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. Interest rates on mortgages are determined in equilibrium according to the borrower's risk of default. The model accounts for the observed patterns of housing consumption, mortgage borrowing, and defaults. Default-prevention policies are evaluated. 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). Two forces affect default. More recourse implies that the punishment for default is harsher; this reduces default. But more recourse also decreases the interest rates offered; this increases borrowing and default. Introducing loan-to-value (LTV) limits contains borrowing. Thus, LTV limits for new mortgages lower mortgage defaults with negligible negative effects on housing demand and welfare. The combination of recourse mortgages and LTV limits reduces the default rate while boosting housing demand. The behavior of economies with alternative prudential regulations is evaluated during a boom-bust episode in aggregate house prices. In the economy with both recourse mortgages and LTV limits, the mortgage default rate is less sensible to fluctuations in aggregate 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 housing market for a stochastic number of periods. Default entails an additional cost: there is a deadweight cost of liquidating houses in foreclosure. 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 individuals' income and house-price stochastic processes using previous estimations that use U.S. households data. We then calibrate five parameters to match four targets: the homeownership rate, the

[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, 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 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, Pence, and Sherlund, 2009; Schwartz and Torous, 2003).

share of homeowners with mortgages, the median house price, financial assets, 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 share of owners with mortgages, mortgage payments, 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 evaluate two policies: the introduction of recourse in mortgage contracts and limiting loan-to-value ratios. Those policies are evaluated in (i) an stationary environment with constant aggregate house prices and (ii) an environment with aggregate fluctuations in house prices.

First, we 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 makes defaults more costly, reducing the probability of a default on that mortgage. On the other hand, in our model with endogenous choice of downpayment and equilibrium pricing of mortgage rates, a harsher recourse policy increases the LTV chosen by households and, therefore, it may increase the default rate. We find that the first 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. The latter situation occurs at the expense of reducing the demand for housing (compare with milder recourse policies).

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

The relationship between recourse and households' ability to self-insure (measured with the insurance coefficients used by Blundell, Pistaferri, and Preston, 2008, and Kaplan and Violante, 2010) follows the hump shape of the relationship between recourse and the default frequency. In particular, 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 nonhousing 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 establishes that all financial wealth above the median income must be used to cover the deficiency (i.e., the outstanding debt above the value of the house at the time of default) is not harsh enough and it would actually 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 milder 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 lower the default rate with mild effects on the demand for housing

[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.

and welfare.[5] For instance, comparing simulations for the benchmark economy with those for a model economy with an 85 percent LTV limit shows negligible differences in homeownership and the types 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.

The performance of economies with alternative prudential regulations is then studied in a context with aggregate fluctuations in house prices. In a sense, these experiments represents stress tests of the mortgage market soundness. We find that the economy with both recourse and LTV limits reduces the responsiveness of defaults to fluctuations in aggregate house prices.

[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 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, Giglio, and Pathak, 2011, and the references therein).

1.1 Related literature

We follow closely the SIM model and calibration presented by Kaplan and Violante (2010) but we incorporate house-price risk, and mortgages into their model housing. Carroll (1997), Huggett (1993, 1996), Krusell and Smith (2006), and Ríos-Rull (1995), among others, also study SIM models.

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 (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. 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 a 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 completely differs from the one presented by Quintin (2012). Moreover, while Quintin (2012) presents a theoretical discussion of the effects of recourse, we show 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 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 showing 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 that recourse on mortgages have only a small effect on U.S. mortgage defaults. 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 to the gains from introducing recourse mortgages as discussed here.

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 statistics on their model with respect to exogenous LTV at origination. They show that higher LTVs at origination 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 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—leads us to study a set of prudential policies richer than the ones studied 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 justifies 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 that in 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

[6] Chatterjee and Eyigungor (2009), Garriga and Schlagenhauf (2010), Guler (2008), and Jeske, Krueger, and Mitman (2013) present other recent quantitative studies of mortgage defaults but do not discuss policies that could mitigate defaults.

obtains from its house without affecting the price of housing. Depreciation shocks are likely to overstate the cost of a decline in the price of a house by implying that the household receives fewer services from its house and cannot buy housing any cheaper. Thus, depreciation shocks are likely to underestimate the benefits from recourse mortgages, which limit households' ability to transfer resources to states with low house prices (or states where households suffer a depreciation shock). This may explain in part why the evaluation of 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 incurs the shock 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 understanding 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 even though 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 mortgage payments. This contrasts with the one-period mortgages 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 are inde-

[7] Empirical studies document the importance of home equity for default decisions. See, for example, Bajari, Chu, and Park (2008),Campbell and Dietrich (1983), Deng, Quigley, and Van Order (2000), Foote, Gerardi, and Willen (2008) Mayer, Pence, and Sherlund (2009), and Schwartz and Torous (2003).

pendent of 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, if the household chooses to repay, it has fewer resources available for nonhousing consumption since the borrowing cost increases. 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 explains Mitman (2012) 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 is 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 using 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 a 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 nonhousing 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 equi-

[8] Chen, Michaux, and Roussanov (2012) discuss the important role of mortgage refinancing in consumption smoothing.

librium. These last features are essential for evaluating recourse policies, which we find affect equilibrium down payments greatly. Pricing mortgages in equilibrium 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 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 makes 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 discusses our calibration and show the main predictions of the quantitative model for nontargeted moments. Section 4 presents the long run consequences of introducing prudential regulation. Section 5 studies how the economies with prudential regulation in place react to change in aggregate house prices and compare it with the benchmark economy calibrated to the U.S. Section 6 concludes.

2 The model

We study a life cycle SIM model close to that of 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 to their study, we assume that (i) in addition to consuming nondurable 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 mortgage contracts.

At the beginning of the period, the household observes the realization of its earnings 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 $\chi_{t,t+s}$ denotes 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 that of 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 (i) allowing the household to choose whether to own or rent the house it lives in and (ii) incorporating houses of different size. We assume that if the household owns a house, it must live in the house it owns. For simplicity, we also 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. 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 show this is sufficient for accounting for the life cycle profile of the average house value. As do Jeske, Krueger, and Mitman (2013), 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 for individual i is given by p_t^i. This price changes stochastically over time. The cost of buying a house of size h is $\xi_B hp$, and the cost of selling a house of size h is $\xi_S hp$.

2.2 Earnings and house-price stochastic processes

Both house prices and earnings are exogenous processes. Each period, household i receives income y_t^i. During working age, income has a fixed effect, a persistent component, a life cycle component, and an i.i.d component, as in Kaplan and Violante (2010):

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

where f^i denotes the fixed effect, l_t denotes the life cycle component, ε_t^i is a transitory component, and z_t^i is a permanent component that follows a random walk

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

We assume ε_t^i is normally distributed with variance σ_ε^2. After retirement, the household receives a percentage of the last realization of the permanent component of its working-age income.

As is standard in the housing literature, we model house price shocks as an autoregressive process and we allow for correlation between earnings and house prices.[9] In particular, following Nagaraja, Browny, and Zhao (2009), the log of the housing price is assumed to follow an AR(1) process:

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

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.

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 each household may have up to one mortgage. The household cannot take 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. Mortgage payments 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

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

prepay its mortgage, the household must 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, and q^* denotes the present discounted value of future mortgage payments at the risk free rate; i.e.,

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

where $n = T - t$. Note that since we allow borrowers to prepay their mortgages 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 mortgages.

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 $p_t(1 - \overline{\xi}_S)$, with $0 \leq \overline{\xi}_S \leq 1$. The household must rent in the period in which default occurs. After that period, the household regains the option of becoming a homeowner with probability ψ or stays in default and must rent with probability $1 - \psi$.

As is standard in models with mortality risk and no bequests, wealth is annuitized. Thus, in this model, we need to annuitize both financial and housing wealth. Each period, a household with assets receives a transfer equal to its discounted expected next-period wealth. The price of an annuity is the survival probability discounted at the risk free rate.

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:

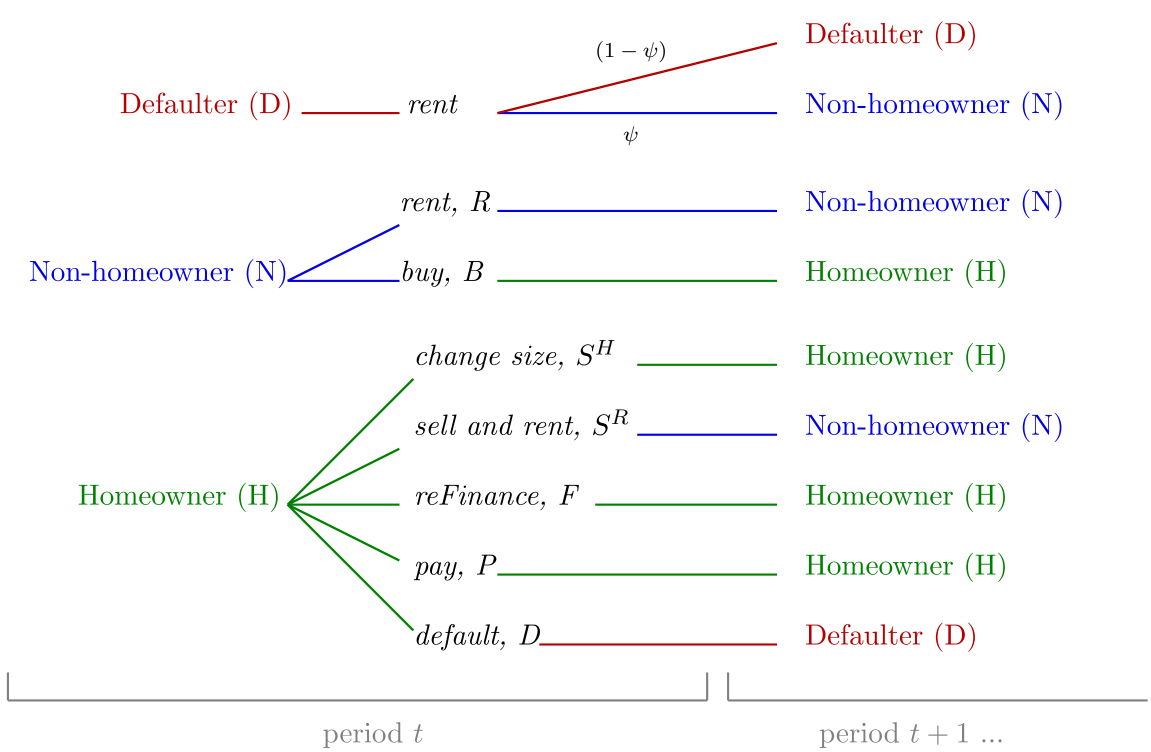
$$\epsilon(h', b', p, n) = \max\left\{0, \frac{1-\chi_n}{1+r}\left[h'\mathbb{E}[p'|p](1-\xi_S) - q^*(n-1)b'\right]\right\}.$$

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.

2.4 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 clean credit who 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.

Figure 1: Households' choices



Note: ψ is the probability a defaulter can access the housing market in the next period. The functions R, B, S^H, S^R, F, P and D are the interim value functions.

2.4.1 Non-homeowner

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

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

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 non-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.

2.4.2 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:

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

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

2.4.3 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 it borrows. The latter is determined by how much the household promises to pay next period (b') and is given by $b'q(b', a', z, p, h', n)$, where q denotes the market price of that mortgage. Thus, the expected discounted lifetime utility of a buyer satisfies

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

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

where the indicator $I_{b'>0}$ takes a value of 1 if the individual buys the house with a mortgage and 0 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).

2.4.4 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:

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

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

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

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

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

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

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

$$b'q(h', b', a', z, p, n) \leq ph. \tag{9}$$

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

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

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

$$S^R(h,b,w,z,p,n) = \max_{a'\geq 0}\left\{u\left(c,h^R\right) + \beta\chi_n \mathbb{E}\left[N(w',z',p',n-1) \mid z,p\right]\right\} \tag{10}$$
$$s.t. \qquad c = w - q^*(n)b + ph\left(1-\xi_S\right) - \frac{\chi_n}{1+r}a',$$
$$w' = \exp(f + l_{n-1} + z' + \varepsilon') + a'.$$

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

$$
\begin{aligned}
& S^{H}(h, b, w, z, p, n)=\max_{\{b' \geq 0, a' \geq 0, h'\}}\left\{u\left(c, h'\right)+\beta \chi_{n} \mathbb{E}\left[H(h', b', w', z', p', n-1) \mid z, p\right]\right\} && (11)\\
s.t. \quad & c=w-q^{*}(n) b-\xi_{P} \\
& +p h\left(1-\xi_{S}\right)+b' q(h', b', a', z, p, n)-I_{b'>0} \xi_{M}-\left(1+\xi_{B}\right) p h'+\epsilon(h', b', p, n)-\frac{\chi_{n}}{1+r} a', \\
& w'=\exp(f+l_{n-1}+z'+\varepsilon')+a', \\
& b' q(h', b', a', z, p, n) \leq p h', && (12)\\
& h' \in\left\{h_{1}, \ldots, h_{M}\right\}.
\end{aligned}
$$

2.4.5 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

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

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 1 (0) if the optimal choice of an household is to make (to not make) its current-period mortgage payment; I_{prepay} is equal to 1 (0) if its optimal choice is (is not) to prepay its mortgage (which the household does when it refinances or sells the house); I_{default} is equal to 1 (0) if its optimal choice is (is not) to default. Note then that if the household asks for a mortgage promising to pay b' next period, the amount it borrows is given by $b' q(h', b', a', z, p, n)$.

3 Calibration

We calibrate the model using U.S. data. Most parameter values are from previous studies. Whenever possible, we use as a reference the 2001 Survey of Consumer Finances (SCF).[10] Table 1 presents the value of all parameters in the model.

Table 1: Parameter values

Parameter	Value	Definition	Basis
b_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	0.020	Risk-free rate	Kocherlakota and Pistaferri (2009)
γ	2.00	Risk aversion	Standard in the literature
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	Board of Governors, Federal Reserve
ξ_P	0.070	Cost of prepaying mortgage	Board of Governors, Federal Reserve
δ	0.02	Payments decay	Average inflation

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

[10] 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 it is before the large swings in average U.S. house prices, and we calibrate our model without changes in the aggregate house prices (we study such changes in section 5).

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, 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.

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 $r = 2$ percent. 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 Board of Governors of the Federal Reserve System.[11] The depreciation of mortgage installments is set considering an inflation rate of 2 percent. We assume there are five house sizes the household can buy, which are evenly distributed between 2 and 10.

We calibrate the remaining five parameter values (the size of the house available for rent, the mean price of houses, the discount factor, the nonhousing consumption weight in the utility function, α, and the probability of regaining access to the mortgage market after a default) to match five 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 (nonhousing) savings-to-income ratio (SCF). The nonhousing consumption weight in the utility function α and the mean price of houses $\bar{p}$ are the key parameters to match the share of homeowners with mortgages and 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).[12] Table 2 presents the fit of the targets

[11] See "Mortgage Refinancings," available at http://www.federalreserve.gov/pubs/refinancings/default.htm.

[12] 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 exist 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 true that some defaulting households can quickly obtain new loans, especially 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).

obtained with our benchmark calibration and the implied parameter values. The model matches the targeted moments closely.

Table 2: Targets and Fit

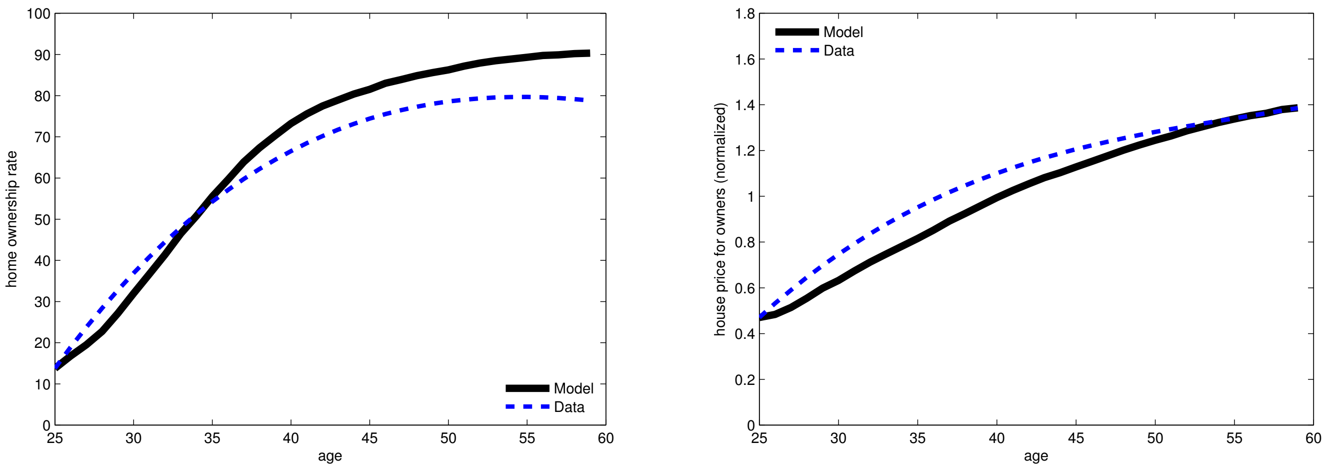
Variables	Data	Model
Homeownership rate	0.66	0.66
Homeowners with mortgages	0.82	0.83
Median price / median income	2.80	2.91
Median (saving/income)	0.85	0.77
Median down payment	0.18	0.17
Parameter	Value	Definition
h^R	1.43	Size rental house
α	0.9	Nonhousing weight in the utility
$\bar{p}$	4.48	Mean house price
β	0.946	Discount factor
ψ	0.667	Probability default ends

Source: SCF 2001 and Paniza Bontas (2010).

3.1 Fit of nontargeted moments

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

Figure 2: Demand for housing over the life cycle (nontargeted)



Note: The left (right) panel presents the homeownership rate (average price of houses)

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). Finally, our model slightly overstate the mean home equity (30 percent in the model vs. 24 percent in the data).[13]

Figure 3.1 shows that the model produces plausible implications for the distribution of mortgage down payments.[14]

[13]Here, we use as reference from the data a statistics provided by CoreLogic, which collects data on house prices and mortgages. For the year 2001, if the same statistic is computed from the SCF we obtain 42 percent.

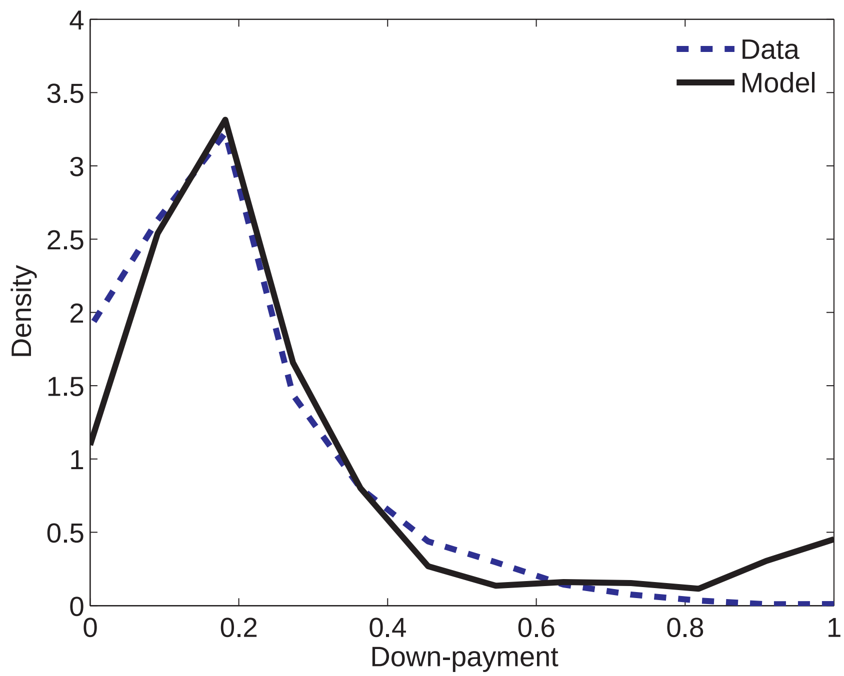
[14]Down payment data are not available in the SCF. We constructed the empirical distribution of down payments using data on combined LTV ratios at origination for the 2000-09 period presented by Paniza Bontas (2010).

Table 3: The model's fit of nontargeted statistics

Variables	Data	Model
Median payment / median Income	0.15	0.12
Default rate (%)	0.50	0.59
Mean home equity / mean house price, mortgagees*	0.24	0.30

Source: The homeowners with mortgages and payments data is from the SCF; The default rate data is the calibration target presented by Jeske, Krueger, and Mitman (2013) and Mitman (2012). The data on home equity is from CoreLogic.

Figure 3: Distribution of down payments



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

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 relinquishes its house to the bank, 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.[15]

In addition, Table 4 shows that our model has plausible predictions about the circumstances that trigger a mortgage default. Households default only when they have sufficient negative equity. This is in line with the evidence in Foote, Gerardi, and Willen, 2008 who show that negative equity is a necessary (but not sufficient) condition for default. They also show that negative income shocks increase the probability of default. Table 4 shows that in our model income also matters: defaulters' income is significantly lower than the income of other households.

Table 4: Equity and income for defaulters and 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

Overall, the results presented above indicate that our framework is a reasonable quantitative model of (i) the demand for housing and mortgages and (ii) 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.

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

4 Long run effects of prudential policy

In this section we evaluate two regulations: recourse and maximum LTV limits. First, we show how each policy affects the long run equilibrium with constant aggregate house prices. Then, we show how different combinations of these policies would affect housing consumption, mortgage borrowing, and defaults.

4.1 Recourse mortgages

In this subsection, we study model economies with recourse mortgages.[16] That is, we use the baseline model parameterization but 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.[17] Thus, a defaulting household must use all its financial wealth w in excess of the threshold $\phi\tilde{w}$ to pay any amount of its mortgage debt $q^*(n)b$ that was not covered by the sale 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.

[16] 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 lower than the ones that make recourse operative.

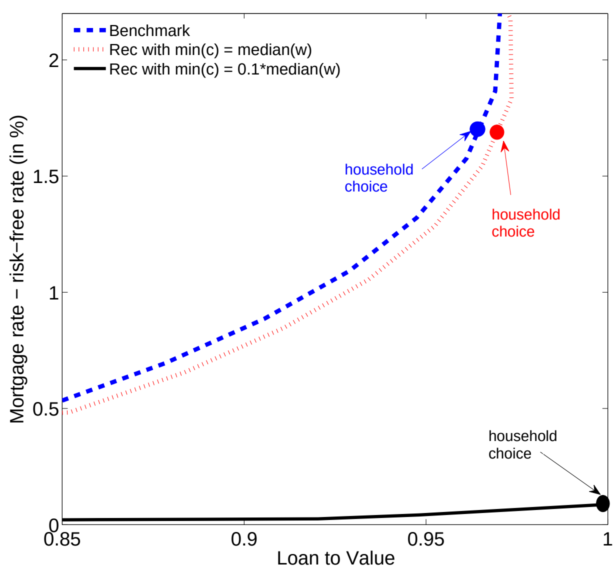
[17] This formulation resembles means-testing features often present in debt relief legislation (see, for instance, the U.S. Bankruptcy Abuse Prevention and Consumer Protection Act of 2005).

Table 5: Effects of recourse mortgages, long run

		Recourse, $\phi =$							
	Benchmark	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 income	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

Note: House sizes are normalized to 1 in the benchmark.

Figure 4: Mortgage spread with and without recourse



In addition, the results displayed in Table 5 indicate 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 (see Figure 4) and, in particular, allows them to choose higher LTVs. However, with the harsher recourse rules in Table 5, households choose

LTVs lower than the ones they choose with softer recourse rules. They do so because when the harsher rules apply defaulting becomes so onerous that households want to eliminate the possibility of default (the default frequency is zero in the simulations).

Somewhat surprisingly, when recourse policies are relatively mild (from $\phi = 4$ to $\phi = 1$ in Table 5), as recourse becomes harsher the default rate increases. Eventually, increasing recourse has the opposite effect (from $\phi = 1$ to $\phi = 0$ in Table 5), that is, it reduces mortgage defaults. On the one hand, given the LTV, a harsher recourse policy increases the cost of defaulting and, therefore, reduces the probability of default. On the other hand, a harsher recourse policy increases the LTV chosen by households and may increase it enough to increase the default frequency.

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

On the one hand, a harsher recourse policy may increase a household's benefit from assuming default risk. But why would a household assume more default risk? First, with a harsher recourse policy, for a given increase in default risk, the household can lower further 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. Negative income shocks that could trigger a mortgage default are factors 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 near future (see section 6.2). Thus, households may have a lower preference for contracts that transfer resources to states with negative shocks to the price of housing (as defaultable mortgages do increasingly 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 a 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 previously mentioned, 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 presents 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. Next, we study the effect of introducing LTV limits with non-recourse mortgages and later the effects of combining LTV limits with recourse mortgages.

4.2 LTV limits

In this subsection, we study model economies with LTV limits for new mortgages. That is, we solve the benchmark model but change only the LTV limit in constraints (5), (9) and (12) 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 remain the same as in the benchmark.

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

Table 6: Effects of LTV limits

Variable	Benchmark	LTV limit at 90%	LTV limit at 85%	LTV limit at 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

Note: House sizes are normalized to 1 in the benchmark.

Our findings shed light on current policy debates. For instance, in the U.S., the proposed Qualified Residential Mortgage (QRM) for the United States[18] would require higher interest rates for borrowers whose down payment is less than 20 percent of the house price. 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). We find that eliminating mortgages with an LTV lower than 80 percent would reduce ownership by only 2 percentage points and would have a negligible effect on house sizes. Thus, our results cast doubt on the aforementioned criticisms.

We identify two reasons LTV limits may have negligible effects on housing demand in our simulations. First, LTV limits have only a small effect on the demand for housing because in economies with LTV limits, 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 higher when the default probability is higher. LTV limits make it harder for a household that defaulted to buy a new house and, therefore, lower

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

the default probability and the mortgage interest rate. However, we find that the second reason is not quantitatively important in our simulations.

4.3 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? Previous subsections show that recourse mortgages could relax households' borrowing constraints and thus increase 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 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 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 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 homeownership and containing default. Furthermore, the economy with both policies features a default rate even lower than 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.

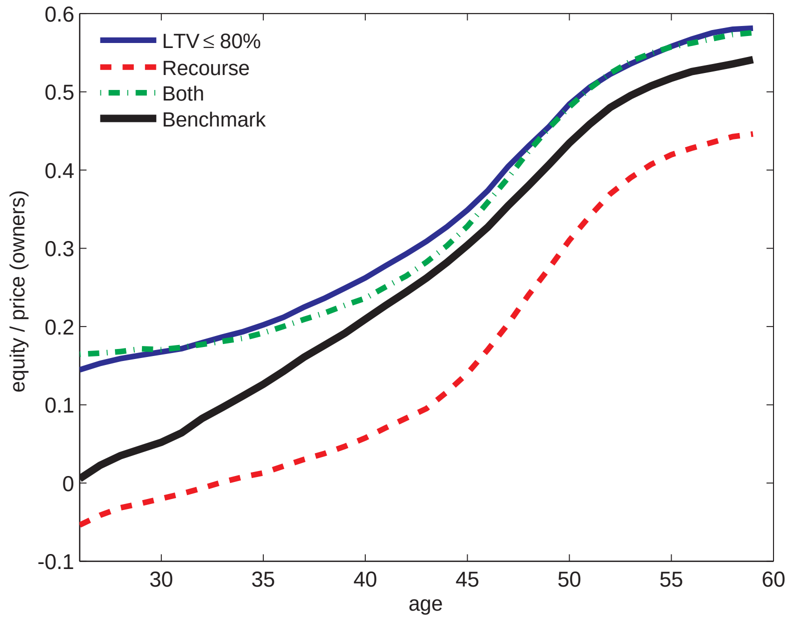
Table 7: Combining recourse mortgages and LTV limits

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

Note: House sizes are normalized to 1 in the benchmark.

As previously discussed, 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 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.

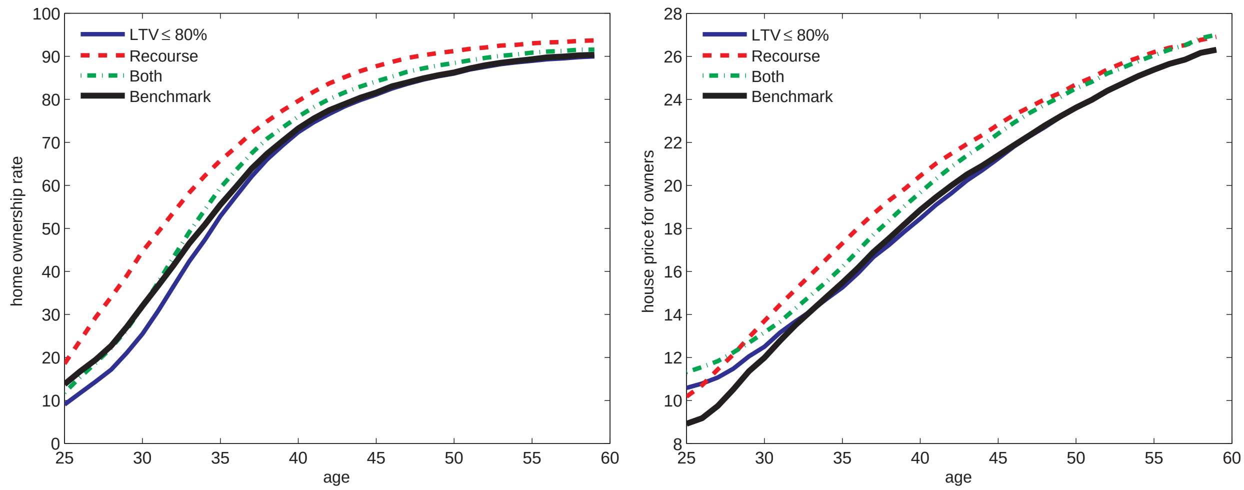
Figure 5: Equity in economies with different policies



Note: Recourse allows for garnishment of all defaulters' wealth above the median income.

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 younger than 27 years of age, for which the rate is only slightly lower. Furthermore, on average houses are larger in the economy with default-prevention policies than in the benchmark, as indicated by a higher mean house price.

Figure 6: Housing demand in economies with different policies



Note: The left (right) panel presents the homeownership rate (mean house price for homeowners). Recourse allows for garnishment of all defaulters' wealth above the median income.

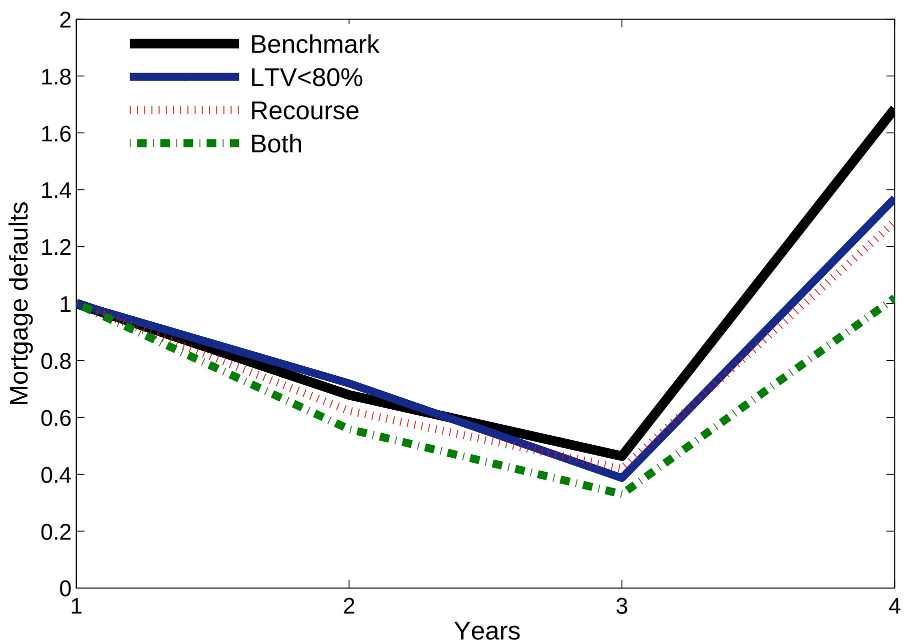
5 Large swings in the aggregate house prices

In previous section, we compared 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 section, we 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 (i) a 15 percent increase in the average price of housing over two years and then (ii) a 15 percent decline 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 (i) the benchmark economy (with non-recourse mortgages and without LTV limits), (ii) an economy with an 80 percent LTV limit, (iii) an economy with recourse mortgages that allow for garnishment of all defaulters' financial wealth above the median income level ($\phi = 1$), and (iv) an economy that combines these LTV and recourse rules. The previous section show that the model economy with the combination of these prudential policies would feature a default rate significantly lower than in the benchmark economy. In this section, we test whether the default rate would remain low in the economy with these prudential policies after the proposed swings in house prices.[19]

Figure 7 shows 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 the LTV limit, the default rate grows less than in the benchmark economy but from a higher initial value, resulting in a higher year-4 rate (1.1 instead of 1 percent).

Figure 7: Default rate after a large decline in house prices following a housing boom



The gains from combining recourse mortgages and LTV limits are confirmed in a similar exercise. Now, we simulate a 22 percent decline in the average house price over three years

[19]The median income recourse rule is the type 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 from existing assets).

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 percent and 4.23 percent, respectively. When the 80 percent LTV limits and recourse at the median wealth level are combined, the year-4 default rate is much lower: only 1.18 percent.

6 Welfare

6.1 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 in the no-recourse benchmark economy. Table 8 shows that a household benefits from being born in an economy with recourse mortgages.

Table 8: Ex ante welfare gains from recourse mortgages

	Recourse, $\phi =$							
Variable	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

Note: CE mean Consumption Equivalence units.

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 as the homeownership rate (see Table 5) and are maximized by the rule that maximizes ownership. Recourse mortgages are beneficial because they expand the household's borrowing opportunities (see 4). However, as previously discussed, when recourse becomes very harsh, households dislike the possibility of defaulting so much they may choose to not buy a house.

A large literature (in law, history, and economics) emphasizes that facilitating defaults can enhance welfare because the ability to repudiate debts can play an important role in helping households deal with adverse shocks (see Athreya, Tam, and Young, 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, Pistaferri, and Preston (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.[20] The insurance coefficient is interpreted as the share of the variance of shock x that does not translate into consumption growth.

Table 9: Insurance coefficients with recourse mortgages

		Recourse, $\phi =$							
Variable	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 shows that the share of the variance of house-price shocks that translates into consumption growth is significantly smaller than the one for income shocks (even more so when compared with the insurance coefficient of persistent income shocks). Households that do not expect to adjust their housing consumption will not significantly adjust their nonhousing consumption after a house-price shock, because they expect the housing price will 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.

There are two possible effects of a negative house-price shock. On the one hand, a negative house-price shock may have a negative effect on homeowners' wealth and, therefore, it may

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

have a negative effect on nonhousing consumption. On the other hand, a negative house-price shock lowers the cost of housing consumption and, therefore, leaves more resources available for nonhousing consumption.[21] 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) nonhousing consumption.

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 follows 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 the severity of the recourse rule increases 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 significantly lowering the default rate may harm households' ability to self-insure. In the next subsection, we show this is not the case when recourse mortgages are combined with LTV limits.

Figure 8 and Table 10 illustrate the effects described in the previous paragraph. Both the figure and the table present welfare gains from a 5 percent decline in house prices.[22] Figure 8 illustrates how house-price declines tend to hurt older households which are likely to be net sellers of housing, but benefit younger households which are likely to be net buyers of housing. This figure also shows 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). This result resembles the findings presented by Glover, Heathcote, Krueger, and Ríos-Rull (2012) for asset prices declines during the Great Recession.

[21] In theory, households could still choose to lower nonhousing consumption if the substitution effect dominates the income effect.

[22] Welfare gains do not include lenders' capital losses, as discussed in subsection 6.3.

Figure 8: Welfare effect of a 5 percent decline in house prices

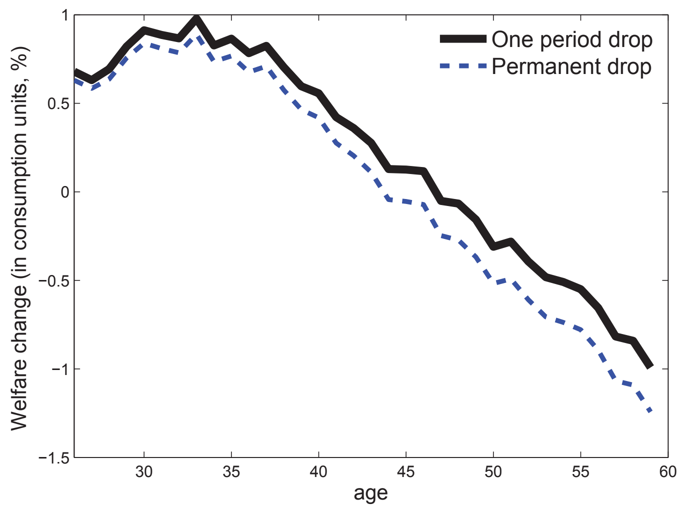


Table 10: Welfare effect of a 5 percent decline in house prices

Group	Young	Old
All	0.52	-0.84
Homeowners	0.75	-1.03
Renters	0.26	0.25
- Low cash-on-hand wealth	0.26	0.23
- High cash-on-hand wealth	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

Note: Households younger than 50 years of age are "young."

Table 10 shows that welfare gains are indeed concentrated among those likely to be net buyers of housing. In particular, welfare gains are larger for renters than for homeowners, and even renters who are old (¿50 years of age) experience welfare gains (on average). This 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 wealth or expected future income) experience larger gains from the decline in house prices.

6.2 Ex ante welfare gains from LTV limits

Table 11 shows that a household would prefer to be born in an economy with higher LTV limits. Recall that in our model endogenous borrowing constraints prevent households from consuming more housing. LTV limits are likely to tighten these constraints. Table 11 also shows that about half of the welfare losses from being born in the economy with an 80 percent LTV limit could be compensated with a recourse rule that relaxes the household's borrowing constraint. Recall also that 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 (or recourse mortgages) that reduce the mortgage default rate should be interpreted as a lower bound.

Table 11: Ex ante welfare gains from LTV limits

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

Note: CE mean Consumption Equivalence units.

Table 12 shows that combinations of recourse mortgages and LTV limits that successfully reduce the frequency of mortgage defaults while increasing homeownership do not present significant changes in households' ability to self-insure compared with the benchmark economy. Since economies with LTV limits have more home equity (see Table 6 and Figure 5), a softer recourse rule is required to lower the default rate. Such a softer rule is still consistent with defaults by households that would require a large adjustment in nonhousing consumption to pay their mortgage.

Table 12: Insurance coefficients with LTV limits

	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

6.3 Welfare gains from introducing prudential regulations

In previous subsections we discussed welfare gains for households 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 excluding lenders' gains (losses) from the introduction of policies that lower (increase) the default probability.

Table 13: Distribution of welfare gains from implementing different policies

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

Note: Recourse allows for garnishment of all defaulters' wealth above the median income. CE mean Consumption Equivalence units.

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 default 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 tighten the borrowing constraints. A small share of households expects to be able to afford higher down payments and benefits from the lower mortgage rate implied by LTV limits. Again, since our model does not feature positive feedback from a lower default rate to the banking sector or house prices (Campbell, 2012; Campbell, Giglio, and Pathak, 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 implementation of median-income recourse mortgages produces a 3.97 percent increase in the value of lenders' mortgage holdings. In contrast, implementation of the 80 percent LTV limit produce a small (0.01 percent) decline in the value of mortgage holdings. Consistently, the joint implementation of both policies produces a 3.89 percent increase in this value.

Table 14 presents the distribution of households' welfare gains after implementation of default-prevention policies when lenders' capital gains are distributed across households. The table presents results for two distribution rules of the lenders' capital gains. The left panel presents welfare gains when lenders' capital gains are equally distributed across households. The secondary-market price of a mortgage at the beginning of a period is given by

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

Let M denote the number of households in the simulations and let the superscript $j \in \{B,P\}$ denotes benchmark (B) and alternative policy (P), respectively. The lump-sum transfer

τ received by all households when the new policy is introduced satisfies[23]

$$M\tau = \sum_{i=1}^{M} \left[b_i \tilde{q}^P(h_i, b_i, w_i + \tau, z_i, p_i, n_i) - b_i \tilde{q}^B(h_i, b_i, w_i, z_i, p_i, n_i) \right]. \tag{13}$$

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:

$$\tau_i = b\tilde{q}^P(h, b, w + \tau_i, z, p, n) - b\tilde{q}^B(h, b, w, z, p, n). \tag{14}$$

We use the maximum τ_i that satisfies equation (14).

Table 14: Welfare gains when lenders' capital gains are distributed across households

	Lump-sum transfers			Individualized transfers		
Welfare gains	LTV $\leq$ 80%	Recourse	Both	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

Note: Recourse allows for garnishment of all defaulters' wealth above the median income. CE mean Consumption Equivalence units.

Note: 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.

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

The greater household losses from introduction of this recourse policy are mostly mitigated with individualized transfers. For example, the 5 percent of households that suffer the larger wel-

[23] If there is more than one solution, we use the maximum τ that satisfies equation (13).

fare losses with 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. The default probability for these households is lowered the most by introducing recourse. Thus, the market price of these households' mortgages increases the most with recourse. This explains why these households receive the largest individualized transfers.

7 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 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 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 results in 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 prevents high default rates after sharp declines in the price of housing.

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