# 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. This mechanism can account for up to 40% of the recovery gap during the Great Recession between the U.S. (mostly a non-recourse economy) and European economies with recourse mortgage systems. Recourse mortgages also generate larger welfare inequality following credit shocks. General equilibrium effects cause most of the differences across mortgage systems. Liquid assets play a larger role in explaining default with recourse mortgages.

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

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

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

# 1 Introduction

Mortgage systems vary in striking ways through time and across countries. As discussed by Campbell (2017), Campbell, Clara and Cocco (2018) and Piskorski and Seru (2018), an important research question is what are the main lessons from the Great Recession for mortgage design. In a recourse mortgage, the defaulter remains liable for the difference between the balance due and the value recovered by foreclosing the house. In this paper we argue that whether mortgages allow for recourse or not is very important for macroeconomic dynamics once an economy is in a liquidity trap.

We build an incomplete-markets model that features non-recourse and recourse mortgage default, endogenous borrowing spreads, house prices and labor income. There is heterogeneity in housing tenure, leverage and savings, like in Corbae and Quintin (2015), Garriga and Hedlund (2017) or Jeske, Krueger and Mitman (2013) among others. The model yields empirically realistic distributions of leverage, housing tenure and marginal propensities to consume. Using this quantitative framework, our paper shows that the recourse feature of European mortgages can account for up to 40% of the slower recovery in consumption of Europe relative to the U.S. Moreover, credit shocks with recourse mortgages cause larger welfare inequality than with non-recourse mortgages.

The key insight from this paper is that in a liquidity trap, default with non-recourse mortgages has positive aggregate effects, even in the presence of reasonable deadweight losses from foreclosure. By a liquidity trap we refer to a situation where nominal wage rigidities are binding, interest rates are at the zero-lower bound and the economy becomes “demand-driven”. That is, output is below fundamentals, like in Guerrieri and Lorenzoni (2017), Korinek and Simsek (2016) or Schmitt-Grohé and Uribe (2017) among others. The intuition is that, in a liquidity trap, prices (including the nominal interest rate) do not fall enough to stimulate aggregate demand for consumption, which keeps unemployment high and house prices low. Thus, there are gains from mechanisms that redistribute wealth towards the borrowers with high propensity to consume. Default with non-recourse mortgages is a mechanism to do so, since the debt obligation disappears when the lender repossesses the house that serves as collateral. In fact, it is the only permanent mechanism since debt relief policies are usually “one-off policies” (Agarwal et al. 2017, Gabriel, Iacoviello and Lutz 2016), and equity mortgages are still rarely used (Greenwald, Landvoigt and Van Nieuwerburgh 2018, Piskorski and Tchistyi 2017). By contrast, recourse reduces the strength of the redistribution mechanism associated with default and therefore magnify the impact of nominal rigidities.

A comparison of aggregate data for the U.S. and Europe provides suggestive evidence of the previous mechanism. In practice the U.S. is mostly non-recourse while most European countries have recourse systems (Willen 2014). Interestingly, countries such as Ireland, Spain and the U.S. had similar patterns pre-crisis and at the start of the crisis. However, their economic recoveries have been very different. Figure 1 illustrates these dynamics.

Insert Figure 1 about here

Pre-crisis, housing prices and mortgage debt raised during the 1996-2006 period together with current account deficits (Bernanke 2010, Gete 2009). At the start of the crisis, on both sides of the Atlantic housing prices fell by a similar amount, economic performance tanked, and by 2009 monetary policy hit the zero-lower bound (Gros 2014). However, over the 2011-2013 period the U.S. economy grew by about 4.5% 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.[1] In the U.S. it took four years for housing prices to start to recover while in Ireland or Spain it took more than six years. In these two countries, it took nearly seven years for aggregate consumption to stop falling.

Figure 1 panels (e) and (f) motivate the mechanism that we explore. Through default, U.S. households have reduced their mortgage debt burden since 2007 much faster than households in Ireland or Spain. In these two countries lenders have full recourse to the borrowers' personal assets and future income until all the mortgage debt is paid. The European mortgage recourse system depressed the consumption of the low-income households unable to discharge their debts. This contributed to a deeper and more persistent recession.

We quantify the general equilibrium effects, both in steady-state and along the dynamic transition path, after an unexpected credit shock that tightens borrowing limits and drives the economy into a liquidity trap, like in Guerrieri and Lorenzoni (2017). We find that following credit shocks that trigger similar falls in house prices at impact in both economies like in Figure 1(a), the decline in aggregate consumption and its time to recover is about four and two times larger respectively under recourse. Moreover, the rise in unemployment and the recovery time of house prices are roughly twice as large with recourse.

Our results indicate that non-recourse systems would be more effective at providing debt relief and stimulating aggregate demand during liquidity traps in economies with more nominal rigidities like Europe. However, without recourse, credit would be more expensive for high risk households.

[1] Public 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 (Gros 2014).

There are four features of our model that are key for the results, and that make the model consistent with the data. First, both housing prices and labor income are endogenous in a general equilibrium framework. Second, credit spreads are endogenous. Third, there are housing transaction costs. Fourth, mortgages are long-term contracts.

Endogenous housing prices and labor income are important because we show that general equilibrium forces account for most of the differences in consumption 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.[2]

Endogenous spreads create housing illiquidity. For example, highly leveraged households cannot access their home equity when spreads increase. Transaction costs also make housing to be illiquid. This is important because illiquid housing increases the exposure of homeowners to idiosyncratic and aggregate risk making default more likely. For this reason, the distribution over liquid wealth is very correlated with the heterogeneity in mortgage spreads and default.

Long-term debt matters for two reasons. First, it prevents debt from disappearing after one period. Thus, non-recourse is important as it is the only way for over-indebted households to default and start afresh. Second, long-term debt allows the model to be consistent with the small direct links between debt and consumption documented by Ganong and Noel (2017). In models with one-period debt, when LTV limits tighten (or if house prices fall) some households are immediately forced to cut consumption to delever. Thus, those models mechanically create a strong direct link between debt and consumption. This contrasts with our model where this link is dictated by the endogenous payment, prepayment and default decisions which in turn depend upon the mortgage system.

In the model, like in the data, there is large heterogeneity in the marginal propensity to consume (MPC) that correlates with leverage. For example, highly leveraged households have very high MPC to liquid income but low MPC to house prices. Households with large housing equity have low MPCs out of income.[3] The interactions between these heterogeneities and mortgage design are key to explain aggregate consumption dynamics and economic recoveries.

The rest of the paper is organized as follows. Section 2 briefly discusses the related literature. Section 3 presents the model. Section 4 discusses the parametrization and the fit of the model. Section 5 analyzes the default decision. Section 6 contains the core exercise. Section 7 concludes.

[2] Garriga and Hedlund (2017) have a similar feedback loop. They endogenize house prices but not income.

[3] These facts are documented by Ganong and Noel (2017), Kaplan, Mitman and Violante (2016), and Mian, Rao and Sufi (2013).

The definition of the corresponding equilibrium concept and all numerical details are in the Online Appendix.

## 2 Related Literature

This paper connects four different literatures. First, we contribute to the literature that explores the consequences of cross-country variation in mortgage market structure. Campbell (2013) is an early survey. Recent research has focused on the role of adjustable versus fixed rates mortgages (Auclert 2017, Campbell and Cocco 2003, Campbell, Clara and Cocco 2018, Di Maggio et al. 2017, Garriga, Kydland and Šustek 2017, Guren, Krishnamurthy and McQuade 2018), high leveraged mortgages (Corbae and Quintin 2015), equity mortgages (Greenwald, Landvoigt and Van Nieuwerburgh 2018, Kung 2015, Piskorski and Tchistyi 2017), recourse mortgages affecting the choice of leverage before crises (Hatchondo, Martinez and Sánchez 2015), and on the role of automatically indexed mortgage contracts and debt relief polices (Piskorski and Seru 2018).[4]

It is interesting to highlight that Corbae and Quintin (2015) find that recourse economies are less sensitive to aggregate housing 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.

Second, we contribute to the growing literature that studies liquidity traps. Like, for example, Auclert and Rognlie (2018), Eggerston and Krugman (2012), Farhi and Werning (2016), Guerrieri and Lorenzoni (2017), Korinek and Simsek (2016) or Schmitt-Grohé and Uribe (2017). This literature has focused on models with one-period debt and no default. We show that long-term debt and default generate a powerful mechanism that influences economic recoveries. The mechanism is new in the literature since long-term debt alters the link between debt and consumption.

Third, we connect with the literature on mortgage default (see Foote and Willen 2017 for a recent survey). A major insight from this literature is that the level of liquid assets is the key determinant of default. We confirm that result. Moreover, we show that in recourse economies liquid assets are more important drivers of default than in non-recourse countries. This is a relevant result when comparing default rates across countries.

In our model, like in dynamic models of mortgage default as Campbell and Cocco (2015),

[4] Reher (2017) studies mortgage design in an analytical model with demand externalities.

the link between home equity and default is non-linear. Default probabilities raise dramatically for high leverage mortgagors. This is a fact stressed by Ganong and Noel (2017). In this paper we bring insights from general equilibrium to this literature. Moreover, we highlight that lack of default is welfare reducing when nominal rigidities bind and there are no mechanisms for debt reduction.

Fourth, our paper contributes to the literature on the effects of social insurance policies on credit markets (see for example Athreya, Tam and Young 2015, Athreya, Mustre-del-Río and Sánchez 2018, Chatterjee et al. 2007, Livshits, MacGee and Tertilt 2007 or Mitman 2016). This literature has focused on unsecured credit.[5] A consensus in the literature is that debt relief policies are ex-ante beneficial only for sudden large shocks, because these policies make credit expensive and so sensitive to borrower circumstances that the overall ability to smooth consumption is substantially worsened. Here we are the first to analyze debt relief in mortgage markets in general equilibrium. This is important because the multiplier effect of debt relief happens in a liquidity trap.

# 3 Model

We analyze an infinite horizon economy composed by a continuum of households and lenders, a representative firm, and the government. Households face uninsurable idiosyncratic income and house value risk. Time is discrete and denoted by $t$. The non-housing consumption good serves as numeraire. We consider mortgage loans with non-recourse and recourse.

## 3.1 Households

Households have preferences over non-housing consumption $c$ and housing services $s$. The period utility is $u(c, s)$. Preferences are time-separable and the future is discounted at rate $\beta$. The expected lifetime utility of a household is

$$\mathbb{E} \sum_{t=0}^{\infty} \beta^t u(c_t, s_t). \tag{1}$$

Households can obtain housing services by owning a house or by renting it. The flow of housing services from ownership equals the size of the house, $s = h$.

[5] Eberly and Krishnamurthy (2014) study mortgage debt relief in a partial equilibrium analysis.

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.

## 3.2 Deposits and Houses

Households invest in one-period deposits $a' \geq 0$ paying real interest rate $r_{t+1}$ between time $t$ and $t+1$. It is convenient to price deposits as bonds. The price of a deposit is $q_t^A = \frac{1}{1+r_{t+1}}$.

The economy has a constant aggregate stock of owner-occupier housing $H$. Houses are available in discrete sizes $h \in \{\underline{h}, ..., \bar{h}\}$. The housing price per unit 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. Owners can only have one house and cannot rent it. This assumption simplifies the solution of the model and does not affect the key mechanisms that we study.

Houses are risky assets. They are subject to 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. These shocks are idiosyncratic across households and independent across time. Their probabilities are given by $f_\delta(\delta)$.

For the rental market, we assume a perfectly elastic supply of rental housing that generates a constant unit price of rental $p^S$.

## 3.3 Mortgages and Default

### 3.3.1 Mortgage Contracts

Mortgages are long-term and real.[6] We model them as bonds such that a mortgage issued at time $t$ specifies the amount to be repaid $m'$ and the price at origination $q_t^0$. That is, a mortgagor that chooses to repay $m'$ receives $q_t^0 m'$ funds today. The mortgage price $q_t^0$ depends on the characteristics and assets of the borrower and accounts for the probability of default and prepayment. More specifically, a mortgagor with house $h'$, savings $a'$ and realized labor shock $e$ that chooses to repay $m'$ faces a mortgage price $q_t^0(m', h', a', e)$. The function $q_t^0$ will be endogenously determined below. Mortgage originations are subject to an exogenous LTV cap

[6] Assuming real mortgages simplifies the model and emphasizes alternative mechanisms to the inflation channels studied in Garriga, Kydland and Šustek (2017).

$\theta$. Lenders incur a proportional origination cost $\zeta_0$.

The beginning-of-period outstanding balance $m$ evolves according to

$$m' = (m - x)(1 + r^M_{t+1}), \tag{2}$$

where $x$ is the payment and $r^M_{t+1}$ is the mortgage interest rate between time $t$ and $t+1$. The mortgage interest rate is linked to the deposit rate through

$$1 + r^M_{t+1} = (1 + r_{t+1})(1 + \zeta_m), \tag{3}$$

where $\zeta_m$ are the servicing costs incurred by the lender. The outstanding balance decays geometrically at rate $\lambda$, that is, $m' = \lambda m$. This structure avoids introducing time to maturity into the already large state space of households' dynamic programming problem. Moreover, together with (2), the mortgage payment at time $t$ becomes

$$x = m - \frac{\lambda m}{1 + r^M_{t+1}}. \tag{4}$$

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

Households have the option of prepaying and refinancing the mortgage by paying off their existing balance $m$ and taking out a new mortgage. In this case, households incur a prepayment penalty that is a proportion $\zeta_p$ of the existing balance.

### 3.3.2 Default and Recourse

Default entails deadweight costs such that the value of a foreclosed house is reduced in a proportion $\zeta_d$. That is, if a household with house of size $(1-\delta)h$ defaults after the depreciation shock, then the lender only receives $(1-\zeta_d)p^H_t(1-\delta)h$. Moreover, a defaulter is excluded from mortgage markets for a random amount of time. That is, in each period, a household in default can apply again for mortgage credit with probability $\xi$.[7]

If the mortgage is non-recourse, the sale of the house extinguishes completely the mortgage debt. 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 $m > (1-\zeta_d)p^H_t(1-\delta)h$, then the lender garnishes the minimum between the remaining balance $m$ and a fraction $\phi$ of the household's

[7] This stochastic penalty ensures the convergence of the solution method discussed in the Online Appendix.

labor income and savings. That is, the maximum amount that the lender can garnish at time $t$ cannot be larger than $\phi(y_t + a)$, where $y_t$ is labor income.

With recourse the mortgage payments are made until the outstanding debt is fully repaid or the defaulter can re-enter the mortgage market, whichever occurs first. Thus, the difference between a defaulter with or without recourse is that if the mortgage has recourse the household needs to keep making payments if the sale of the house was not enough to cover the mortgage balance. All possible mortgage regimes are parametrized by $\phi$. Therefore, we refer to $\phi$ as the "recourse parameter".

## 3.4 Household's Disposable Income

Like Schmitt-Grohé and Uribe (2016), 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 $e$.

Denote by $W_t$ and $P_t$ 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, that is, $e\frac{L_t}{\bar{L}}$. There is a proportional tax $\tau_t$ on labor income and a lump-sum transfer $T_t$. Household's disposable income is

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

## 3.5 Household's Problem

A household starts time $t$ as a homeowner ($O$), renter ($R$), or past defaulter ($D$). For a homeowner, the individual state variables are the house size $h$, mortgage balance $m$, financial wealth $a$, idiosyncratic labor endowment $e$ and house depreciation shock $\delta$. For renters, the individual state variables are the financial wealth $a$ and idiosyncratic labor endowment $e$. In addition, past defaulters have their debt balance $m$ as a state variable ($m = 0$ if mortgages are non-recourse). We denote the value functions of homeowners, 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.

### 3.5.1 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 $J_t^B(a, e)$,

$$J_t^B(a,e) = \max_{c,h',m',a' \geq 0} \left\{ u(c,h') + \beta \mathbb{E} \left[ V_{t+1}^O(h', m', a', e', \delta') \right] \right\} \quad \text{s.t.} \tag{6}$$

$$c + (1+\zeta_b) p_t^H h' + q_t^A a' = y_t(e) + a + q_t^0(m', h', a', e) m', \tag{7}$$

$$q_t^0(m', h', a', e) m' \leq \theta p_t^H h'. \tag{8}$$

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

$$J_t^R(a,e) = \max_{c,s,a' \geq 0} \left\{ u(c,s) + \beta \mathbb{E} \left[ V_{t+1}^R(a', e') \right] \right\} \quad \text{s.t.} \tag{9}$$

$$c + p^S s + q_t^A a' = y_t(e) + a. \tag{10}$$

The value of being a renter is the maximum of the two options:

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

### 3.5.2 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 $J_t^K(h, m, a, e, \delta)$,

$$J_t^K(h,m,a,e,\delta) = \max_{c,a' \geq 0} \left\{ u(c,h) + \beta \mathbb{E} \left[ V_{t+1}^O(h, \lambda m, a', e', \delta') \right] \right\} \quad \text{s.t.} \tag{12}$$

$$c + p_t^H \delta h + x + q_t^A a' = y_t(e) + a, \tag{13}$$

$$x = m - \frac{\lambda m}{1 + r_{t+1}^M}. \tag{14}$$

2) To prepay the mortgage while keeping the current house and choose a new mortgage

amount $m'$ (refinance), or no mortgage, $m' = 0$. The value function in this case is $J_t^F(h, m, a, e, \delta)$,

$$J_t^F(h, m, a, e, \delta) = \max_{c, m', a' \geq 0} \left\{ u(c, h) + \beta \mathbb{E}\left[V_{t+1}^O(h, m', a', e', \delta')\right] \right\} \quad \text{s.t.} \tag{15}$$

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

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

3) To sell the house (and prepay the mortgage if any). The value function is $J_t^S(h, m, a, e, \delta)$. We assume that households selling the house must be renters next period. Moreover, the seller has to cover depreciation costs on the house before selling and prepay the existing mortgage balance $m$:

$$J_t^S(h, m, a, e, \delta) = \max_{c, s, a' \geq 0} \left\{ u(c, s) + \beta \mathbb{E}\left[V_{t+1}^R(a', e')\right] \right\} \quad \text{s.t.} \tag{18}$$

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

4) To default on its mortgage (if she has one). We assume that defaulters become renters and do not cover the housing depreciation costs. The value function is $J_t^D(h, m, a, e, \delta)$. This value function depends on whether the mortgage is recourse or not.

4a) *Recourse mortgage.* In this case, 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:

$$J_t^D(h, m, a, e, \delta) = \max_{c, s, a' \geq 0} \left\{ u(c, s) + \beta \mathbb{E}\left[\xi V_{t+1}^R(a', e') + (1 - \xi)V_{t+1}^D(m', a', e')\right] \right\} \quad \text{s.t.} \tag{20}$$

$$c + p^S s + x_D + q_t^A a' = y_t(e) + a, \tag{21}$$

$$x_D = \max\left\{ \min\left\{ m - (1 - \zeta_d)p_t^H(1 - \delta)h, \phi(y_t(e) + a) \right\}, 0 \right\}, \tag{22}$$

$$m' = (m - (1 - \zeta_d)p_t^H(1 - \delta)h - x_D)(1 + r_{t+1}^M). \tag{23}$$

4b) *Non-recourse mortgage.* In this case, after the sale of the foreclosed house, any remaining debt disappears:

$$J_t^D(h, m, a, e, \delta) = \max_{c, s, a' \geq 0} \left\{ u(c, s) + \beta \mathbb{E}\left[\xi V_{t+1}^R(a', e') + (1 - \xi)V_{t+1}^D(0, a', e')\right] \right\} \quad \text{s.t.} \tag{24}$$

$$c + p^S s + q_t^A a' = y_t(e) + a. \tag{25}$$

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

$$V_t^O(h,m,a,e,\delta) = \max\left\{J_t^K(\cdot), J_t^F(\cdot), J_t^S(\cdot), J_t^D(\cdot)\right\}. \tag{26}$$

#### 3.5.3 Defaulter

A defaulter has to rent today and, if her mortgage had recourse, make debt payments. Her value function is (20) if recourse and (24) if non-recourse inputting that she has no house $(h=\delta=0)$

$$V_t^D(m,a,e) = J_t^D(0,m,a,e,0). \tag{27}$$

## 3.6 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. That is, for a loan of size $q_t^M(m',h',a',e)m'$, the lender needs to earn $(1+r_{t+1}^M)$ in expectation. We differentiate between the recourse and non-recourse case.

### 3.6.1 Recourse Mortgages

In the case of recourse mortgages, the price $q_t^M$ is determined by:

$$\begin{aligned} q_t^M(m',h',a',e)m' = \frac{1}{1+r_{t+1}^M}\mathbb{E}\Big[&\underbrace{I_K'\left(x' + q_{t+1}^M(\lambda m',h',a_K'',e')\lambda m'\right)}_{\text{pay + continuation value}} \\ &+ \underbrace{(I_F'+I_S')(1+\zeta_p)m'}_{\text{prepay}} + \underbrace{I_D'((1-\zeta_d)p_{t+1}^H(1-\delta')h' + x_D' + q_{t+1}^D(m_D'',a_D'',e')m_D'')}_{\text{default (house sale + debt service + continuation value)}}\Big]. \end{aligned} \tag{28}$$

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 by $a_D''$ those of mortgagors in default. The value of a recourse mortgage in default is:

$$q_t^D(m_D',a_D',e)m_D' = \frac{1-\xi}{1+r_{t+1}^M}\mathbb{E}\Big[\underbrace{x_D' + q_{t+1}^D(m_D'',a_D'',e')m_D''}_{\text{debt service + continuation value}}\Big]. \tag{29}$$

### 3.6.2 Non-Recourse Mortgages

In the case of non-recourse mortgages, the price $q_t^M$ is determined by:

$$q_t^M(m',h',a',e)m' = \frac{1}{1+r_{t+1}^M}\mathbb{E}\Big[\underbrace{I_K'\left(x'+q_{t+1}^M(\lambda m',h',a_K'',e')\lambda m'\right)}_{\text{pay + continuation value}} \\ + \underbrace{(I_F'+I_S')(1+\zeta_p)m'}_{\text{prepay}} + \underbrace{I_D'(1-\zeta_d)p_{t+1}^H(1-\delta')h'}_{\text{default (house sale)}}\Big]. \tag{30}$$

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

## 3.7 Lenders

Lenders originate long-term mortgages, pool them and perfectly diversify household idiosyncratic risk. The cost of the one-period deposits $B_{t+1}^b$ issued to fund the mortgages must equal the expected revenue from collecting periodic mortgage payments, prepayments, selling foreclosed houses, receiving debt service payments (if recourse), and government transfers. These transfers are such that any ex-post profits or losses experienced by lenders (induced by uninsurable aggregate shocks like the one we study in Section 6.2) are completely absorbed into the government budget. Thus, the transfers capture a bailout during recessions.[8] An implication is that mortgage originations are fully funded with the issuance of deposits:

$$q_t^A B_{t+1}^b = (1+\zeta_0)(1+\zeta_m)\left(\int I_B q_t^0 m'\, d\Psi_t^R + \int I_F q_t^0 m'\, d\Psi_t^O\right), \tag{31}$$

where $I_B$ and $I_F$ are indicator functions for the decisions of buying a house and refinancing. $\Psi_t^R$ and $\Psi_t^O$ are the distributions over renters' $(a,e)$ and homeowners' states $(h,m,a,e,\delta)$. The Online Appendix discusses in more detail the lenders' balance sheet and the derivation of (31).

## 3.8 Wage Rigidities and Unemployment

We introduce nominal rigidities by assuming that nominal wages are downwardly rigid as in Auclert and Rognlie (2018), Eggertsson, Mehrotra and Robbins (2018), Guerrieri and Lorenzoni

[8]This assumption simplifies the problem of pricing deposits when there are ex-post profits and losses. Otherwise, we would need to add the net worth of lenders as an additional state variable to our already large state space.

(2017), and Schmitt-Grohé and Uribe (2016, 2017). That is, nominal wages cannot fall from period to period below a wage norm:

$$W_t \geq \gamma W_{t-1}. \tag{32}$$

In the expression above, the parameter $\gamma$ controls the degree of rigidity. For instance, if $\gamma = 1$, 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,

$$Y_t = AL_t, \tag{33}$$

where $A$ is the productivity level, which is constant over time.

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

$$L_t \leq \bar{L} \tag{34}$$

$$(\bar{L} - L_t)(W_t - \gamma W_{t-1}) = 0. \tag{35}$$

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.

## 3.9 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 $\tau_t$. The government finances exogenous spending $G_t$ and the transfers to the lenders $T_t^b$. Its budget constraint is given by:

$$\tau_t \int \frac{W_t}{P_t} e \frac{L_t}{\bar{L}} \, d\Psi_t + \int p^S s \, d\Psi_t = G_t + T_t + T_t^b, \tag{36}$$

where $\Psi_t$ is the overall distribution over households' states.

In Section 6, when we study unanticipated shocks, the government spending $G_t$ adjusts in order to keep the government 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 government spending to shut down an additional channel arising from 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. Moreover, transfers to lenders $T_t^b$ adjust such that the credit condition (31) holds.

# 4 Parametrization and Fit of the Model

We parametrize the steady-state of the model to match key U.S. statistics prior to the Great Recession. 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 6 for 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 parametrization. A period in the model is a quarter. We assume that in steady-state the economy is at full employment, $L_0 = \bar{L}$.

## 4.1 Exogenous Parameters

*Idiosyncratic earnings process, technology and labor market.* For the labor earnings process, we assume a persistent component that follows an AR(1) process and a i.i.d transitory component like Storesletten, Telmer and Yaron (2004). The parameters at annual frequency are: persistence parameter $\rho = 0.977$, variance of the shocks to the persistent component $\sigma_\eta^2 = 0.0166$, and variance of the transitory shocks $\sigma_\epsilon^2 = 0.0630$.[9] We choose the productivity level $A$ to normalize median quarterly labor income to one. Regarding the downward nominal wage rigidity parameter, we set $\gamma = 1$ as in Auclert and Rognlie (2018), and Guerrieri and Lorenzoni (2017).

*Housing market.* We set the cost of buying a house to $\zeta_b = 0.025$ and the cost of selling to $\zeta_s = 0.05$, which are consistent with the values estimated in the literature (see Berger and Vavra 2015 for example), and with evidence reported by Gruber and Martin (2003) that the

[9]The Online Appendix explains how we convert these values into quarterly frequency. 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.

costs of selling are larger than those of buying. For the idiosyncratic depreciation shock we use a two-point distribution, and set as low outcome the no depreciation case, $\underline{\delta} = 0$.

*Mortgage market.* We set the mortgage origination cost to $\zeta_0 = 0.4\%$ 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 an annual mortgage risk-free rate of 3.5%. Concerning the maximum LTV at origination and the prepayment penalty we set them to $\theta = 1$ and $\zeta_p = 0.035$ respectively.[10] 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. It is also consistent with the typical length of time (between 5 and 7 years) devoted to debt service after default in most of continental Europe (Gros 2014). The deadweight costs of foreclosures, $\zeta_d = 0.22$, follows Pennington-Cross (2006) who reports that the selling price of a foreclosed property is about 22% lower.

*Government.* We set the labor income tax to $\tau = 0.25$ and choose the lump-sum transfer $T$ such that in steady state about 40% of households receive a net transfer from the government (Kaplan, Moll and Violante 2018). Given these values, the government budget constraint (36) determines government expenditures, which for our benchmark steady state equals 14% of output.

## 4.2 Endogenous Parameters

We assume a CRRA utility function over a CES aggregator for non-housing consumption and housing services:

$$u(c, s) = \frac{\left[(1-\eta)c^{\frac{\epsilon-1}{\epsilon}} + \eta s^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon(1-\sigma)}{\epsilon-1}}}{1-\sigma}. \tag{37}$$

The parameters $\sigma$, $\epsilon$, and $\eta$ are 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.

We set the nine endogenous parameters to target the following moments from the 2004 Survey of Consumer Finances (SCF): 1) a homeownership rate of 68.4%; 2) a median net worth (relative to annual average income) of 0.567; 3) a median housing wealth for owners (relative to annual median income) of 3.21; 4) an average mortgage debt for owners (relative to annual

[10] In the early 2000s prepayment penalties were especially common for subprime mortgages, with typical amounts between 3% and 5% of the prepaid loan balance (Mayer, Piskorski and Tchistyi 2013). After the 2008 mortgage crisis, the Dodd-Frank Act limited prepayment penalties on mortgages.

median income) of 20.5; 5) a median mortgage debt for owners (relative to annual median income) of 1.62; 6) a median debt-to-value (DTV) of 58.3%; and 7)-10) the share of mortgagors with DTV larger than 70%, 80%, 90% and 95%. Outside of the SCF, we also target: 11) an annual foreclosure rate of 1.15% following the data from the Mortgage Banker's Association on foreclosures for 2004; 12) the average house depreciation rate of 1.48% for the period 1960-2002 reported by Jeske, Krueger and Mitman (2013); and 13) an annual deposit 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 1 reports the resulting endogenous parameters and Table 2 compares the empirical targets with the model-generated moments.

Insert Tables 1 and 2 about here

## 4.3 Model Fit

The model fits the data well. For example, it generates realistic outcomes for the relevant housing and mortgage variables, like the homeownership (66.1%) and foreclosure (1.24% annual) rates, the minimum house value (around $100K), the house depreciation rate (1.26% annual), price-to-rent ratio (13.1, close to the U.S. median price-to-rent ratio of 11.27 reported by Zillow for 2015) and mortgage maturity (36 years).

It is important to highlight that the model is consistent with the empirical literature in two key dimensions 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 fraction of homeowners with no liquid wealth. For example, in the model the fraction of wealthy illiquid households, that is, households with zero liquid wealth but positive housing holdings ($a = 0$ and $h > 0$), is 18.9%. This value is close to the 20% reported by Kaplan and Violante (2014) using the SCF 2004, or by Berger and Vavra (2015) using PSID data.

The model is also consistent with moments not targeted but important for the questions studied. For example, the median owner house size relative to the median renter house is 2.46, in the range of the 2013 American Housing Survey which reports 1.85. The model yields a ratio of mean income for homeowners to mean income for renters of 1.90, close to the value of 2.49 found in the SCF 2004. The fraction of non-movers in owner-occupied units (over a period of one year) averages 94.9% during 2006-2016 in Current Population Survey data and the model counterpart is 96.7%. This last result suggests a realistic degree of housing illiquidity, which is important for consumption dynamics.

Very importantly, Figure 2(a) shows that the model generates rich heterogeneity in MPCs out of liquid income, like in the empirical literature (see, for example, Misra and Surico 2014).[11] Table 3 reports the MPCs out of a permanent increase in house prices and the MPCs out of a purely transitory increase in income for different groups. The overall MPC out of house prices is 0.21. The corresponding elasticity is 0.25,[12] which closely matches estimates reported by Mian, Rao and Sufi (2013), Berger et al. (2017), and Kaplan, Mitman and Violante (2016). Moreover, the overall MPC out of liquid income is 0.25, which closely matches the empirical estimates reported, for example, in Parker et al. (2013) and Misra and Surico (2014).[13]

Insert Figure 2 about here

Also it is crucial that in the model underwater mortgagors respond less to debt relief policies that do not affect their current budget constraints, like documented by Ganong and Noel (2017). Thus, house price shocks are not equivalent to cash transfers for underwater mortgagors that find refinancing costly.

Finally, like in the empirical literature, debt-to-value (DTV) is a key determinant for the MPC out of house prices. Figure 2(b) plots the DTV distribution in the steady-state. When DTV is high ($\geq 80\%$), 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, essentially do not change consumption following higher house prices. Table 3 highlights that the effects on consumption from house prices work through the medium DTV ($\in [50\%, 80\%)$) and low DTV ($< 50\%$) households. These are the households able to refinance and benefit from the easier and cheaper credit brought by the higher house prices.

Insert Table 3 about here

However, Table 3 shows that households with high DTV and low liquid wealth have extremely large consumption responses to income changes, around 0.50, like in Kaplan and Violante (2014). This is key for the interaction of the mortgage system with the economy as we discuss below.

[11] The MPC is measured as the fraction spent today in non-housing consumption for each extra dollar received.

[12] This elasticity is the percentage change in consumption divided by the percentage change in house prices.

[13] See the Online Appendix for the details on how we compute the MPCs in the model so that they are directly comparable to the empirical evidence.

# 5 Drivers of Default

Before studying the interaction between the mortgage system and the economy, in this section we analyze the drivers of default.

Figure 3 and Table 4 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, there is no value of strategic default because the defaulter remains liable for any debt after the house is foreclosed.[14] Thus, there is three times less default in the steady-state with recourse mortgages.

Insert Figure 3 and Table 4 about here

With recourse mortgages, default is accounted for by households with high DTV ($\geq 80\%$). These are mortgagors who had low income, or negative house value shocks, and face large mortgage payments relative to the value of their house. Among these highly leveraged households, the level of liquid assets is the key determinant of default. Households without liquid assets default twice more often than households whose liquid assets allow them to smooth out 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 a region of strategic default which 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 housing equity. As Table 4 shows, with non-recourse mortgages the level of liquid assets is less relevant to explain default differences across mortgagors.

When we compare default across mortgage regimes, we find that having no liquid assets is specially important with recourse mortgages. To see this result we simulated the models with and without recourse and run a regression of the probability of default on the homeowners' states. We include a triple interaction term of having no liquid assets ($a = 0$), high DTV ($\geq 80\%$) and being a recourse mortgage. We find that, for high DTV mortgagors, switching from non-recourse to recourse increases the role of illiquid assets by more than three times.

[14] Default is considered strategic if the household defaults even if she is able to repay.

# 6 Mortgage Design and Slow Recoveries

Now we study the interactions between mortgage recourse and macroeconomic dynamics. We study a credit supply shock that we model as an exogenous transitory decrease in the LTV limit $\theta$. Before analyzing the dynamics, we discuss the steady state.

## 6.1 The Steady State

The key difference between recourse and non-recourse mortgages is who bears the risk from falls in house prices. With non-recourse that risk is suffered by the lenders. If house prices fall the mortgagor gives the house to the lender and walks away from the debt. The steady state default rate with recourse is around 68% lower than in the non-recourse economy. Thus, without recourse, lending rates are higher, especially for the riskier borrowers (high DTV mortgagors). Figure 4 shows this result. The figure plots the mortgage spread as a function of DTV for households with the median house and different levels of income.

Insert Figure 4 about here

Moreover, 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).

Table 5 summarizes the steady state equilibrium for both mortgage systems.[15] The recourse economy has a larger median DTV among mortgagors and a larger share of debtors in the upper tail of the DTV distribution. Recourse leads to a stock of mortgage debt about 19% larger relative to non-recourse and an average mortgage debt for homeowners 12% larger. Low-income borrowers are more leveraged with recourse mortgages.

Insert Table 5 about here

Homeownership rates are roughly 4% larger under recourse. This is consistent with the observed homeownership rates for the U.S. and Europe during the pre-crisis period. Average

[15] To make the comparison across mortgage regimes fair, we parametrize the discount factor $\beta$ and the aggregate housing supply $H$ to ensure a 1% annual risk-free deposit rate and a house price of one in both mortgage regimes. The other parameters remain at the values reported in Table 1. As benchmark recourse parameter we set $\phi = 0.2$ that is consistent with the U.S. Title III of the Federal Wage Garnishment Law. In Section 6.6 we analyze the sensitivity of the results to different values of the recourse parameter $\phi$.

homeownership rate in the U.S. was around 69% in 2004-06, while in Ireland and Spain it was 79.9% and 83.2% respectively.

## 6.2 The Liquidity Trap: Aggregate Effects

We study the perfect-foresight transition to a one-time unexpected shock that decreases the LTV limit to $\theta'$ at time $t = 1$. The shock reverts to the original level at rate $\kappa = \frac{(\theta - \theta')}{24}$ per quarter.[16] We study the differences of the transition between the non-recourse and recourse economies.[17,18] For both economies the LTV limit $\theta_t$ follows the linear path

$$\theta_t = \min\{\theta, \theta' + \kappa \cdot (t-1)\}. \tag{38}$$

Figure 5 plots the aggregate effects. The credit shock causes less mortgage originations and a lower demand for housing. House prices fall. The fall in house prices, together with the tightening of the borrowing limit, reduces the amount of liquidity that households have for consumption. Aggregate demand falls.

Insert Figure 5 about here

If the economy had no nominal rigidities, the fall in aggregate demand would have no effect on output. After the shock, real interest rates and wages would fall to generate new demand for goods from the savers (the wealthy households) and demand from the firms for labor. However, with the wage norm (32) the wages are downward rigid. Once nominal wages hit the wage norm, that is $W_t = W_0$, labor demand from the firms is lower than labor supply. Unemployment arises.[19] Moreover, binding nominal wages and the linear production technology (33) yield a constant price level. Thus, the nominal interest rate equals the real interest rate. Like Auclert and Rognlie (2018), we capture the zero-lower bound assuming that the real rate remains fixed at the steady state level $r_t = r_0$. Thus, aggregate demand is depressed and the

[16] We select $\kappa$ such that the LTV limit reverts to the original level after 24 quarters.

[17] In the non-recourse economy, we choose the value for the LTV limit $\theta' = 0.70$ such that the default rate approximately doubles at impact, like in the data of Figure 1(f). In the recourse economy, we choose the value for the LTV limit $\theta' = 0.83$ such that the drop in the equilibrium house price at impact is like in the non-recourse economy, consistent with the data in Figure 1(a).

[18] To shut down a redistribution channel arising from changes in fiscal policy, the government keeps the budget balanced during the transition by adjusting government spending $G_t$ according to (36), while keeping taxes and transfers to households fixed at their steady state levels, that is $\tau_t = \tau_0$ and $T_t = T_0$. Transfers to lenders $T_t^b$ adjust such that the lenders' balance sheet (A1) discussed in the Online Appendix equals (31).

[19] The unemployment rate at time $t$ is $100 \cdot (1 - \frac{L_t}{L})$.

economy enters into a liquidity trap. Output becomes demand-driven.

There is a negative self-reinforcing loop between unemployment and housing prices. Unemployment reduces labor income, this reduces demand for housing and house prices fall even more. Lower housing prices push aggregate demand further down and unemployment increases even more. The nominal rigidities prevent prices (wages and interest rates) from playing an equilibrating role. The adjustment happens mostly through unemployment and housing prices.

Figure 5 reports results for a shock that triggers a similar endogenous fall in house prices in an economy with recourse and in another without it. In the recourse economy the unemployment rate raises to 17.9% at impact rather than 10.8% and aggregate consumption falls by 11.1% rather than 2.71%. In the recourse economy, house prices and employment levels take 11 and 16 more quarters to recover respectively.[20] Although mortgage originations fall at impact by more in non-recourse, they take 17 more quarters to recover in the recourse economy. Aggregate consumption takes 23 quarters to recover rather than 10. The cumulated consumption responses (the sum of yearly deviations from the steady-state level along the transition path) is -26.1% in recourse, which is much larger than the -3.08% value in non-recourse.

Thus, Figure 5 shows that the economy with recourse has a deeper recession and a slower recovery than the economy without recourse, even in the presence of reasonable foreclosures costs. When comparing Figure 5(c) with the data from Figure 1(b) we find that the recourse mechanism accounts for around 40% of the observed recovery gap in consumption between the U.S. and Europe over the first seven years since 2007 (28 quarters in the model).[21]

Next we discuss the mechanism that drives the previous results.

## 6.3 The Liquidity Trap: Inspecting the Mechanism

Figure 6 helps to understand what drives the aggregate results discussed before. It plots percent deviations from the steady-state consumption conditional on initial DTV and liquid assets.

Insert Figure 6 about here

[20] We define the recovery time as the number of quarters that it takes following the LTV shock for the variable to be within 25 basis points from the pre-shock level.

[21] In the data of Figure 1(b), we define the recovery gap at time $t$ as the difference of the deviations from the 2007 level at time $t$ between the U.S. and the average of Ireland and Spain. Then, we compute the time-series average of the recovery gaps for the first 7 years since 2007. In Figure 5(c), the recovery gap at time $t$ is the difference of the deviations from the steady-state at time $t$ between the non-recourse and recourse economies.

For the non-recourse economy, the consumption response of high DTV households, renters and low DTV households is similar. The households that react the most are those with medium DTV, especially if they do not have liquid assets ($a = 0$). Although high DTV households have the highest income MPC, their consumption is essentially insensitive to the fall in house prices and LTV limit, as opposed to the consumption of medium DTV households who see their access to credit vanished. Moreover, a fraction of high DTV households default and see their debts forgiven. This allows them to sustain their consumption.

Figure 5(f) shows that the default rate is higher for the non-recourse economy relative to recourse over all the transition. At impact the default rate is roughly twice as large in the non-recourse economy, despite recourse displaying a larger increase in unemployment and a larger mass of mortgagors in the upper tail of the DTV distribution at the time when the shock hits. Many mid and low-wealth, high-indebted households that would have defaulted under non-recourse prefer to keep their mortgages and not to default under recourse.

The absence of default as a mechanism for debt relief explains Figure 6 in the recourse economy. Medium and high DTV households have the largest drops in consumption. Their reaction is very similar because with recourse mortgages the high DTV households cannot use default as a mechanism to cushion their fall in wealth and labor income.

Non-recourse mortgages cause smaller and shorter recessions because of two reasons: 1) there are less medium and high DTV households who are the households reducing more their consumption in the crisis, this is what we could call "the macroprudential effect of non-recourse"; 2) because through default, they help high DTV households to reduce their consumption by less. This is what we could call the "stimulative effect of non-recourse". Table 3 showed that high DTV households have the largest MPC out of income. Most of the liquidity that those households obtain from reducing their debt burden is allocated to consumption.

### 6.4 The Liquidity Trap: Partial vs General Equilibrium Effects

Now we analyze whether the previous results are driven by the different rates of default or by the different price reaction to the shock. Figure 7 decomposes consumption following Kaplan, Moll and Violante (2018). Let $C_t$ be the aggregate consumption at time $t$. By totally differentiating we get a decomposition for the response of $C_1$ at impact ($t = 1$) into three parts: 1) the partial equilibrium response to the exogenous LTV limit path $\{\theta_t\}_{t=1}^{\infty}$ while keeping house prices $p^H$ and employment $\bar{L}$ fixed at their steady state levels; 2) the response to the time path of equilibrium house prices $\{p_t^H\}_{t=1}^{\infty}$ while keeping the LTV limit $\theta$ and employment $\bar{L}$ fixed at their steady state levels levels; and 3) the response to the time path of equilibrium employment $\{L_t\}_{t=1}^{\infty}$ which is computed in a similar way,

$$dC_1 = \underbrace{\sum_{t=1}^{\infty} \frac{\partial C_1}{\partial \theta_t} d\theta_t}_{\text{direct effect}} + \underbrace{\sum_{t=1}^{\infty} \left( \frac{\partial C_1}{\partial p_t^H} dp_t^H + \frac{\partial C_1}{\partial L_t} dL_t \right)}_{\text{indirect effects}}. \tag{39}$$

The aggregate responses at longer horizons ($t \geq 2$) are decomposed in a similar way.

Insert Figure 7 about here

The first term in (39) is the direct effect from a change in the path of the LTV limit. Here, we keep house prices and employment constant. Tighter LTV limits affects directly the ability to borrow and refinance. Consumption drops because new mortgagors can leverage less, existing owners extract less equity and renters need to save more for the downpayment.

The remaining terms in (39) reflect indirect, general equilibrium effects from changes in house prices and employment. Because of the reasons discussed before, higher unemployment and lower housing prices imply lower consumption.

Indirect effects are considerably larger than the direct effect. In the non-recourse economy, the combined indirect effects account for 89% of the first year consumption response, while the direct effect accounts for 7% of the response.[22] In recourse, the contribution of the indirect effects to the response is 86%, while the contribution of the direct effect is 10%.

These results highlight that the benefits from non-recourse mortgages come through faster recoveries in house prices and lower unemployment rates once in the liquidity trap. Looking only at the response of consumption and defaults for fixed income and house prices is not correct to compare mortgage systems.

### 6.5 Welfare Analysis

Now we study the welfare implications of the two mortgage regimes. We study the unexpected shock discussed above and we focus on households heterogeneous across these dimensions: status (renter, homeowner, past defaulter), housing ($h$), debt ($m$), savings ($a$), labor endowment ($e$), and house depreciation ($\delta$). We denote by $z$ the state variable (that is, $z = (a, e)$ if the household enters the period as renter, $z = (h, m, a, e, \delta)$ if the she enters as homeowner,

[22] The reminder are higher-order terms as the decomposition only holds exactly for infinitesimal changes.

and $z = (m, a, e)$ if she enters as past defaulter).

We measure welfare with the conditional consumption-equivalent variation (CEV) that we define as the constant percentage change in per-period non-housing consumption $\omega(z)$, which makes the household indifferent between the shock path discussed before and the steady-state equilibrium without the shock (or pre-shock). Formally, for each state $z$ we solve for the value of $\omega(z)$ that satisfies

$$\mathbb{E}\left[\sum_{t=1}^{\infty} \beta^{t-1} u\left([1+\omega(z)]c_t, s_t\right) \,\Big|\, z\right] = \mathbb{E}\left[\sum_{t=1}^{\infty} \beta^{t-1} u\left(\tilde{c}_t, \tilde{s}_t\right) \,\Big|\, z\right], \tag{40}$$

where $\{c_t, s_t\}_{t=1}^{\infty}$ and $\{\tilde{c}_t, \tilde{s}_t\}_{t=1}^{\infty}$ refer to the steady state and the transition induced by the unexpected LTV shock respectively. If $\omega(z) < 0$ the household suffers a welfare loss when she goes through the transition.

Table 6 contains the results. The LTV shock leads to welfare losses for households of all groups on average. The losses are much larger in the recourse than in the non-recourse economy. That is, recourse mortgages amplify welfare losses from a negative shock. The average welfare loss is seven times larger in the recourse economy. Moreover, recourse mortgages generate larger cross-sectional dispersion in welfare losses.

Insert Table 6 about here

In the non-recourse economy, high and low DTV mortgagors experience similar welfare losses on average, but for different reasons. The drop in consumption of high DTV mortgagors, unable to tap their home equity, is essentially due to the rise of unemployment and subsequent fall of earnings. However, the default option cushions their welfare loss. Low DTV suffer mostly by the tightening in the LTV limit and falling house prices and labor income. Medium DTV households have the largest welfare loss as they are hit by the LTV limit, house prices and labor income. Among all households, renters and previous defaulters suffer the less the LTV shock and mainly due to raising unemployment.

In the recourse economy, highly indebted mortgagors (DTV $\geq 80\%$) suffer the largest welfare losses. These households are extremely exposed to idiosyncratic shocks since default with recourse does not provide any insurance value. Low and medium DTV mortgagors also suffer because house prices fall more and more persistently with default. Lower collateral value reduces the ability to obtain credit and smooth idiosyncratic shocks. In other words, an economy with recourse mortgages has less ways to smooth consumption. High unemployment and difficult access to credit hits renters and past defaulters.

To recap, recourse leads not only to lower welfare on average over the transition but cause inequality as measured by the cross-sectional dispersion of welfare losses.

### 6.6 Sensitivity Analysis

Table 7 confirms that our core results are robust to plausible changes in the recourse parameter $\phi$.[23]

Insert Table 7 about here

The fall in aggregate consumption and the rise of unemployment at impact becomes larger as the recourse parameter increases. The default rate at impact is lower for all recourse regimes relative to non-recourse. Aggregate consumption needs more quarters to return to the original level as the recourse parameter increases. Thus, with higher recourse the recoveries are slower.

The bottom panel of Table 7 reports the consumption response over the first year due to each effect, for different economies as the recourse parameter $\phi$ changes.

The substantial contribution of the indirect effects on the change in consumption discussed in Section 6.4 is remarkably robust to changes in the recourse parameter $\phi$. In all the economies reported in Table 7, the indirect effects account for at least 84% of the consumption response. Further, as the degree of recourse increases, the contribution of the employment effect to the response strengthens while the house price effect weakens.

## 7 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 more frequently. 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, which is a form of social insurance. This redistribution has positive aggregate effects once an economy

[23] For each value of the recourse parameter $\phi$, we parametrize again the discount factor $\beta$ and housing stock $H$ while keeping the other parameters at the values in Table 1, in the same way we discussed in Section 6.1. In each case, we choose the value of the borrowing limit $\theta'$ in (38) such that the fall in house prices at impact is similar across the economies.

is in a liquidity trap as it cushions the fall in house prices and lowers unemployment. In our model, outside the liquidity trap there are no aggregate gains from the wealth redistribution associated with default, but only the deadweight losses associated with foreclosures.

In addition, recourse mortgages increase financial fragility as leverage is higher and cause larger welfare inequality after credit crises. Thus, this 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.

# References


Agarwal, S., Amromin, G., Ben-David, I., Chomsisengphet, S., Piskorski, T. and Seru, A.: 2017, Policy intervention in debt renegotiation: Evidence from the home affordable modification program, *Journal of Political Economy* **125**(3), 654–712.

Athreya, K., Mustre-del Río, J. and Sánchez, J.: 2018, The persistence of financial distress.

Athreya, K., Sánchez, J. M., Tam, X. S. and Young, E. R.: 2015, Labor market upheaval, default regulations, and consumer debt, *Review of Economic Dynamics* **18**(1), 32–52.

Auclert, A.: 2017, Monetary policy and the redistribution channel.

Auclert, A. and Rognlie, M.: 2018, Inequality and aggregate demand.

Berger, D., Guerrieri, V., Lorenzoni, G. and Vavra, J.: 2017, House prices and consumer spending, *The Review of Economic Studies* **85**(3), 1502–1542.

Berger, D. and Vavra, J.: 2015, Consumption dynamics during recessions, *Econometrica* **83**(1), 101–154.

Bernanke, B.: 2010, Monetary policy and the housing bubble, *Speech at the Annual Meeting of the American Economic Association, Atlanta, Georgia* .

Bernanke, B.: 2017/4/12, How big a problem is the zero lower bound on interest rates?, *Brookings Blog* .

Campbell, J. Y.: 2013, Mortgage market design, *Review of Finance* **17**(1), 1–33.

Campbell, J. Y.: 2017, Keynote address to the 10th Macro Finance Society Workshop.

Campbell, J. Y., Clara, N. and Cocco, J.: 2018, Structuring mortgages for macroeconomic stability.

Campbell, J. Y. and Cocco, J. F.: 2003, Household risk management and optimal mortgage choice, *The Quarterly Journal of Economics* **118**(4), 1449–1494.

Campbell, J. Y. and Cocco, J. F.: 2015, A model of mortgage default, *The Journal of Finance* **70**(4), 1495–1554.

Chatterjee, S., Corbae, D., Nakajima, M. and Ríos-Rull, J.-V.: 2007, A quantitative theory of unsecured consumer credit with risk of default, *Econometrica* **75**(6), 1525–1589.

Corbae, D. and Quintin, E.: 2015, Leverage and the foreclosure crisis, *Journal of Political Economy* **123**(1), 1–65.

Di Maggio, M., Kermani, A., Keys, B. J., Piskorski, T., Ramcharan, R., Seru, A. and Yao, V.: 2017, Interest rate pass-through: Mortgage rates, household consumption, and voluntary deleveraging, *American Economic Review* **107**(11), 3550–88.

Eberly, J. and Krishnamurthy, A.: 2014, Efficient credit policies in a housing debt crisis, *Brookings Papers on Economic Activity* **2014**(2), 73–136.

Eggertsson, G. B. and Krugman, P.: 2012, Debt, deleveraging, and the liquidity trap: A Fisher-Minsky-Koo approach, *The Quarterly Journal of Economics* **127**(3), 1469–1513.

Eggertsson, G. B., Mehrotra, N. R. and Robbins, J. A.: 2018, A model of secular stagnation: Theory and quantitative evaluation, *American Economic Journal: Macroeconomics* .

Farhi, E. and Werning, I.: 2016, A theory of macroprudential policies in the presence of nominal rigidities, *Econometrica* **84**(5), 1645–1704.

Foote, C. and Willen, P.: 2017, Mortgage-default research and the recent foreclosure crisis.

Gabriel, S. A., Iacoviello, M. M. and Lutz, C.: 2016, A crisis of missed opportunities? Foreclosure costs and mortgage modification during the Great Recession.

Ganong, P. and Noel, P.: 2017, The effect of debt on default and consumption: Evidence from housing policy in the Great Recession.

Garriga, C. and Hedlund, A.: 2017, Mortgage debt, consumption, and illiquid housing markets in the great recession.

Garriga, C., Kydland, F. E. and Šustek, R.: 2017, Mortgages and monetary policy, *Review of Financial Studies* **30**(10), 3337–3375.

Gete, P.: 2009, Housing markets and current account dynamics, *PhD Dissertation, University of Chicago* .

Greenwald, D., Landvoigt, T. and Van Nieuwerburgh, S.: 2018, Financial fragility with SAM?

Gros, D.: 2014/7/22, Why has the U.S. recovered more quickly than Europe?, *World Economic Forum* .

Gruber, J. W. and Martin, R. F.: 2003, Precautionary savings and the wealth distribution with illiquid durables.

Guerrieri, V. and Lorenzoni, G.: 2017, Credit crises, precautionary savings, and the liquidity trap, *The Quarterly Journal of Economics* **132**(3), 1427–1467.

Guren, A. M., Krishnamurthy, A. and McQuade, T. J.: 2018, Mortgage design in an equilibrium model of the housing market.

Hatchondo, J. C., Martinez, L. and Sánchez, J. M.: 2015, Mortgage defaults, *Journal of Monetary Economics* **76**, 173–190.

Jeske, K., Krueger, D. and Mitman, K.: 2013, Housing, mortgage bailout guarantees and the macro economy, *Journal of Monetary Economics* **60**(8), 917–935.

Kaplan, G., Mitman, K. and Violante, G.: 2016, Non-durable consumption and housing net worth in the Great Recession: Evidence from easily accessible data.

Kaplan, G., Moll, B. and Violante, G. L.: 2018, Monetary policy according to HANK, *American Economic Review* **108**(3), 697–743.

Kaplan, G. and Violante, G. L.: 2014, A model of the consumption response to fiscal stimulus payments, *Econometrica* **82**(4), 1199–1239.

Kiley, M. T. and Roberts, J. M.: 2017, Monetary policy in a low interest rate world, *Brookings Papers on Economic Activity* .

Korinek, A. and Simsek, A.: 2016, Liquidity trap and excessive leverage, *The American Economic Review* **106**(3), 699–738.

Kung, E.: 2015, Mortgage market institutions and housing market outcomes.

Livshits, I., MacGee, J. and Tertilt, M.: 2007, Consumer bankruptcy: A fresh start, *American Economic Review* **97**(1), 402–418.

Mayer, C., Piskorski, T. and Tchistyi, A.: 2013, The inefficiency of refinancing: Why prepayment penalties are good for risky borrowers, *Journal of Financial Economics* **107**(3), 694–714.

Mian, A., Rao, K. and Sufi, A.: 2013, Household balance sheets, consumption, and the economic slump, *The Quarterly Journal of Economics* **128**(4), 1687–1726.

Misra, K. and Surico, P.: 2014, Consumption, income changes, and heterogeneity: Evidence from two fiscal stimulus programs, *American Economic Journal: Macroeconomics* **6**(4), 84–106.

Mitman, K.: 2016, Macroeconomic effects of bankruptcy and foreclosure policies, *American Economic Review* **106**(8), 2219–55.

Parker, J. A., Souleles, N. S., Johnson, D. S. and McClelland, R.: 2013, Consumer spending and the economic stimulus payments of 2008, *The American Economic Review* **103**(6), 2530–2553.

Pennington-Cross, A.: 2006, The value of foreclosed property, *Journal of Real Estate Research* **28**(2), 193–214.

Piskorski, T. and Seru, A.: 2018, Mortgage market design: Lessons from the Great Recession, *BPEA Conference Draft, Spring* .

Piskorski, T. and Tchistyi, A.: 2017, An equilibrium model of housing and mortgage markets with state-contingent lending contracts.

Reher, M.: 2017, Mortgage design with demand externalities.

Rouwenhorst, K. G.: 1995, Asset pricing implications of equilibrium business cycle models, *Frontiers of Business Cycle Research* .

Schmitt-Grohé, S. and Uribe, M.: 2016, Downward nominal wage rigidity, currency pegs, and involuntary unemployment, *Journal of Political Economy* **124**(5), 1466–1514.

Schmitt-Grohé, S. and Uribe, M.: 2017, Liquidity traps and jobless recoveries, *American Economic Journal: Macroeconomics* **9**(1), 165–204.

Storesletten, K., Telmer, C. I. and Yaron, A.: 2004, Consumption and risk sharing over the life cycle, *Journal of Monetary Economics* **51**(3), 609–633.

Willen, P.: 2014, Comments and discussion, *Brookings Papers on Economic Activity* pp. 119–136.

# Tables

Table 1: Benchmark Parametrization.

| Parameter | Value | Interpretation |
|---|---|---|
| Exogenous parameters | | |
| $\zeta_b$ | 0.025 | Cost of buying a house |
| $\zeta_s$ | 0.05 | Cost of selling a house |
| $\zeta_0$ | 0.4% | Mortgage origination cost |
| $\zeta_p$ | 0.035 | Prepayment penalty |
| $\zeta_m$ | 0.61% | Mortgage servicing cost |
| $\zeta_d$ | 0.22 | Foreclosure cost |
| $\xi$ | 0.0417 | Probability defaulter re-entries mortgage market |
| $\theta$ | 100% | Maximum LTV at mortgage origination |
| $\rho$ | 0.977 | Persistence earnings shocks (annual) |
| $\sigma_n$ | 0.129 | Standard deviation persistent shock (annual) |
| $\sigma_\varepsilon$ | 0.251 | Standard deviation transitory shock (annual) |
| $\underline{\delta}$ | 0 | Low realization housing depreciation |
| $\phi$ | 0 | Recourse parameter (benchmark case is non-recourse) |
| $A$ | 1 | Productivity level (median labor earnings = 1) |
| $\gamma$ | 1 | Downward nominal wage rigidity |
| $\bar{h}$ | 30 | Maximum house size |
| $\tau$ | 0.25 | Proportional tax on labor income |
| $T$ | 0.2 | Lump-sum transfer to households |
| Endogenous parameters | | |
| $\beta$ | 0.977 | Discount factor |
| $\sigma$ | 1.031 | CRRA parameter |
| $\epsilon$ | 0.544 | Intratemporal elasticity of substitution |
| $\eta$ | 0.525 | Housing share in consumption |
| $\underline{h}$ | 8.54 | Minimum house size |
| $\lambda$ | 0.994 | Mortgage amortization parameter |
| $\bar{\delta}$ | 0.190 | High realization of housing depreciation |
| $f_\delta(\bar{\delta})$ | 0.017 | Probability high depreciation shock |
| $p^s$ | 0.019 | Rental price |

Note: Section 4 and the Online Appendix discuss the details.

Table 2: Steady State Moments.

| Variable | Model | Target |
|---|---|---|
| **Targeted moments** | | |
| Risk-free rate (% annual) | 1 | 1 |
| Homeownership rate (%) | 66.1 | 68.4 |
| Ratio median net worth to annual average income | 0.559 | 0.567 |
| Ratio median housing wealth (for owners) to annual median income | 3.32 | 3.21 |
| Ratio average mortgage debt (for owners) to annual median income | 1.92 | 2.05 |
| Ratio median mortgage debt (for owners) to annual median income | 1.80 | 1.62 |
| Median DTV mortgagors (%) | 65.2 | 58.3 |
| % of mortgagors with DTV $\geq$ 70% | 28.8 | 33.7 |
| % of mortgagors with DTV $\geq$ 80% | 16.9 | 20.1 |
| % of mortgagors with DTV $\geq$ 90% | 5.84 | 8.94 |
| % of mortgagors with DTV $\geq$ 95% | 4.40 | 4.30 |
| Default rate (% annual) | 1.24 | 1.15 |
| Average depreciation rate (% annual) | 1.26 | 1.48 |
| **Non-Targeted moments** | | |
| Price-to-rent ratio (annual) | 13.1 | 11.3 |
| Ratio median house size for owners vs. renters | 2.46 | 1.85 |
| Ratio average income for owners vs. renters | 1.90 | 2.49 |
| Share of homeowners who do not move over a year (%) | 96.7 | 94.9 |
| Share of wealthy illiquid households ($a = 0$ and $h > 0$) (%) | 18.9 | 20.0 |

Note: Section 4 and the Online Appendix discuss the details. DTV is debt-to-value. Targeted moments are those moments used to parametrize the model. Non-targeted moments are moments not used in the parametrization.

Table 3: Marginal Propensity to Consume (MPC)

| | MPC out of income | | MPC out of house price | |
|---|---|---|---|---|
| Subgroup | All mortgagors | Illiquid households | All mortgagors | Illiquid households |
| DTV $\geq 80\%$ | 0.37 | 0.59 | 0.03 | 0.05 |
| DTV $\in [50\%, 80\%)$ | 0.20 | 0.41 | 0.29 | 0.46 |
| DTV $< 50\%$ | 0.18 | 0.14 | 0.21 | 0.15 |
| All households | 0.25 | | 0.21 | |

Note: The MPC out of income is the fraction consumed today out of an unexpected, purely transitory increase in liquid income (the model equivalent of \$500). The MPC out of house prices is the fraction consumed today out of an unexpected, permanent increase of 1% in house prices. DTV is 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. Section 4.3 and the Online Appendix discuss the details.

Table 4: Probability of Default (% Annual)

| | Non-Recourse | | Recourse | |
|---|---|---|---|---|
| Subgroup | All mortgagors | Illiquid households | All mortgagors | Illiquid households |
| DTV $\geq 80\%$ | 5.95 | 7.03 | 1.33 | 3.18 |
| DTV $\in [50\%, 80\%)$ | 0.37 | 0.38 | 0.00 | 0.00 |
| DTV $< 50\%$ | 0.00 | 0.00 | 0.00 | 0.00 |
| All mortgagors | 1.24 | | 0.39 | |

Note: Default rates are expressed in annual terms. DTV is debt-to-value. Illiquid households are those with no liquid asset holdings ($a = 0$). All calculations refer to the steady-state. Section 5 discusses the details.

Table 5: Steady State

| | Non-Recourse | Recourse |
|---|---|---|
| Garnishment fraction on disposable earnings ($\phi$) | 0 | 0.2 |
| Discount factor ($\beta$) | 0.977 | 0.975 |
| Stock of owner-occupier housing ($H$) | 8.15 | 8.61 |
| Risk-free rate (% annual) | 1 | 1 |
| House price ($p^H$) | 1 | 1 |
| Homeownership rate (%) | 66.1 | 70.4 |
| Ratio median net worth to annual average income | 0.559 | 0.512 |
| Ratio average mortgage debt (for owners) to annual median income | 1.92 | 2.14 |
| Median DTV mortgagors (%) | 65.2 | 69.1 |
| % of mortgagors with DTV $\geq$ 70% | 28.8 | 47.3 |
| % of mortgagors with DTV $\geq$ 80% | 16.9 | 29.7 |
| % of mortgagors with DTV $\geq$ 90% | 5.84 | 10.4 |
| % of mortgagors with DTV $\geq$ 95% | 4.40 | 7.40 |
| Default rate (% annual) | 1.24 | 0.39 |
| Ratio median house size for owners vs. renters | 2.46 | 2.74 |
| Ratio average income for owners vs. renters | 1.90 | 2.24 |
| Share of wealthy illiquid households ($a = 0$ and $h > 0$) (%) | 18.9 | 18.6 |

Note: Default rates are expressed in annual terms. DTV is debt-to-value. Illiquid households are those with no liquid asset holdings ($a = 0$). Section 6.1 discusses the details.

Table 6: Welfare Changes (CEV)

| | Non-Recourse | | Recourse | |
|---|---|---|---|---|
| Subgroup | Average | Std. Dev. | Average | Std. Dev. |
| DTV $\geq 80\%$ | -0.49 | 0.14 | -4.03 | 0.83 |
| DTV $\in [50\%, 80\%)$ | -0.64 | 0.37 | -3.81 | 0.73 |
| DTV $< 50\%$ | -0.42 | 0.15 | -3.07 | 0.31 |
| Renters | -0.29 | 0.35 | -2.72 | 0.37 |
| Defaulters | -0.43 | 0.14 | -3.34 | 0.57 |
| All households | -0.49 | 0.35 | -3.50 | 0.84 |

Note: The consumption equivalent variation (CEV) is the percentage change in non-housing consumption that makes the household suffering the LTV shock indifferent between that scenario and the steady state without the shock. The value is negative if the household has lower expected discounted sum of utilities when the shock hits. Subgroups are constructed based on the households' states just before the shock hits ($t = 1$). Averages are computed using the cross-sectional distribution at the steady state. Section 6.5 defines the CEV and the Online Appendix discusses the numerical implementation.

Table 7: Sensitivity to Recourse Parameter

| | Recourse parameter | | | | | |
|---|---|---|---|---|---|---|
| Variable | $\phi = 0$ | $\phi = 0.05$ | $\phi = 0.1$ | $\phi = 0.15$ | $\phi = 0.2$ | $\phi = 0.25$ |
| Change in consumption (%) | -2.71 | -5.93 | -7.48 | -8.49 | -11.1 | -17.0 |
| Recovery time (quarters) | 10 | 16 | 18 | 22 | 23 | 49 |
| Change in LTV limit (%) | -30.1 | -23.2 | -20.3 | -18.4 | -17.2 | -12.5 |
| Change in house prices (%) | -8.24 | -8.82 | -8.15 | -8.11 | -8.25 | -8.60 |
| Unemployment rate (%) | 10.8 | 14.9 | 15.9 | 18.5 | 17.9 | 26.2 |
| Default rate (% annual) | 2.37 | 1.99 | 1.54 | 1.51 | 1.32 | 1.46 |
| Change in originations (%) | -11.4 | -13.5 | -9.20 | -13.3 | -7.21 | -9.95 |
| Change in consumption due to: | | | | | | |
| Direct effect: LTV limit (%) | 7 | 12 | 12 | 12 | 10 | 6 |
| Indirect effect: House prices (%) | 49 | 30 | 22 | 23 | 20 | 19 |
| Indirect effect: Employment (%) | 40 | 56 | 63 | 61 | 66 | 73 |
| Other (%) | 4 | 2 | 3 | 4 | 4 | 2 |

Note: First quarter responses. The changes in consumption, house prices and mortgage origination volume are measured in percentage deviation from the corresponding steady state values. The recovery time is the number of quarters that it takes since the period of the shock until the variable is within 25 basis points from the pre-shock level. Default and unemployment rates are expressed in percentage levels. The decompositions for the changes in consumption are measured over the first year. Section 6.6 discusses the details.

# Figures

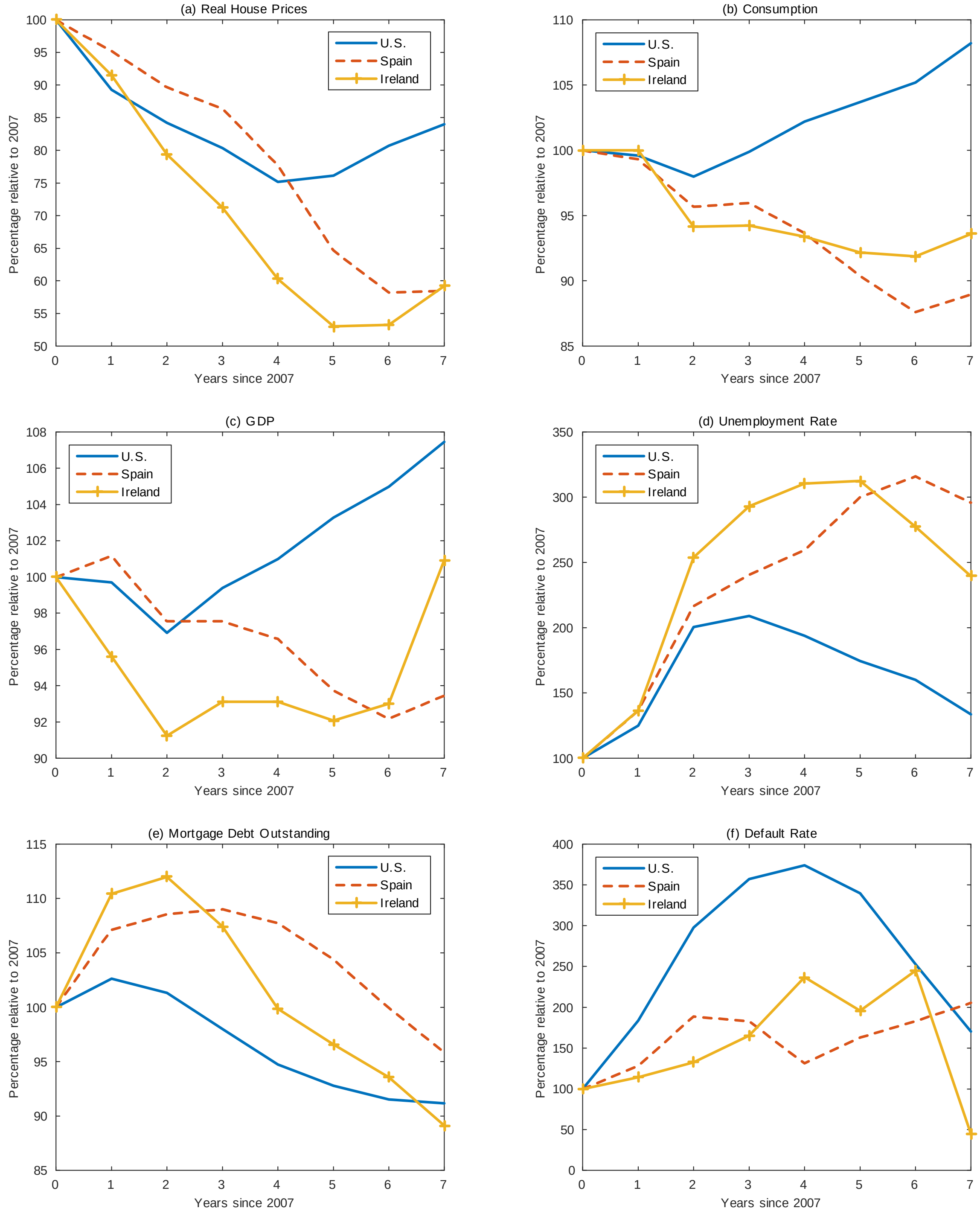



**Figure 1. Comparing Recoveries in Non-Recourse versus Recourse Countries.** The U.S. is in practice a non-recourse economy, while Ireland and Spain are recourse. Sources: see the Online Appendix.

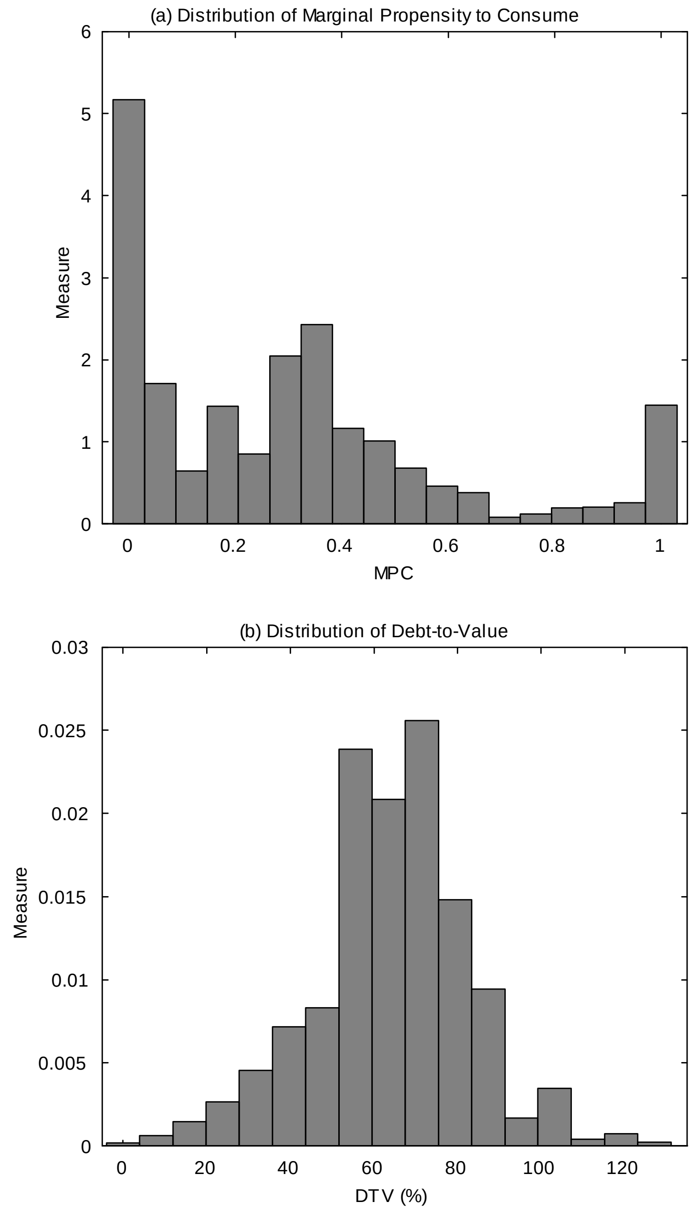
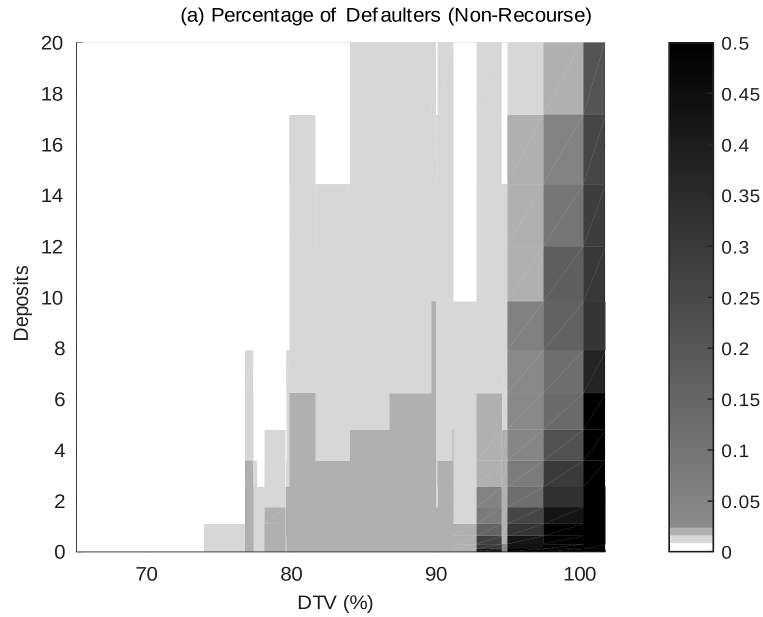



**Figure 2. Cross-sectional Distributions of Marginal Propensity to Consume (MPC) out of Liquid Wealth and Debt-to-Value (DTV) in the Non-Recourse Economy.** These panels plot the distributions in the steady state of the non-recourse model.



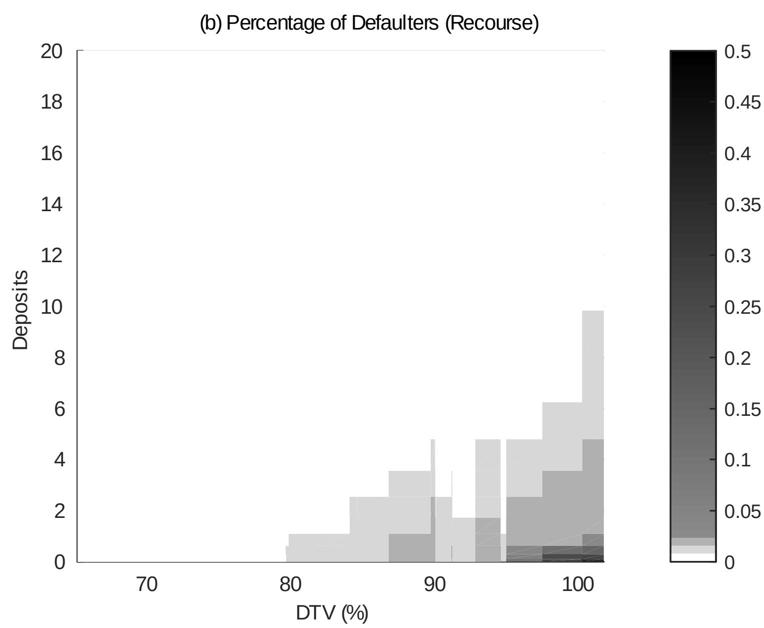




**Figure 3. Percentage of Homeowners Defaulting in Non-Recourse versus Recourse Economies.** The shades of the panels capture the percentage of households defaulting for a given debt-to-value (DTV) and deposits. Panel (a) is the non-recourse economy while panel (b) is the recourse economy.

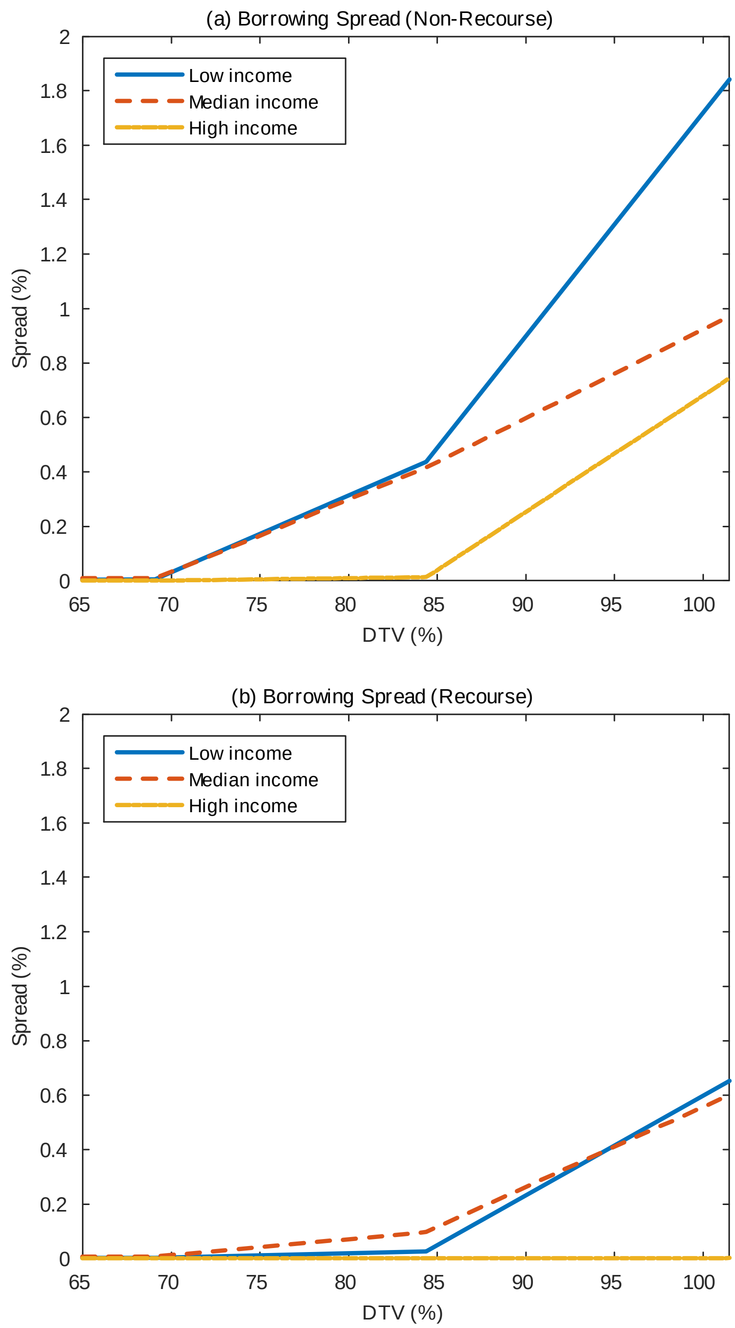



**Figure 4. Borrowing Spreads in Non-Recourse versus Recourse Economies.** This figure plots the spread between the mortgage rate that a borrower would face and the mortgage risk-free rate, as a function of the debt-to-value (DTV) of the borrower, and for three income levels. Panel (a) is the non-recourse economy while panel (b) is the recourse economy.

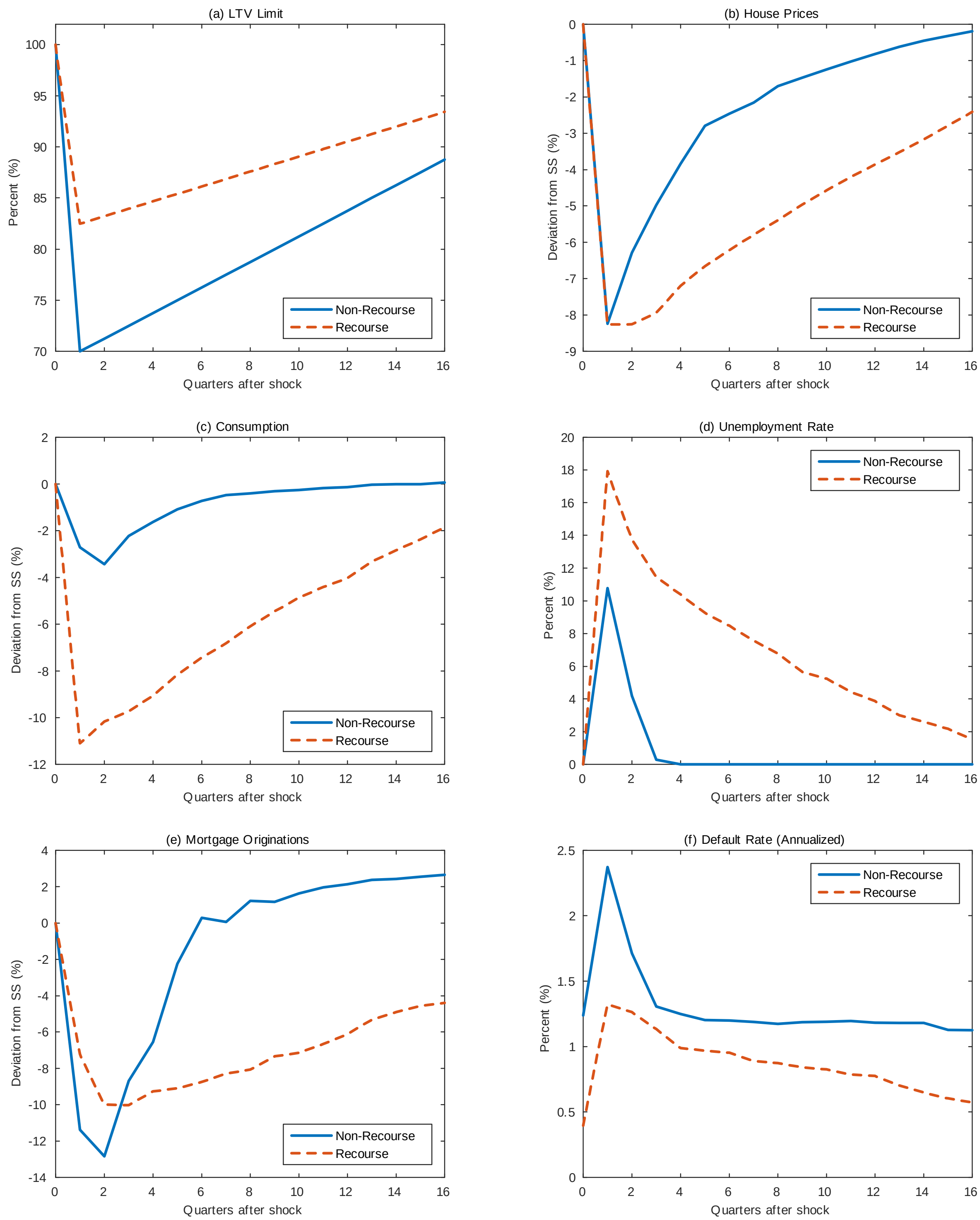



**Figure 5. Dynamics of Non-Recourse and Recourse Economies Following an Unexpected Loan-to-Value Shock.** The panels compare the response of the economies with and without mortgage recourse to a decrease in the LTV limit.

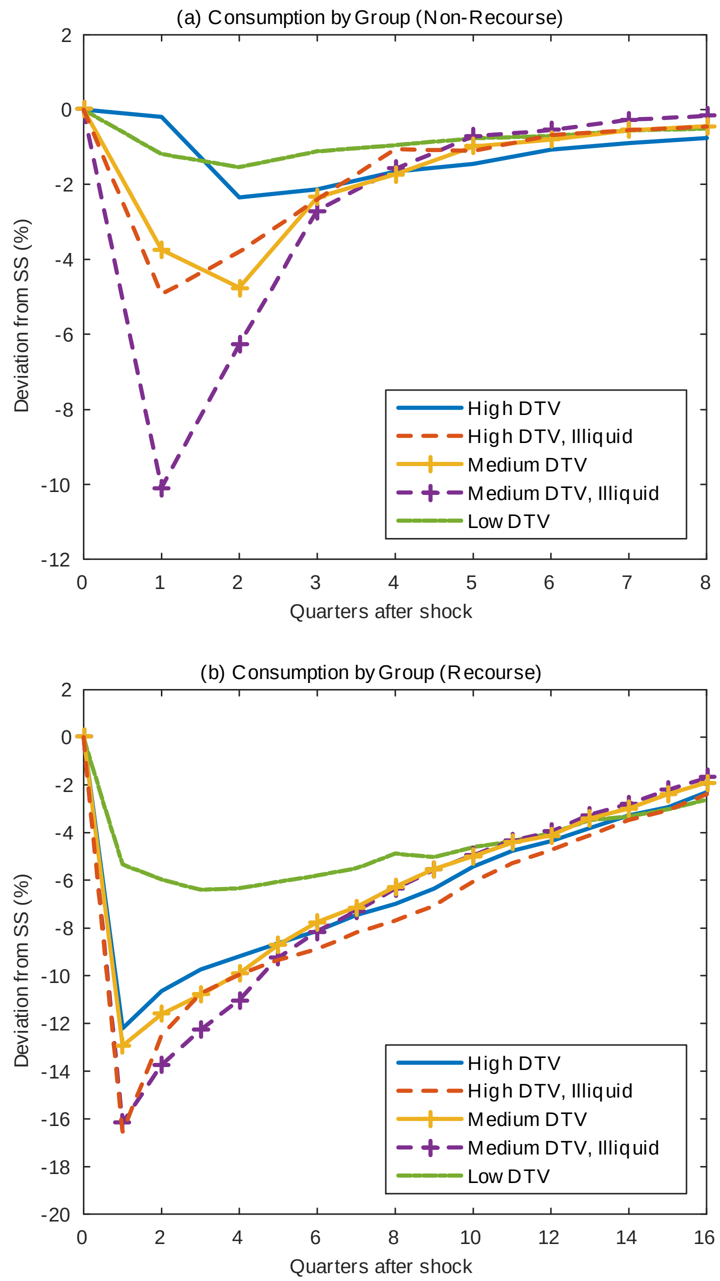



**Figure 6. Consumption Response by Initial DTV and Liquid Assets.** The panels plot the response of consumption to a change in the LTV limit parameter conditional on initial DTV and liquid assets. The labels are low DTV ($< 50\%$), medium DTV ($\in [50\%, 80\%)$) and high DTV ($\geq 80\%$). Illiquid households are those with no liquid asset holdings ($a = 0$). Section 6.3 discusses the details. Panel (a) is the non-recourse economy while panel (b) is the recourse economy.

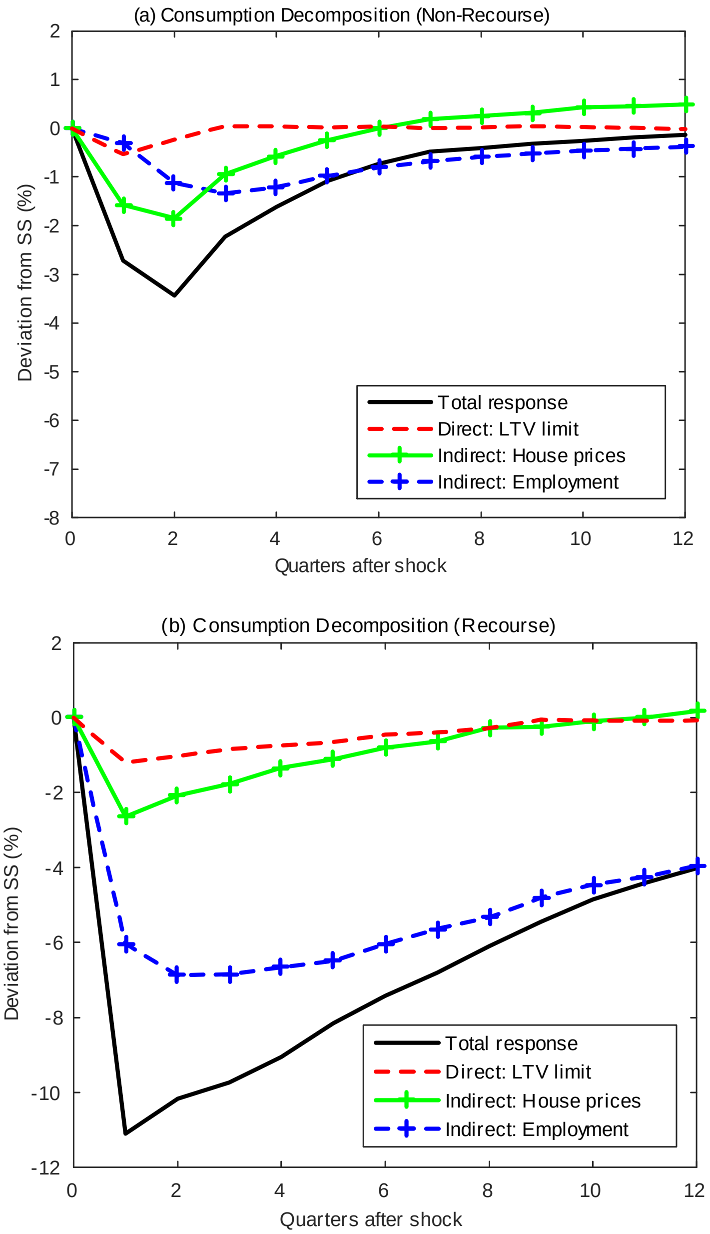



**Figure 7. Decomposing the Channels Driving Aggregate Consumption.** The panels plot the response of aggregate consumption to a change in the LTV limit parameter. In each panel there are four lines: i) the total response; ii) the response due to the LTV shock; iii) the response due to the change in housing prices triggered by the LTV shock; iv) the response due to the change in labor demand triggered by the LTV shock. Section 6.4 discusses the details. Panel (a) is the non-recourse economy while panel (b) is the recourse economy.

# A Online Appendix. NOT FOR PUBLICATION

## A.1 Data Sources of Figure 1

For real house prices, we use the OECD Analytical House Price database.

For consumption we use the OECD data retrieved from FRED: Gross Domestic Product by Expenditure in Constant Prices: Private Final Consumption Expenditure for Ireland (NAEXKP02IEA661S), Spain (NAEXKP02ESA661S), and U.S. (NAEXKP02USA661S).

For GDP we use the OECD data retrieved from FRED: Gross Domestic Product by Expenditure in Constant Prices: Total Gross Domestic Product for Ireland (NAEXKP01IEA661S), Spain (NAEXKP01ESA661S), and U.S. (NAEXKP01USA661S).

For the unemployment rate we use the OECD data retrieved from FRED: Unemployment Rate: Aged 15-64: All Persons for Ireland (LRUN64TTIEA156N), Spain (LRUN64TTESA156N), and U.S. (LRUN64TTUSA156N).

For the mortgage debt outstanding we use data from DATASTREAM: IR Mortgage Loans: Outstanding - Residential (IRMLTORMB), ES Mortgage Loans: Outstanding - Residential (ESMLTORMB), U.S. Mortgages - Households & Nonprofit Organizations (US15MGTLA).

For defaults in the U.S. we use foreclosure rate data from CoreLogic, Inc. We proxy defaults for Ireland and Spain using "arrears on mortgage or rent payments" from Eurostat. A closer concept in the U.S. is the serious delinquency rate, which we also obtained from CoreLogic, Inc. Using this data in Figure 1(f) instead of foreclosures gives similar results.

## A.2 Lenders' Balance Sheet

The balance sheet of the lenders is:

$$q_t^A B_{t+1}^b + T_t^b + \int \Big[ I_K\big(x - \frac{\zeta_m \lambda m}{1 + r_{t+1}^M}\big) + (I_F + I_S)(1+\zeta_p)m + I_D((1-\zeta_d)p_t^H(1-\delta)h + x)\Big] d\Psi_t^O$$
$$+ \int \big(x_D - \frac{\zeta_m m'_D}{1 + r_{t+1}^M}\big)\, d\Psi_t^D = B_t^b + (1+\zeta_0)(1+\zeta_m)\left(\int I_B q_t^0 m' \, d\Psi_t^R + \int I_F q_t^0 m' \, d\Psi_t^O\right), \quad \text{(A1)}$$

where $B_t^b$ are the deposits issued by the banks (with negative values denoting debt) and $x = x_D = m'_D = 0$ if mortgages are non-recourse. $T_t^b$ are transfers from the government. Any ex-post profits or losses experienced by lenders (induced by uninsurable aggregate shocks like the one we study in Section 6.2) are completely absorbed into the government budget through the transfer $T^b_t$. This assumption allows to overcome the pricing of deposits when there are ex-post profits and losses. Further, this assumption along with (A1) implies (31).

## A.3 Equilibrium

We define an equilibrium as follows:

**Definition.** Given a mortgage recourse system ($\phi$), an equilibrium is a sequence of house prices, mortgage price functions, and real interest rates $\{p^H_t, q^M_t(m', h', a', e), q^D_t(m', a', e), r_t\}^\infty_{t=0}$, labor employment $\{L_t\}^\infty_{t=0}$, government policy $\{\tau_t, T_t, T^b_t, G_t\}^\infty_{t=0}$, household decision rules, and distributions over households' states $\{\Psi^R_t(a, e), \Psi^O_t(h, m, a, e, \delta), \Psi^D_t(m, a, e)\}^\infty_{t=0}$, 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 time $t$:

1. The household decision rules are optimal.
2. The mortgage pricing functions satisfy (28), (29) if recourse; or (30) if non-recourse.
3. The lenders' credit condition (31) holds.
4. The government budget constraint (36) holds.
5. The distribution of households is consistent with the decision rules and the exogenous law of motion for the idiosyncratic labor and depreciation shocks.
6. All markets clear, except possibly for the labor market:
   (a) Housing market clears: $\int h' \, d\Psi_t = H$.
   (b) Labor market either clears or there is involuntary unemployment according to (34) and (35).
   (c) Deposit market clears: $\int a' \, d\Psi_t = B^b_{t+1}$.
   (d) Goods market clears: $\int c \, d\Psi_t + I^H_t + Z^\zeta_t + G_t = Y_t$, where $I^H_t$ is the investment to cover both the housing net depreciation and the foreclosure costs:

$$I^H_t = \int (I_K + I_F + I_S) p^H_t \delta h \, d\Psi^O_t + \int I_D p^H_t (1 - (1 - \zeta_d)(1 - \delta)) h \, d\Psi^O_t,$$

and $Z_t^\zeta$ is aggregate spending on housing transaction and mortgage costs:

$$Z_t^\zeta = \zeta_b \int I_B p_t^H h' \, d\Psi_t^R + \zeta_s \int I_S p_t^H h \, d\Psi_t^O + \zeta_m \left( \int I_K \frac{\lambda m}{1 + r_{t+1}^M} \, d\Psi_t^O + \int \frac{m'}{1 + r_{t+1}^M} \, d\Psi_t^D \right)$$
$$+ ((1 + \zeta_0)(1 + \zeta_m) - 1) \left( \int I_B q_t^0 m' \, d\Psi_t^R + \int I_F q_t^0 m' \, d\Psi_t^O \right).$$

## A.4 Consumption-Shelter Decision

We simplify the renter maximization problems (9), (18), (20), and (24) by first solving analytically the static problem of how to allocate resources between non-housing consumption ($c$) and shelter ($s$). Denote by $g$ the resources available for total consumption, that is

$$g = \begin{cases} y_t(e) + a - q_t^A a' & \text{if renter that keeps renting,} \\ y_t(e) + a + (1 - \zeta_s) p_t^H h - p_t^H \delta h - (1 + \zeta_p) m - q_t^A a' & \text{if owner that sells,} \\ y_t(e) + a - x - q_t^A a' & \text{if defaulter,} \end{cases}$$

where $x = 0$ if mortgages are non-recourse.

The problem of allocating $g$ resources between consumption $c$ and shelter $s$ is

$$U(g) = \max_{c,s \geq 0} \frac{\left[ (1 - \eta) c^{\frac{\epsilon - 1}{\epsilon}} + \eta s^{\frac{\epsilon - 1}{\epsilon}} \right]^{\frac{\epsilon(1 - \sigma)}{\epsilon - 1}}}{1 - \sigma} \quad \text{s.t.}$$
$$c + p^S s = g.$$

The closed-form solution to the maximization problem is $c(g) = g - p^S s$, and

$$s(g) = \frac{\eta^\epsilon (p^S)^{1-\epsilon}}{(1 - \eta)^\epsilon + \eta^\epsilon (p^S)^{1-\epsilon}} \frac{g}{p^S}.$$

The associated indirect utility is

$$U(g) = \frac{\left[ (1 - \eta)^\epsilon + \eta^\epsilon (p^S)^{1-\epsilon} \right]^{\frac{1-\sigma}{\epsilon - 1}} g^{1-\sigma}}{1 - \sigma}.$$

## A.5 Labor Income Process

As explained in Section 4.1, we specify a labor income process as in Storesletten, Telmer and Yaron (2004), but without life cycle effects or permanent shocks at birth. The parameters estimated by them (persistence, variance of persistent and transitory shocks) are annual. We transform them into quarterly values using a similar method as in Garriga and Hedlund (2017).

For the persistent shocks, we assume that households draw a new shock every one year in expectation. Specifically, we assume that in each quarter a household keeps her current persistent shock with probability 0.75, and that with probability 0.25 the household draws a new shock (in which case the household might receive the same persistent income shock) from a transition matrix calibrated to the process of the persistent component in Storesletten, Telmer and Yaron (2004). They estimate an annual persistence coefficient of 0.977 and a variance of persistence shocks of 0.0166. We discretize this AR(1) process using the method of Rouwenhorst (1995) into a 5-point Markov chain. Denote by $\pi$ the obtained transition probability matrix. Therefore, the quarterly transition matrix for the persistent shock is:

$$\pi_z = 0.75 I_5 + 0.25\pi = \begin{bmatrix} 0.9887 & 0.0111 & 0.0002 & 0.0000 & 0.0000 \\ 0.0028 & 0.9888 & 0.0083 & 0.0001 & 0.0000 \\ 0.0000 & 0.0056 & 0.9888 & 0.0056 & 0.0000 \\ 0.0000 & 0.0001 & 0.0083 & 0.9888 & 0.0028 \\ 0.0000 & 0.0000 & 0.0002 & 0.0111 & 0.9887 \end{bmatrix},$$

where $I_5$ is the identity matrix.

For the transitory shocks, we assume that the annual transitory shock is the sum of four independent quarterly transitory shocks. Also, we assume that all households receive the same initial persistent shock. Therefore, all the dispersion in initial labor income is due to different realizations of the transitory shock. Let the log labor productivity be $\ln e = z + \varepsilon$, where $z$ and $\varepsilon$ are the persistent and transitory components. Note that in steady-state the labor productivity multiplied by the real wage becomes labor income. Labor productivity over one year such that $z$ stays constant is:

$$\ln e_{\text{year}} = \ln\left(\sum_{i=1}^{4} e_i\right) = \ln\left(\sum_{i=1}^{4} \exp(z + \varepsilon_i)\right) = z + \ln\left(\sum_{i=1}^{4} \exp(\varepsilon_i)\right).$$

Then, we solve for the variance of $\varepsilon_i$ that gives a variance for $\ln e_{\text{year}}$ equal to 0.0630, which is the value reported by Storesletten, Telmer and Yaron (2004). We simulate the annual labor productivity for 10,000 households, drawing four quarterly shocks, adding them and taking logs. We search over the variance using an optimization routine. The solution is a variance for quarterly transitory shocks of 0.2331. Then, we discretize the quarterly transitory shock into a 3-point Markov chain using the method of Rouwenhorst (1995).

## A.6 Stationary Equilibrium

Define the expected value functions, which are functions of the current holdings of housing ($h$), mortgage ($m$), deposits ($a$), and the previous realization of labor productivity ($e_-$), as

$$\begin{aligned} EV_t^R(a, e_-) &= \sum_e f(e|e_-)V_t^R(a, e), \\ EV_t^O(h, m, a, e_-) &= \sum_e \sum_\delta f(e|e_-)f(\delta)V_t^O(h, m, a, e, \delta), \\ EV_t^D(m, a, e_-) &= \sum_e f(e|e_-)\left[\xi V_t^R(a, e) + (1-\xi)V_t^D(m, a, e)\right], \end{aligned}$$

where the expectations are taken over the current period shocks ($e$ and $\delta$).

The value functions, mortgage pricing functions, and decision rules are solved over a predetermined fixed grid on house size ($h$), mortgage debt ($m$), deposit holdings ($a$), labor productivity ($e$), and depreciation shock ($\delta$). When solving the decision rules for $m'$ and $a'$, we allow for choices that are off grids and use linear interpolation for evaluation of the value and mortgage pricing functions. Following Hatchondo, Martinez and Sapriza (2010), we update the value and mortgage pricing functions jointly rather than using nested loops. Moreover, the stochastic penalty $\xi$ ensures convergence of the value and pricing function iteration solution method. We focus on full employment stationary equilibria, that is $L_t = \bar{L}$ for all $t$. Below we outline the algorithm to solve the model numerically:

1. Guess prices $(p^H, r)$, the expected value functions $EV^R$, $EV^O$, $EV^D$, mortgage price functions $q^M$ and $q^D$, and distributions $\Psi^R$, $\Psi^O$, and $\Psi^D$. We approximate the distributions with discrete density functions (histograms) over the corresponding state spaces, that is $(a, e)$ for renters ($R$), $(h, m, a, e, \delta)$ for homeowners ($O$), and $(m, a, e)$ for defaulters ($D$).

2. Solve the household problems (6), (9), (12), (15), (18), (20), and (24) using the guessed expected value functions $EV^R$, $EV^O$, and $EV^D$ on the right-hand-side of the Bellman equation, and the guessed mortgage price functions $q^M$ and $q^D$. For values of $m'$ (either as explicit choice as in (6) or indirectly generated as in (20)), approximate the value and mortgage pricing functions using linear interpolation. The solution gives value functions $V^R_{\text{new}}$, $V^O_{\text{new}}$, $V^D_{\text{new}}$, and policies $P^R_{\text{new}}$, $P^O_{\text{new}}$, and $P^D_{\text{new}}$.[24] Compute $EV^R_{\text{new}}$, $EV^O_{\text{new}}$, and $EV^D_{\text{new}}$.

[24]For households that enter the period as renters ($R$), the policy set $P^R_{\text{new}}$ is a set of the corresponding choice rules; namely, the discrete choices $I_B$ and $I_R$; non-housing consumption $c_B$, house $h'_B$, mortgage $m'_B$, and deposits $a'_B$ for home-buyers, and non-housing consumption $c_R$, shelter $s_R$, and deposits $a'_R$ for renters that keep renting. Similar definitions hold for households starting the period as homeowners ($O$) and defaulters ($D$).

3. Compute the implied mortgage price functions $\tilde{q}^M$ and $\tilde{q}^D$ from (28), (29), and (30), using the obtained policy functions $P^O_{\text{new}}$ and $P^D_{\text{new}}$. Update the pricing functions using a relaxation parameter $\mu$: $q^M_{\text{new}} = \mu\tilde{q}^M + (1-\mu)q^M$ and $q^D_{\text{new}} = \mu\tilde{q}^D + (1-\mu)q^D$.

4. Check whether the new values $EV^R_{\text{new}}$, $EV^O_{\text{new}}$, $EV^D_{\text{new}}$, and pricing mortgage functions $q^M_{\text{new}}$, $q^D_{\text{new}}$ are sufficiently close to their respective guesses under the sup-norm metric and a predetermined tolerance. If not, set (update) the guesses to the new values and repeat steps 2-3.

5. Iterate forward the distributions $\Psi^R$, $\Psi^O$, and $\Psi^D$ one time to obtain $\Psi^R_{\text{new}}$, $\Psi^O_{\text{new}}$, and $\Psi^D_{\text{new}}$ using the converged policy functions $P^R_{\text{new}}$, $P^O_{\text{new}}$, and $P^D_{\text{new}}$. We use a non-stochastic simulation method. The transition for the household status, that is renter $(R)$, owner $(O)$ and defaulter $(D)$ is governed by the discrete choices. The transitions for $h'$, $m'$ and $a'$ are given by the policy functions. Whenever the choices for $m'$ and $a'$ are off grids, the transition is approximated by assigning mass to the adjacent grid points proportionally in a way that preserves total mortgage holdings and deposits. See Young (2010) for a description of non-stochastic simulation in this manner. Transitions for labor efficiency and depreciation shocks follow the exogenous probability transition matrices.

6. Check whether the iterated distributions $\Psi^R_{\text{new}}$, $\Psi^O_{\text{new}}$, and $\Psi^D_{\text{new}}$ are sufficiently close to their respective guesses. If not, set the guesses equal to the iterated distributions and repeat until the distributions converge under the sup-norm metric and a predetermined tolerance.

7. Compute the excess housing and credit demand using the converged distributions $\Psi^R_{\text{new}}$, $\Psi^O_{\text{new}}$, $\Psi^D_{\text{new}}$, and decision rules $P^R_{\text{new}}$, $P^O_{\text{new}}$, $P^D_{\text{new}}$. Check if excess demand in housing and credit markets is close to zero within tolerance. If not, adjust prices $(p^H, r)$ and repeat 1-7 until markets clear.

The value functions, pricing functions, and decision rules are solved on a grid. The number of grid points for $h$ is 10, for $m$ is 24, for $a$ is 24, for $e$ is 15, and for $\delta$ is 2. When solving the decision rules for $m'$ and $a'$ we allow for choices that are off the grid. Specifically, we search over 48 points for $m'$ and 48 points for $a'$. These choices imply $15 \times 24 = 360$ states for renters $(R)$, $15 \times 2 \times 10 \times 24 \times 24 = 172,800$ states for owners $(O)$, $15 \times 24 = 360$ states for defaulters $(D)$ (in the case of recourse there are $15 \times 24 \times 24 = 8,640$ states).

For $h$ we use an equally spaced grid from $\underline{h}$ (a parameter obtained from SMM) to $\bar{h}$ which is set to 30 times the annual median labor income in the benchmark parametrization. For $m$, $a$, $m'$, $a'$, we construct polynomial spaced grids with points concentrated at the lower bound by taking an equally spaced grid, $z$ from $[0,1]$, then constructing the grid for $m$ as $\underline{m}+(\bar{m}-\underline{m})z^{1/k}$ and similarly for the other variables. We use $k=0.4$.

To ensure continuity of the excess demand functions with respect to prices, we introduce a small level of randomness in the discrete choices made by households. This is done by adding a random shock to the value of each choice, where each shock is drawn independently from a Type I Extreme Value distribution with scale parameter $\nu$. For instance, the default decision of an owner $I_D$ (now being a probability rather than a binary choice) becomes

$$I_D(h,m,a,e,\delta)=\frac{\exp\left(J^D(\cdot)/\nu\right)}{\exp\left(J^K(\cdot)/\nu\right)+\exp\left(J^F(\cdot)/\nu\right)+\exp\left(J^S(\cdot)/\nu\right)+\exp\left(J^D(\cdot)/\nu\right)}.$$

Moreover, the value of a household entering the period as an owner becomes

$$V^D(h,m,a,e,\delta)=\nu\ln\left[\exp\left(J^K(\cdot)/\nu\right)+\exp\left(J^F(\cdot)/\nu\right)+\exp\left(J^S(\cdot)/\nu\right)+\exp\left(J^D(\cdot)/\nu\right)\right].$$

In practice, we apply the appropriate transformations to prevent overflow due to exponentiation. Similar formulas apply for the choice between buying a house or keep renting for a household that enters the period as renter (with no default flag).

The distance between the guessed and new value and mortgage pricing functions is solved to $10^{-5}$ under the sup-norm metric. For distributions, the distance is solved to $10^{-8}$ under the same metric.

It should be clear that once the stationary equilibrium prices $(p^H, r)$ are found according to the procedure above, transfers to lenders $T^b$ and government spending $G$ are determined from (A1) and (36).

## A.7 Parametrization Using SMM

As discussed in Section 4.2, the parameters to be set are the discount factor $\beta$, the inverse of the coefficient of intertemporal substitution $\sigma$, the intratemporal elasticity of substitution $\epsilon$, the share of housing in consumption $\eta$, the minimum house size $\underline{h}$, the mortgage amortization parameter $\lambda$, the high realization of the depreciation shock $\bar{\delta}$, its probability $f_\delta(\bar{\delta})$, and the rental price $p^S$. After solving a stationary equilibrium, we compute the following moments: the homeownership rate, median net worth (relative to mean income), median housing wealth for owners (relative to median income), mean mortgage debt for owners (relative to median income), median DTV, the share of mortgagors with DTV larger than 70%, 80%, 90% and 95%, the annual foreclosure rate, the average house depreciation rate (annualized), and the annual risk-free rate. Then, we construct the following metric between model and targets:

$$\Theta = \sum_{i=1}^{9} \left( \frac{M_i^{\text{model}} - M_i^{\text{target}}}{M_i^{\text{target}}} \right)^2 .$$

That is, we minimize the squared percentage deviation from these moments and their model counterparts using equal weights. We search over the parameters to minimize $\Theta$ using a combination of global and local optimization routines.

There are nine parameters which are solved jointly to match thirteen data targets. Table 2 reports the empirical targets with the model-generated moments. Table 1 shows the resulting parameters.

## A.8 Transitional Dynamics

We solve for the perfect foresight transition path (that is, households became aware and perfectly anticipate this path after entering period $t = 1$) induced by the exogenous LTV limit shock (38). We assume that the transition path from the initial steady state and returning back takes $T$ quarters. The assumption that the shock in $t = 1$ is unanticipated implies that we know the distributions $\Psi_1^R$, $\Psi_1^O$, and $\Psi_1^D$ as they are equal to the ones in the steady state ($t = 0$). We also know the ending expected values $EV_{T+1}^R$, $EV_{T+1}^O$, $EV_{T+1}^D$, and pricing functions $q_{T+1}^M$, $q_{T+1}^D$.

To focus on a liquidity trap episode, we assume that nominal wages bind during the transition phase, that is $W_t = W_0$ for all $t \geq 1$. This assumption coupled with linear production technology implies that the price level is constant. Also, we assume that the nominal interest rate binds at the zero-lower bound, implying that the real interest rate stays constant at the stationary equilibrium level, that is $r_t = r_0$ for all $t \geq 1$. Thus, the economic adjustment to the shock is done through changes in house prices $p_t^H$ and labor employment $L_t$.

During the transition path, taxes $\tau_t$ and transfers to households $T_t$ are held constant, while transfers to lenders $T_t^b$ and government spending $G_t$ are endogenous and determined residually from (A1) and (36). We outline the shooting algorithm below:

1. Guess the approximate length of the transition path, $T$. Guess a sequence $\{p_t^H, L_t\}_{t=1}^T$.

2. Use the decision rules and pricing functions for $t = T+1$ to compute the pricing functions $q_T^M$ and $q_T^D$ from (28) and (29) if mortgages are recourse, or from (30) otherwise. With $q_T^M$ and $q_T^D$, compute the expected values $EV_T^R$, $EV_T^O$, $EV_T^D$, and decisions $P_T^R$, $P_T^O$, $P_T^D$ by

solving (6), (9), (12), (15), (18), (20), and (24). Proceed backwards in this way, computing the remaining sequence of expected values and policies going from $t = T - 1$ to $t = 1$.

3. Find the pair $(\tilde{p}_1^H, \tilde{L}_1)$ that clears the housing and credit markets at $t = 1$ given the expected values and pricing functions $EV_2^R$, $EV_2^O$, $EV_2^D$, $q_1^M$, $q_1^D$ found in Step 2 and the distributions $\Psi_1^R$, $\Psi_1^O$, $\Psi_1^D$. Then, compute the implied distributions $\Psi_2^R$, $\Psi_2^O$, $\Psi_2^D$. Iterate forward in this way to compute a sequence of updated aggregates $\{\tilde{p}_t^H, \tilde{L}_t\}_{t=1}^T$.

4. Check whether the updated aggregates $\{\tilde{p}_t^H, \tilde{L}_t\}_{t=1}^T$ are close to the guessed ones $\{p_t^H, L_t\}_{t=1}^T$ under the sup-norm. If not, update the initial guess using a relaxation parameter $\mu$: $\mu\tilde{p}_t^H + (1-\mu)p_t^H$ and $\mu\tilde{L}_t + (1-\mu)L_t$ for all $t$ and go back to Step 1.

The distance between the guessed and new sequence of house prices and employment levels is solved to $10^{-5}$ under the sup-norm metric. At any point, we impose that $L_t \leq \bar{L}$ holds. When iterating forward to obtain the implied distributions in Step 3, we use the same non-stochastic simulation method as described in A.6.

## A.9 Survey of Consumer Finances Data

All targets in Table 2 are calculated using the Survey of Consumer Finances (SCF) except for the risk-free rate, foreclosure rate, average depreciation rate, price-to-rent ratio, share of homeowners that do not move, and share of wealthy illiquid households. We choose the SCF 2004 since this is the last year the survey was conducted prior to the Great Recession. Since households are infinitely-lived in our model, we restrict the sample to prime age households (head age between 25 and 60) to control for strong life-cycle effects.

We define net worth of a household in the model (in terms of the state variables) as house value minus outstanding mortgage balance plus liquid asset holdings, i.e. $p^H h - m + a$. We take the total value of primary residence of household and the total value of mortgages and home equity loans secured by the primary residence in the SCF as the empirical counterparts for the house value $p^H h$ and mortgage balance $m$ in the model. Following Kaplan and Violante (2014), we proxy liquid assets $a$ in the model as the sum of the total value in checking, savings, money market, and call accounts; plus directly held pooled investment funds, bonds, stocks, and T-bills. The SCF does not record cash holdings. In the SCF 2004 the median wealth in checking, savings, money market, and call accounts is \$2,800 (2004 dollars). We impute cash holdings by increasing proportionately all individual household holdings of the assets above by the factor $1+(69\times 2)/2,800 = 1.049$ (for details, see Kaplan and Violante 2014 Appendix B.1).

DTV is computed in the SCF as the ratio of mortgage balance over the house value. We take the total annual household income in the SCF as counterpart for total household income before taxes and transfers in the model, which in steady state is $\frac{W}{P}e + (1 - q^A)a$. Since the model is at quarterly frequency, to compute the model moments involving annual average and median income reported in Table 2 we simply multiply the average and median income by 4.

## A.10 Computation of MPCs in the Model

Consider a steady state environment and drop the time subscript $t$. For a household entering the period as a homeowner ($O$), define the value function in terms of current disposable income (5), $y = y(e)$, rather than in terms of the labor endowment shock $e$, and we make explicit the dependency on house prices $p^H$, that is $V^O(h, m, a, y, \delta; p^H)$, and denote by $c(h, m, a, y, \delta; p^H)$ the associated optimal current consumption. Since we consider a stationary environment, the house price argument means that both current and future house prices equal $p^H$.

The MPC out of an unexpected, transitory increase of $k$ units in income is

$$\text{MPC}_y(h, m, a, y, \delta; p^H) = \frac{c(h, m, a, y + k, \delta; p^H) - c(h, m, a, y, \delta; p^H)}{k}$$

that is, the fraction consumed out of $k$ additional units of liquid wealth. The papers cited in Section 4.3 report that households spend roughly 25% of fiscal stimulus payments (a transfer around \$500 on average) on non-durables in the quarter that they receive them. To make the model quarterly MPCs comparable to the empirical evidence, we take the model counterpart of a \$500 transfer which is approximately $k = 0.1$. Note that by leaving the future income process unchanged, this purely transitory increase does not alter the next period value functions.

The MPC out of an unexpected, permanent increase of $k$ in house prices is

$$\text{MPC}_{p^H}(h, m, a, y, \delta; p^H) = \frac{c(h, m, a, y, \delta; p^H + k) - c(h, m, a, y, \delta; p^H)}{k}.$$

To make results comparable with the empirical evidence, we take $k = 0.01$ which corresponds to a 1% increase in the steady state house price level $p^H = 1$. Note that this permanent change in house prices alters the next period value functions.

The elasticity of current consumption to house prices is computed as

$$\text{MPC}_{p^H}(h, m, a, y, \delta; p^H) \cdot \frac{p^H}{c(h, m, a, y, \delta; p^H)}.$$

A similar procedure gives the MPCs for renters ($R$) and defaulters ($D$). To compute the moments reported in Table 3 we aggregate across households using the equilibrium steady state distribution of the benchmark economy with no-recourse.

## A.11 Computation of Welfare Changes (CEV)

In Section A.6 we introduced random shocks to the value of each discrete choice available (i.e. "taste shocks") as a function of the status of the household (renter, homeowner, defaulter). Denote by $z$ the state variable in the period the LTV limit shock hits. That is, $z = (a, e)$ if the household enters the period as a renter, $z = (h, m, a, e, \delta)$ if she enters as homeowner, and $z = (m, a, e)$ if she enters as a defaulter. When we introduce the taste shocks, the consumption equivalent variation (CEV), $\omega(z)$, for a household with state variable $z$ is defined as:

$$\mathbb{E}\left[\sum_{t=1}^{\infty} \beta^{t-1}\left(u\left([1+\omega(z)]c_t, s_t\right) + \varepsilon_t(z)\right) \,\middle|\, z\right] = \mathbb{E}\left[\sum_{t=1}^{\infty} \beta^{t-1}\left(u\left(\tilde{c}_t, \tilde{s}_t\right) + \tilde{\varepsilon}_t(z)\right) \,\middle|\, z\right], \tag{A2}$$

where $\{c_t, s_t\}_{t=1}^{\infty}$ and $\{\tilde{c}_t, \tilde{s}_t\}_{t=1}^{\infty}$ are the consumption paths generated by the policy functions at the steady state and after the LTV shock hits respectively, conditional on the household having initial state $z$. Likewise, $\{\varepsilon_t\}_{t=1}^{\infty}$ and $\{\tilde{\varepsilon}_t\}_{t=1}^{\infty}$ are the realizations of the taste shocks.

By definition, the left-hand side of (A2) is $V(z) = V^R(z)$ if the household enters the period as renter, $V(z) = V^O(z)$ if she enters as an owner, and so on. Similarly, the right-hand side is $\tilde{V}_1(z) = \tilde{V}^R(z)$ if the households enters the period as renter when the shock hits at $t = 1$, etc. The expected discounted sum of taste shocks in steady state can be rewritten as

$$\mathbb{E}\left[\sum_{t=1}^{\infty} \beta^{t-1}\varepsilon_t(z) \,\middle|\, z\right] = V(z) - \mathbb{E}\left[\sum_{t=1}^{\infty} \beta^{t-1}\, u\left(c_t, s_t\right) \,\middle|\, z\right].$$

Therefore, by rewriting (A2), the CEV, $\omega(z)$, can be obtained as the solution to

$$\mathbb{E}\left[\sum_{t=1}^{\infty} \beta^{t-1}\, u\left([1+\omega(z)]c_t, s_t\right) \,\middle|\, z\right] = \tilde{V}_1(z) - V(z) + \mathbb{E}\left[\sum_{t=1}^{\infty} \beta^{t-1}\, u\left(c_t, s_t\right) \,\middle|\, z\right]. \tag{A3}$$

The advantage of this procedure is that avoids the direct computation of the expected discounted sum of taste shocks (which in turn depends on the realization of the discrete choices), since in the solution method to the household problem (see Section A.6) we compute the probability over choices rather than the realization of these shocks.

Given a state $z$, solving for CEV involves computing the expectations in (A3) (the values

$V(z)$ and $\tilde{V}_1(z)$ are computed as described in Sections A.6 and A.8). We do this using Monte Carlo simulation. We take $10,000$ households with initial state $z$. First, we start with a guess for $\omega$. Second, we simulate each household forward for 50 periods (quarters) and compute the discounted sum of utility values. Third, we approximate the expectations in (A3) by computing the cross-sectional average of the discounted sum of utilities. Fourth, we adjust $\omega$ and repeat until (A3) is satisfied. Equipped with the CEVs $\omega(z)$ for all $z$, we compute the average and standard deviations reported in Table 6 using the stationary distributions conditional on the households with initial state $z$ in the subgroup of interest (DTV$\geq$ 80%, DTV$<$ 50%, etc.).

# References


Garriga, C., and A. Hedlund. 2017. Mortgage debt, consumption, and illiquid housing markets in the great recession. Working paper.

Hatchondo, J. C., L. Martinez, and H. Sapriza. 2010. Quantitative properties of sovereign default models: Solution methods matter. *Review of Economic Dynamics* 13(4):919–933.

Kaplan, G., and G. L. Violante. 2014. A model of the consumption response to fiscal stimulus payments. *Econometrica* 82(4):1199–1239.

Rouwenhorst, K. G. 1995. Asset pricing implications of equilibrium business cycle models. In *Frontiers of business cycle research*. In T. F. Cooley. Princeton, NJ: Princeton UP.

Storesletten, K., C. I. Telmer, and A. Yaron. 2004. Consumption and risk sharing over the life cycle. *Journal of Monetary Economics* 51:609–33.

Young, E. R. 2010. Solving the incomplete markets model with aggregate uncertainty using the Krusell-Smith algorithm and non-stochastic simulations. *Journal of Economic Dynamics and Control* 34(1):36–41.