Mortgage Borrowing Caps: Leverage, Default and Welfare

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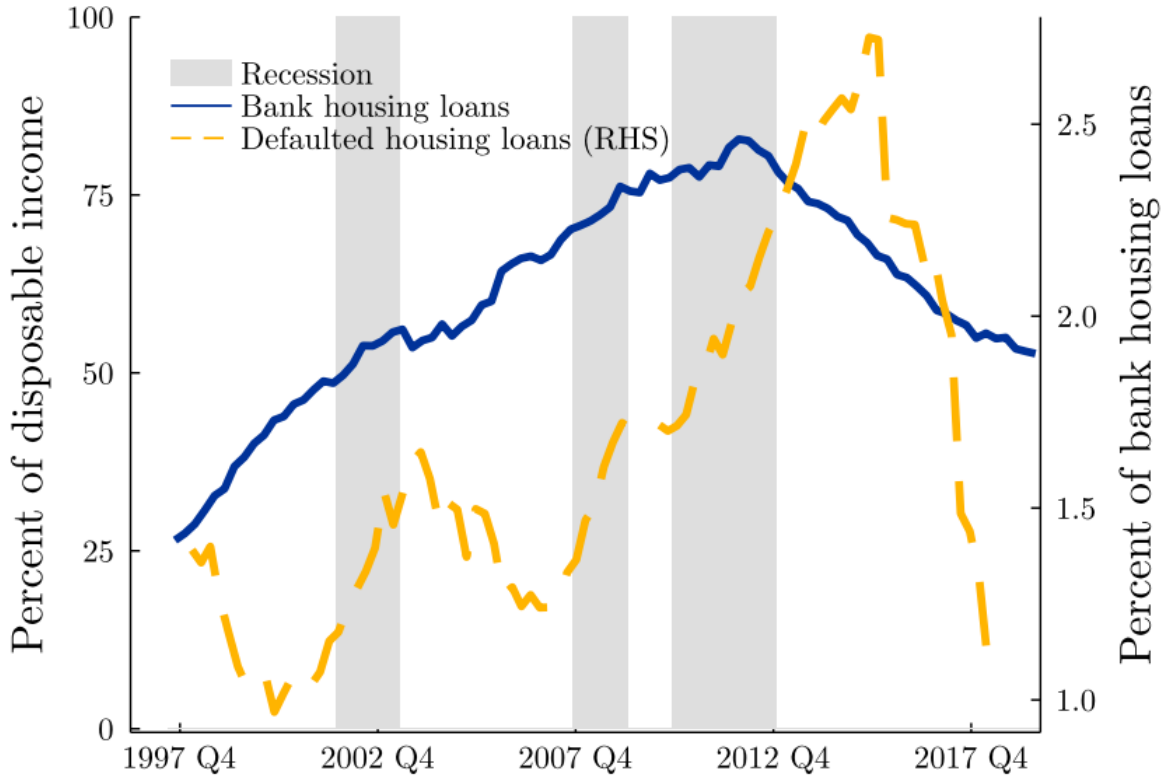
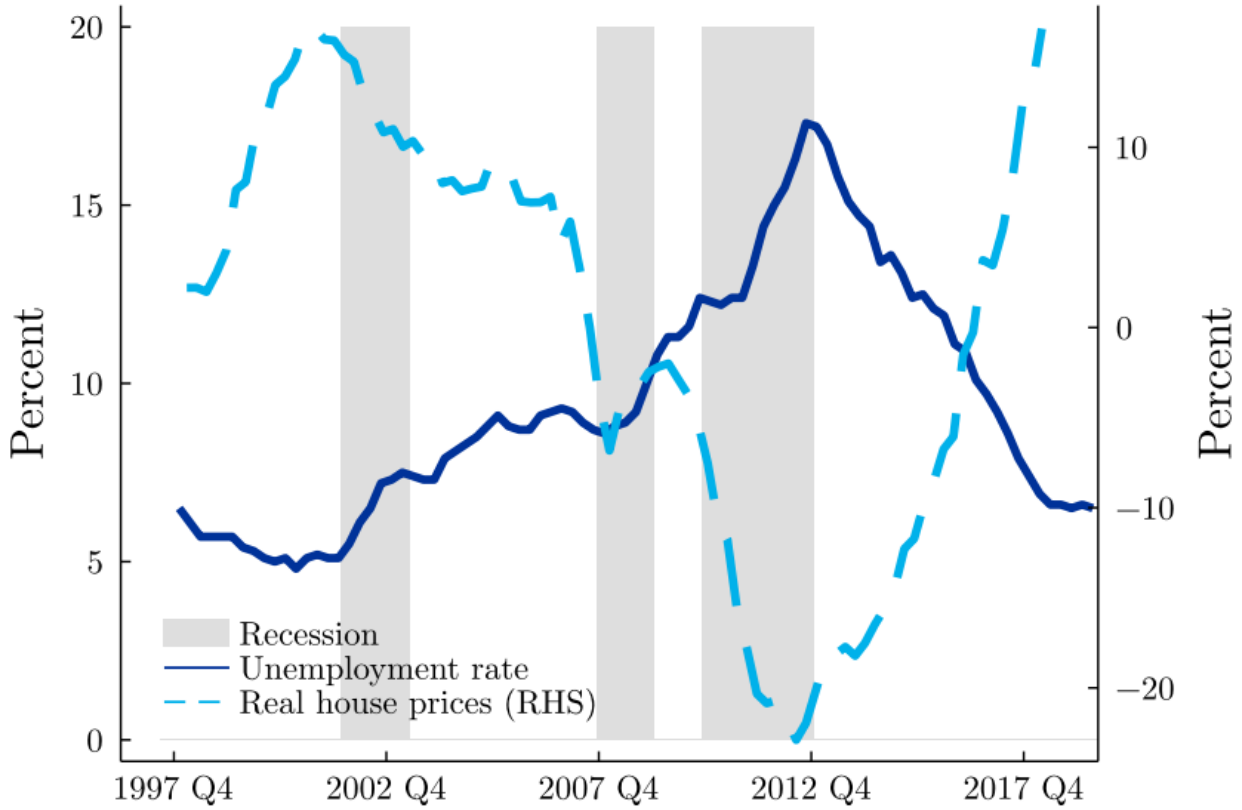
Introduction





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Question

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- What are the welfare implications of borrowing caps?

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  - Dodd-Frank act in the U.S. included an “Ability-to-Repay” rule, which increases the cost of originating high leverage loans (Defusco et al. 2020);
  - Total of sixty economies have enacted some form of explicit limit on household lending standards since 1990 (Acharya et al. 2020).

Approach

- Study the specific **macroprudential policy** introduced **in Portugal** in 2018
  - LTV and PTI caps on mortgage loan contracts at origination

- Build a calibrated **structural model** with housing, rental markets, endogenous house prices and long-term defaultable mortgages

- Quantify **aggregate** effects as well as effects along the income and wealth **distributions**

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- Through the structural calibrated model:
  - Quantify the effect of each borrowing cap **separately**;
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- Through the structural calibrated model:
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  - Quantify the effect of **different** borrowing cap **levels**;
  - Quantify the response of the economy to exogenous shocks with and without caps.

- Empirically:
  - Use loan-level data to document the distribution of LTV and PTI ratios on new mortgage loans in Portugal.

Main findings

- Between steady states:
    - Mortgage debt / Outupt: **-31%**
    - LTV ratio: **-27%**
    - Mortgage default rate: **-94%**
    - House prices: **-2%**

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- Welfare
    - -1.9% CEV (wealth and income-poor households most affected)

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- Impact comes mostly from **LTV cap** and low interest rates
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  - PTI cap + idiosyncratic risk: LTV ↑ → incentive to default ↑ (*pre-emptive borrowing*)

Borrowing caps policy

Policy enacted in Portugal

- Macroprudential policy
  - Announced in February 2018 and implemented in July 2018

- Scope:
  - All financial institutions granting consumer credit in Portugal
  - New loans for house pruchase, mortgages and consumption loans

- Goal:
  - “Enhance the resilience of the financial sector and the sustainability of households’ financing, thereby minimizing defaults”.

Policy details

Regulation	Scope	Cap
LTV cap	Household permanent residence	$\leq 90\%$
	Other purposes	$\leq 80\%$
	Property owned by the financial institution	$\leq 100\%$
PTI cap	Loans (except credit cards)	$\leq 50\%$
Maturity cap	Housing	≤ 40 years
	Auto loans, education, renewable energy	≤ 10 years
	Other consumer credit	≤ 7 years

From policy to model

- LTV cap
  - On loans for house purchase with real estate guarantee

$$\frac{Loan}{Value\ of\ house} \leq 0.9$$

- PTI cap
  - On all non-credit card consumer credit

$$\frac{Loan\ payments}{After-tax\ labor\ income} \leq 0.5$$

Data

Data

- **Central Credit Register** of Banco de Portugal (2019)
  - Loan-level information on loan characteristics
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- **Banking Conduct Supervision** reporting (2017)
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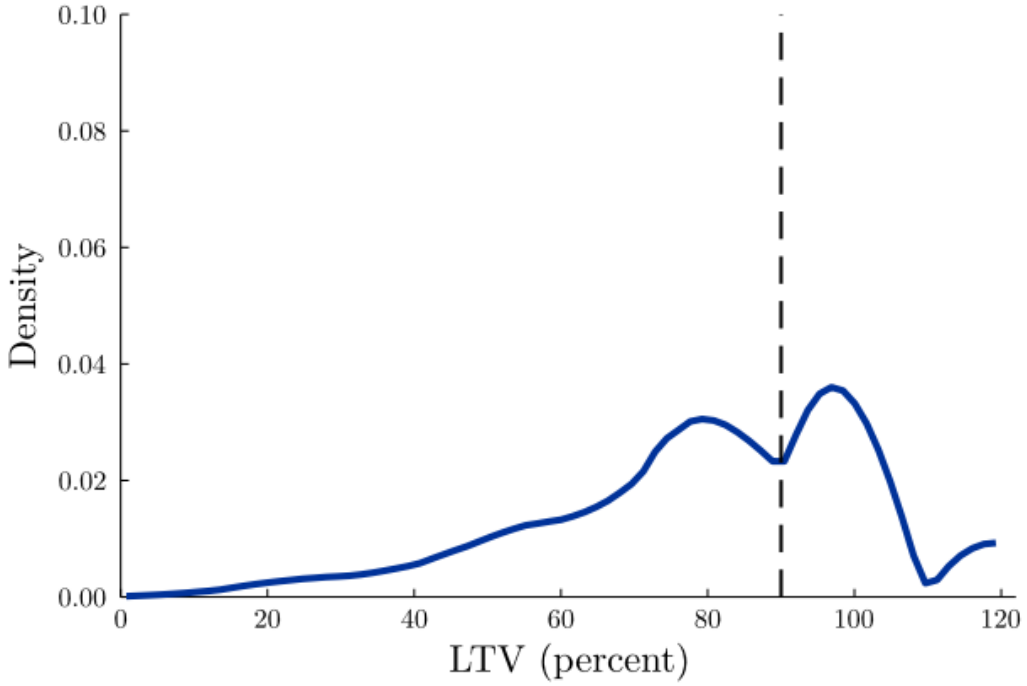
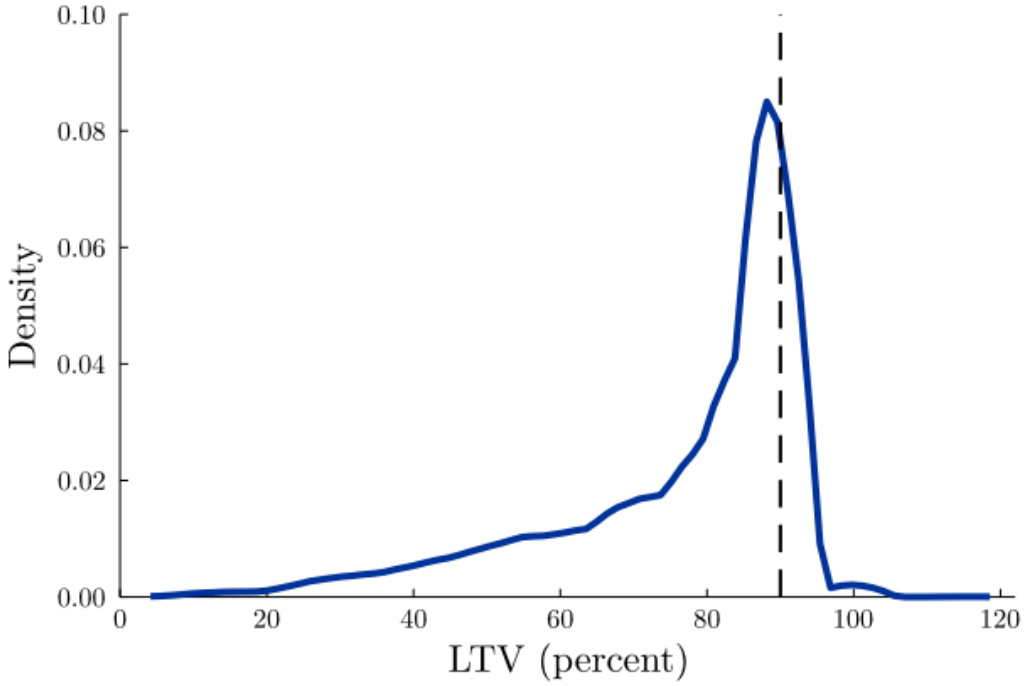
- Concept of mortgage credit
  - Purpose: purchase of household's main residence
  - Collateral: household's main residene; no guarantors.

Empirical documentation

LTV distribution (new mortgage loans)

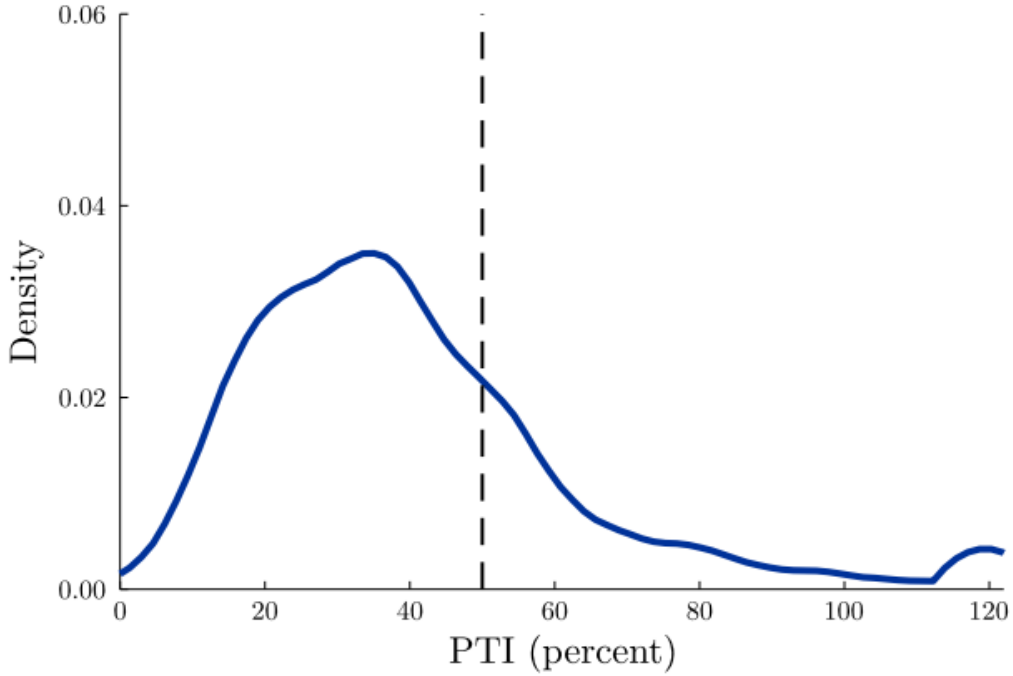


(a) LTV distribution (pre-policy)

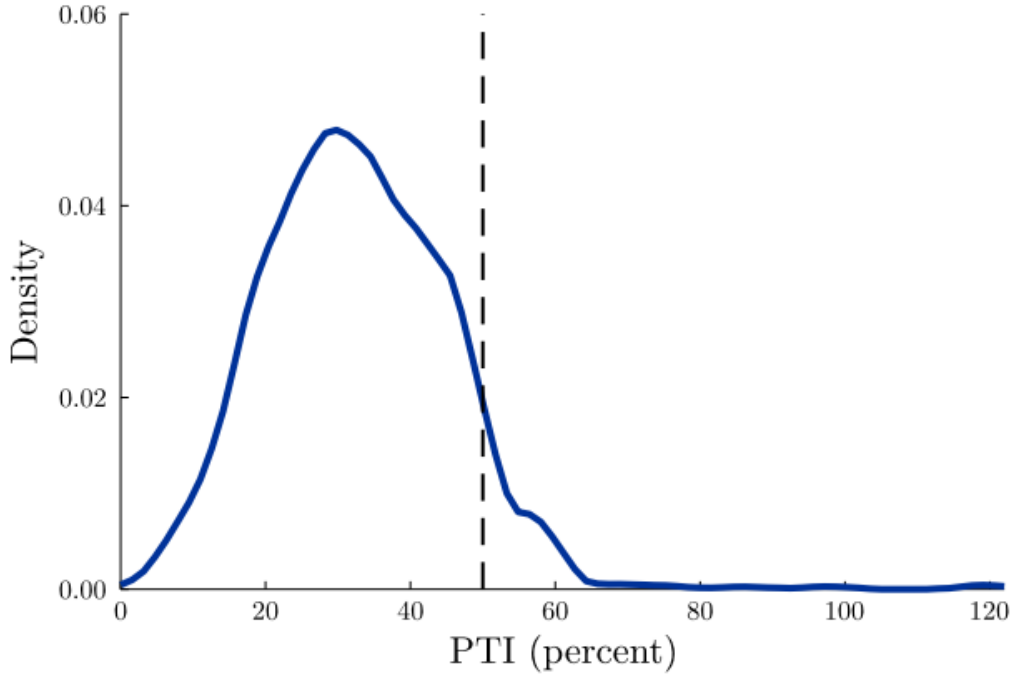


(b) LTV distribution (post-policy)

PTI distribution (new mortgage loans)



(c) PTI distribution (pre-policy)



(d) PTI distribution (post-policy)

LTV and PTI joint distribution in 2017

Table: Share of new loans (percent)

	$PTI \leq 50$	$50 < PTI \leq 60$	$PTI > 60$
$LTV \leq 80$	38	4	6
$80 < LTV \leq 90$	10	2	2
$90 < LTV$	27	5	7

- 39% of new loans above LTV cap
- 26% of new loans above PTI cap

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- **53% of new mortgage loans above caps**

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LTV $\leq$ 80	39	3	0
80 $<$ LTV $\leq$ 90	53	3	1
90 $<$ LTV	1	0	0

- 1% of new loans above LTV cap
- 7% of new loans above PTI cap

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- 7% of new loans above PTI cap
- **8% of new mortgage loans above caps**

Model

Model

Structural model in the tradition of Hatchondo et al. (2015), Favilukis et al. (2017) and Kaplan et al. (2020)

- Households:
  - OLG + idiosyncratic labor income risk + retirement
  - Utility over consumption of non-durables and housing services
  - Assets: risk-free bond and housing
  - Mortgage loans: long-run, defaultable, subject to recourse

Model

- Financial intermediaries
  - Competitive pricing (zero expected profits in each contract)
  - Exogenous LTV and PTI caps on mortgages at origination
  - Exogenous maturity (until death of household)

- Non-durable consumption goods sector
  - Production function: $F(K, N) = K^{\alpha} N^{1-\alpha}$

- Construction Sector
  - Production function: $Y_h = A_h L^{\varphi} Z^{1-\varphi}$

Model

- Rental sector
  - Owns and rents housing units
  - Determines rental rate ρ

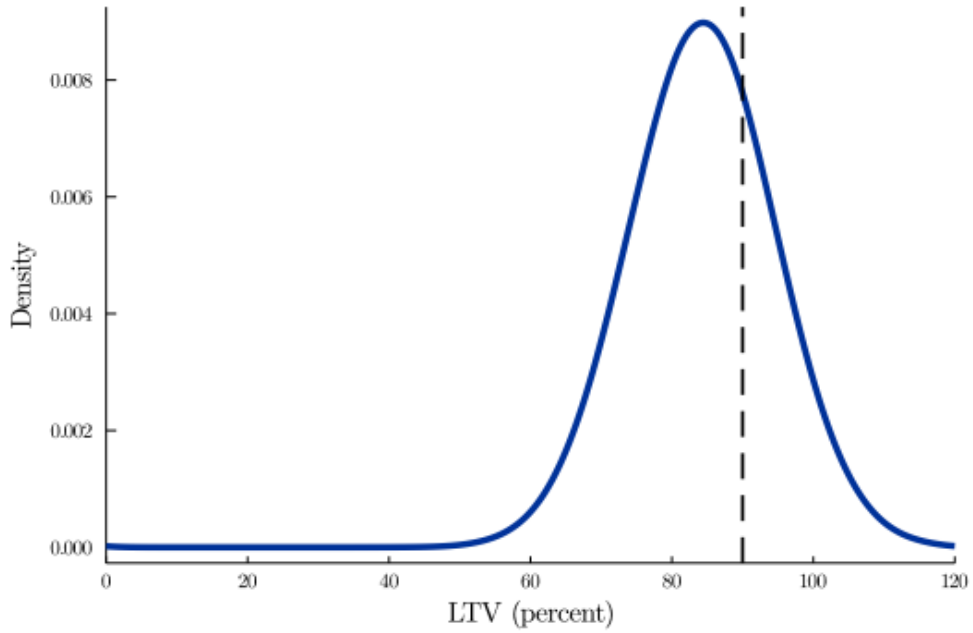
- Government
    - Taxes properties, consumption, labor and rental income
    - Issues land permits ($\bar{L}$), provides free housing and manages social security

Equilibrium definition

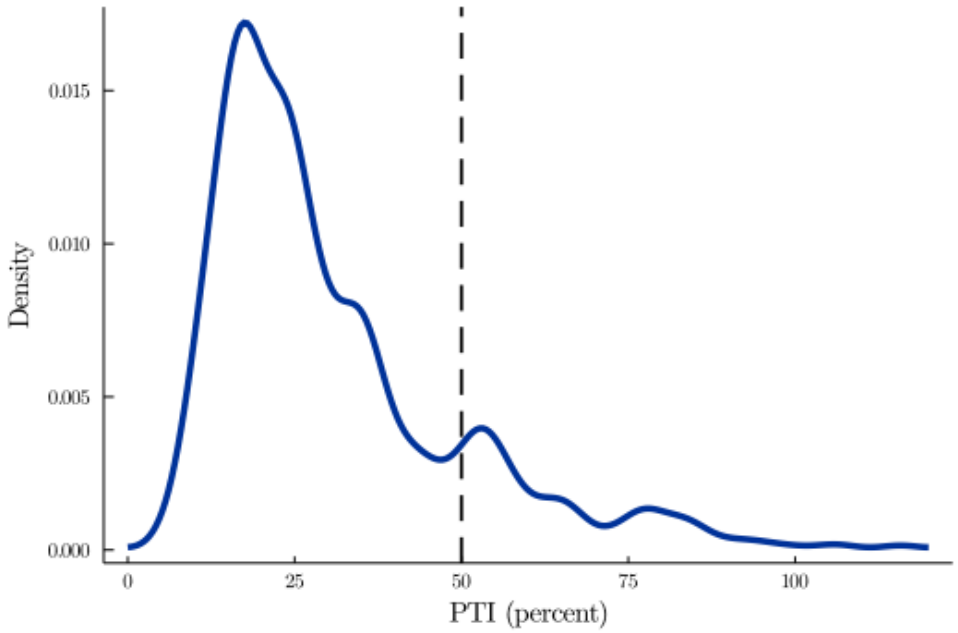
- Recursive stationary competitive equilibrium: set of value functions, policies and prices such that:
    - Invariant household distribution
    - Households optimize
    - Markets clear
    - Government budget constraint holds

Results

Model fit: LTV and PTI at origination

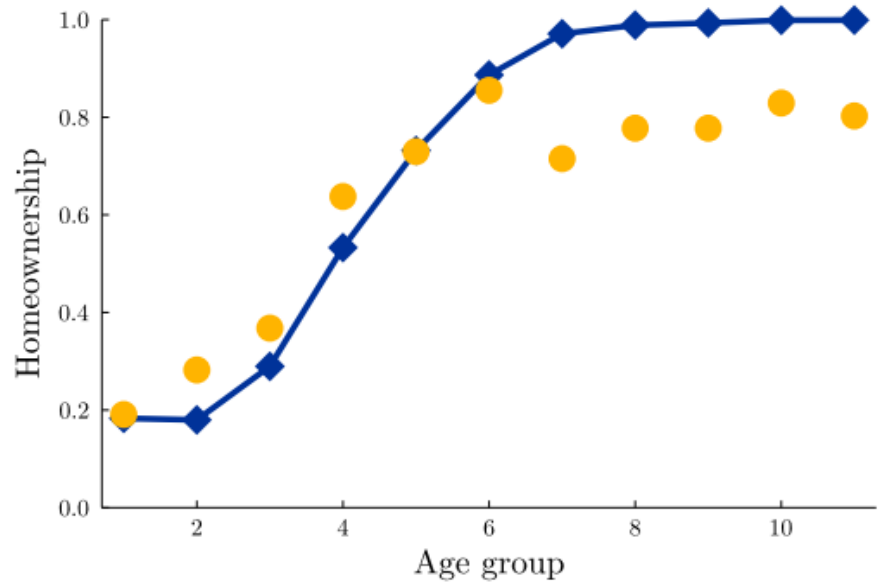


(a) LTV distribution at origination

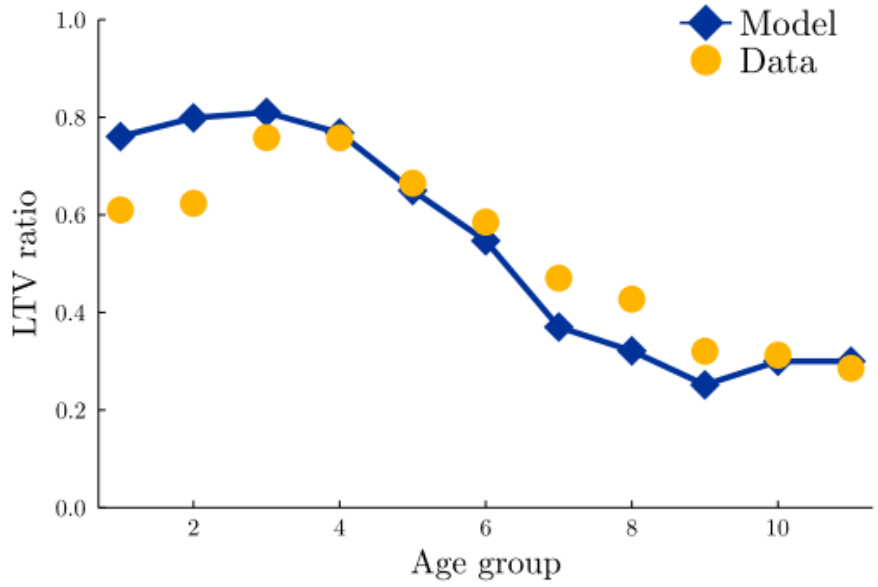


(b) PTI distribution at origination

Model fit: Life-cycle homeownership and LTV



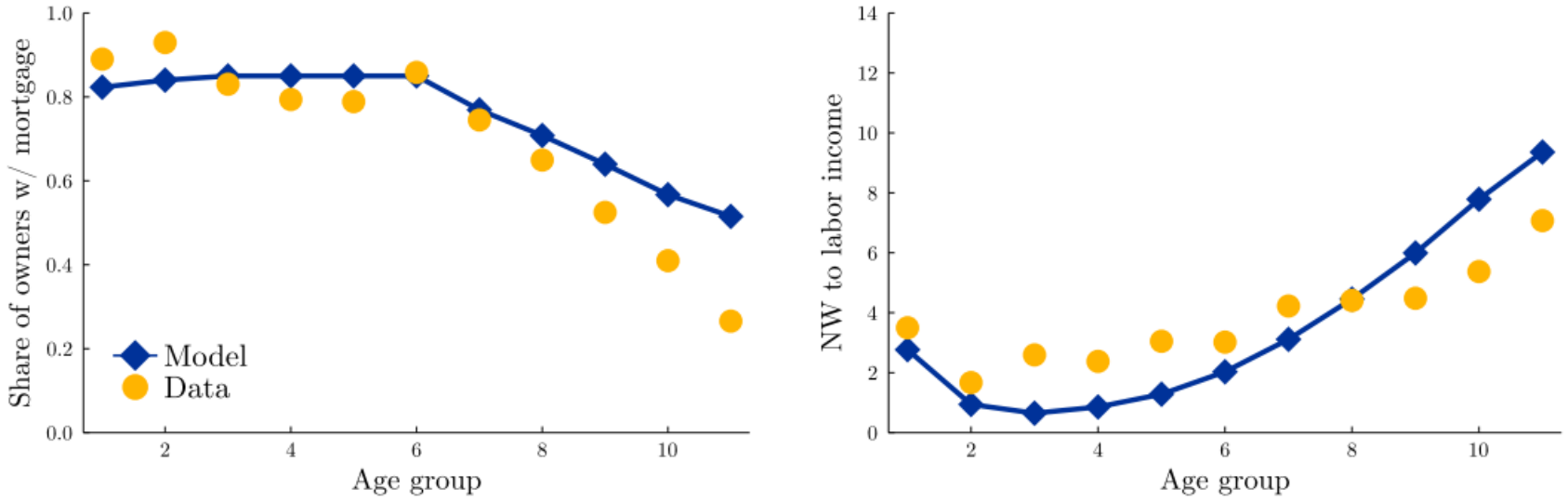
(a) Homeownership life-cycle



(b) LTV life-cycle

- Low homeownership at the start of life;
- High LTV at the start of life.

Model fit: Life-cycle Debt Financing and Net Worth



(c) Share of homeowners with mortgage across life-cycle

(d) Net worth life-cycle

- Decline in extensive margin of debt over the life cycle;
- Accumulation of net worth over the life cycle.

Impact of borrowing caps

- Main policy experiment
  - LTV: 1.2 → 0.9
  - PTI: 1.2 → 0.5

Impact of caps: Aggregate results

	Baseline	Both caps
Leverage and foreclosure		
Mortgage debt to GDP	0.48	0.33
Share of homeowners w/ mortgage	0.51	0.46
LTV	0.41	0.30
Foreclosure rate (%)	0.53	0.03
Homeownership and prices		
Homeownership rate	0.78	0.71
House price	1.00	0.98
Mortgage interest rate (%)	1.11	1.13

- Mortgage debt / GDP: -31%
- Foreclosure rate: -94%

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Homeownership rate	0.78	0.71	0.70
House price	1.00	0.98	0.98
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- LTV cap accounts for total fall in debt and foreclosure

Impact of caps: Aggregate results

	Baseline	Both caps	LTV cap	PTI cap
Leverage and foreclosure				
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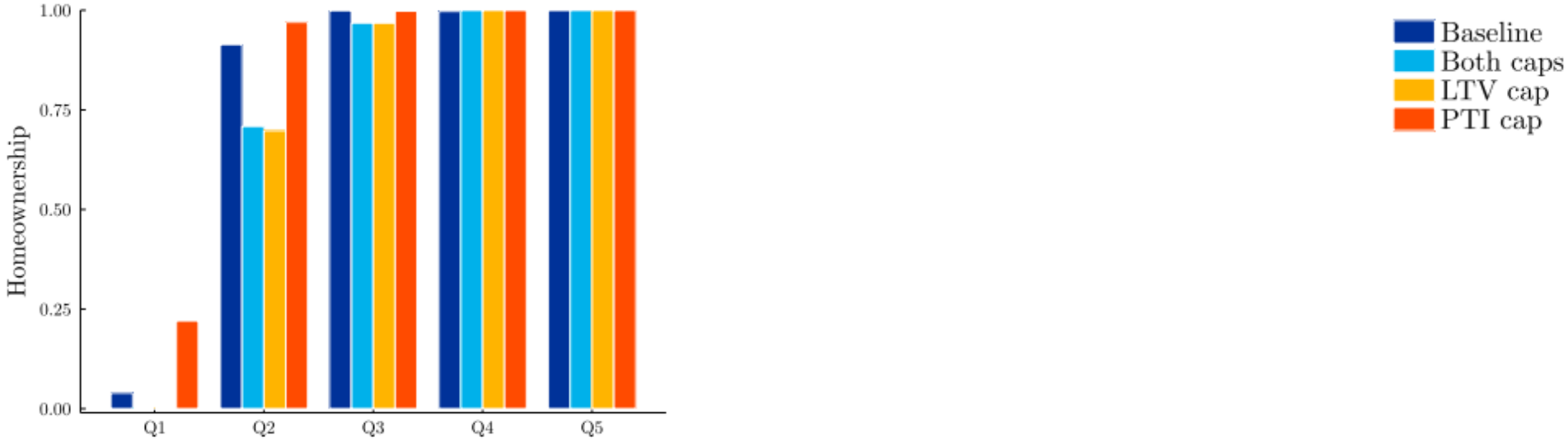
Share of homeowners w/ mortgage	0.51	0.46	0.46	0.54
LTV	0.41	0.30	0.30	0.42
Foreclosure rate (%)	0.53	0.03	0.03	0.55
Homeownership and prices				
Homeownership rate	0.78	0.71	0.70	0.81
House price	1.00	0.98	0.98	1.00
Mortgage interest rate (%)	1.11	1.13	1.13	1.11

- PTI cap raises Mortgage debt / GDP
- PTI cap raises the foreclosure rate

Impact of caps: Across income distribution



(a) Homeownership

- Home ownership most affected in bottom quintiles

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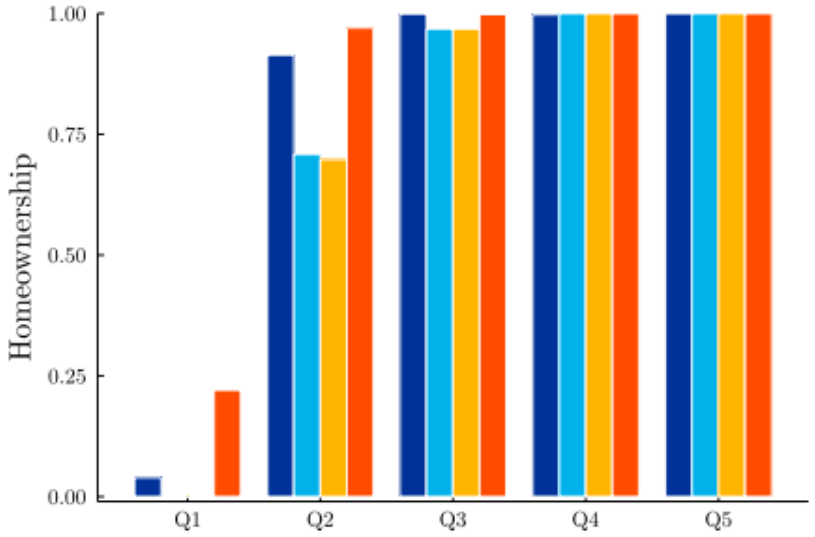

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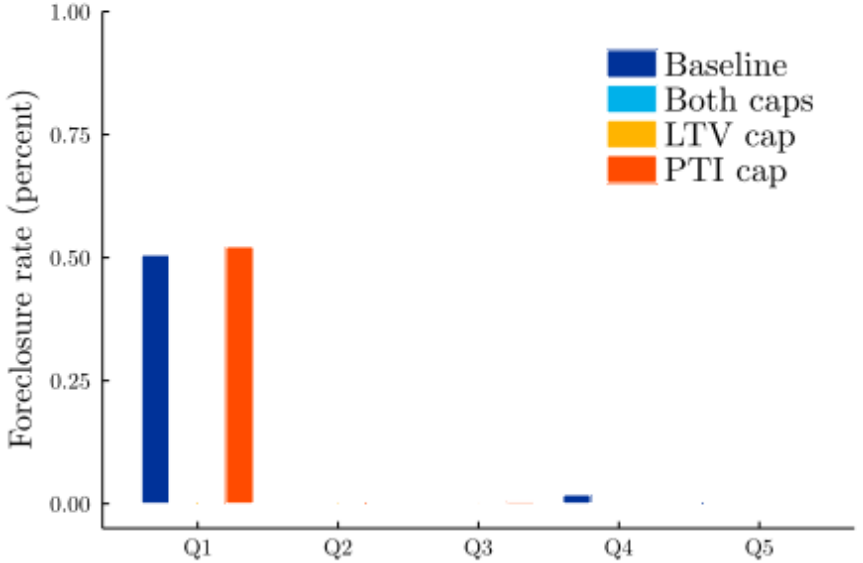
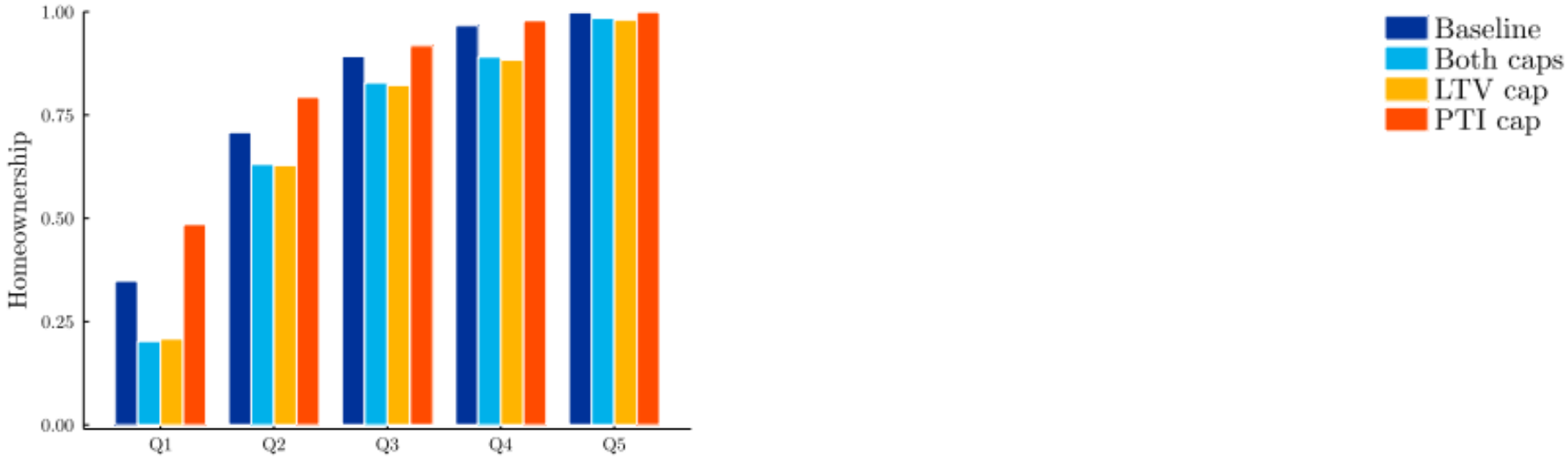


(d) Foreclosure rate

- Home ownership most affected in bottom quintiles
- Foreclosure limited to 1st quintile

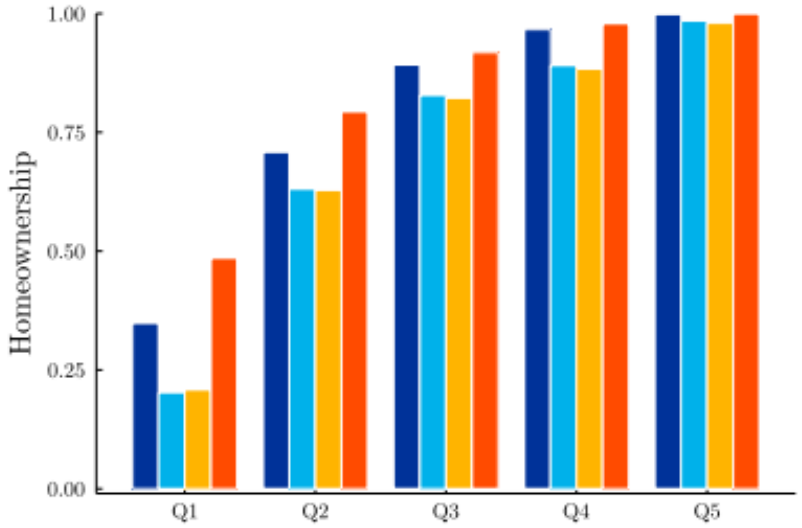
Impact of caps: Across wealth distribution



(a) Homeownership

- Home ownership impacted across all quintiles

Impact of caps: Across wealth distribution



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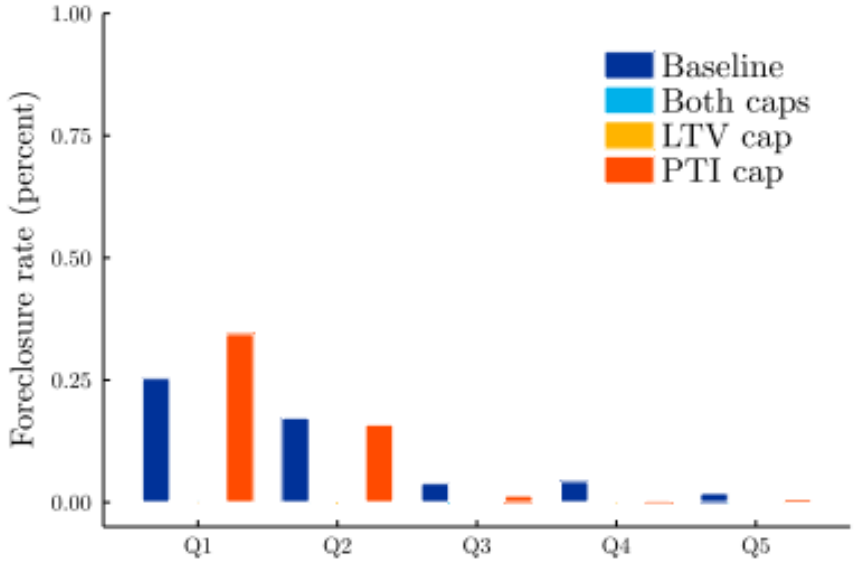


(d) Foreclosure rate

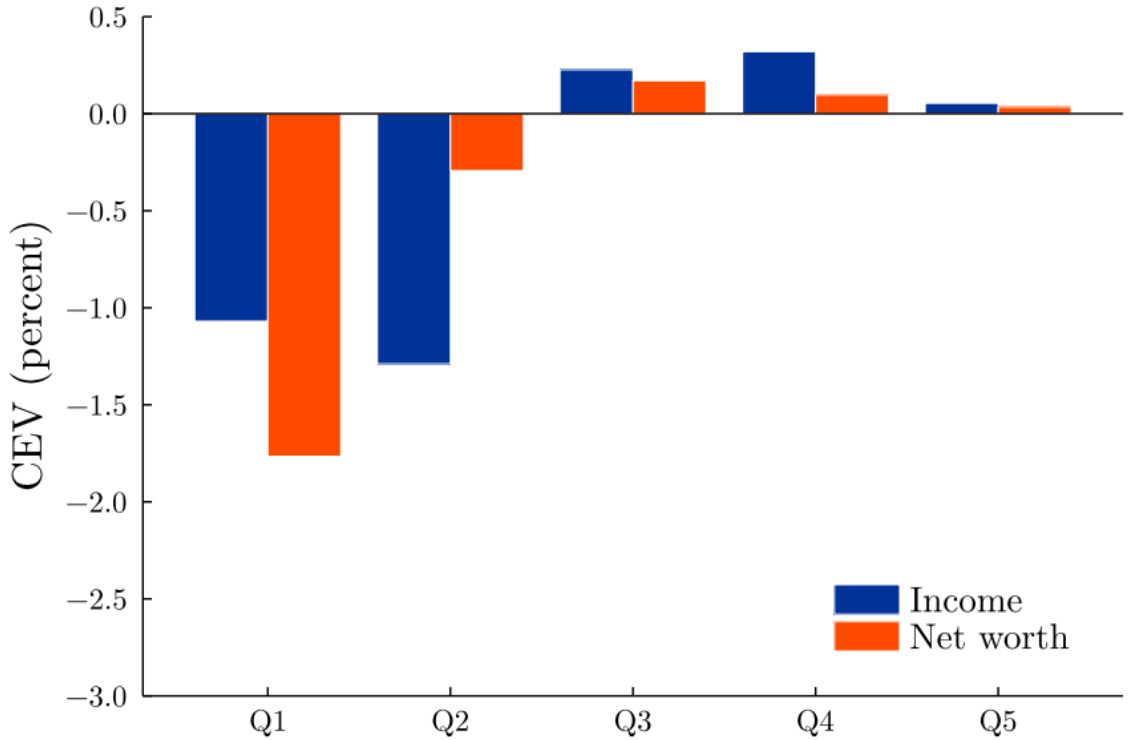
- Home ownership impacted across all quintiles
- Foreclosure eliminated with LTV but rises with PTI in bottom quintile

Impact of caps: Welfare

	Both caps	LTV cap	PTI cap
Unborn	-1.1	-1.1	0.0
Unborn (transition)	-1.9	-1.9	0.0
Average	-0.1	-0.1	0.0
Average (transition)	-0.3	-0.3	0.0

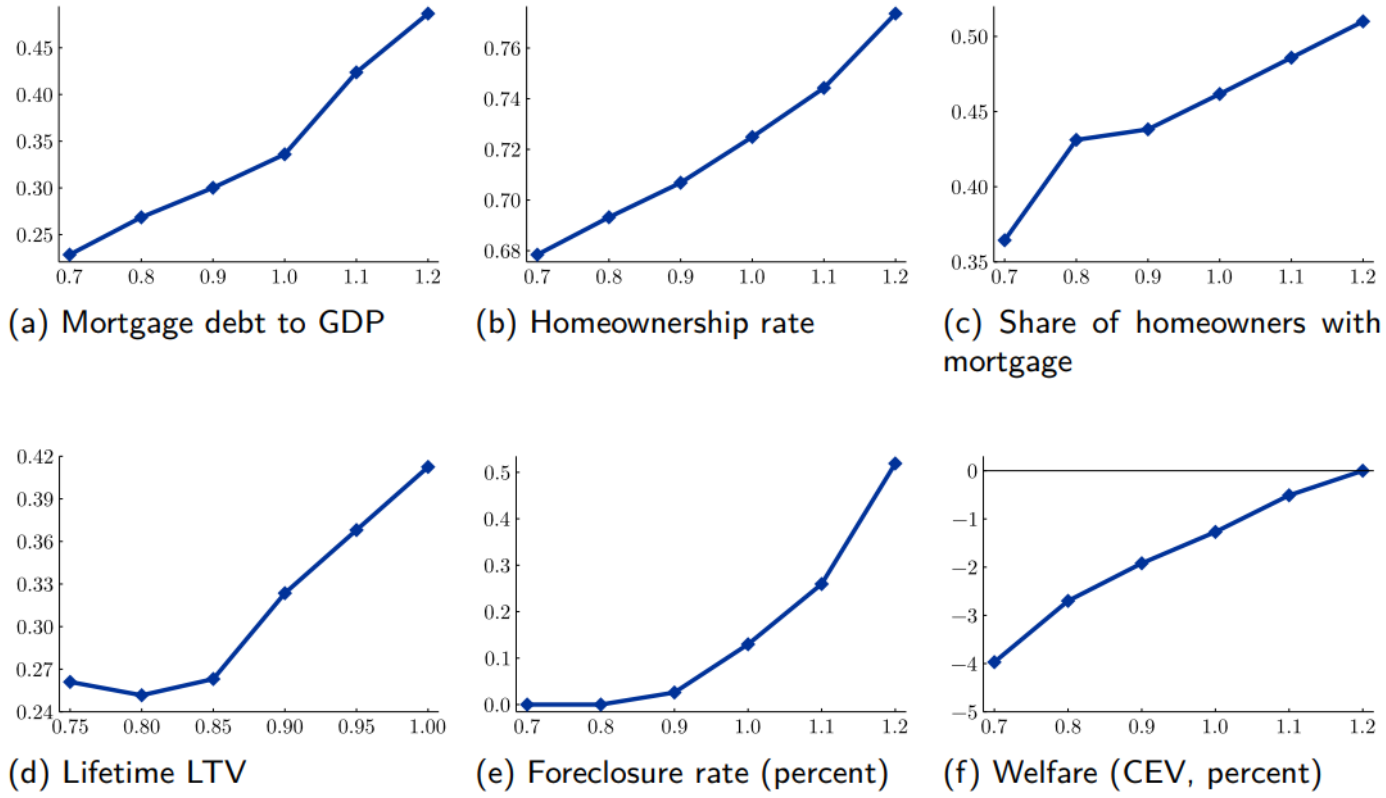
- **Constrained** credit access → Higher **welfare costs** (in CEV) for households entering the economy

Impact of caps: Welfare across distribution



- Welfare **costs** for bottom quintiles of income and wealth distributions
- *A complete welfare analysis would require aggregate risk in the model*

Impact of caps: Alternative LTV levels

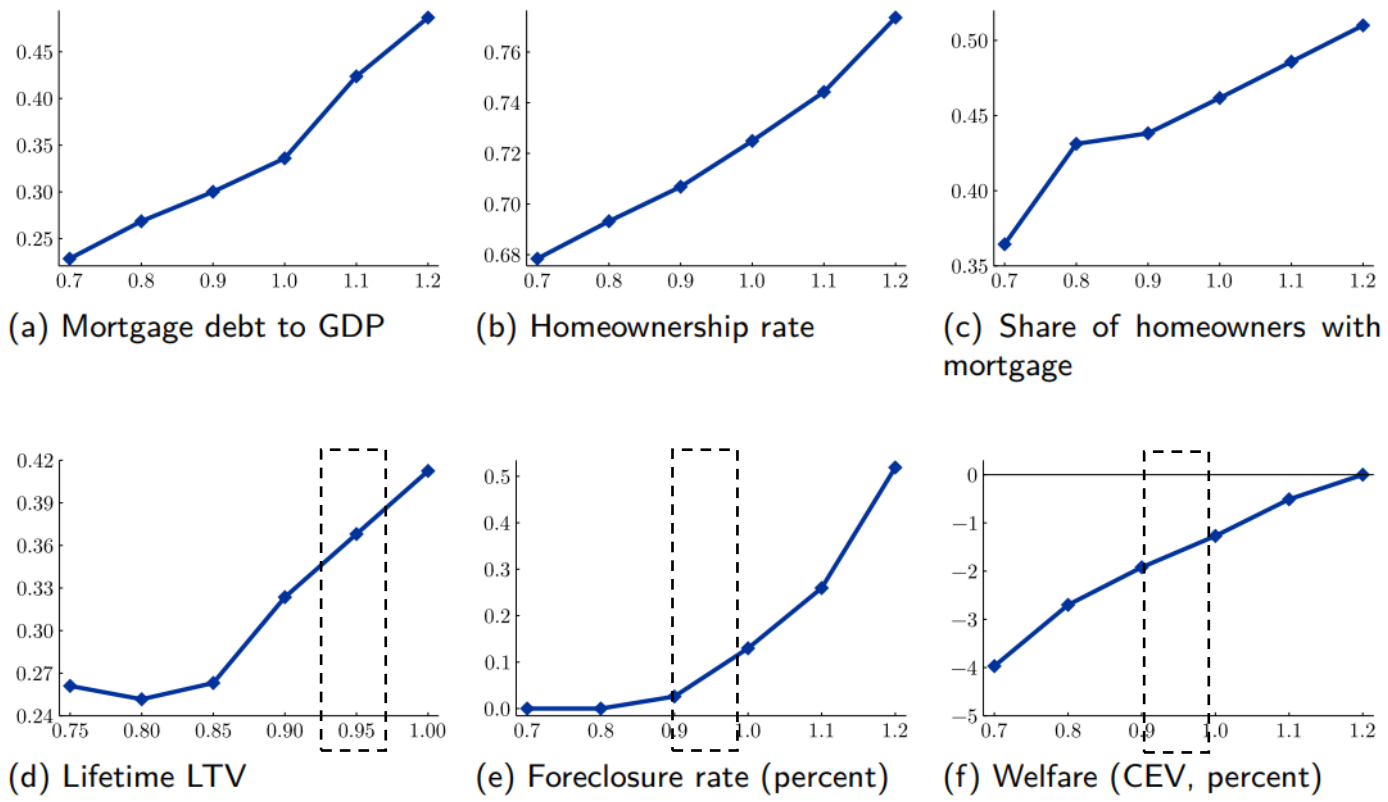


(a) Mortgage debt to GDP (b) Homeownership rate (c) Share of homeowners with mortgage

(d) Lifetime LTV (e) Foreclosure rate (percent) (f) Welfare (CEV, percent)

- Linear effect on home ownership
- Linear effect on intensive and extensive margins of mortgage choice

Impact of caps: Alternative LTV levels



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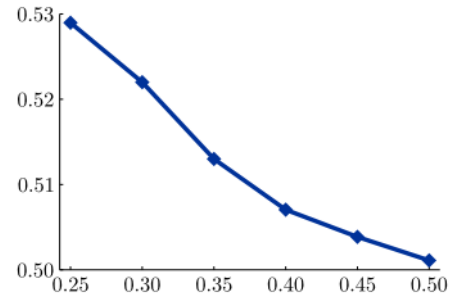
Impact of caps: Alternative PTI levels



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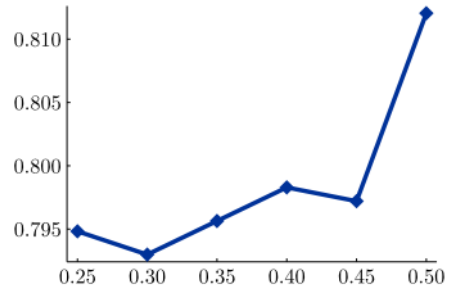
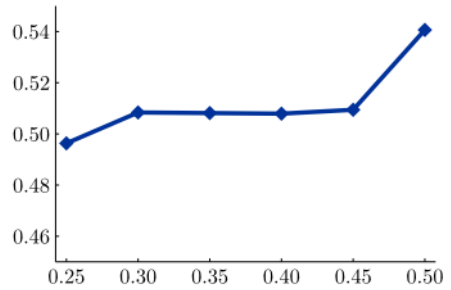
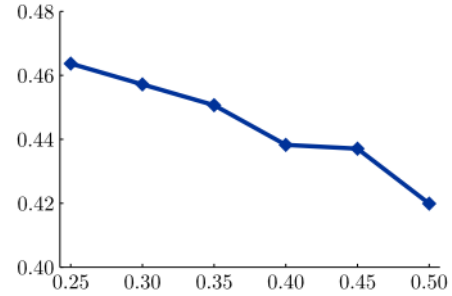


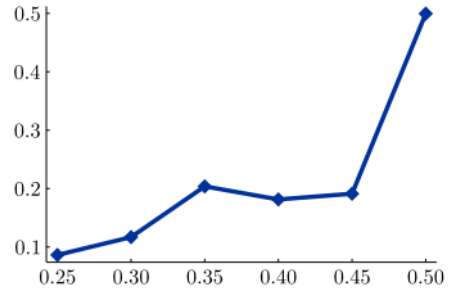
(b) Homeownership rate



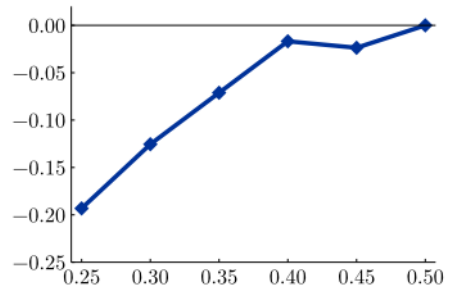
(c) Share of homeowners with mortgage



(d) Lifetime LTV



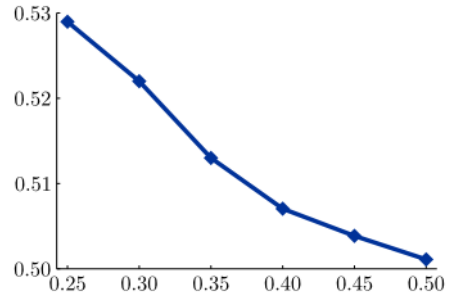
(e) Foreclosure rate (percent)



(f) Welfare (CEV, percent)

- Minimal impact of PTI cap on home ownership
- Lowering PTI cap increases Mortgage / GDP ratio

Impact of caps: Alternative PTI levels



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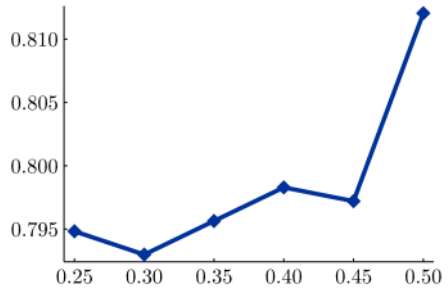

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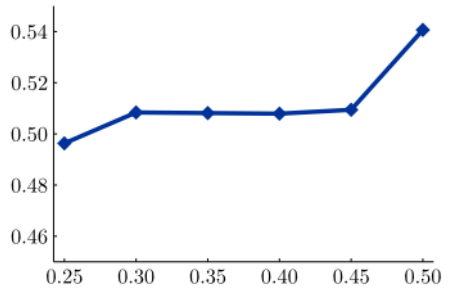
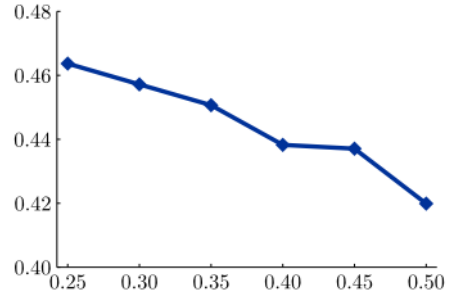


(c) Share of homeowners with mortgage



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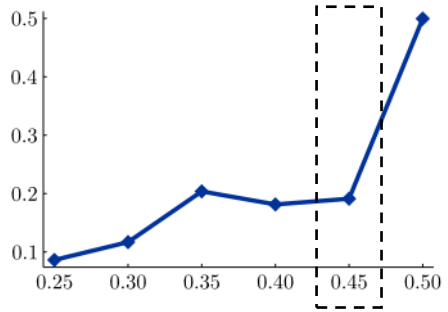

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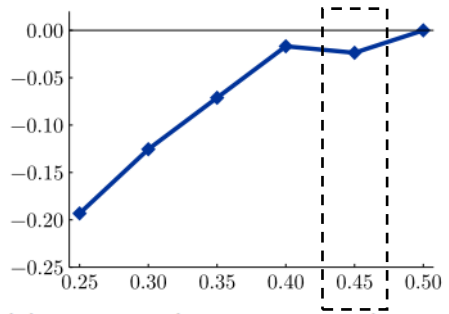

(f) Welfare (CEV, percent)

- Minimal impact of PTI cap on home ownership
- Lowering PTI cap increases Mortgage / GDP ratio

Conclusion

- We calibrate a structural model of mortgage debt and default to the Portuguese economy
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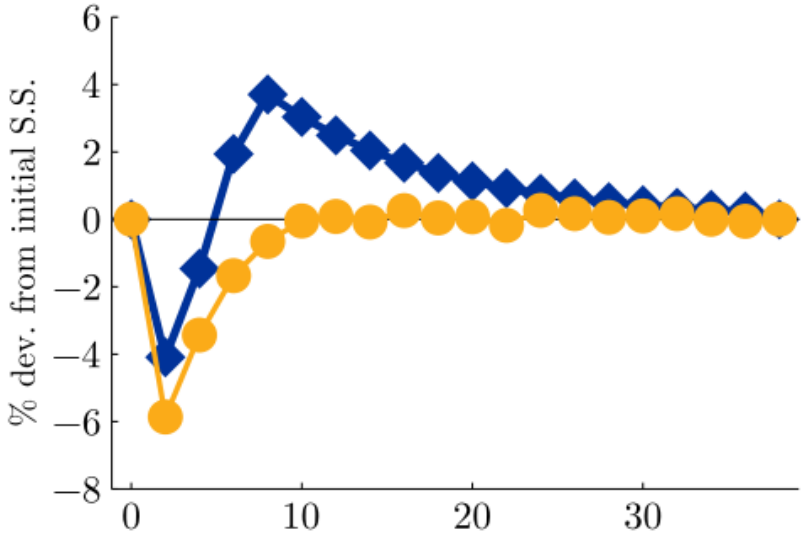
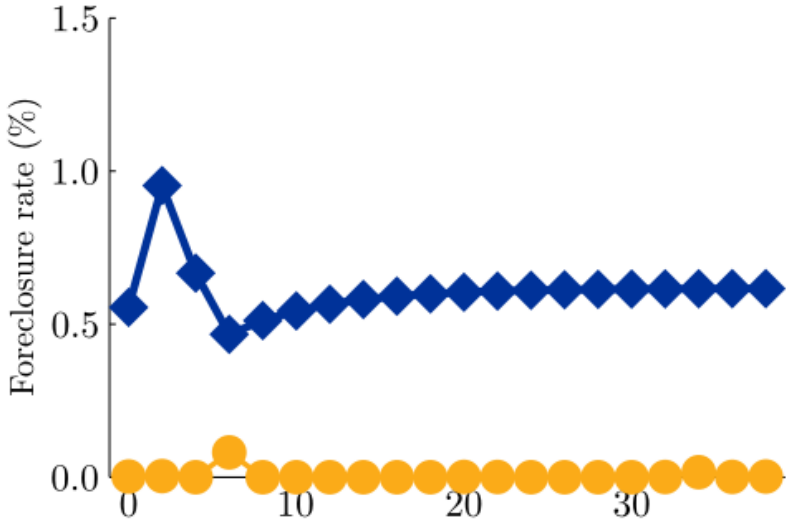
- Welfare costs centered around lowest quintiles of income and wealth distributions
- Welfare analysis limited by absence of aggregate risk in the model
- Next step: add aggregate risk

Thank you

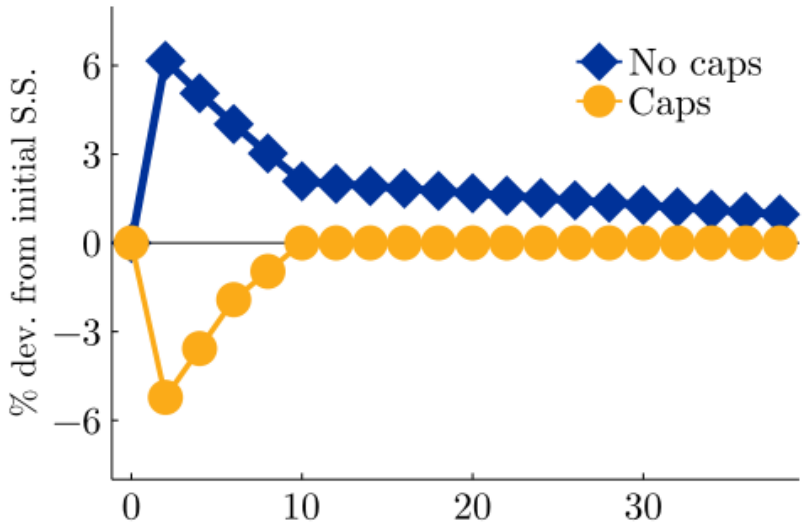
Exogenous shock 1: House price crash



(a) House prices



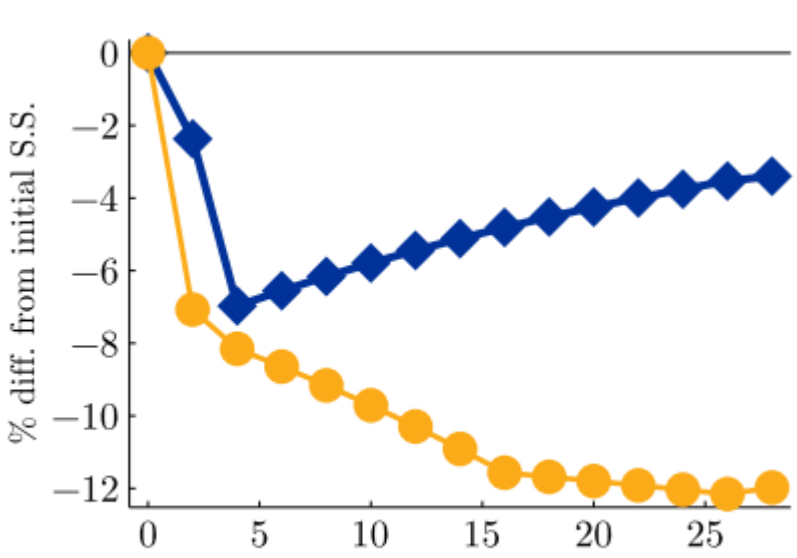
(b) Foreclosure rate



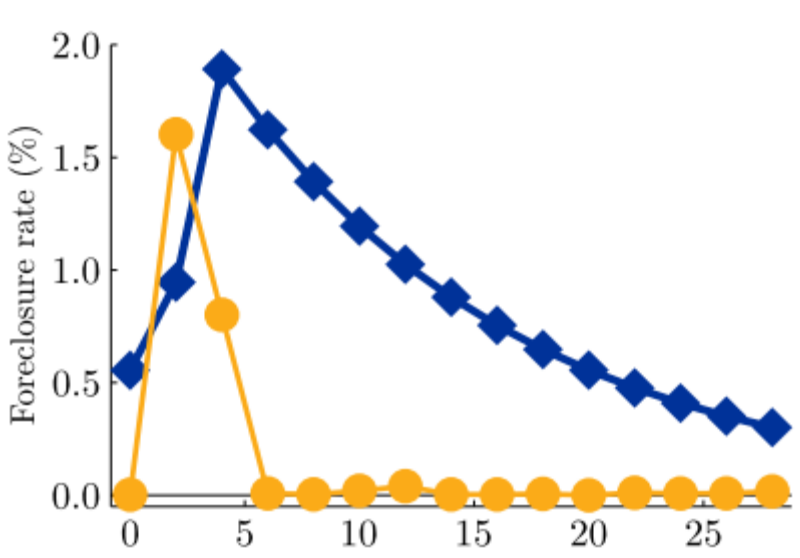
(c) Mortgage debt

- No caps: temporary rise in foreclosures as prices drop, but quick price recovery
- Caps: foreclosures unchanged, but longer house price recovery

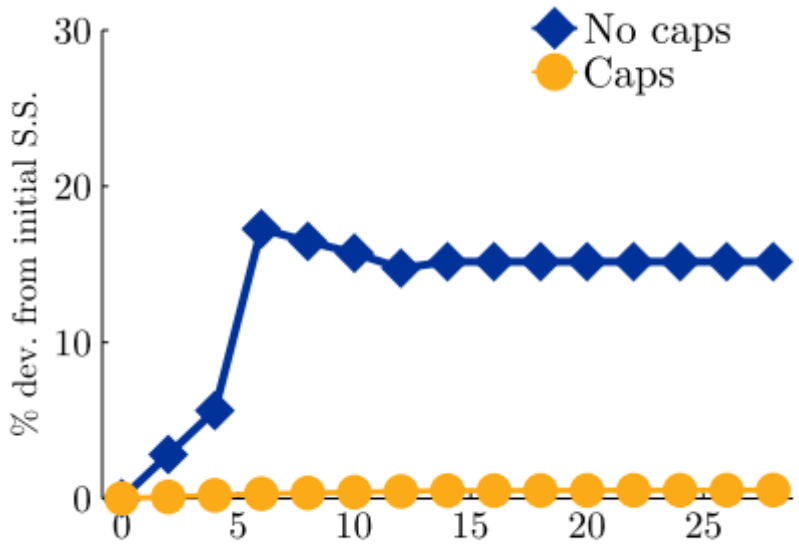
Exogenous shock 2: Monetary policy tightening



(a) House prices



(b) Foreclosure rate



(c) Mortgage debt

- No caps: faster recovery of house market, but foreclosures and debt increase
- Caps: house prices drop; foreclosure rate rises, but rapidly returns to zero

Annex

Households

- Preferences

Expected lifetime utility: $$\mathbb{E}_0 \left[\sum_{j=1}^{J} \beta^{j-1} \left[S_j u_j(c_j, s_j) + (1 - S_j) v(\flat) \right] \right], \tag{1}$$

Period utility: $$u_j = \frac{e_j [(1-\varphi) c_j^{1-\gamma} + \varphi s_j^{1-\gamma}]^{\frac{1-\vartheta}{1-\gamma}} - 1}{1-\vartheta}, \tag{2}$$

Utility from bequests: $$v(\flat) = \nu \frac{(\flat - \underline{\flat})^{1-\vartheta} - 1}{1-\vartheta}, \tag{3}$$

Households

- Endowment

$$\ln y_j^w = \ln w + a + f_j + \varepsilon_j, \qquad (4)$$

j = age; y_j^w = labour income endowment

$\ln w + a$ = permanent component

$\in_j$ = persistent component

f_j = age profile

- Bond:

One-period risk-free bond b_j with exogenous fixed price q_b and implied interest rate $r_b = \frac{1}{q_b} - 1$ set in the world market

Households

- Housing
  - Own: $h \in \mathcal{H} = \{h^1, ..., h^N\}$ at price p_h, $s_j = \omega h_j, \omega > 1$
  - Rent: $\tilde{h} \in \tilde{\mathcal{H}} = \{\tilde{h}^1, ..., \tilde{h}^{\tilde{N}}\}$ at price ρ, $s_j = \tilde{h}_j$

  - Period expenses: $(\delta_h + \tau_h) p_h h_j,$ (5)

    δ_h = housing depreciation rate

    τ_h = property tax rate

  - Transaction cost: $\kappa_h p_h h$

Households

- Mortgages
  - Fixed origination cost: κ^m
  - Funds received: $q_j m_{j+1}$
  - Individual-specific price of the mortgage: q_j
  - Mortgage balance: m'
  - Base lending rate: $r_m = r_b(1+\iota)$
  - Intermediation wedge: ι
  - Mortgage price: $q_j(\mathbf{x}_{j+1}, \mathbf{y}_j)$
  - All available characteristics of the borrower: $\mathbf{x}_{j+1} := (b_{j+1}, h_{j+1}, m_{j+1})$
  - Known elements of the labor productivity endowment process: $\mathbf{y}_j := (a, \varepsilon_j)$
  - Down payment made by households: $p_h h_{j+1} - q_j(\mathbf{x}_{j+1}, \mathbf{y}_j) m_{j+1}$

Households

- LTV cap: $q_j(\mathbf{x}_{j+1}, \mathbf{y}_j) m_{j+1} \leq \lambda^m p_h h_{j+1}.$ (6)

  Funds borrowed — Collateral value

- PTI cap: $\pi_j^{\min}(m_{j+1}) \leq \lambda^\pi \left(y_j - \mathcal{T}(y_j)\right),$ (7)

  Regular payment — After-tax labor income

- τ = labor income tax liability

- Minimum installment: $\pi_j^{\min}(m_{j+1}) = m_{j+1} \frac{r_m(1+r_m)^{J-j}}{(1+r_m)^{J-j}-1},$ (8)

Households

- Refinancing: pay residual balance + origination cost

- Recourse: pay fraction κ_d of after-tax y_j and b_j if default occurs
  - Recourse payment: $\Phi = \min(\kappa_d[y_j - \mathcal{T}(y_j) + b_j], m^d)$

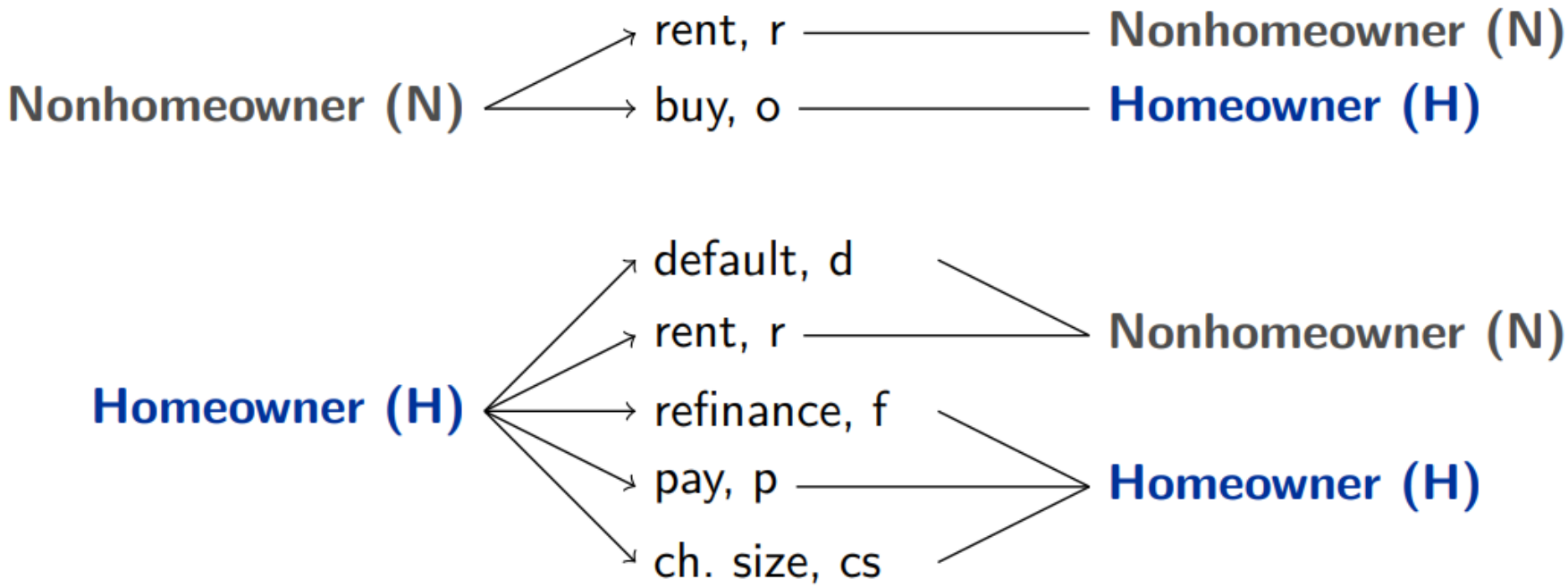
- Sale price of foreclosed house by financial intermediary:

$$\Omega = (1 - \delta_h^d - \tau_h - \kappa_h)p_h h$$

where

$$\delta_h^d > \delta_h$$

Dynamic program of households



Problem of a non-homeowner

- Choice between continuing to rent or to buy a house

$$\mathbb{V}_j^N(b_j, \mathbf{y}_j) = \max\left\{V_j^r(b_j, \mathbf{y}_j), V_j^o(b_j, \mathbf{y}_j)\right\}$$

Value of renting

Value of acquiring the house

Problem of a non-homeowner

- Rent:

$$V_j^r(b_j, \mathbf{y}_j) = \max_{c_j, \tilde{h}_{j+1}, b_{j+1}} u_j(c_j, s_j) + \beta \mathbb{E}_\varepsilon \left[\mathbb{V}_{j+1}^N(b_{j+1}, \mathbf{y}_{j+1}) \right] \qquad \text{(A-1)}$$

$$s.t.:$$

$$c_j(1+\tau_c) + q_b b_{j+1} + \rho \tilde{h}_{j+1} \leq b_j + y_j - \mathcal{T}(y_j, \rho \tilde{h}_{j+1})$$

$$c_j \geq 0, b_{j+1} \geq 0,\ s_j = \tilde{h}_{j+1} \in \tilde{\mathcal{H}},\ y_j \sim \Xi(\mathbf{y}_j).$$

Problem of a non-homeowner

- Buy:

$$V_j^o(b_j, \mathbf{y}_j) = \max_{c_j, h_{j+1}, b_{j+1}, m_{j+1}} u_j(c_j, s_{j+1}) + \beta \mathbb{E}_\varepsilon \left[\mathbb{V}_{j+1}^H(\mathbf{x}_{j+1}, \mathbf{y}_{j+1}) \right] \quad \text{(A-2)}$$

$$s.t.:$$

$$c_j(1+\tau_c) + q_b b_{j+1} + \underbrace{p_h h_{j+1} + \kappa_m \mathbb{1}_{m_{j+1}>0}}_{\text{House and mortgage cost}} \leq$$

$$b_j + y_j - \mathcal{T}(y_j, \rho \tilde{h}_{j+1}) + \underbrace{q_j(\mathbf{x}_{j+1}, \mathbf{y}_j) m_{j+1}}_{\text{Funds}} \quad \text{(A-3)}$$

$$q_j(\mathbf{x}_{j+1}, \mathbf{y}_j) m_{j+1} \leq \lambda^m p_h h_{j+1} \quad \text{(A-4)}$$

$$\pi_j^{\min}(m_{j+1}) \leq \lambda^\pi (y_j - \mathcal{T}) \quad \text{(A-5)}$$

$$c_j \geq 0,\ b_{j+1} \geq 0,\ s_j = \omega h_{j+1},\ h_{j+1} \in \mathcal{H},\ y_j \sim \Xi(\mathbf{y}_j)$$

Problem of a homeowner

- Choice between paying mortgage (if it exists), refinancing, selling house and buy another one or renting one and defaulting

$$\mathbb{V}_j^H(\mathbf{x}_j, \mathbf{y}_j) = \max \begin{cases} \text{Pay :} & V_j^p(\mathbf{x}_j, \mathbf{y}_j) \\ \text{Refinance :} & V_j^f(\mathbf{x}_j, \mathbf{y}_j) \\ \text{Sell :} & \mathbb{V}_j^N(b_j^n, \mathbf{y}_j) \\ \text{Default :} & V_j^d(\mathbf{x}_j, \mathbf{y}_j) \end{cases}$$

Problem of a homeowner

- Pay

$$V_j^p(\mathbf{x}_j, \mathbf{y}_j) = \max_{c_j, b_{j+1}, \pi_j} u_j(c_j, s_j) + \beta \mathbb{E}_\varepsilon \left[\mathbb{V}_{j+1}^H(\mathbf{x}_{j+1}, \mathbf{y}_{j+1}) \right] \quad \text{(A-7)}$$

$$s.t.:$$

$$c_j(1+\tau_c) + q_b b_{j+1} + \underbrace{(\delta_h + \tau_h) p_h h_j + \pi}_{\text{Maintenance and installment}} \leq b_j + y_j - \mathcal{T}(y_j, 0)$$

$$\pi_{j-1}^{\min}(m_j) \leq \pi_j \leq (1+r_m) m_j \quad \text{(A-8)}$$

$$m_{j+1} = (1+r_m) m_j - \pi_j$$

$$c_j \geq 0,\ b_{j+1} \geq 0,\ s_j = \omega h_{j+1},\ h_{j+1} = h_j,\ y_j \sim \Xi(\mathbf{y}_j).$$

Problem of a homeowner

- Refinance

$$V_j^f(\mathbf{x}_j, \mathbf{y}_j) = \max_{c_j, b_{j+1}, m_{j+1}} u_j(c_j, s_j) + \beta \mathbb{E}_\varepsilon \left[\mathbb{V}_{j+1}^H(\mathbf{x}_{j+1}, \mathbf{y}_{j+1}) \right] \qquad \text{(A-9)}$$

$$s.t.:$$

$$c_j(1+\tau_c) + q_b b_{j+1} + (\delta_h + \tau_h) p_h h_j + (1+r_m) m_j + \kappa_m$$
$$\leq b_j + y_j - \mathcal{T}(y_j, 0) + q_j(\mathbf{x}_{j+1}, \mathbf{y}_j) m_{j+1}$$

$$q_j(\mathbf{x}_{j+1}, \mathbf{y}_j) m_{j+1} \leq \lambda^m p_h h_j$$

$$\pi_j^{\min}(m_{j+1}) \leq \lambda^\pi (y_j - \mathcal{T})$$

$$c_j \geq 0,\ b_{j+1} \geq 0,\ s_j = \omega h_{j+1},\ h_{j+1} = h_j, m_{j+1} > m_j,\ y_j \sim \Xi(\mathbf{y_j}).$$

Problem of a homeowner

- Sell: $\check{\mathbb{V}}_j^N(b_j^n, \mathbf{y}_j)$

where $$b_j^n = b_j + \underbrace{(1 - \delta_h - \tau_h - \kappa_h)p_h h_j - (1 + r_m)m_j}_{\text{Net proceeds from sale}}, \qquad \text{(A-6)}$$

Problem of a homeowner

- Default:

$$V_j^d(\mathbf{x}_j, \mathbf{y}_j) = \max_{c_j, \tilde{h}_{j+1}, b_{j+1}} u_j(c_j, s_j) + \beta \mathbb{E}_\varepsilon \left[\mathbb{V}_{j+1}^N(b_{j+1}, \mathbf{y}_{j+1}) \right] \qquad \text{(A-10)}$$

$$s.t.:$$

$$c_j(1+\tau_c) + q_b b_{j+1} + \rho \tilde{h}_{j+1} \leq b_j + y_j - \mathcal{T}(y_j, \rho \tilde{h}_{j+1}) + \Phi$$

$$\Phi = \max\{(1 - \delta_h^d - \tau_k - \kappa_h) p_h h_j - (1 + r_m) m_j, -\kappa_d (b_j + y_j - \mathcal{T})\}$$

$$c_j \geq 0,\ b_{j+1} \geq 0,\ s_j = \tilde{h}_{j+1} \in \tilde{\mathcal{H}},\ y_j \sim \Xi(\mathbf{y}_j),$$

Financial intermediaries

- Issue m_{j+1} with wedge ι over r_b
- Risk-neutral and competitive (zero-expected profits in each contract)
- Mortgage pricing function:

$$q_j(\mathbf{x}_{j+1}, \mathbf{y}_j) = \frac{1}{(1+r_m)m_{j+1}} \mathbb{E}_\varepsilon \{q_{\text{sell}} + q_{\text{default}} + q_{\text{pay}}\}. \tag{9}$$

- Payoffs:

$$q_{\text{sell}} = \left[g^n_{j+1} + g^f_{j+1}\right](1+r_m)m_{j+1} \tag{10}$$

$$q_{\text{pay}} = \left[1 - g^n_{j+1} - g^f_{j+1} - g^d_{j+1}\right] \cdot$$

$$\left(\pi_{j+1}(\mathbf{x}_{j+1}, \mathbf{y}_{j+1}) + q_{j+1}(\mathbf{x}_{j+2}, \mathbf{y}_{j+1})[(1+r_m)m_{j+1} - \pi_{j+1}(\mathbf{x}_{j+1}, \mathbf{y}_{j+1})]\right) \tag{11}$$

Financial intermediaries

$$q_{\text{default}} = g^d_{j+1} \cdot \Big[\underbrace{\min\Big\{(1-\delta^d_h-\tau_h-\kappa_h)p'_h h_{j+1}, m_{j+1}(1+r_m)\Big\}}_{\text{Collateral value}} + \\ + \underbrace{\min\Big\{\kappa_d(b_{j+1}+y_{j+1}-\mathcal{T}), m_{j+1}(1+r_m)-(1-\delta^d_h-\tau_h-\kappa_h)p'_h h_{j+1}\Big\}}_{\text{Recourse payment}}\Big] \tag{12}$$

Construction sector

- Problem: $$\max_{Z} \; p_h A_h \bar{L}^{\varphi} Z^{1-\varphi} - p_L \bar{L} - Z. \qquad (15)$$
- Output given by: $$Y_h = A_h L^{\varphi} Z^{1-\varphi}, \qquad (14)$$
  - Z = Final goods input; $\bar{L}$ = construction/land permits
- Eq. new housing given by:
$$Y_h = A_h^{\frac{1}{\varphi}} \left[p_h(1-\varphi)\right]^{\frac{1-\varphi}{\varphi}} \bar{L}, \qquad (16)$$
- Eq. price of land:
$$p_L = \varphi(1-\varphi)^{\frac{1-\varphi}{\varphi}} (p_h A_h)^{\frac{1}{\varphi}}$$

Rental sector

- Equilibrium rental price:

$$\rho = \psi + p_h - \frac{1 - \delta_h - \tau_h}{1 + r_b} p'_h - \tau_r(\rho - \psi - \delta_h p'_h - \tau_h p'_h), \qquad (13)$$

Operating costs

Rental income tax rate

Government

- Taxes labor and rental income, consumption and properties
- Issues new land permits ($\bar{L}$)
- Wasteful government expenditure (G) and provision of public housing (H^G)
- Pension income before taxes until death:

$$y_{\text{ret}} = \rho_{ss} \frac{\bar{y}^w_{J_{\text{ret}}-1}}{1+\tilde{\tau}_{ss}}, \tag{19}$$

Gross replacement rate

- Labour income tax rate:

$$\mathcal{T}\left(y_j, \tilde{h}_j\right) = \tau_y^0 \left(\max\left[\frac{y_j}{1-\tau_{ss}} - \min\{\tau_\rho \rho \tilde{h}_j, \bar{\tau}_\rho\}, 0 \right] \right)^{-\tau_y^1}, \tag{18}$$

Equilibrium

- Recursive stationary competitive equilibrium, comprising a set of value functions, policies and prices such that:

  - Invariant household distribution
  - Households optimize
  - Markets clear
  - Government budget constraint holds

Rental market

$$\tilde{H} = \sum_{j=1}^{J} \Bigg[\underbrace{\int_{\mathbb{X}^H} \tilde{h}_{j+1}^{N} \left(b_j^n(\mathbf{x}_j^H), \mathbf{y}_j \right) \left[1 - g_j^o \left(b_j^n(\mathbf{x}_j^H), \mathbf{y}_j \right) \right] g_j^n(\mathbf{x}_j^H) \, d\mu_j^H}_{\text{Homeowners who choose to sell the house and rent}}$$

$$+ \underbrace{\int_{\mathbb{X}^H} \tilde{h}_{j+1}^{H}(b_j^d(\mathbf{x}_j^H), \mathbf{y}_j) g_j^d(\mathbf{x}_j^H) \, d\mu_j^H}_{\text{Homewoners who default}} + \underbrace{\int_{\mathbb{X}^N} \tilde{h}_{j+1}^{N}(\mathbf{x}_j^N) \left[1 - g_j^o(\mathbf{x}_j^N) \right] \, d\mu_j^N}_{\text{Non-homeowners who decide to keep renting}} \Bigg]$$

Housing market clearing

$$\underbrace{Y_h}_{\text{Construction}} + \underbrace{\sum_{j=1}^{J}\left[\int_{\mathbb{X}^H} h_j^H(\mathbf{x}_j^H)\left[g_j^n(\mathbf{x}_j^H) + (1-(\delta_h^d-\delta_h))g_j^d(\mathbf{x}_j^H)\right]d\mu_j^H\right]}_{\text{House sales and foreclosures}}$$

$$+ \underbrace{\sum_{j=J_{\text{ret}}}^{J}\hat{S}_j\int_{\mathbb{X}^H} h_{j+1}^H(\mathbf{x}_j^H)\,d\mu_j^H}_{\text{Bequests}} - \underbrace{\delta_h(H+\tilde{H})}_{\text{Depreciation}}$$

$$= \sum_{j=1}^{J}\Bigg[\underbrace{\int_{\mathbb{X}^N} h_{j+1}^N(\mathbf{x}_j^N)g_j^o(\mathbf{x}_j^N)\,d\mu_j^N}_{\text{House purchases by non-homeowners}} +$$

$$\underbrace{\int_{\mathbb{X}^H} h_{j+1}^N(b^n(\mathbf{x}_j^H),\mathbf{y}_j)g_j^o(b^n(\mathbf{x}_j^H),\mathbf{y}_j)g^n(\mathbf{x}_j^H)\,d\mu_j^H}_{\text{House purchases by homeowners}}\Bigg],$$

Non-durable goods market

$$Y_c = \sum_{j=1}^{J} \Bigg\{ \underbrace{\int_{\mathbb{X}^H} c_j^H(\mathbf{x}_j^H) d\mu_j^H + \int_{\mathbb{X}^N} c_j^N(\mathbf{x}_j^N) d\mu_j^N}_{\text{Non-durable consumption expenditures}}$$

$$+ \underbrace{\kappa_h p_h \int_{\mathbb{X}^H} h_j^H(\mathbf{x}_j^H)[g_j^N(\mathbf{x}_j^H) + g_j^d(\mathbf{x}_j^H)]\, d\mu_j^H}_{\text{Transaction fees}}$$

$$+ \underbrace{\kappa_m \left[\int_{\mathbb{X}^N} g_j^o(\mathbf{x}_j^N)\, d\mu_j^N + \int_{\mathbb{X}^H} g_j^o(b^n(\mathbf{x}_j^H), \mathbf{y}_j) + g_j^f(\mathbf{x}_j^H)\, d\mu_j^H \right]}_{\text{Origination expenditures}}$$

$$+ \underbrace{\iota r_b \int_{\mathbb{X}^H} m_j(\mathbf{x}_j^H) d\mu_j^H}_{\text{Intermediation costs}} \Bigg\} + \underbrace{\sum_{j=J_{\text{ret}}}^{J} \hat{S}_j \kappa_h \int_{\mathbb{X}^H} h_{j+1}^H(\mathbf{x}_j^H) d\mu_j^H}_{\text{Transaction fees from wills}} + \psi \tilde{H} + \delta_k K + Z + G + NX,$$

Government budget clearing

$$\underbrace{H^G\delta_h + G + r_b B^G + \int_{\mathbb{Y}^{\text{ret}}} y^{\text{ret}} d\mu^{\text{ret}}}_{\text{Public housing, consumption, debt service, and SS}} = \underbrace{\sum_{j=1}^{J}\left[\int_{\mathbb{X}^H} \mathcal{T}(y_j, 0)\, d\mu_j^H + \int_{\mathbb{X}^N} \mathcal{T}(y_j, \rho\tilde{h})\, d\mu_j^N\right]}_{\text{Labor taxes}}$$

$$+ \underbrace{\frac{\tilde{\tau}_{ss} + \tau_{ss}}{1 + \tilde{\tau}_{ss}} \sum_{j=1}^{J_{\text{ret}}-1}\left[\int_{\mathbb{X}^H} y_j^w d\mu_j^H + \int_{\mathbb{X}^N} y_j^w d\mu_j^N\right]}_{\text{Social Security contributions}}$$

$$+ \underbrace{\tau_c \sum_{j=1}^{J}\left[\int_{\mathbb{X}^H} c_j^H(\mathbf{x}_j^H) d\mu_j^H + \int_{\mathbb{X}^N} c_j^N(\mathbf{x}_j^N) d\mu_j^N\right]}_{\text{Consumption taxes}} + \underbrace{p_L \bar{L}}_{\text{Land/permits}}$$

$$+ \underbrace{\tau_h p_h (H + \tilde{H} - H^G)}_{\text{Property taxes}} + \underbrace{(\tilde{H} - H^G)(\rho - \psi - \tilde{\delta}_h p_h - \tau_h p_h)\tau_r}_{\text{Rental income taxes}},$$

Calibration: external

Description	Parameter	Value	Source
Demographics			
Maximum model age	J	30	-
Period of retirement	J_{Jret}	23	-
Survival probability by age	$\{S_j\}$	-	Statistics Portugal
Preferences			
Consumption equivalence scale	$\{e_j\}$	-	HFCS
EOS of housing/non-durable consumption	$1/\gamma$	1.250	Piazzesi et al. (2007)
Risk aversion	ϑ	2.000	Kaplan et al. (2020)
Endowment			
Life cycle profile of earnings	$\{\chi_j\}$	-	Brinca et al. (2021)
Auto-correlation (persistent component)	ρ_ε	0.335	Brinca et al. (2021)
Std. dev. (persistent component)	σ_ε	0.439	Brinca et al. (2021)
Financial instruments			
Risk-free interest rate	r_b	0.010	Assumption
Origination cost	κ_m	0.045	1000€ in the model
LTV cap	λ^m	1.200	Authors' calculation
PTI cap	λ^π	1.190	Authors' calculation

Calibration: external (cont.)

Housing			
Depreciation rate	δ_h	0.019	Penn World Table
Transaction cost	κ_h	0.089	Authors' calculations
Production			
Capital share	α	0.449	Statistics Portugal
Land share	φ	0.400	Assumption
Capital depreciation rate	δ_k	0.038	Penn World Table
Government and SS			
Consumption tax rate	τ_c	0.125	Statistics Portugal
Property tax rate	τ_h	0.007	Portuguese Tax Authority
Rental income tax rate	τ_r	0.280	Portuguese Tax Authority
Tax level parameter	τ_0^y	0.937	Brinca et al (2021)
Tax progressivity parameter	τ_1^y	0.136	Brinca et al (2021)
Fraction of rent which is deductible	τ_ρ	0.150	Portuguese Tax Authority
Maximum rent deduction	$\bar{\tau}_\rho$	-	Portuguese Tax Authority
Government consumption to output	g	0.169	Statistics Portugal
SS tax employee	τ_{ss}	0.110	Portuguese Social Security
SS tax employer	$\tilde{\tau}_{ss}$	0.238	Portuguese Social Security
Gross replacement rate	ρ_{ss}	0.547	OECD

Table 4. External calibration summary

Calibration: internal

Description	Parameter	Value	Target	Model	Data
Discount Factor	β	0.982	NW to GDP	2.613	2.561
Housing utility weight	φ	0.131	Share of housing expenditures	0.215	0.209
Ownership extra utility	ω	1.005	Homeownership	0.776	0.747
Management costs	ψ	0.013	Homeownership < 35	0.411	0.419
Bequest motive strength	ν	55.58	Ratio of NW of 75/50	2.272	0.914
Bequests as luxury goods	$\bar{b}$	0.011	Fraction of retired with zero NW	0.0	0.05
S.D. permanent component	σ_a	0.370	S.D. of log household earnings	0.824	0.824
Housing grid	$\mathcal{H}$	-	Housing NW/NW		
			p10	0.195	0.252
			p50	0.396	0.751
			p90	0.946	0.993
Minimum rental size	$\tilde{h}_1$	0.01	Public housing as a share of housing stock	0.054	0.064
Rental grid size	$\tilde{N}$	4	Earnings homeowners/nonhomeowners	1.671	1.604
Depreciation rate	δ_h^d	0.201	Depreciation rate of foreclosed properties	0.250	0.250
Intermediation wedge	ι	0.140	Average rate on new mortgages	0.011	0.011
Attachment limit	κ_d	0.233	Foreclosure rate	0.005	0.005
Building permits	$\bar{L}$	0.146	Residential housing investment to GDP	0.027	0.028

Table 5. Internal calibration summary

Necessary condition for default

- Agent begins period with $b = 0$ and $y_j^w - \tau < \pi^{min}$
- Sell and rent: $\underbrace{(1 - \delta_h - \tau_h - k_h)p_h h - (1 + r_m)m}_{\text{Equity value}}$
- Default: $\underbrace{\left(1 - \delta_h^d - \tau_h - k_h\right)p_h h - (1 + r_m)m}_{\text{Equity value in default}}$
- Equity value in default < 0 $\Rightarrow$ $k_d\left(y_j^w - \tau\right)$