducing LTV limits alone and later the effects of combining LTV limits with recourse mortgages.

We find that LTV limits lower the default rate with negligible effects on the demand for housing. For instance, comparing simulations for the benchmark economy with those for a model economy with an 80 percent LTV limit shows negligible differences in housing consumption, while the LTV-limit economy features a default rate 70 percent lower than the one in the benchmark. Nevertheless, we find that an 80 percent LTV limit may be insufficient to prevent a sharp increase in the mortgage default rate after large declines in the aggregate price of housing.

The mild effect of LTV limits on homeownership sheds light on important policy debates. For instance, in the U.S., qualified residential mortgage rules make higher down payments necessary for 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). Since these rules can be viewed as a flexible LTV limit for new mortgages, our results cast doubt on these arguments.

We next show there may be important complementarities between recourse mortgages and LTV limits. Economies with both recourse mortgages and LTV limits feature a lower default rate and higher housing consumption than the benchmark, thus achieving the two most-cited goals of mortgage policies. Furthermore, combining recourse mortgages and LTV limits is necessary to greatly reduce the increase in the mortgage default rate that follows after large declines in the aggregate price of housing.

1.1 Related Literature

We extend models used in quantitative studies of households' earnings risk (see Kaplan and Violante, 2010, and the references therein) by incorporating housing, idiosyncratic housing-price risk, and mortgages. Our modeling of mortgages extends the equilibrium default model used in quantitative studies of credit card debt (Athreya, 2005; Chatterjee, Corbae, Nakajima, and Ríos-Rull, 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 mortgages (Athreya, 2008; Athreya, Tam, and Young, 2011; Chatterjee and Gordon, 2012; Li and Sarte, 2006; Livshits, MacGee, and Tertilt, 2007). We depart from these studies by focusing on collateralized long-term debt (mortgages) and shocks to the price of the collateral (housing). Studying collateralized debt allows us to consider LTV limits as an alternative default-prevention policy and discuss important complementarities between recourse mortgages and LTV limits.

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 find a nonmonotonic relationship between the degree of recourse and mortgage default. Furthermore, the mechanism through which a harsher recourse policy increases the default frequency in our environment is different from the one presented by Quintin (2012). In addition, while Quintin (2012) presents a theoretical discussion of the effects of recourse mortgages, we show it is possible for recourse to increase mortgage defaults in a quantitative model that matches several features of the data.

Corbae and Quintin (2014) study the role of the introduction of mortgage contracts with low down payments 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 showing that introducing recourse mortgages lowers the mortgage default rate and increases home ownership. Analyzing a larger set of recourse policies and presenting a richer model of origination LTVs allows us to present the nonmonotonic effect of the degree of recourse on default and ownership. Corbae and Quintin's (2014) recourse mortgages are such that a fraction of financial assets can be confiscated in the default period. In contrast, we assume that cash in hand (both financial assets and earnings) can be confiscated.[3]

Mitman (2012) presents a quantitative study of the interactions among recourse on mortgages, bankruptcy, and mortgage defaults across U.S. states. He finds that recourse mortgages have only a small effect on U.S. mortgage defaults because households can file for bankruptcy. 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 (2014) and in this paper.[4] Mitman (2012) also finds that nonrecourse is the optimal policy. This is in sharp contrast to the gains from introducing recourse mortgages presented here and by Corbae and Quintin (2014). This contrast may be due to different assumptions on the duration of mortgage contracts and the nature of housing shocks (following previous studies, Mitman, 2012, assumes one-period mortgages and models shocks to the house value as depreciation shocks that affect the services a household obtains from its house without affecting the price of housing in the economy).

We are unaware of studies using theoretical models to evaluate the effects of LTV limits for new mortgages. Campbell and Cocco (2012) study a framework with an exogenous origination LTV and present comparative statics with respect to that variable. They show that higher origination LTVs are related to 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 well 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 us to discuss the effects of LTV limits on homeownership, a key element of policy debates.

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 presents the recursive formulation of the model. Section 4 discusses our calibration. Section 5 shows that predictions of the benchmark model (without prudential regulations) fit the data. Section 6

[3]Limiting confiscation to only assets or income would imply introducing an additional state variable into our model, increasing the computational cost significantly. Confiscation of income is often a legal possibility with recourse mortgages. For instance, in U.S. states with recourse mortgages, an employer can be forced to withhold an employee's income exceeding exempted wages.

[4]Chatterjee and Eyigungor (2009), Garriga and Schlagenhauf (2010), Guler (2014), and Jeske, Krueger, and Mitman (2013) present other recent quantitative studies of mortgage defaults but do not discuss policies that could mitigate defaults.

compares economies with different prudential regulations in place. Section 7 concludes.

2 The Model

We model the choices of a household that lives T periods and works until age $t = W \leq T$.[5] In contrast to previous quantitative studies of idiosyncratic earnings risk, we assume that (i) in addition to consuming nondurable goods, the household consumes housing; (ii) in addition to idiosyncratic earning shocks, the household faces idiosyncratic shocks to the price of housing; and (iii) borrowing options are endogenously given by lenders' zero-profit conditions on mortgage contracts.

At the beginning of the period, the household observes the realization of its earnings and housing-price shocks. After observing these shocks, the household makes its housing and financial decisions. We let β denote the subjective discount factor.

2.1 Housing

We present a stylized model of housing that follows closely that of Campbell and Cocco (2003). The household must live in a house and, in any given period, it may own up to one house.

We depart from Campbell and Cocco (2003) by (i) allowing the household to choose whether to own or rent the house it lives in and (ii) incorporating houses of different sizes. The latter allows us to account for the increasing life cycle profile of the mean house price observed in the data. If the household owns a house, it must live in the house it owns. For simplicity, we assume the household does not need to pay rent if it chooses to be a renter. This assumption guarantees that the household is always able to afford housing. There are $M + 1$ house sizes and the house with the smallest size is the one available for rent. Let $h \in \left\{h^R, h_1, ..., h_M\right\}$ denote a house size, where h^R is the size of the house available for rent.

The utility u derived from consumption c and from living in a house of size h displays a constant elasticity of substitution between the two goods:

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

[5] In previous versions of this study, we assume stochastic death and find essentially the same results.

where γ denotes the risk aversion parameter, α governs the degree of intra-temporal substitutability between housing and nondurable consumption goods, and θ determines the expenditure share for housing.

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

2.2 Earnings and Housing-Price Stochastic Processes

Both the price of housing and earnings follow exogenous processes. Each period, household i receives income y_t^i. During working age, income has a fixed effect f^i, a life cycle component l_t, an i.i.d component ε_t^i, and a persistent component z_t^i:

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

where ε_t^i is normally distributed with variance σ_ε^2, and

$$z_t^i = z_{t-1}^i + e_t^i.$$

After retirement, the household receives a fraction of the last realization of the persistent component of its working-age income. To mimic the U.S. Social Security retirement benefits, we assume that this fraction is a decreasing function of pre-retirement income:

$$\text{replacement ratio} = Max\{A_0 + A_1\ exp(f^i + l_W + z_W^i), A_2\}.$$

As is standard in the housing literature, we model housing-price shocks as an autoregressive process, and we allow for correlation between earnings and the price of housing.[6] In particular, following Nagaraja, Browny, and Zhao (2009), the log of the housing price is assumed to follow an AR(1) process:

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

where $\bar{p}$ is the mean price, and e_t^i and ν_t^i are jointly normally distributed with correlation $\rho_{e,\nu}$ and variances σ_e^2 and σ_ν^2.

[6] Thus, we explicitly allow for predictability in house prices as in Corradin, Fillat, and Vergara-Alert (2010) and Nagaraja, Browny, and Zhao (2009).

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.

A mortgage for a household of age t is a promise to make payments for the next $T-t$ periods or to prepay its debt in any period before T. Mortgage payments decay at rate δ. This allows us to account for the decline in the real value of mortgage payments due to inflation. To prepay its mortgage, the household must pay the value of the remaining payment obligations discounted at the rate r, $q^*(n)b$, where $n = T - t$, b denotes the current-period mortgage payment, and

$$q^*(n) = 1 + \frac{1-\delta}{1+r} + ... + \left(\frac{1-\delta}{1+r}\right)^n = \frac{1 - \left(\frac{1-\delta}{1+r}\right)^{n+1}}{1 - \frac{1-\delta}{1+r}} \text{ for } n \geq 1. \tag{2}$$

Computing the prepayment amount using the opportunity cost of lending r instead of using the mortgage interest rate allows us to economize a state variable (which is significant given the high computational cost of the exercises we present). This is unlikely to have significant quantitative effects: the mortgage interest rate is given by the opportunity cost of lending plus a default premium, and the majority of households choose down payments high enough to make the default premium negligible (which is consistent with the very low mortgage default rates observed in the data). Note that since every period, we allow the household to prepay its mortgage and ask for a new mortgage, the household can choose a decreasing or increasing pattern of mortgage payments and change the effective duration of its mortgages. There is a limit to the mortgage origination LTV and a fixed cost ξ_M of signing a mortgage contract. Mortgage loans are the only loans available to the household.

The household can default on its mortgage. If the household chooses to default, it hands its house over to the lender, who sells it with a discount at price $ph(1-\overline{\xi}_S)$, with $0 \leq \overline{\xi}_S \leq 1$. The household must rent in the period in which it defaults.

We allow for recourse mortgages: if the proceeds from the foreclosed house sale are not enough to pay the household's debt ($ph(1-\overline{\xi}_S) < q^*(n)b$), the lender may be able to garnish some of the household's financial wealth. Each recourse period in which the household has not paid the totality of its debt, the lender can garnish the lesser of (i) a share κ of the household's cash-in-hand wealth, and (ii) the household's cash-in-hand wealth in excess of an exempted amount.[7] We express the exempted amount $\phi\tilde{w}$ as a share ϕ of the median income in the benchmark economy $\tilde{w}$. Thus, each period in which the household is in default it must transfer to the lender

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

where $w = \exp(f + l_n + z + \varepsilon) + a \geq 0$ denotes the household's cash-in-hand wealth (labor income plus savings) at the beginning of the period.

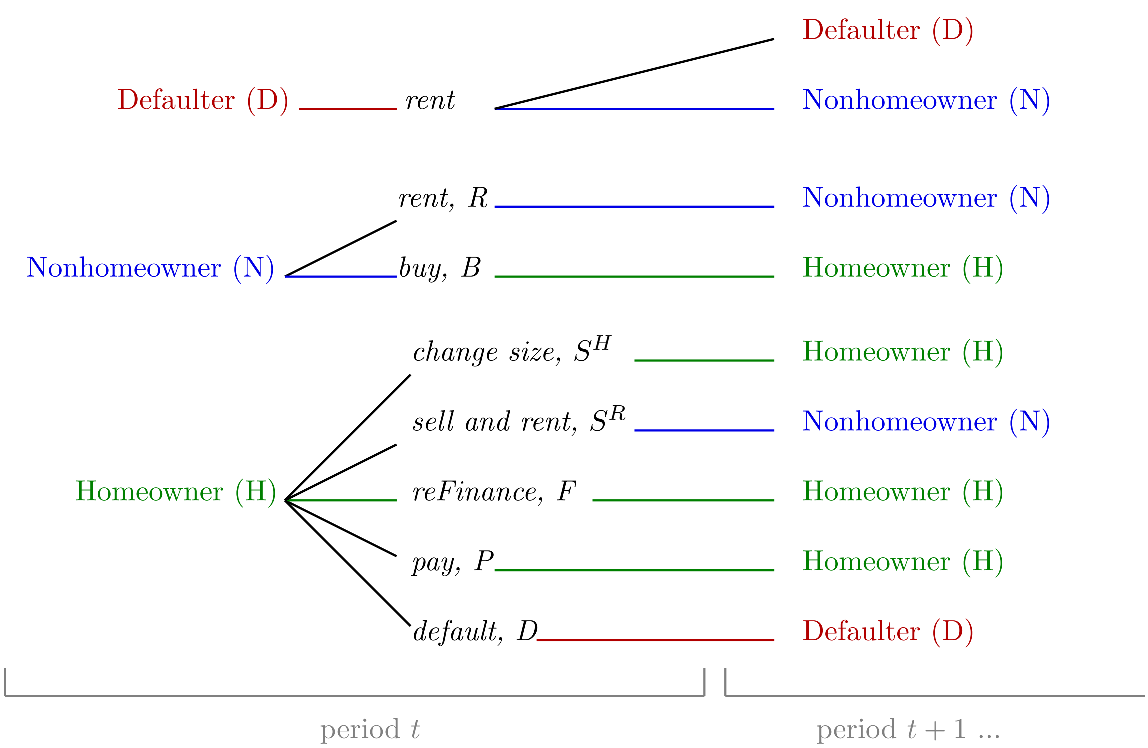
To economize a state variable, we assume the duration of the recourse period is stochastic. A defaulting household starts making recourse payments Φ in the default period, and each period it may be freed from recourse payments with probability ψ. The household also exits recourse when it finishes paying its debt. After exiting recourse, the household regains the option of becoming a homeowner.

3 Recursive Formulation

The household can enter each period as (i) a defaulter (who defaulted in a previous period and did not pay its debt yet), (ii) a nonhomeowner with clean credit who can choose whether to buy a house, or (iii) a homeowner. Figure 1 presents household choices in each of these three situations and the corresponding value functions.

[7] In most countries, recourse allows for collection of personal assets and future income. To economize a state variable, our recourse rule does not distinguish assets from income and thus uses cash-in-hand wealth. Our recourse rule features both means testing through exemptions and a limit to the share of resources that can be taken by lenders, both common characteristics of attachment rules. For instance, in the U.S. wages below a legal amount (30 hours per week multiplied by the prevailing minimum wage) cannot be withheld. If wages exceed that amount, the employer is obligated to withhold the lesser of the wages in excess of the exempted amount and 25 percent of the wages. Similar exemptions exist for attachment of personal assets.

Figure 1: Household Choices



Note: R, B, S^H, S^R, F and P denote interim value functions.

3.1 Nonhomeowner

If the household does not own a house, it must 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

$$N(w, z, p, n) = \max_{I_{rent} \in \{0,1\}} \{I_{rent} R(w, z, p, n) + (1 - I_{rent}) B(w, z, p, n)\}, \tag{3}$$

where R denotes the lifetime utility of a nonhomeowner 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.

3.2 Renter

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

$$R(w, z, p, n) = \max_{a' \geq 0} \left\{ u\left(c, h^R\right) + \beta \mathbb{E}\left[N(w', z', p', n-1) \mid z, p\right] \right\}, \tag{4}$$

$$\begin{aligned} s.t. \qquad & c = w - \frac{a'}{1+r} \\ & w' = \exp(f + l_{n-1} + z' + \varepsilon') + a'. \end{aligned}$$

3.3 Buyer

A household that decides to buy a house must choose the size of the house (h'), the amount of savings (a'), and the amount borrowed. The latter is given by $b'q(b', a', z, p, h', n)$, where b' denotes the next-period mortgage payment and q is defined in Subsection 3.5. The expected discounted lifetime utility of a buyer satisfies

$$B(w, z, p, n) = \max_{\{b' \geq 0, a' \geq 0, h'\}} \{u(c, h') + \beta \mathbb{E}\left[H(h', b', w', z', p', n-1) \mid z, p\right]\} \tag{5}$$

$$\begin{aligned} s.t. \qquad & c = w + b'q(h', b', a', z, p, n) - I_{b'>0}\xi_M - \frac{a'}{1+r} - (1 + \xi_B)ph', \\ & w' = \exp(f + l_{n-1} + z' + \varepsilon') + a', \\ & b'q(h', b', a', z, p, n) \leq \lambda p h', \qquad (6) \\ & h' \in \{h_1, ..., h_M\}, \end{aligned}$$

where the indicator $I_{b'>0}$ takes a value of 1 if the household buys the house with a mortgage and of 0 otherwise, and H denotes the expected discounted lifetime utility of a household that enters the period as a homeowner. Equation (6) imposes a mortgage LTV limit (λ).

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, or (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:

$$H(h,b,w,z,p,n) = \max_{I_P\in\{0,1\},I_F\in\{0,1\},I_D\in\{0,1\},I_S\in\{0,1\}} \{I_P P(\cdot) + I_F F(\cdot) + I_D D(\cdot) + I_S S(\cdot)\} \tag{7}$$
$$s.t. \quad 1 = I_P + I_F + I_D + I_S.$$

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

$$P(h,b,w,z,p,n) = \underset{a'\geq 0}{Max} \{u(c,h) + \beta \mathbb{E}[H(b(1-\delta), w', z', p', h, n-1) \mid z, p]\} \tag{8}$$
$$s.t. \quad c = w - b - \frac{a'}{1+r},$$
$$w' = \exp(f + l_{n-1} + z' + \varepsilon') + a'.$$

Mortgage Refinancer. To refinance, the household must prepay its mortgage and choose the next-period payment of its new mortgage $b' \geq 0$ (the household can also 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

$$F(h,b,w,z,p,n) = \max_{b'\geq 0, a'\geq 0} \left\{ u\left(c,h\right) + \beta \mathbb{E}\left[H(h,b',w',z',p',n-1) \mid z,p\right] \right\} \tag{9}$$

$$\begin{aligned} s.t. \quad & c = y - q^{*}(n)b + q(h',b',a',z,p,n)b' - I_{b'>0}\xi_M - \frac{a'}{1+r}, \\ & w' = \exp(f + l_{n-1} + z' + \varepsilon') + a', \\ & b'q(h',b',a',z,p,n) \leq \lambda ph. \end{aligned} \tag{10}$$

Mortgage Defaulter. If the household defaults, it is still free to adjust its financial wealth. A defaulting household becomes a renter until it exits the recourse period. Thus, the value of defaulting is given by

$$D(h,b,w,z,p,n) = \underset{a'\geq 0}{Max} \begin{cases} u\left(c,h^R\right) + \beta \mathbb{E}\left[N(w',z',p',n-1) \mid z,p\right] & \text{if } I_{rm}b' = 0 \\ u\left(c,h^R\right) + \beta \mathbb{E}\left[\psi N(w',z',p',n-1) + (1-\psi)D(0,b',w',z',p',n-1) \mid z,p\right] & \text{otherwise,} \end{cases} \tag{11}$$

$$s.t. \quad c = w - \Phi(h,b,w,p,n) - \frac{a'}{1+r}, \tag{12}$$

$$\begin{aligned} & w' = \exp(f + l_{n-1} + z' + \varepsilon') + a', \\ & b' = \frac{[q^{*}(n)b - ph(1-\overline{\xi}_S) - \Phi(h,b,w,p,n)](1+r)}{q^{*}(n-1)}, \end{aligned} \tag{13}$$

where I_{rm} is an indicator function equal to 1 (0) if the mortgage is (not) a recourse mortgage.

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

$$S(h,b,w,z,p,n) = \max_{I_{rentS}\in\{0,1\}} \left\{ I_{rentS}S^R(h,b,w,z,p,n) + (1-I_{rentS})S^H(h,b,w,z,p,n) \right\},$$

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 adjust only its financial wealth. Thus, its lifetime utility is given by

$$S^R(h,b,w,z,p,n) = \max_{a'\geq 0} \left\{ u\left(c, h^R\right) + \beta \mathbb{E}\left[N(w',z',p',n-1) \mid z,p\right] \right\} \tag{14}$$

$$\begin{aligned} s.t. \quad & c = w - q^*(n)b + ph\left(1-\xi_S\right) - \frac{a'}{1+r}, \\ & w' = \exp(f + l_{n-1} + z' + \varepsilon') + a'. \end{aligned}$$

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

$$S^H(h,b,w,z,p,n) = \max_{\{b'\geq 0, a'\geq 0, h'\}} \left\{ u\left(c, h'\right) + \beta \mathbb{E}\left[H(h',b',w',z',p',n-1) \mid z,p\right] \right\} \tag{15}$$

$$\begin{aligned} s.t. \quad & c = w - q^*(n)b + ph\left(1-\xi_S\right) + b'q(h',b',a',z,p,n) - I_{b'>0}\xi_M - (1+\xi_B)ph' - \frac{a'}{1+r}, \\ & w' = \exp(f + l_{n-1} + z' + \varepsilon') + a', \\ & b'q(h',b',a',z,p,n) \leq \lambda p h', \qquad (16) \\ & h' \in \left\{h_1, ..., h_M\right\}. \end{aligned}$$

3.5 Mortgages

When the household asks for a mortgage that promises to pay b' next period, the amount it borrows is given by $b'q(h',b',a',z,p,n)$, where

$$q(h',b',a',z,p,n) = \frac{q_{\text{pay}} + q_{\text{prepay}} + q_{\text{default}}}{1+r} \tag{17}$$

and

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

In the expressions above, $\hat{I}_P$, $\hat{I}_F$, $\hat{I}_S$, and $\hat{I}_D$ denote the optimal choice of a homeowner (i.e., the solution to problem 7 above), $a''_P = \hat{a}_P(h,b',w',z',p',n-1)$ denotes the optimal saving choice of a household that pays its mortgage next period (i.e., the solution to problem 8 above), and $w''_D = \exp(f + l_{n-2} + z'' + \varepsilon'') + \hat{a}_D(h, b', w', z', p', n-1)$, $a''_D = \hat{a}_D(h, b', w', z', p', n-1)$ denotes the optimal saving choice of a household that defaults next period (i.e., the solution to problem 11 above),

$$b''_D = \frac{[q^*(n-1)b' - \Phi(h', b', w', p', n-1)](1+r)}{q^*(n-2)}$$

denotes the debt in two periods for a household that defaults next period, and

$$q^D(b', w', z, n) = (1-\psi)\mathbb{E}\left[\frac{\Phi(0, b', w', 0, n-1) + b'' q^D(b''_D, w''_D, z', n-1)}{(1+r)b'}\right]$$

is such that $b' q^D(b', w', z, n)$ denotes the secondary market price of a mortgage in default with current-period promised payments given by b' (i.e., the secondary market price of the right to collect the recourse payments corresponding to that mortgage).

3.6 Equilibrium definition

A recursive equilibrium is characterized by

1. a set of value functions N, R, B, H, P, F, D, S, S^R, and S^H,

2. rules for nonhomeowners' renting $\hat{I}_{rent}$; renters' savings $\hat{a}_R$; buyers' savings $\hat{a}_B$, borrowing $\hat{b}_B$ and housing $\hat{h}_B$; homeowners' choices of paying the mortgage $\hat{I}_P$, refinancing $\hat{I}_F$, defaulting $\hat{I}_D$, and selling the house $\hat{I}_S$; mortgage payers' savings $\hat{a}_P$; mortgage refinancers' savings $\hat{a}_R$ and borrowing $\hat{b}_R$; defaulters' savings $\hat{a}_D$; sellers' renting $\hat{I}_{rentS}$; seller-renters' savings $\hat{a}_{SR}$; seller-buyers' savings $\hat{a}_{SB}$, borrowing $\hat{b}_{SB}$ and housing $\hat{h}_{SB}$,

3. and a price function q,

such that

i. given a price function q; the policy rules $\hat{I}_{rent}$, $\hat{a}_R$, $\hat{a}_B$, $\hat{b}_B$, $\hat{h}_B$, $\hat{I}_P$, $\hat{I}_F$, $\hat{I}_D$, $\hat{I}_S$, $\hat{a}_P$, $\hat{a}_R$, $\hat{b}_R$, $\hat{a}_D$, $\hat{I}_{rentS}$, $\hat{a}_{SR}$, $\hat{a}_{SB}$, $\hat{b}_{SB}$, $\hat{h}_{SB}$, and the value functions N, R, B, H, P, F, D, S, S^R, and S^H solve the Bellman equations (3)-(16).

ii. given policy rules $\left\{\hat{a}_P, \hat{a}_D, \hat{I}_P, \hat{I}_F, \hat{I}_S, \hat{I}_D\right\}$, the price function q satisfies equation (17).

4 Calibration

We calibrate the model using U.S. data. Whenever possible, we use as a reference the 2001 Survey of Consumer Finances (SCF).[8] Table 1 presents parameter values obtained without using simulations of the model.

Table 1: Parameter Values

Parameter	Value	Definition	Basis
a_0	$0.65y_0$	Initial wealth	SCF
σ_ν^2	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, Browny, and Zhao (2009)
l	–	Income, life-cycle component	Kaplan and Violante (2010)
σ_ε^2	0.0630	Variance of ε	Kaplan and Violante (2010)
σ_e^2	0.0166	Variance of e	Kaplan and Violante (2010)
f	$+-0.459$	Income fixed effects	Storesletten, Telmer, and Yaron (2004)
r	0.030	Risk-free rate	Standard in the literature
γ	2.000	Risk aversion	Standard in the literature
α	0.500	Elasticity of substitution	Standard in the literature
ξ_B	0.030	Cost of buying, households	Gruber and Martin (2003)
ξ_S	0.030	Cost of selling, households	Gruber and Martin (2003)
$\bar{\xi}_S$	0.220	Cost of selling, bank	Pennington-Cross (2006)
ξ_M	0.150	Cost of signing mortgage	U.S. Federal Reserve
δ	0.020	Payments decay	Average inflation
A_0	0.7156	Replacement ratio	U.S. Social Security
A_1	-0.040	Replacement ratio	U.S. Social Security
A_2	0.140	Replacement ratio	U.S. Social Security
ϕ	∞	Recourse exemption	No recourse
I_{rm}	0	Recourse indicator	No recourse
λ	1	LTV limit	Positive down payment

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 at age 95. A household's initial asset position is

[8] We use households between 25 and 60 years of age that are not in the top 5 percentile of the wealth distribution. We choose the year 2001 because we calibrate our model without changes in the aggregate price of housing (we study such changes in Section 6) and thus, we want to use data from before the larger swings in average U.S. house prices (the boom in real house prices had just begun in 2001).

65 percent of its initial income, which allows us to match the mean net asset position at age 25 in the SCF.

We input into the model stochastic processes for income and the price of housing estimated using micro data. We pin down the variance of housing-price innovations (σ_ν^2) and the correlation of income and housing-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, Browny, and Zhao (2009).

The parameters $\sigma_e, \sigma_\varepsilon$ and the life cycle component of the income process are calibrated following Kaplan and Violante (2010). As in Storesletten, Telmer, and Yaron (2004), the fixed effect takes two values, -0.459 and 0.459. Parameter values for the retirement income are chosen to make the replacement ratio decline with income, from 69 percent to 14 percent, consistently with the U.S. replacement ratios (Aon, 2008). This implies an average replacement ratio of 47 percent, which is close to the replacement ratio in other quantitative studies (see, for example, Conesa and Krueger, 1999). Mean income is 5.74.

The values of the risk-free interest rate ($r = 0.02$), household's risk aversion parameter ($\gamma = 2$) and elasticity of intratemporal substitution ($\alpha = 0.5$) are within the range of accepted values. Hanushek and Quigley (1980) estimate elasticities of 0.5 for Phoenix and 0.6 for Pittsburgh. Siegel (2008) finds an elasticity of 0.5, which is also the point estimate presented by Li, Liu, and Yao (2014).[9]

We set the cost of buying and selling a house using estimates in Gruber and Martin (2003) and Pennington-Cross (2006). The cost of signing a mortgage is the average cost reported by the Board of Governors of the Federal Reserve System. The depreciation of mortgage installments is set considering an inflation rate of 2 percent.

We assume that there is no recourse (ϕ is sufficiently high and $I_{rm} = 0$) and that the household cannot borrow more than the value of the house it buys ($\lambda = 1$). There are seven house sizes the household can buy, $\{2, 4, 6, 8, 10, 15, 20\}$. We show this is sufficient for accounting for the life

[9] In previous versions of this study, we assume a Cobb-Douglas utility function and find essentially the same results.

Table 2: Targets and Fit

Parameter	Value	Definition
β	0.935	Discount factor
h^R	1.49	Size rental house
$\bar{p}$	4.48	Mean house price
θ	0.11	weight of durables
Variables	Data	Model
Median (saving/income)	0.80	0.78
Homeownership rate	0.66	0.66
Median house value / median income	2.80	2.91
Median down payment	0.18	0.17

Source: SCF 2001 and Paniza Bontas (2010).

cycle profile of the average house value.

We calibrate the remaining four parameter values (the size of the house available for rent, the mean price of houses, the discount factor, and the weight of non-durable consumption in the utility function) to make four statistics from the model simulations approximate their data counterparts.[10] The size of the house available for rent is the key parameter to match homeownership (SCF). The discount factor is the key parameter to match the median (nonhousing) savings-to-income ratio (SCF). The mean price of housing is the key parameter to match the median house value-to-median income ratio (SCF). The nonhousing consumption weight in the utility function is the key parameter to match the median down payment (Paniza Bontas, 2010). Table 2 presents the fit of the targets obtained with our benchmark calibration and the implied parameter values. The model matches the targeted moments closely.

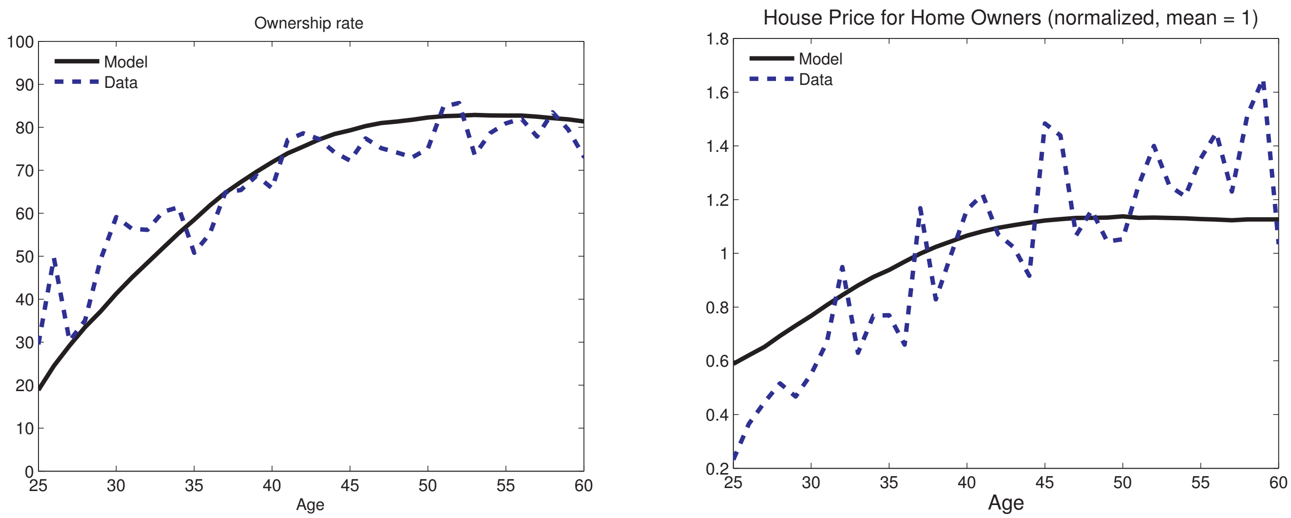
5 Fit of Nontargeted Moments

In this section, we describe model predictions not targeted in the calibration regarding the demand for housing, the use of mortgage loans, and mortgage defaults. In terms of the demand for housing, our calibration targets (and matches reasonably well) the homeownership rate and

[10] We solve the model using linear interpolation with evenly distributed grid points. We use 10 grid points for b, 15 grid points for w, 20 grid points for a, 10 grid points for z. Expectations are computed using 20 Gauss-Legendre quadrature points over p', 10 points over z', and 8 points over eps'. We simulate the behavior of 10,000 households (5,000 of each type) during their lifetime. Statistics are computed using Census data to assign population weights to each cohort.

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, while the housing price is exogenous and independent of age, older households tend to buy more housing, making the mean house price increase over the life cycle.

Figure 2: Demand for Housing over the Life Cycle (nontargeted)

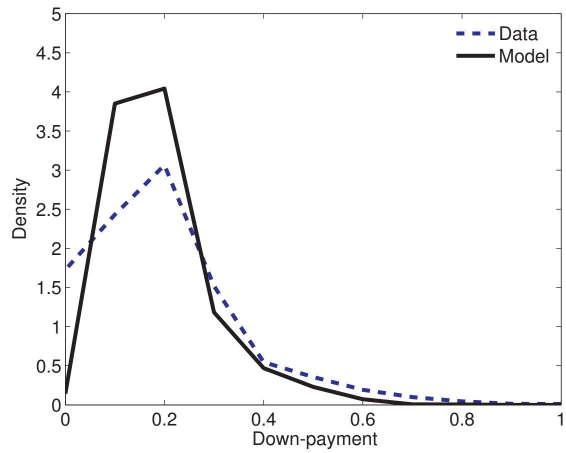


Note: The left panel presents the homeownership rate. The right panel presents the average house value (ph) for homeowners.

Regarding the use of mortgage loans, Figure 3 shows that the model produces plausible implications for the distribution of mortgage down payments.[11] Table 3 shows that mortgage payments in the data are higher than those in the model simulations. Notice, however, that mortgage 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). Table 3 also shows that our model slightly overstates the mean home equity reported by CoreLogic, which is lower than the 42 percent in the 2001 SCF.[12]

[11]Down payment data are not available in the SCF. We constructed the empirical distribution of down payments

Figure 3: Distribution of Down Payments



Source: The empirical distribution is constructed using data presented by Paniza Bontas (2010).

Figure 3 also shows that (as in the data) the majority of households in our stimulations choose to pay significant down payments, making their mortgages virtually default-free (this is also reflected in the very low default rate presented in Table 3). Thus, most mortgage loans originate at a rate very close to the one that reflects the lenders' opportunity cost, independent of the household's characteristics. Nevertheless, modeling the mortgage rate as a function of the loan and the household's characteristics is essential for obtaining a plausible distribution of down payments and for measuring how the household's borrowing opportunities would change with the policies we study.

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, Krueger, and Mitman (2013) and Mitman (2012). They explain that the quarterly foreclosure rate was 0.4 percent between 2000 and 2006, and the ratio of mortgages in foreclosure eventually ending in liquidation was 25 percent in 2005. They argue that since a default in their model (as in ours) implies that the household

using data on combined LTV ratios at origination for the 2000-09 period presented by Paniza Bontas (2010).

[12] The CoreLogic measure of housing equity may be more accurate because it uses transaction data to estimate house values. The SCF measure relies on self-reported house price data.

Table 3: **The Model's Fit of Nontargeted Statistics**

Variables	Data	Model
Median payment/median income	0.15	0.11
Mean home equity/mean house price, mortgagees	0.24	0.28
Default rate (%)	0.50	0.47
Insurance coefficient, permanent shock	0.36	0.40
Insurance coefficient, transitory shock	0.95	0.88

Source: Payments data are from the SCF. The data on home equity are from CoreLogic. The default rate data is the calibration target presented by Jeske, Krueger, and Mitman (2013) and Mitman (2012). Insurance coefficients for earning shocks are computed for the data by Blundell, Pistaferri, and Preston (2008). The insurance coefficient for shock x_{it} is given by $\mu^x = 1 - \frac{cov(\Delta log(c_{it}), x_{it})}{var(x_{it})}$, where the variance and covariance are taken cross-sectionally over the entire population. To compute insurance coefficients, log consumption and log earnings are defined as residuals from an age profile. The insurance coefficient is interpreted as the share of the variance of shock x that does not translate into consumption growth.

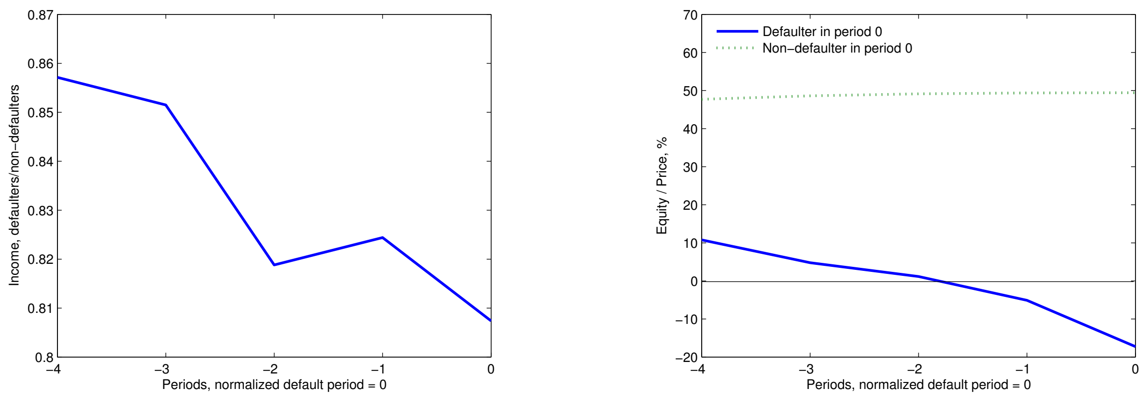
relinquishes its house to the lender, the default rate in the simulations should be compared with the liquidation rate in the data. They also argue that since the default rate in the data is for a period of strong appreciation of house prices, they should target a higher default rate.[13]

In addition, Table 3 shows that the model generates reasonable responses of consumption to earnings shocks. This lends confidence to the model predictions for consumption adjustments in response to the policies we study. In Section 6 we show that the ability of households to self-insure against both earnings and housing-price shocks is not significantly affected by these policies.

Using data from Massachusetts, Foote, Gerardi, and Willen (2008) show that negative equity is a necessary but not a sufficient condition for default: less than 10 percent of the homeowners with negative equity default on their mortgages. They also argue that income shocks play the role of trigger events for default. Figure 4 shows our model is consistent with their findings: for households that default, both income and home equity are lower and decline in the periods preceding defaults.

[13] In Figure 6, we illustrate how our model generates a lower default rate during a period of strong appreciation of house prices.

Figure 4: Model Dynamics of Income (Left) and Home Equity (Right) Before Default



Note: We control for age differences between defaulters and non-defaulters by computing for each group first the mean for each age and later the mean across ages.

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.

6 Economies with Prudential Policy

In this section we evaluate two regulations: recourse mortgages and LTV limits. We first study the effect of each of these policies separately. We later show that there may be significant gains from combined implementation of both policies.

6.1 Recourse Mortgages

In this subsection, we study model economies with recourse mortgages.[14] Table 4 presents model simulations for different values of three parameters that we use to characterize the recourse policy (all other parameter values are those used in the benchmark calibration): the level of cash-in-

[14]Note that since we do not model the labor supply decision, 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 occurs in part because people would choose to default for asset and income levels lower than the ones at which recourse becomes operative.

hand wealth exempt from attachment as a percentage of the median income (ϕ), the maximum percentage of cash-in-hand wealth that can be attached (κ), and the (expected) duration of the attachment period (ψ).

The first panel in Table 4 presents different limits for the cash-in-hand wealth exempt from attachment, with an attachment period of one year and no limit for the percentage of cash-in-hand wealth that can be attached. The second panel presents the same exercises but with the assumption that only 25 percent of cash-in-hand wealth can be attached (this is an attachment limit for wages in the U.S.). The third panel assumes that 50 percent of cash-in-hand wealth is exempt from attachment (an attachment exemption for wages in the U.S.), an expected attachment period of six years (the usual duration of attachment periods in the U.K.; Lea, 2010), and different limits to the percentage of wealth that can be attached. Overall, Table 4 presents results for 15 different recourse policies.

Table 4 shows that the relationship between the degree of recourse and the default rate is nonmonotonic. Somewhat surprisingly, recourse policies that increase the cost of defaulting may increase the default rate. For instance, the economies with recourse mortgages with an exemption from attachment equal to the median income in the first two panels of Table 4 (third column) have a default rate higher than the one in the benchmark. For an exemption equal to 50 percent of the median income and an attachment limit of 25 percent of cash-in-hand wealth, the default rate is higher with a harsher recourse rule of six years of attachment than with one year of attachment (second and third panels of Table 4).

Furthermore, it may be difficult to lower the default rate significantly with recourse mortgages. Table 4 shows that recourse mortgages only imply a default rate that is half the one in the benchmark for very low levels of exempted wealth (below 25 percent of the median income). The default rate is zero only with a very harsh recourse rule with an exemption level of 10 percent of the median income and no limit on the percentage of wealth that can be attached.

Why can the default rate be higher in economies with a recourse policy that implies a higher cost of defaulting? Table 4 shows that a harsher recourse policy may increase the LTV chosen by households, increasing the level of mortgage payments and lowering housing equity. Therefore, since affordability and equity are key determinants of the default rate (Figure 4), a harsher

Table 4: Long-Run Effects of Recourse Mortgages

		One year of attachment, 100% attachment limit Exemption % of median income (ϕ)				
	Benchmark	100	50	25	10	5
Homeownership rate	0.66	0.68	0.70	0.74	0.73	0.72
Mean house size (owners)	1.00	1.04	1.06	1.07	1.07	1.07
Median down payment	0.17	0.10	0.00	0.00	0.00	0.00
Default rate (%)	0.47	0.68	0.41	0.10	0.00	0.00
Median payment/median income	0.11	0.14	0.16	0.16	0.16	0.16
Median (equity/price), mortgagees	0.24	0.09	0.04	0.01	0.01	0.02
IC permanent shock	0.40	0.42	0.42	0.42	0.40	0.40
IC transitory shock	0.88	0.88	0.88	0.88	0.89	0.89
IC housing-price shock	0.87	0.88	0.88	0.87	0.85	0.85
Ex-ante welfare gains	0.00	1.50	2.36	2.78	2.53	2.32

		One year of attachment, 25% attachment limit Exemption as % of median income (ϕ)				
	Benchmark	100	50	25	10	5
Homeownership rate	0.66	0.68	0.69	0.70	0.70	0.70
Mean house size (owners)	1.00	1.03	1.02	1.01	1.01	1.01
Median down payment	0.17	0.12	0.08	0.06	0.06	0.06
Default rate (%)	0.47	0.55	0.34	0.23	0.20	0.20
Median payment/median income	0.11	0.13	0.14	0.14	0.14	0.14
Median (equity/price), mortgagees	0.24	0.11	0.09	0.09	0.09	0.09
IC permanent shock	0.40	0.41	0.41	0.41	0.41	0.41
IC transitory shock	0.88	0.88	0.88	0.88	0.88	0.88
IC housing-price shock	0.87	0.88	0.88	0.88	0.88	0.88
Ex-ante welfare gains	0.00	1.36	1.65	1.69	1.65	1.65

		Six years of attachment, 50% exemption Attachment limit as % of wealth (κ)				
	Benchmark	10	25	40	50	65
Homeownership rate	0.66	0.75	0.76	0.76	0.76	0.76
Mean house size (owners)	1.00	1.05	1.05	1.05	1.05	1.05
Median down payment	0.17	0.00	0.00	0.00	0.00	0.00
Default rate (%)	0.47	0.43	0.42	0.40	0.38	0.37
Median payment/median income	0.11	0.16	0.17	0.17	0.17	0.17
Median (equity/price), mortgagees	0.24	0.01	0.00	0.00	0.00	0.00
IC permanent shock	0.40	0.42	0.42	0.42	0.42	0.42
IC transitory shock	0.88	0.88	0.88	0.88	0.88	0.88
IC housing-price shock	0.87	0.87	0.87	0.87	0.87	0.86
Ex-ante welfare gains	0.00	2.81	2.97	3.00	2.99	2.99

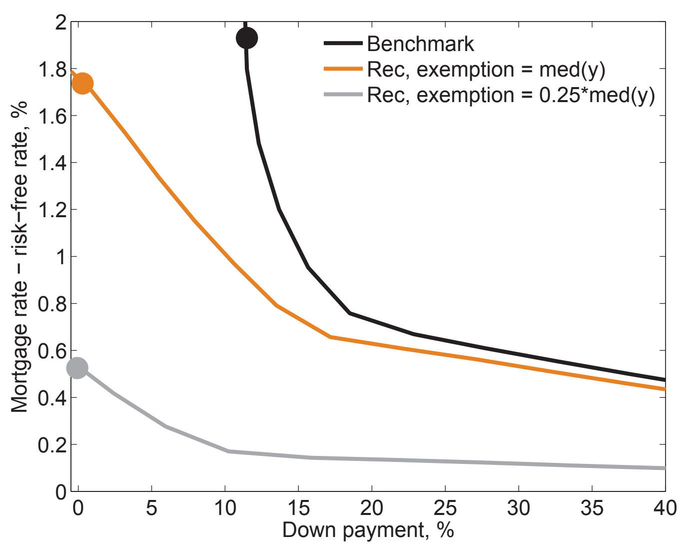
Note: The first (second) panel assumes $\psi = 1$ (one year of attachment of defaulter's wealth), $\kappa = 1$ ($\kappa = 0.25$) implying that lenders can attach up to 100% (25%) of the defaulter's wealth. The third panel assumes $\psi = 0.167$ (six years of attachment in expectation) and an exemption of 50% of the median income. House sizes are normalized to 1 in the benchmark. Ex-ante welfare gains are measured as the proportional increase in (housing and non-durable) consumption that would compensate a new-born household for living in the benchmark instead of in the economy with a prudential policy.

recourse policy may increase the default frequency.

But why would a household choose a higher LTV and assume more default risk when the punishment for defaulting is harsher? A household can use a higher-LTV mortgages to consume more housing sooner at the expense of exposing itself to costly defaults. The household dislikes defaults because of the associated costs (including, for instance, the cost of moving to a different house) and because future default decisions need not be optimal from an ex-ante perspective. Two forces explain why a harsher recourse policy may increase a household's benefit from assuming default risk.

First, with a harsher recourse policy, an increase in the LTV results in a smaller increase in default risk. This occurs because the LTV is less important for a household's default decision, as illustrated by the flattening of the mortgage spread curve implied by harsher recourse policies in Figure 5. Figure 5 also illustrates how a household that is eager to borrow chooses a higher LTV when the spread curve is flatter.

Figure 5: Mortgage Spread with and without Recourse



Note: The figure is for a nonhomeowner buying a house with $h' = 2$ (smallest house to buy), $a' = 0$, $f = -0.459$ (low), $w = 0.40$, $z = -0.14$, $p = 0.46$, and $n = 65$. Recourse mortgages do not have an attachment limit, and have an attachment duration of one year.

Second, households dislike default risk less when default is more likely to be triggered by income shocks. Households would like to insure against negative income shocks, and mortgage defaults provide this insurance. Recall that Figure 4 indicates that negative income shocks trigger defaults. Thus, mortgage defaults provide debt relief to households that suffer these shocks. 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 Figure 7). Thus, households are less eager to acquire contracts that transfer resources to states with negative shocks to the price of housing (as defaultable mortgages do increasingly with a softer recourse rule).

Table 4 shows that the effect of the degree of recourse in the demand for housing (as represented by ownership and house sizes) and welfare is also nonmonotonic. The demand for housing may increase with the degree of recourse because a harsher recourse rule lowers the mortgage interest rate households pay for each LTV (see Figure 5), making households more willing to ask for high-LTV mortgages (as reflected in the lower median down payment reported in Table 4). This allows households to buy larger houses sooner in their life cycle. However, with the harsher recourse rules in Table 4, households become more reluctant to ask for high-LTV mortgages. With these recourse rules, the cost of defaulting is so high that households do not default after very adverse income shocks, and thus are obliged to make large adjustments in non-housing consumption. Therefore, households choose lower LTV mortgages that imply lower payments, which they are more likely to be able to afford without large adjustments in non-housing consumption. To be able to afford lower-LTV mortgages, households delay home purchases and choose smaller houses (since changes in the recourse rule affect only high-risk borrowers, there is no change in the median down payment reported in Table 4).

Table 4 also shows that the effect of recourse on ex-ante welfare closely follows the effect of recourse on housing consumption. Table 5 presents the distribution of welfare gains from introducing recourse mortgages in the benchmark economy computed considering the transition paths for each household, and shows that welfare gains from recourse mortgages may be significantly higher than the ex-ante new-born gains presented in Table 4. The ability of households to self-insure against earnings and housing-price shocks is not significantly affected by the recourse policy.[15]

Table 5: Welfare Gains from Prudential Policies

	Recourse mortgages	LTV limit	Recourse mortgages with LTV limit
Ex-ante new-born gain	1.65	-0.47	0.55
25th percentile gain	0.82	-0.37	-0.12
Median gain	3.44	-0.11	3.17
75th percentile gain	8.99	-0.05	9.02

Note: Recourse mortgages have an exemption equal to 50 percent of median income, an attachment limit of 25 percent of cash-in-hand wealth, and an attachment duration of one year. Mortgages that existed before the introduction of recourse mortgages continue to be nonrecourse. The LTV limit is 80 percent.

We also study the evolution of the mortgage default rate during large swings in the aggregate price of housing. Because of the computational burden of these exercises, we study only one recourse policy—with an exemption equal to 50 percent of median income, an attachment limit of 25 percent of cash-in-hand wealth, and an expected attachment duration of one year.[16] Figure 6 shows that the increase in mortgage defaults triggered by a large decline in the aggregate price of housing may be significant in economies with recourse mortgages, and it may even be larger than the one observed in an economy without recourse mortgages.[17]

Figure 7 shows that many households benefit from a large decline in the price of housing.[18] These are households that expect to consume more housing in the future (renters and young

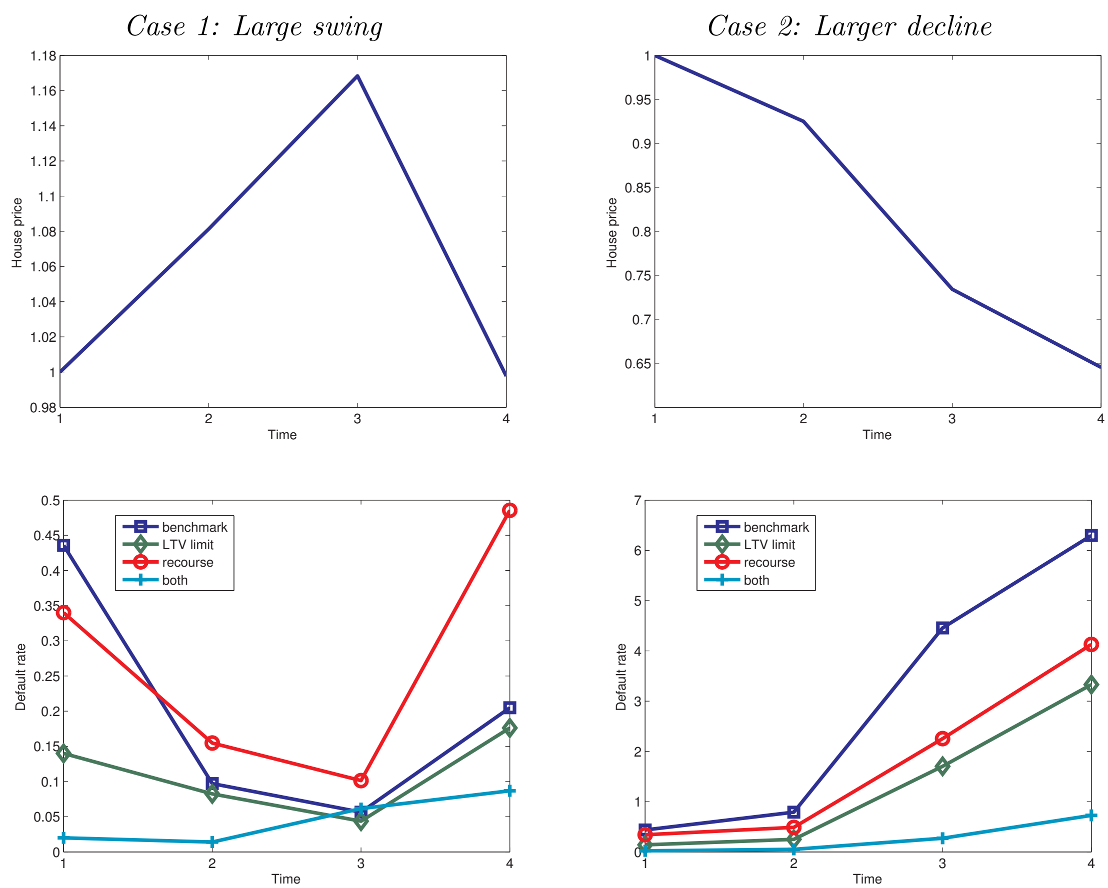
[15]Insurance coefficients in Table 4 show that the average adjustment is nonhousing consumption after a housing-price shock is small and comparable to the average adjustment in nonhousing consumption after a transitory shock to earnings. Households that do not expect to adjust their housing consumption will not significantly adjust their nonhousing consumption after a housing-price shock, because they expect the housing price to revert to its mean. This finding 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 expects to stay in its house. Households that expect to buy (sell) housing in the future typically benefit from (are hurt by) a negative housing-price shock and choose higher (lower) nonhousing consumption.

[16]This is a relatively mild 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 of his state, the debtor is subject to a means test that could force him to file under Chapter 13 (under which a percentage of debts must be paid over a period of three to five years) as opposed to Chapter 7 (under which debts are paid only from existing assets).

[17]It is difficult to compare model predictions from these experiments with the recent behavior of mortgage defaults in the U.S. (the foreclosure rate peaked slightly above 3 percent while the seriously delinquent rate peaked at 5.1 percent; Noeth and Sengupta, 2011). This is because (i) there were massive government interventions to help homeowners with negative equity and (ii) banks may have delayed foreclosures to avoid recognizing losses. Some important government interventions include the National Foreclosure Mitigation Counseling program, the Making Home Affordable programs, and the Neighborhood Stabilization Program.

[18]Because we model declines in the aggregate price of housing as unanticipated, we present welfare gains for one-time declines instead of considering consecutive declines as in Figure 6.

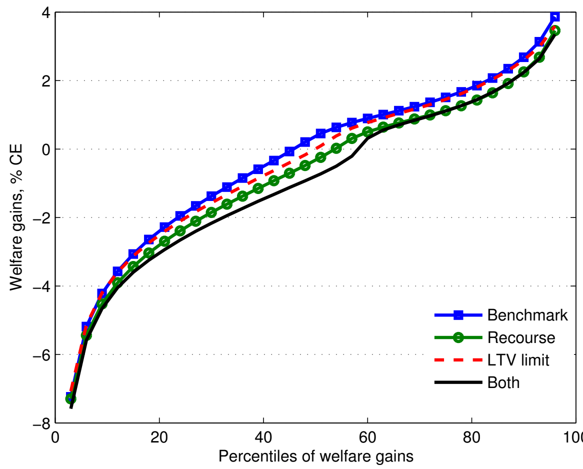
Figure 6: Large Changes in the Aggregate Price of Housing



Note: The starting point is our benchmark economy with a constant aggregate house price $\bar{p}$, which is normalized to 1. Changes in $\bar{p}$ are unexpected and, once they occur, are believed to be permanent. Because of the computational burden, for each exercise we follow the model economy for only four years. Recourse mortgages have an exemption equal to 50 percent of median income, an attachment limit of 25 percent of cash-in-hand wealth, and an attachment duration of one year. The LTV limit is 80 percent.

owners who expect to buy larger houses).

Figure 7: Welfare Gains after a Large Aggregate Decline in the Price of Housing



Note: The figure assumes a 28 percent unanticipated decline in $\bar{p}$ and the price of housing for all households. Recourse mortgages have an exemption equal to 50 percent of median income, an attachment limit of 25 percent of cash-in-hand wealth, and an expected attachment duration of one year. The LTV limit is 80 percent.

Figure 7 also shows that welfare gains from a large decline in the price of housing are smaller in the economy with recourse mortgages. This is not surprising and should not be interpreted as an argument against recourse mortgages. Recourse mortgages deprive debtors from insurance against declines in the price of housing, and Figure 7 presents a very extreme case in which such insurance would be useful (a large and expected-to-be-permanent decline in the price of housing). Losses in one extreme negative scenario do not overturn the large ex-ante welfare gains from recourse mortgages presented in Tables 4 and 5. Furthermore, the economy with recourse mortgages features a higher ownership rate and thus, since declines in the price of housing are good for renters and tend to be bad for homeowners, gains from price declines are smaller in this economy. In addition, a lower housing price favors households because it improves housing affordability, which we established is less of a problem with recourse mortgages (that allow for lower down payments).

In sum, our results indicate that while recourse policies have potential for mitigating mortgage defaults, the implementation of these policies presents difficulties. It may be difficult to significantly reduce the default rate with recourse mortgages, and a recourse policy that is too mild may even increase default risk. Furthermore, a recourse policy that is too harsh may reduce the boost to housing consumption and welfare implied by recourse mortgages. Since the increase in default risk implied by mild recourse policies is the result of low origination LTVs, this problem could be mitigated by imposing LTV limits for new mortgages. Next, we study the effect of introducing LTV limits with nonrecourse mortgages and later the effects of combining LTV limits with recourse mortgages.

6.2 LTV Limits

In this subsection, we solve the benchmark model but change only the LTV limit λ in constraints (6), (10), and (16) of the household's problem. We now allow the household to borrow only a fraction of the value of the house it buys instead of 100 percent as in the benchmark. All other parameter values are the ones in the benchmark calibration.

Table 6 shows that economies with a stricter LTV limit feature a significantly lower mortgage default rate. This occurs because with a stricter LTV limit, households are forced to have more home equity when they buy their house and, thus, are less likely to have sufficient negative equity to trigger a default in the future. However, the economy with an 80 percent LTV limit cannot avoid a very high default rate after the larger shock to the aggregate price of housing presented in Figure 6.

Table 6 also presents a negligible impact of LTV limits on the demand for housing (both ownership and the average size of houses). We identify two reasons why this happens in our simulations. First, in economies with LTV limits, young households save more 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 rates are lower when the default probability is lower. LTV limits make it harder for a household that defaulted to buy a new house and, therefore, lower the default probability and the mortgage interest rate. However, we find that the second reason is not quantitatively important in our simulations: even with the 100 percent LTV limit in the benchmark, most households choose to pay significant down payments

Table 6: Long Run Effects of LTV Limits

		LTV limit at		
	Benchmark	90%	85%	80%
Homeownership rate	0.66	0.66	0.66	0.66
Mean house size (owners)	1.00	1.01	1.00	1.00
Median down payment	0.17	0.17	0.17	0.20
Default rate (%)	0.47	0.40	0.25	0.14
Median payment/median income	0.11	0.11	0.11	0.10
Median (equity/price), mortgagees	0.24	0.24	0.26	0.28
IC permanent shock	0.40	0.40	0.40	0.40
IC transitory shock	0.88	0.88	0.88	0.89
IC housing-price shock	0.87	0.87	0.86	0.86
Ex-ante welfare gains	0.00	-0.12	-0.24	-0.47

Note: House sizes are normalized to 1 in the benchmark. Ex-ante welfare gains are measured as the proportional increase in (housing and non-durable) consumption that would compensate a new-born household for living in the benchmark economy instead of in the economy with a LTV limit.

and thus do not pay a significant default premium in their mortgages (as reflected in the low default rate in the simulations).

The negligible response of ownership to LTV limits presented in Table 6 sheds light on current policy debates. For instance, in the U.S., the proposed Qualified Residential Mortgage (QRM) would imply higher interest rates for borrowers whose down payment is less than 20 percent of the house price.[19] 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, the QRM rules imply an increased 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). Our results cast doubt on these criticisms.

Table 6 also shows that LTV limits imply welfare losses. Recall that in our model endogenous borrowing constraints prevent households from consuming more housing. A stricter LTV limit tightens these constraints. Table 5 shows that, not surprisingly, ex-ante the welfare losses from tightening borrowing constraints for newborns presented in Table 6 are at the high end of the losses implied by introducing this policy in the benchmark economy. Furthermore, recall that

[19]For QRM details, see "Summary of the Ability-to-Repay and Qualified Mortgage Rule and the Current Proposal."

since our model does not feature negative feedback from a higher default rate to the banking sector or house prices (Campbell, 2012; Campbell, Giglio, and Pathak, 2011), our measure of welfare gains from introducing LTV limits that reduce the mortgage default rate should be interpreted as a lower bound. Table 6 also shows that LTV limits do not imply significant changes in the ability of households to self-insure.

6.3 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? Could it prevent large increases in the mortgage default rate after a collapse in the aggregate price of housing? Previous subsections show that recourse mortgages could relax households' borrowing constraints and thus increase housing consumption but could be ineffective in significantly reducing the rate of mortgage defaults. In contrast, LTV limits would lower the default rate, but at the expense of worsening households' borrowing constraints. Furthermore, neither of these two prudential policies could prevent large increases in the mortgage default rate after a collapse in the aggregate price of housing. In this subsection, we study the effects of combining these two policies.

Table 7 shows there may be important complementarities between recourse mortgages and LTV limits. We perform the exercise for relatively mild recourse rules that respect attachment limits observed in the U.S. and thus could be easier to implement. Economies with both recourse mortgages and LTV limits feature 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 homeownership and containing default. Tables 5 and 7 show that welfare gains from introducing recourse mortgages together with LTV limits could be substantial.

Figure 6 shows that complementarities between recourse mortgages and LTV limits could also be key for preventing large increases in the mortgage default rate after a collapse in the aggregate price of housing. After the larger aggregate shock we study, the default rate in the economy with both LTV limits and recourse mortgages is less than 25 percent of the default rate in economies with only one of these policies. With both policies, while the aggregate shock produces a large increase in the share of owners with negative equity, the cost of defaulting implied by recourse mortgages is large enough to prevent a large increase in the default rate. Without LTV limits, equity would be too low. Without recourse mortgages, the cost of defaulting would be too low.

Table 7: Long Run Effects of Recourse Mortgages with LTV Limits

		One year of attachment LTV limit at			Six years of attachment LTV limit at		
	Benchmark	100%	90%	80%	100%	90%	80%
Homeownership rate	0.66	0.69	0.69	0.68	0.76	0.71	0.68
Mean house size (owners)	1.00	1.02	1.04	1.04	1.05	1.07	1.07
Median down payment	0.17	0.08	0.10	0.20	0.00	0.10	0.20
Default rate (%)	0.47	0.34	0.15	0.02	0.42	0.04	0.00
Median payment/median income	0.11	0.14	0.13	0.12	0.17	0.15	0.12
Median (equity/price), mortgagees	0.24	0.09	0.14	0.22	0.00	0.10	0.21
IC permanent shock	0.40	0.41	0.41	0.42	0.42	0.41	0.41
IC transitory shock	0.88	0.88	0.88	0.89	0.88	0.88	0.89
IC housing-price shock	0.87	0.88	0.87	0.85	0.87	0.85	0.85
Ex-ante welfare gains	0.00	1.65	1.23	0.55	2.97	1.57	0.60

Note: The assumed exemption is 50% of the median income and lenders can attach up to 25% of the defaulter's wealth. House sizes are normalized to 1 in the benchmark. Ex-ante welfare gains are measured as the proportional increase in (housing and non-durable) consumption that would compensate a new-born household for living in the benchmark instead of in the economy with a default-prevention policy.

7 Conclusions

We presented a model with idiosyncratic income and housing-price risk that 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 there may be important complementarities between these two policies.

We first showed that recourse policies have potential for mitigating mortgage defaults, but the implementation of these policies could present difficulties. It may not be possible to significantly reduce the default rate with plausible recourse policies, and a recourse policy that is too mild may even increase default risk. Furthermore, a recourse policy that is too harsh may reduce the boost to housing consumption and welfare implied by recourse mortgages.

We also found that these concerns about undesirable effects of recourse mortgages 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 negligible. We then showed that an economy that combines recourse mortgages with LTV limits results in a lower default rate and a stronger demand for housing. Furthermore, we found that combining recourse mortgages and LTV limits may be necessary to prevent high default rates after sharp declines in the price of housing.

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