Mortgage Design and Slow Recoveries. The Role of Recourse and Default.*

Pedro Gete† and Franco Zecchetto‡

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Abstract

We show that mortgage recourse systems, by discouraging default, magnify the impact of nominal rigidities and cause deeper and more persistent recessions. Default mitigates liquidity traps because it redistributes wealth towards the borrowers with the highest marginal propensity to consume. This redistribution has positive aggregate effects when nominal rigidities are binding. This mechanism can account for up to 30% of the recovery gap during the Great Recession between the U.S. (mostly a non-recourse economy) and European economies with recourse mortgage systems. General equilibrium effects account for most of the differences in default rates and aggregate outcomes across mortgage systems.

Keywords: Aggregate Demand, Consumption, Default, Foreclosures, Housing, Liquidity Traps, Mortgages, Nominal Rigidities, Recovery

JEL Classification: E51, H81, G21, R2

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†IE Business School. Maria de Molina 12, 28006 Madrid, Spain. Email: pedro.gete@ie.edu.

‡ITAM Business School. Río Hondo 1, CDMX 01080, Mexico. Email: franco.zecchetto@itam.mx.
1 Introduction

There is a wide consensus that the decline in housing prices that started in 2007 moved both Europe and the U.S. into a liquidity trap and triggered the Great Recession (see for example Draghi 2008, or Yellen 2016). Campbell (2017) discusses that an important research question is: what are the main lessons from that experience with regard to mortgages and the macroeconomy. Mortgage systems vary in striking ways through time and across countries. Recent research has focused on the role of adjustable versus fixed rates mortgages (Campbell et al. 2017, Di Maggio et al. 2017, Garriga et al. 2017 or Guren et al. 2017), on the role of high leveraged mortgages (Corbae and Quintin 2015) and on equity mortgages (Kung 2015, Piskorski and Tchistyi 2017 or Greenwald et al. 2017).

In this paper we focus on another key characteristic of a mortgage system, whether it allows for recourse or not. We show that recourse mortgages amplify liquidity traps in the presence of long-term mortgages. The mortgage systems of the U.S. and most European countries are very different in this regard. We show that the recourse feature of the European mortgages can account for up to 30% of the slow recovery of Europe relative to the U.S.\footnote{Hatchondo, Martinez and Sanchez (2015) show that recourse affects the choice of leverage before crises. Corbae and Quintin (2015) find that recourse economies are less sensitive to aggregate home price shocks. We obtain the opposite result because we analyze a model with both endogenous house prices and nominal rigidities that allow for demand-driven output.}

In a non-recourse mortgage, the debt obligation disappears when the lender repossesses the house that serves as collateral. In a recourse mortgage, the lender can pursue a defaulted borrower for the balance of the mortgage after foreclosing on the home. For example, in Ireland or Spain mortgage debt is never extinguished, not even after a personal bankruptcy. Even if most U.S. states are in theory recourse states, recourse is rarely enforced because of the legal hurdles and costs associated with pursuing borrowers for the difference between what the borrower owes and what the lender recovers from the foreclosure (Ghent and Kudlyak 2011, Harris and Meir 2015, Willen 2014). Thus, in practice the U.S. is mostly non-recourse and for most U.S. borrowers, foreclosure results in the complete elimination of their mortgage obligations. This is not the case in most European countries that have recourse systems. Moreover, in most of Europe the length of a bankruptcy proceeding is measured in years, not months or weeks, as in the U.S., during which time almost all income must be devoted to debt service.

The main results of the paper are: 1) in a liquidity trap, mortgage default has positive aggregate effects, even in the presence of reasonable deadweight losses from foreclosure. By a liquidity trap we refer to a situation when nominal wage rigidities are binding, interest rates
are at the zero lower bound and the economy becomes "demand-driven" with output below fundamentals (see for example Korinek and Simsek 2016 or Schmitt-Grohé and Uribe 2017). The intuition is that, in a liquidity trap, prices (including the nominal interest rate) do not fall enough to stimulate savers’ consumption. Thus, there are gains from mechanisms that redistribute wealth from the savers unwilling to consume towards the borrowers with high propensity to consume. We show that default is a mechanism to do so. In fact, it is the only permanent mechanism since debt relief policies are usually "one-off policies" (Agarwal et al. 2017, Gabriel et al. 2016), and equity mortgages are rarely used. 2) Non-recourse mortgages allow over-indebted households to default and start afresh, rather than reduce their consumption for years. Thus, in a liquidity trap, default with non-recourse mortgages stimulates aggregate demand generating positive gains for the economy from reducing unemployment. Outside the liquidity trap, that is, when nominal rigidities do not bind, default only generates redistribution with no positive aggregate effects.

We quantify the previous results by studying how fast Europe would have recovered if at the onset of the 2008 crisis it would have switched its mortgage system from being a recourse to a non-recourse system. Interestingly, countries as Ireland, Spain and the U.S. had similar patterns pre-crisis and at the start of the crisis. Pre-crisis housing prices and mortgage debt raised during the 1996-2006 period together with current account deficits (Gete 2009, Bernanke 2010). Figure 1 shows that in 2007 housing prices fell by a similar amount in these countries. Gross (2014) discusses how the beginning of the financial crisis affected Europe and the United States in a very similar way. On both sides of the Atlantic, monetary policy hit the zero-lower bound and economic performance tanked in 2009. However, over the 2011-2013 period the U.S. economy grew by about 4.5 percentage points more on a per capita basis. The main reason for the gap is the difference in private consumption, which grew in the U.S., but fell in the Eurozone. As Figure 1 shows, in the U.S. it took four years for prices to start to recover while in Spain or Ireland it took more than 6 years. In these two countries, it took nearly seven years for aggregate consumption to stop falling. Thus, the top two panels of Figure 1 show that the length of the recession and the dynamics of the recovery have been very different across the two continents.

The bottom panel of Figure 1 plots the motivation for this paper. Through default, U.S. households have reduced their debt burden from the peak in 2007 considerably faster than households in Ireland or Spain. These two countries have mortgage systems that grant lenders

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2Long-term debt is a key element of the analysis as it prevents debt from disappearing at the end of each period.

3Public consumption and investment actually subtracted more demand in the U.S. than in the European Union. The contraction of private investment in Europe accounted for one-third of the growth gap (Gross 2014).
full recourse to the borrowers’ personal assets and future income until all the mortgage debt is paid. Thus, households were less willing to default in Ireland or Spain than in the U.S.

The default decision in our model resembles the "double trigger" class of models. That is, most defaulted borrowers are underwater and face negative income shocks. This is consistent with the evidence in Gerardi et al. (2017) that changes in ability to pay have large estimated effects on default. The link between home equity and default is non-linear with the default probability raising dramatically for high leverage mortgagors. This insight is consistent with recent optimizing dynamic models of mortgage default (Campbell and Cocco 2015) and with the empirical evidence (Ganong and Noel 2017).

There are two features of our model that are key for the results and make the model consistent with the data. First, both housing prices and labor income are endogenous in a general equilibrium framework. This allows mortgage design to have macroeconomic effects. This is important because we show that general equilibrium forces account for most of the differences in default among mortgage systems. That is, recourse and non-recourse mortgages provide different incentives to default, but the main reason why these two systems differ is because they trigger very different dynamics for housing prices and employment dynamics. This is novel in the default literature, which has so far focused on partial equilibrium models like Deng et al. (2007) or Campbell and Cocco (2015) in which there is no feedback from default into housing prices and income, and then into new defaults.\(^4\)

Second, mortgages are long-term contracts with endogenous credit spreads. These ingredients are essential to capture the links between mortgage design and consumption. For example, the marginal propensity to consume (MPC) of leveraged households is very high to income but low to house prices (facts documented by Ganong and Noel 2017, Kaplan et al. 2017 and Mian et al 2013) because the refinancing spreads are high for leveraged households. Thus, these households cannot easily use higher house prices to consume while they react strongly to changes in income.

The paper suggests that non-recourse systems are better for economies with severe nominal rigidities, like Europe. We estimate that the previous mechanism explains up to 30% of the different recoveries of the U.S. and Europe from the 2008 financial crisis. The European mortgage recourse system depressed the consumption of the low-income households unable to discharge their debts. This caused a deeper and more persistent recession because Europe lacked the positive aggregate effects of default that happen in liquidity traps, that is, once the price systems

\(^4\)Relative to general equilibrium models with short term debt and no default, like Guerrieri and Lorenzoni (2017) or Eggerston and Krugman (2016), in this model the link between debt and consumption is not mechanical but driven by the default and refinancing decisions.
of the economy are not working due to the nominal rigidities.

This paper contributes to the literature that explores the causes and consequences of cross-country variation in mortgage market structure. Campbell (2013) surveys and encourages that literature. We have previously cited recent additions to the literature. A key insight from our paper is that mortgage systems that discourage default are welfare reducing when an economy faces nominal rigidities and lacks equity mortgages, or mechanisms for debt reduction. Agarwal et al. (2017), Gabriel et al. (2016) and Ganong and Noel (2017) provide empirical support for the consumption gains from lowering mortgage payments to mortgagors.

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 discusses the benchmark calibration. Section 4 analyzes the key mechanisms of the model. Section 5 studies a crisis in economies with and without mortgage recourse. Section 6 concludes.

2 Model

We analyze an economy composed by a continuum of households and lenders, a representative firm, and a central bank. The consumption good serves as numeraire.

2.1 Households

Households are infinitely lived and have preferences over non-durable consumption \( c \) and housing services \( s \),

\[
\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[ (1-\eta)c_t^{\frac{1}{1-\sigma}} + \eta s_t^{\frac{1}{1-\sigma}} \right]^{\frac{1}{1-\sigma}}.
\]

The parameters \( \beta, \sigma, \epsilon, \) and \( \eta \) are respectively the discount factor, the intertemporal elasticity of substitution, the intratemporal elasticity of substitution between non-housing consumption and housing services, and the share of housing services in total consumption. Households can obtain housing services \( s \) by owning a house or by renting it. The flow of housing services from ownership equals the size of the house, \( s = h \).

Households inelastically supply a stochastic labor endowment \( e \). This endowment follows a finite state Markov chain with transition probabilities \( f_e(e'|e) \). We denote by \( \bar{L} \) the aggregate labor endowment.
2.2 Deposits and Houses

There are one-period deposits \( a' \geq 0 \) paying real interest rate \( r_{t+1} \) between periods \( t \) and \( t+1 \). For computational easiness we price deposits as bonds such that the price of a deposit is
\[
q_t^{A} = \frac{1}{1 + r_{t+1}}.
\]

Houses are available in discrete sizes \( h \in \mathcal{H} = \{h, ..., \bar{h}\} \). The price per unit of house is \( p_t^H \). There are proportional transaction costs \( \zeta_b \) and \( \zeta_s \) of buying and selling houses. These costs make housing wealth less liquid than financial wealth. To make the houses risky assets, there are house depreciation shocks \( \delta \) such that if a household has a house of size \( h \) today, then at the start of the next period the size of the house is \( (1 - \delta)h \). Thus, these shocks alter the value of a house. The shocks are idiosyncratic across households and independent across time. Their probabilities are \( f_\delta(\delta) \).

Our rental market is basically exogenous as we assume a perfectly elastic supply of rental housing that generates a constant unit price of rental housing, \( p^S \). We assume that owners can only have one house and cannot rent it. This assumption simplifies the model and does not affect the key mechanisms that we study.

2.3 Mortgages and Default

2.3.1 Mortgages

Mortgages are long-term and real.\(^5\) We model them as bonds such that a mortgage issued in period \( t \) specifies the amount to be repaid \( m' \) and the mortgage price function at origination \( q_t^0 \). A mortgagor with house \( h' \), savings \( a' \) and labor shock \( e \) that chooses to repay \( m' \) receives \( q_t^0(m', h', a', e)m' \) funds today. The function \( q_t^0 \) discussed below accounts for the probability of borrower’s default, prepayment, and borrower’s assets. Mortgage originations are subject to an exogenous maximum loan-to-value (LTV) cap \( \theta \). Lenders incur a proportional origination cost \( \zeta_0 \).

The mortgage balance evolves according to
\[
m' = (m - x)(1 + r_{t+1}^M)
\]

\(^5\)Assuming real mortgages simplifies and emphasizes alternative mechanisms to the inflation channels studied in Garriga et al. (2017).
where $m$ is the existing mortgage balance at the start of time $t$, $x$ is the payment, and

$$1 + r_{t+1}^M = (1 + r_{t+1})(1 + \varsigma_m)$$

(3)

is the mortgage rate, where $\varsigma_m$ are servicing costs incurred by the lender. We assume that the mortgage balance decays geometrically at rate $\lambda$, that is, $m' = \lambda m$. This implies a payment at time $t$ of

$$x = m - \frac{\lambda m}{1 + r_{t+1}^M}.$$  

(4)

The parameter $\lambda$ proxies the duration of the mortgage. For example, if $\lambda = 0$ then the mortgage is a one-period contract.

Households can prepay their mortgage and obtain a new one. In order to do so, they have to pay off their remaining mortgage balance $m$ plus a prepayment penalty which is a proportion $\varsigma_p$ of the remaining balance.

### 2.3.2 Mortgage Systems: Recourse and Non-Recourse

Default entails deadweight costs such that the value of a foreclosed house is reduced in a proportion $\varsigma_d$. That is, if a household with house of size $(1 - \delta)h$ after depreciation shock defaults then the lender only receives $(1 - \varsigma_d)p^H_t(1 - \delta)h$. A defaulter is excluded from mortgage markets for a random amount of time. That is, households in default can apply for mortgage credit with probability $\xi$.  

If the mortgage is non-recourse, the sale of the house extinguishes completely the mortgage debt. However, if the mortgage has recourse and the revenue from the foreclosed house sale is not enough to cover the remaining mortgage balance, that is, if $m > (1 - \varsigma_d)p^H_t(1 - \delta)h$, then the lender garnishes the minimum between: 1) the remaining balance $m$, and 2) a fraction $\phi$ of the household’s income and savings. That is, the maximum amount that the lender can garnish in period $t$ cannot be larger than $\phi(y_t + a_t)$. These payments are made until the outstanding debt is fully repaid or the defaulter re-enters the mortgage market, whichever occurs first. Thus, in the model the only difference between a defaulter with or without recourse is that if the mortgage had recourse the household needs to keep making payments if the sale of the house was not enough to cover the mortgage balance.  

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6This stochastic penalty is a mechanism to ensure convergence of the value functions. We calibrate it to match the average time excluded from mortgage markets and in recourse mortgages, the average time a defaulter household pays her debts.
2.4 Household’s Income

We allow for the possibility of a rationing equilibrium in which the firm’s labor demand $L_t$ falls short of supply, that is, $L_t < \bar{L}$. In this case, households are symmetrically rationed such that they supply a fraction $\frac{L_t}{\bar{L}}$ of their labor endowment $e$.

$W_t$ and $P_t$ denote the nominal wage and the price level. Labor income is the real wage $\frac{W_t}{P_t}$ times the amount of labor that households are effectively supplying $e\frac{L_t}{\bar{L}}$. There is a proportional tax $\tau_t$ and a lump-sum transfer $T_t$. Household’s disposable income is

$$y_t(e) = (1 - \tau_t) \frac{W_t}{P_t} e \frac{L_t}{\bar{L}} + T_t. \quad (5)$$

2.5 Household’s Problem

A household starts period $t$ as a homeowner ($O$), renter ($R$), or defaulter ($D$). For a homeowner, the individual state variables are the house size $h$, the mortgage balance $m$, the financial wealth $a$, the idiosyncratic labor $e$ and the house depreciation shock $\delta$. For renters, the individual state variables are the financial wealth $a$ and the idiosyncratic labor $e$. In addition, defaulters have their debt balance $m$ as a state variable. We denote the value functions of homeowner, renters and past defaulters as $V_t^O(h, m, a, e, \delta)$, $V_t^R(a, e)$, and $V_t^D(m, a, e)$ respectively.

2.5.1 Renter

A renter with access to the mortgage market has two options: 1) to buy a house and potentially obtain a mortgage loan, the value function in this case is $J_t^R(a, e)$,

$$J_t^R(a, e) = \max_{c, h', m', a', e' \geq 0} \left\{ u(c, h') + \beta \mathbb{E} \left[ V_t^O(h', m', a', e', \delta') \right] \right\} \text{ s.t.} \quad \begin{align*}
&c + (1 + \zeta_b)p_t^H h' + q_t^A a' = y_t(e) + a + q_t^0(m', h', a', e)m', \\
&q_t^0(m', h', a', e)m' \leq \theta p_t^H h'. \quad (7) \quad (8)
\end{align*}$$

Or, 2) to keep renting, the value function in this case is $J_t^R(a, e)$,

$$J_t^R(a, e) = \max_{c, s, a' \geq 0} \left\{ u(c, s) + \beta \mathbb{E} \left[ V_t^R(a', e') \right] \right\} \text{ s.t.} \quad \begin{align*}
&c + p^S s + q_t^A a' = y_t(e) + a. \quad (9) \quad (10)
\end{align*}$$
The value of being a renter is the highest of the two options:

$$V_t^R(a, e) = \max \left\{ J_t^B(a, e), J_t^R(a, e) \right\}. \quad (11)$$

### 2.5.2 Homeowner

A homeowner chooses among four options: 1) to keep her current house making the mortgage payments if she had a mortgage balance, the value function in this case is $J_t^K(h, m, a, e, \delta)$,

$$J_t^K(h, m, a, e, \delta) = \max_{c, m', a', \delta} \left\{ u(c, h) + \beta \mathbb{E} \left[ V_{t+1}^O(h, \lambda m, a', e', \delta') \right] \right\} \quad \text{s.t.} \quad (12)$$

$$c + p_t^H \delta h + x + q_t^A a' = y_t(e) + a,$$

$$x = m - \frac{\lambda m}{1 + r_{t+1}}. \quad (13)$$

2) To refinance or prepay the mortgage while keeping the current house, the value function in this case is $J_t^F(h, m, a, e, \delta)$,

$$J_t^F(h, m, a, e, \delta) = \max_{c, m', a', \delta} \left\{ u(c, h) + \beta \mathbb{E} \left[ V_{t+1}^O(h, m', a', e', \delta') \right] \right\} \quad \text{s.t.} \quad (15)$$

$$c + p_t^H \delta h + (1 + \zeta_p)m + q_t^A a' = y_t(e) + a + q_t^0(m', h', a', e)m', \quad (16)$$

$$q_t^0(m', h', a', e)m' \leq \theta p_t^H h. \quad (17)$$

This owner who refinances prepays her mortgage and chooses the next-period amount $m'$ of her new mortgage (or no mortgage, $m' = 0$).

3) To sell the house (and prepay the mortgage if any), the value function in this case is $J_t^S(h, m, a, e, \delta)$. If the household sells the house we impose that she must be a renter next period. Moreover, the seller has to cover depreciation costs on the house before selling and prepay the existing mortgage balance $m$:

$$J_t^S(h, m, a, e, \delta) = \max_{c, s, a', \delta} \left\{ u(c, s) + \beta \mathbb{E} \left[ V_{t+1}^R(a', e') \right] \right\} \quad \text{s.t.} \quad (18)$$

$$c + p_t^S s + p_t^H \delta h + (1 + \zeta_p)m + q_t^A a' = y_t(e) + a + (1 - \zeta_s)p_t^H h. \quad (19)$$

4) To default on its mortgage (if she has one), the value function in this case is $J_t^D(h, m, a, e, \delta)$. This value function depends on whether the mortgage is recourse or not. We assume that defaulters become renters and do not cover the housing depreciation costs. Given the transaction
costs associated with selling and buying houses and with new mortgages the default decision depends on household’s income and assets as we will discuss below.

4a) *Recourse Mortgage:* the defaulter pays the minimum between the mortgage balance after the sale of the house and a fraction $\phi$ of its income and savings. Any remaining debt is carried over to the next period:

$$J^D_t(h, m, a, e, \delta) = \max_{c, s, a' \geq 0} \left\{ u(c, s) + \beta \mathbb{E} \left[ \xi V^R_{t+1}(a', e') + (1 - \xi) V^D_{t+1}(m', a', e') \right] \right\} \quad \text{s.t.} \quad (20)$$

$$c + p^s s + x + q^a_a a' = y_t(e) + a, \quad (21)$$

$$x = \max \left\{ \min \left\{ m - (1 - \zeta_d)p^H_t (1 - \delta) h, \phi(y_t(e) + a) \right\}, 0 \right\}, \quad (22)$$

$$m' = (m - (1 - \zeta_d)p^H_t (1 - \delta) h - x)(1 + r^M_{t+1}). \quad (23)$$

4b) *Non-Recourse Mortgage:* after the sale of the foreclosed house, any remaining debt disappears:

$$J^D_t(h, m, a, e, \delta) = \max_{c, s, a' \geq 0} \left\{ u(c, s) + \beta \mathbb{E} \left[ \xi V^R_{t+1}(a', e') + (1 - \xi) V^D_{t+1}(0, a', e') \right] \right\} \quad \text{s.t.} \quad (24)$$

$$c + p^s s + q^a_a a' = y_t(e) + a. \quad (25)$$

The value function for a homeowner is the maximum among the four options:

$$V^O_t(h, m, a, e, \delta) = \max \left\{ J^K_t(\cdot), J^F_t(\cdot), J^S_t(\cdot), J^D_t(\cdot) \right\}. \quad (26)$$

2.5.3 Defaulter

A defaulter has to rent today and, if her mortgage had recourse, make debt payments. Her value function is the same defined above,

$$V^D_t(m, a, e) = J^D_t(0, m, a, e, 0). \quad (27)$$
2.6 Mortgage Pricing

Competitive lenders price mortgages to break even in expectation. That is, inflows from borrowers must be expected to cover the lender’s cost of funds, which is the deposit rate \( r_{t+1} \) plus the servicing costs. In other words, for a loan of size \( q_t^M(m', h', a', e)m' \), to break-even, the lender needs to earn \( (1 + r_{t+1}^M) = (1 + r_{t+1})(1 + \zeta_m) \). We differentiate between the recourse and non-recourse case.

a) Recourse Mortgage. In the case of recourse mortgages, \( q_t^M \) is determined by:

\[
q_t^M(m', h', a', e)m' = \frac{1}{1 + r_{t+1}^M} \mathbb{E} \left[ I_K' (x' + q_{t+1}^M(\lambda m', h', a''_K, e')\lambda m') \right. \\
+ \left. (I_F' + I_S') \right] \tag{28}
\]

pay + continuation value

\[
+ \left. (1 + \zeta_p)m' + I_D'((1 - \zeta_d)p_{t+1}'(1 - \delta')h' + x_D' + q_{t+1}^D(m''_D, a''_D, e')m''_D) \right].
\]

prepay
default (house sale + debt service + continuation value)

The left-hand side of (28) is the cost of funds for the lender. The right-hand side of (28) are the expected next-period payments. \( I_K, I_F, I_S, \) and \( I_D \) are indicator functions to denote the possible borrowers’ decisions. That is, repaying, prepaying (by either refinancing or selling the house) or defaulting. In case of default with recourse the lender receives the payments \( x_D' \). We denote by \( a''_K \) the deposits of the owner that keeps making mortgage payments and \( a''_D \) those of the mortgagor in default. The value of a recourse mortgage in default is:

\[
q_{t}^D(m', a', e)m' = \frac{1 - \xi}{1 + r_{t+1}^M} \mathbb{E} \left[ x' + q_{t+1}^D(m'', a'', e')m'' \right]. \tag{29}
\]

debt service + continuation value

b) Non-Recourse Mortgage. In the case of non-recourse mortgages, \( q_t \) is determined by:

\[
q_t^M(m', h', a', e)m' = \frac{1}{1 + r_{t+1}^M} \mathbb{E} \left[ I_K' (x' + q_{t+1}^M(\lambda m', h', a''_K, e')\lambda m') \right. \\
+ \left. (I_F' + I_S')(1 + \zeta_p)m' + I_D'((1 - \zeta_d)p_{t+1}'(1 - \delta')h') \right]. \tag{30}
\]

pay + continuation value

prepay
default (house sale)

When issuing mortgages, banks incur a proportional origination cost \( \zeta_0 \). Therefore, the mortgage price at origination is \( q_t^0 = \frac{q_t^M}{1 + \zeta_0} \).
2.7 Lenders

The balance sheet of the lenders is:

\[
q_t^A B_{t+1}^b + T_t^b + \int \left[ I_K \left( x - \frac{\zeta_m \lambda m}{1 + r_{t+1}^M} \right) + (I_F + I_S)(1 + \zeta_p) m + I_D((1 - \zeta_d)p_t^R (1 - \delta) h + x) \right] \, d\Psi_t^O \\
+ \int (x_D - \frac{\zeta_m m_D'}{1 + r_{t+1}^M}) \, d\Psi_t^D = B_t^b + (1 + \zeta_0)(1 + \zeta_m) \left( \int I_B q_t^0 m' \, d\Psi_t^R + \int I_F q_t^0 m' \, d\Psi_t^O \right),
\]

where \( B_t^b \) are the deposits issued by the banks (with negative values denoting debt) and \( x_D = m_D' = 0 \) if non-recourse mortgages. \( T_t^b \) are transfers from the government. Any ex-post profits or losses by the banks are completely absorbed into the government budget through the transfer \( T_t^b \) in order to keep the sheet balanced. That is

\[
q_t^A B_{t+1}^b = (1 + \zeta_0)(1 + \zeta_m) \left( \int I_B q_t^0 m' \, d\Psi_t^R + \int I_F q_t^0 m' \, d\Psi_t^O \right).
\]

Thus, the supply of deposits equals the funds needed by the lenders to originate mortgages.

2.8 Wage Rigidities and Unemployment

We follow Auclert and Rognlie (2016), Eggertsson and Mehrotra (2015) and Schmitt-Grohé and Uribe (2016, 2017), and assume that nominal wages are downwardly rigid. That is, nominal wages cannot fall from period to period below a wage norm:

\[
W_t \geq \gamma W_{t-1}.
\]

In this expression, the parameter \( \gamma \) controls the degree of rigidity. If \( \gamma = 1 \), as we use in the quantitative exercise, then nominal wages are perfectly downwardly rigid. If \( \gamma = 0 \), then nominal wages are fully flexible.

Like in Guerrieri and Lorenzoni (2017), workers are hired by competitive firms that produce consumption with a linear technology,

\[
Y_t = AL_t.
\]

The existence of downward nominal rigidities implies that the labor market may not clear at the inelastically supplied level of labor \( \bar{L} \). In this case, the economy will experience involuntary
unemployment ($L_t < \bar{L}$). This feature is captured with a complementary slackness condition in wages and labor:

\begin{align}
L_t &\leq \bar{L} \quad \text{(35)} \\
(\bar{L} - L_t)(W_t - \gamma W_{t-1}) &= 0. \quad \text{(36)}
\end{align}

Therefore, if the wage norm is not binding, then there is full employment ($L_t = \bar{L}$). Conversely, if there is involuntary unemployment ($L_t < \bar{L}$), then the wage norm must be binding. When nominal wages are fixed at $W_t = W$ then nominal price levels are constant $P_t = P$.

### 2.9 Government

The government collects labor taxes and also the profits from the rental suppliers. The tax system consists of a lump-sum transfer $T_t$ and a proportional tax $\tau_t$ to capture the progressive system. The government finances exogenous spending $G_t$ and transfers to the lenders. Its budget constraint is given by:

$$
\tau_t \int \frac{W_t}{P_t} e \frac{L_t}{L} d\Psi_t + \int p^s d\Psi_t = G_t + T_t + T^b_t, \quad \text{(37)}
$$

where $G_t$ is exogenous government spending. In Section 5, when we study unanticipated shocks, the exogenous government spending $G_t$ adjusts in order to keep the budget balanced while taxes and transfers to households are fixed at their steady state levels (that is, $\tau_t = \tau$ and $T_t = T$). We adjust using exogenous spending to avoid changing taxes or transfers that would redistribute wealth across households. Exogenous government spending does not have any direct distributional consequences since this spending is not reverted back to households.

### 2.10 Equilibrium

The economy has a constant aggregate stock of owner-occupier housing ($H$).

**Definition.** Given an interest rate $r$, an equilibrium is a sequence of house prices and mortgage price functions $\{p^H_t, q^M_t(m', h', a', e), q^D_t(m', a', e)\}_{t=0}^{\infty}$, labor employment $\{L_t\}_{t=0}^{\infty}$, government policy $\{\tau_t, T_t, T^b_t, G_t\}_{t=0}^{\infty}$, household decision rules, and distributions over households’ states $\{\Psi^R_t(a, e), \Psi^O_t(h, m, a, e, \delta), \Psi^D_t(m, a, e)\}_{t=0}^{\infty}$, such that, given initial distributions $\Psi^R_0(a, e)$, $\Psi^O_0(h, m, a, e, \delta)$ and $\Psi^D_0(m, a, e)$, at every period $t$: 

13
1. The household decision rules are optimal.

2. The mortgage pricing functions hold.

3. The distribution of households is consistent with the exogenous law of motion and the decision rules.

4. All markets clear, except possibly for the labor market in which (36) holds:

   (a) Owner-occupier housing market: \( \int h' d\Psi_t = H \).

   (b) Labor market either clears or there is involuntary unemployment according to (35) and (36).

   (c) Credit market clears: \( \int a' d\Psi_t = B_{t+1}^b \).

   (d) Goods market: \( \int c d\Psi_t + I_t^H + Z_t^c + G_t = Y_t \), where \( I_t^H \) is the investment to cover both the housing net depreciation and the foreclosure costs:

   \[
   I_t^H = \int (I_K + I_F + I_S) p_t^H \delta h \, d\Psi_t^O + \int I_D p_t^H (1 - (1 - \zeta_d)(1 - \delta)) h \, d\Psi_t^O,
   \]

   and \( Z_t^c \) is aggregate spending on housing transaction and mortgage costs:

   \[
   Z_t^c = \zeta_b \int I_B p_t^H h' \, d\Psi_t^R + \zeta_s \int I_S p_t^H h \, d\Psi_t^O + \zeta_m \left( \int I_K m \frac{\lambda m}{1 + r_{t+1}^M} \, d\Psi_t^O + \int m' \frac{m'}{1 + r_{t+1}^M} \, d\Psi_t^P \right) \\
   + ((1 + \zeta_0)(1 + \zeta_m) - 1) \left( \int I_B q_t^b \, m' \, d\Psi_t^R + \int I_F q_t^b \, m' \, d\Psi_t^O \right). \quad (38)
   \]

3 Calibration

We calibrate the steady-state to match key statistics of households’ balances and of the housing and mortgage markets in the U.S. prior to the Great Recession. Thus, our benchmark case is a non-recourse economy \( (\phi = 0) \). This makes the paper closer to the existing literature and allows to perform a counterfactual in Section 5 when we study what would have happened if the economy have had recourse mortgages.

We divide the parameters into two groups. First, those parameters that we assign exogenously following micro-evidence and standard values in the literature. Second, those parameters endogenously selected to match the targets. Table 1 summarizes the calibration. A period in
the model is a quarter. In steady-state we assume that the economy is at full employment, \( L_0 = \bar{L} \). The Online Appendix contains all the details of this section.

### 3.1 Exogenous Parameters

**Idiosyncratic earnings process and Technology:** we assume a persistent component that follows an AR(1) process and a i.i.d transitory component like Storesletten et al. (2004). The parameters at annual frequency are: persistence parameter \( \rho = 0.977 \), variance of the shocks to the persistent component \( \sigma_q^2 = 0.0166 \), and the variance of the transitory shocks is \( \sigma_z^2 = 0.0630 \). The Online Appendix discusses how we convert these values into quarterly frequency.\(^7\) We select the steady state TFP to normalize median quarterly labor income to one.

**Housing market:** we set the cost of buying a house to \( \zeta_b = 0.05 \) and the cost of selling to \( \zeta_s = 0.025 \) which are consistent with the values used in the literature (see Berger and Vavra 2015 for example), and with the evidence by Gruber and Martin (2003) that the costs of buying are larger than those of selling. For the idiosyncratic depreciation shock we set as lower bound of the support the no shock case, that is, \( \delta = 0 \).

**Mortgage market:** We set the mortgage origination cost \( \zeta_0 \) to 0.4% to be consistent with the average origination costs for 2003-2005 reported in Table 20 of the FHFA Monthly Interest Rate Survey. We use a mortgage servicing cost \( \zeta_m \) that generates a risk-free rate annual mortgage rate of 3.5%. Concerning the maximum LTV at origination and the prepayment penalty we set them to \( \theta = 1.25 \) and \( \zeta_p = 0.035 \) respectively. The probability of reentering the mortgage market, \( \xi = 0.0417 \), implies for defaulters an average exclusion period from credit markets of 6 years that is consistent with U.S. Chapter 7 bankruptcies. The deadweight costs of foreclosures, \( \zeta_d = 0.22 \), follows Pennington-Cross (2006) report that the selling price of a foreclosed property is about 22% lower.

**Government:** We set the labor income tax to \( \tau = 0.25 \) and then the lump-sum transfer \( T \) to be such that in steady state about 40% of households receive a net transfer from the government (Kaplan et al. 2017). Given these values, the government’s budget constraint (37) determines government expenditures, which for our benchmark equal 18.5% of annual output.

\(^7\)We discretize the persistent and transitory components into a 5 and 3-point Markov chain respectively, using the method of Rouwenhorst (1995). Thus, the resulting discrete process has \( 5 \times 3 = 15 \) states.
3.2 Endogenous Parameters and Model Fit

We set the remaining parameters to target the following moments from the 2004 Survey of Consumer Finance (SCF): 1) a homeownership rate of 68.4%; 2) a median net worth (relative to mean income) of 0.567; 3) a median housing wealth for owners (relative to median income) of 3.21; 4) a mean mortgage debt for owners (relative to median income) of 1.62; 5) a median LTV of 58.3%; and 6)-9) the share of mortgagors with LTV larger than 70%, 80%, 90% and 95%. We also target an annual foreclosure rate of 1.15% following the data from the Mortgage Banker’s Association on foreclosures for 2004. The average house depreciation rate of 1.48% matches the 1960-2002 average reported by Jeske et al. (2013). Finally, we target an annual risk-free rate of 1%.

We follow a simulated method of moments and minimize the squared percentage deviation from the previous moments and the model counterparts. Table 2 compares the empirical targets with the model-generated moments and shows that the model fits the data well. For example, it generates realistic outcomes for the relevant housing and mortgage variables. Like the homeownership (67%) and foreclosure (1%) rates, the minimum house value (around $100K), the house depreciation rate (1.5% annual, like in Jeske et al. 2013), price-to-rent ratio (11.31) and mortgage duration (33 years).

It is important to highlight that the model is consistent with the empirical literature in two dimensions key for the mechanisms that we will discuss below: 1) substantial heterogeneity in marginal propensities to consume that correlates with the debt-to-value (DTV) distribution; and 2) the distribution of illiquid wealth. For example, in the model the fraction of wealthy illiquid households, that is, households with zero liquid wealth but positive housing holdings \((a = 0 \text{ and } h > 0)\), is 20.1%. Examples include the SCF 2004, in Berger and Vavra (2015(Berger and Vavra 2015)) or Kaplan and Violante (2016).

The model is also consistent with the data in moments not targeted in the calibration but important for the questions studied. For example, the median owner house size relative to the median renter house is 2.09, consistent with the value of 1.85 obtained from the 2013 American Housing Survey. The model yields a ratio of mean income for homeowners to mean income for renters of 2.25, close to the value of 2.29 found in the 2004 SCF. The frequency of refinancing (mortgagors increasing their debt) is around 13%, similar to the 15% estimated by Buttha and Keys (2016) as mortgagors whose debt grows by at least 5%. The fraction of non-movers in owner-occupied units (over a period of one year) averages 95% during 2006-2016 in Current Population Survey data and the model counterpart is 97.2%. This suggests a realistic degree of housing illiquidity, which in addition to refinancing costs and endogenous credit supply
generates substantial deviations in consumption dynamics from standard incomplete markets models.

4 Default and Marginal Propensity to Consume

Before studying the interaction between the mortgage system and the economy, in this section we analyze the drivers of default and the marginal propensity to consume (MPC), which are key mechanisms in the model and are consistent with the empirical estimates.

4.1 Drivers of Default

Table 3 and Figure 2 show the default decision in the recourse and non-recourse economies as a function of household’s debt-to-value (DTV) and liquid assets. Under recourse the utility from strategic default (that is, the household defaults even if she is able to repay) is non-existent because the defaulter remains liable for any debt after the house is foreclosed. As a consequence Table 3 shows that there is four times less default with recourse mortgages.

With recourse mortgages, default is accounted for by households with high debt-to-value. These are mortgagors who had low income or bad house value shocks and face large mortgage payments relative to the value of the house. Among these highly leveraged households, the level of liquid assets is the key determinant of default. Households without liquid assets default more than three times more often than households whose liquid assets allow them to smooth bad idiosyncratic shocks. For low holdings of liquid assets, even having 20% equity does not eliminate default risk if the household receives a bad idiosyncratic shock.

With non-recourse mortgages, there is strategic default. The region of strategic default depends on the housing transaction costs, house prices, prepayment costs and endogenous credit spreads. Having negative home-equity is not a necessary condition for default, although most of the default is due to the households with low equity in the house. As Table 3 shows, with non-recourse mortgages the level of liquid assets is less relevant to explain default differences across mortgagors.

Figure 3 shows that default risk is priced in the mortgage credit supply. The figure plots the mortgage premium relative to the risk-free rate as a function of DTV for households with the median house and different levels of income. Several messages emerge: 1) mortgage spreads are lower with recourse mortgages since leverage and default risk is smaller; 2) the spreads rise in
particular for the high DTV mortgagors since we are studying economies without government guarantees;\textsuperscript{8} 3) The elasticity of mortgage rates to DTV is decreasing in household’s income. That is, low income households face a much steeper mortgage supply function. This steeper slope prevents risky mortgagors from refinancing as documented by Agarwal et al. (2017); 4) Transitioning from recourse to non-recourse mortgages will increase mortgage rates specially for the low-income leveraged mortgagors.

4.2 Marginal Propensity to Consume (MPC) and Leverage

Figure 4 plots the distributions of MPC out of liquid wealth and of leverage in the steady-state of the non-recourse economy. The units of the MPC are the cents spent in consumption for each extra dollar.\textsuperscript{9} Figure 4 shows that the model generates rich heterogeneity in MPCs, like in the empirical literature (see, for example, Berger et al. 2017). Table 4 helps to understand this heterogeneity. It reports the MPCs out of a permanent change in house prices and of a transitory change in income for different groups.

Debt-to-value is a key determinant for the MPC out of house prices. When DTV is high, mortgagor’s consumption is unresponsive to house price changes. Either the household is already at the DTV constraint, or the risk of default is so high that the changes in housing wealth do not reduce credit spreads enough to allow access to credit. Thus, households with high DTV and low liquid wealth, unable to tap their home equity, do not change consumption much following higher house prices. Table 4 highlights that the effects on consumption from house prices work through the low DTV households. These are the households able to refinance and benefit from the easier and cheaper credit brought by the higher house prices.

However, Table 4 shows that households with high DTV and low liquid wealth have extremely large consumption responses to income changes. This is key for the interaction of the mortgage system with the economy as we discuss in the next section.

Ganong and Noel (2017) provide empirical evidence that underwater mortgagors respond less to debt relief policies that do not affect their current budget constraints. One implication is that house price shocks may not be equivalent to cash transfers for underwater mortgagors that find refinancing costly. This model is consistent with this evidence.

\textsuperscript{8}Gete and Zecchetto (2017) study the effect of government guarantees on mortgage spreads.
\textsuperscript{9}The numerical appendix contains the definition of MPC.
5 Mortgage Systems and Slow Recoveries

This section studies how the design of the mortgage system alters the reaction of the economy to the same shock. We focus on a credit supply shock that we model as an exogenous decrease in the LTV cap $\theta$. The two main results are: 1) the interaction of recourse mortgages and nominal rigidities largely magnifies the impact of negative shocks; 2) the different mortgage systems cause different aggregate outcomes mostly through general equilibrium channels.

Figure 5 shows the unexpected shock to loan to value limits, that is the same for both the recourse and non-recourse economy. This contraction on the borrowing limits induces less mortgage originations and a lower demand for housing from the leveraged households. House prices fall. As Table 4 shows, the consumption of households with low DTV strongly reacts to house prices as lower prices push these households towards their borrowing limit and increase their borrowing spreads. Aggregate consumption falls and nominal wage rigidities cause unemployment. That is, given the lower demand for their products, firms lower their demand for labor. If wages were perfectly flexible this would translate into lower wages and the same employment. However, when wages do not fall the labor market does not clear and there is unemployment. Output becomes demand-driven due to binding downward nominal rigidities. The labor market is rationed.

Unemployment causes lower income and this specially depresses the consumption of the high DTV households, who have the largest MPC from income as Table 4 reports. Moreover, these households, with less home equity and unable to access credit (Figure 5 shows the large drop in originations) lower their demand for housing and house prices fall even more. There is a negative self-reinforcing loop as lower housing prices depress aggregate output and consumption. Unemployment raises, earnings fall, and again house prices fall. The economy, trapped by the zero-lower bound for interest rates and the nominal wage rigidities does not easily self-correct. Here is where the design of the mortgage system is key.

Non-recourse mortgages facilitate default of the high DTV households unable to refinance as we discussed in Section 4.1. Figure 5 shows the larger increase in the default rate of the non-recourse economy. With non-recourse mortgages, households can reduce their debt burden faster. However, many mid and low-wealth, high-indebted households that would have defaulted under non-recourse prefer not to do so under recourse. Moreover, households that default under recourse are still liable for the outstanding mortgage debt, reducing their consumption. Under non-recourse those households have their debt extinguished even if the value of the house did not cover the debt balance.
Thanks to default, leveraged households can obtain liquidity that they allocate to consumption. This mitigates the negative loop discussed before. As a consequence, Figures 5 shows that for a similar fall in housing prices in the non-recourse and recourse economies, the non-recourse economy has a faster recovery in housing prices and aggregate consumption.

Figures 6 and 7 help to understand the different channels at play. They decompose default and consumption into three channels:

\begin{equation}
X_t = \text{consumption or default}
\end{equation}

\begin{equation}
dX_0 = \sum_{t=0}^{\infty} \left( \frac{\partial X_t}{\partial \theta_t} \right)_t d\theta_t + \sum_{t=0}^{\infty} \left( \frac{\partial X_t}{\partial p^H_t} d p^H_t + \frac{\partial X_t}{\partial L_t} dL_t \right),
\end{equation}

The first term in (39) is the direct effects from a change in the path of the LTV limit. Here, we keep house prices and employment constant. The path of LTV limits affects directly the collateral constraint and therefore home buyers and refinancing respond to the changes in the LTV cap. Consumption drops for households that buy a house with high LTV and for poorer renters that were planning to buy a house in the near future (they need to save to put a larger downpayment). Lower LTV makes refinancing harder and some households default.

The remaining terms in (39) reflect indirect, general equilibrium effects from changes in house prices and employment. That is, the fall in LTV limits causes a drop in housing demand. Since housing supply is fixed, house prices fall. Because of the reasons discussed above, this triggers lower consumption and higher default. Moreover, there is a third channel due to the wage rigidities. Sticky wages cannot cushion the lower demand for the products and lower labor demand causes unemployment. High DTV and illiquid mortgagors have the largest consumption response after the fall in income.

Figures 6 and 7 show that the general equilibrium effects are substantially larger than the direct effect, specially for the recourse regime. In the non-recourse case, the indirect effects account for about 71% of the first quarter consumption response, while the direct effect accounts for 29%. The difference between indirect and direct effects is even larger for the recourse economy. Indirect effects account for 87% of the first quarter consumption response, while the direct effect account for only 13% of the response.

The strongest channel is the unemployment channel because this is the channel with higher MPC as discussed in Section 4.1. Thus, the benefit of non-recourse mortgages mostly happen.

\footnote{The Online Appendix contains the details.}
because they allow to reduce the unemployment rate of the economy once this enters into the liquidity trap.

If it was not because of the general equilibrium effects, the structure of the mortgage system would not matter for the economy. An unexpected tightening to the borrowing limit mainly affects renters and low DTV (< 85%) mortgagors by reducing the relative attractiveness of the options of buy and refinance respectively. Renters whose buy option is attractive may cut non-housing consumption in response to the LTV limit tightening since they need to put a larger downpayment. Mortgagors that are willing to refinance might be able to extract less home equity and therefore consume less out of the additional resources. But for these households is unlikely that the default option will become attractive in the near term. Thus, whether mortgages have recourse or not is not relevant without taking into account whether house prices and unemployment can change.

When comparing Figure 5 with the data from Figure 1 we can see that the recourse mechanism can account for 30% of the recovery gap in consumption between the U.S. and Europe. That is, even in the presence of reasonable foreclosures costs, mortgage recourse systems magnify the impact of nominal rigidities by discouraging default and cause deeper and more persistent recessions relative to a non-recourse economy.

6 Conclusions

Several authors, for example, Bernanke (2017) and Kiley and Roberts (2017), argue that the zero lower bound will happen often in the near future. Thus, modern economies will see liquidity traps often. This paper shows that the structure of the mortgage system is a key determinant of the reaction of an economy to a liquidity trap.

We show that recourse mortgages amplify liquidity traps by discouraging default, that is the only mechanism other than fiscal policy to redistribute wealth towards the households with higher propensity to consume. This redistribution has positive aggregate effects once an economy is in a liquidity trap as it allows to lower unemployment. Outside the liquidity trap there are no aggregate gains from the wealth redistribution associated with default, only the deadweight losses associated with foreclosures.

The paper suggests that non-recourse systems are better for economies with more nominal rigidities, like Europe. However, without recourse, access to mortgage credit is much more expensive for low income, high debt mortgagors. Debt relief mechanisms or equity mortgages
could be even better policies as they decouple foreclosures from the wealth redistribution mechanism that we show in this paper. An open area of research is how to design such mechanisms or contracts while mitigating moral hazard.
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## Tables

Table 1: Benchmark calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Interpretation house</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\zeta_b$</td>
<td>0.025</td>
<td>Cost of buying a house</td>
</tr>
<tr>
<td>$\zeta_s$</td>
<td>0.05</td>
<td>Cost of selling a house</td>
</tr>
<tr>
<td>$\zeta_0$</td>
<td>0.4%</td>
<td>Mortgage origination cost</td>
</tr>
<tr>
<td>$\zeta_p$</td>
<td>0.035</td>
<td>Prepayment penalty</td>
</tr>
<tr>
<td>$\zeta_m$</td>
<td>0.61%</td>
<td>Mortgage servicing cost</td>
</tr>
<tr>
<td>$\zeta_d$</td>
<td>0.22</td>
<td>Foreclosure cost</td>
</tr>
<tr>
<td>$\xi$</td>
<td>0.0417</td>
<td>Probability defaulter re-entries mortgage market</td>
</tr>
<tr>
<td>$\theta$</td>
<td>0.977</td>
<td>Persistence earnings shocks (annual)</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.075</td>
<td>Maximum LTV at mortgage origination</td>
</tr>
<tr>
<td>$\sigma_n$</td>
<td>0.129</td>
<td>Standard deviation persistent shock (annual)</td>
</tr>
<tr>
<td>$\sigma_\epsilon$</td>
<td>0.253</td>
<td>Standard deviation transitory shock (annual)</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0</td>
<td>Low realization housing depreciation</td>
</tr>
<tr>
<td>$\phi$</td>
<td>0</td>
<td>Recourse parameter (benchmark case is non-recourse)</td>
</tr>
<tr>
<td>$A$</td>
<td>1</td>
<td>Productivity level (median labor earnings = 1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.975</td>
<td>Discount factor</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>1.147</td>
<td>CRRA parameter</td>
</tr>
<tr>
<td>$\epsilon$</td>
<td>0.537</td>
<td>Intratemporal elasticity of substitution</td>
</tr>
<tr>
<td>$\eta$</td>
<td>0.554</td>
<td>Housing share in consumption</td>
</tr>
<tr>
<td>$h$</td>
<td>9.786</td>
<td>Minimum house size</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>0.992</td>
<td>Mortgage amortization parameter</td>
</tr>
<tr>
<td>$\tilde{\delta}$</td>
<td>0.159</td>
<td>High realization of housing depreciation</td>
</tr>
<tr>
<td>$f_\delta(\tilde{\delta})$</td>
<td>0.024</td>
<td>Probability high depreciation shock</td>
</tr>
<tr>
<td>$p^s$</td>
<td>0.022</td>
<td>Rental price</td>
</tr>
</tbody>
</table>

Note: Section 3 and the Appendix discuss the details.
Table 2: Steady State Moments.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk-free rate (% annual)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Homeownership rate (%)</td>
<td>67.4</td>
<td>68.4</td>
</tr>
<tr>
<td>Ratio median net worth to annual income</td>
<td>0.606</td>
<td>0.567</td>
</tr>
<tr>
<td>Ratio median housing wealth to annual income (for owners)</td>
<td>2.44</td>
<td>3.21</td>
</tr>
<tr>
<td>Ratio average mortgage debt to annual median income (for owners)</td>
<td>1.87</td>
<td>2.05</td>
</tr>
<tr>
<td>Ratio average mortgage debt to annual median income (for owners)</td>
<td>1.79</td>
<td>1.62</td>
</tr>
<tr>
<td>Median DTV mortgagors (%)</td>
<td>63.3</td>
<td>58.3</td>
</tr>
<tr>
<td>% of mortgagors with DTV $\geq 70%$</td>
<td>41.6</td>
<td>33.7</td>
</tr>
<tr>
<td>% of mortgagors with DTV $\geq 80%$</td>
<td>18.0</td>
<td>20.1</td>
</tr>
<tr>
<td>% of mortgagors with DTV $\geq 90%$</td>
<td>5.37</td>
<td>8.94</td>
</tr>
<tr>
<td>% of mortgagors with DTV $\geq 95%$</td>
<td>4.24</td>
<td>4.30</td>
</tr>
<tr>
<td>Foreclosure rate (% annual)</td>
<td>1.01</td>
<td>1.15</td>
</tr>
<tr>
<td>Average depreciation rate (% annual)</td>
<td>1.53</td>
<td>1.48</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Non-Targeted moments</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Price-to-rent ratio (annual)</td>
<td>11.31</td>
<td>11.27</td>
</tr>
<tr>
<td>Ratio house size for owners vs. renters (median)</td>
<td>2.09</td>
<td>1.85</td>
</tr>
<tr>
<td>Ratio income for owners vs. renters (average)</td>
<td>2.25</td>
<td>2.49</td>
</tr>
<tr>
<td>Share of mortgagors who extract equity (%)</td>
<td>12.8</td>
<td>15</td>
</tr>
<tr>
<td>Share of homeowners who do not move over a year (%)</td>
<td>97.2</td>
<td>94.9</td>
</tr>
<tr>
<td>Share of wealthy illiquid households ($a = 0$ and $h &gt; 0$) (%)</td>
<td>20.1</td>
<td>20.0</td>
</tr>
</tbody>
</table>

Note: Section 3 discusses the details. Targeted moments are those moments used to calibrate the model. Non-targeted moments are moments not used in the calibration.
Table 3: Probability of Default (% annual) across Households and Mortgage Systems.

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>All mortgagors</th>
<th>Illiquid households</th>
<th>All mortgagors</th>
<th>Illiquid households</th>
</tr>
</thead>
<tbody>
<tr>
<td>DTV ≥ 85%</td>
<td>7.73</td>
<td>10.2</td>
<td>2.38</td>
<td>7.63</td>
</tr>
<tr>
<td>DTV &lt; 85%</td>
<td>0.13</td>
<td>0.13</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>All mortgagors</td>
<td>1.01</td>
<td></td>
<td>0.24</td>
<td></td>
</tr>
</tbody>
</table>

Note: Default rates are expressed in annual terms. DTV is debt-to-value. Illiquid households are those with no liquid asset holdings ($a = 0$).
Table 4: Marginal Propensity to Consume (MPC) across Households

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>MPC out of income</th>
<th>MPC out of house price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All mortgagors</td>
<td>Illiquid households</td>
</tr>
<tr>
<td>DTV ≥ 85%</td>
<td>0.29</td>
<td>0.50</td>
</tr>
<tr>
<td>DTV &lt; 85%</td>
<td>0.19</td>
<td>0.18</td>
</tr>
<tr>
<td>All households</td>
<td>0.20</td>
<td>0.24</td>
</tr>
</tbody>
</table>

Note: The MPC out of income is the change in non-housing good consumption after an unexpected, transitory 1% income increase. The MPC out of house price is the initial response of non-durable consumption to an unexpected, permanent increase of 1% in housing prices. DTV means debt-to-value. Illiquid households are those with no liquid asset holdings \((a = 0)\). All calculations refer to the steady-state of the non-recourse economy. The Appendix discusses the details.
Figure 1. Comparing Recoveries in Recourse versus Non-Recourse Countries. 
The U.S. is in practice a non-recourse economy, while Ireland and Spain are recourse.
Figure 2. Percentage of Households Defaulting in Recourse versus Non-Recourse Economies. The shades of the panels capture the percentage of households defaulting for a given debt-to-value and deposits ($a$). The top panel is the non-recourse economy while the bottom case is the recourse case.
Figure 3. Borrowing Spreads in Recourse versus Non-Recourse Economies. This figure plots the spread between the mortgage rate that a borrower would face and the risk free rate, as a function of the debt-to-value of the borrower, and for three income levels. The top panel is the non-recourse model while the bottom case is the recourse case.
Figure 4. Cross-sectional Distributions of Debt-to-Value and Marginal Propensity to Consume (MPC) out of Liquid Wealth in the Non-Recourse Economy. These panels plot the distributions in the stationary distribution (that is, before the shock happens) of the non-recourse model.
Figure 5. Dynamics of Recourse and Non-recourse Economies following unexpected Loan-to-Value shock. The panels compare the response of the economies with and without mortgage recourse to a decrease in the LTV cap.
Figure 6. Decomposing the Channels Driving Aggregate Default. The panels plot the response of default to a change in the LTV cap parameter. In each panel there are four lines: a) the total response; b) the change due to the LTV shock; c) the change due to the change in housing prices triggered by the LTV shock; d) the change due to the change in labor demand triggered by the LTV shock. Section 5 discusses the details. The top panel is the non-recourse economy while the bottom case is the recourse case.
Figure 7. Decomposing the Channels Driving Aggregate Consumption. The panels plot the response of aggregate consumption to a change in the LTV cap parameter. In each panel the decomposition is the same as in Figure 6. The top panel is the non-recourse economy while the bottom case is the recourse case.