Financial Fragility with SAM?

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Motivation

- Standard mortgage contracts share house price risk in a particular way
  - Borrower bears all house price risk until default
  - Lender bears tail risk when house prices fall enough to trigger default

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- Foreclosure crisis called into question this risk-sharing arrangement
- Led economists to propose alternative risk-sharing arrangements
  - Popular proposal: Shared Appreciation Mortgage (SAM)
  - Payments fall if house price declines, staving off foreclosures
  - Lender receives share of the upside upon sale

Motivation

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- Foreclosure crisis called into question this risk-sharing arrangement
- Led economists to propose alternative risk-sharing arrangements
- But is it safe to shift house price losses to lenders?
  - Banks and credit unions hold $5.5T in mortgage debt on balance sheets
  - Large undiversifiable component to house price risk
  - Losses inflicted at times when banks may be fragile already
  - Offset by improved risk sharing/reduced defaults? Need GE model.

This Paper

- **Question**: how do Shared Appreciation Mortgage (SAM) contracts influence financial stability and risk sharing?
- **Approach**: build GE model of mortgage and housing market with explicit financial sector to intermediate between borrowers and savers.
  - Start from realistic mortgage debt contracts: long-term, nominal, prepayable, defaultable
  - Consider different forms of mortgage payment indexation (SAMs)
- **Main insights**:
  1. Indexing to aggregate house prices increases financial fragility
  2. Indexing to relative local prices can dampen fragility
  3. Schemes that help risk sharing often hurt financial sector profits

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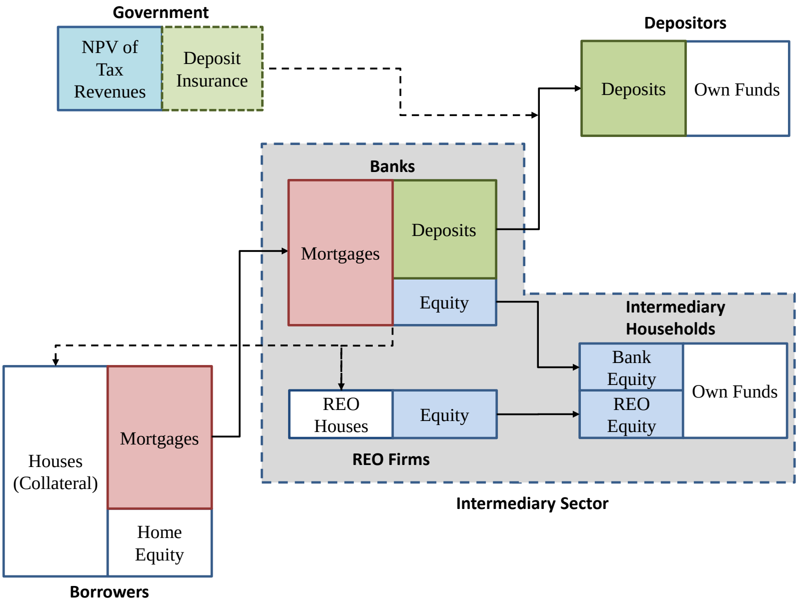
  - Start from realistic mortgage debt contracts: long-term, nominal, prepayable, defaultable
  - Consider different forms of mortgage payment indexation (SAMs)
- **Policy conclusion**: only carefully designed mortgage indexation leads to aggregate stability and risk-sharing benefits.
  - Commonly proposed features like asymmetric and interest-only adjustment have important macro consequences.

Related Literature

- Asset pricing models with financial intermediaries:
  - Brunnermeier + Sannikov 14, 15 ,17, Gârleanu + Pedersen 11, Gertler + Karadi 11, He + Krishnamurthy 12, 13, 15, Adrian + Boyarchenko 12, Savov + Moreira 16
  - Contribution: split banks and borrowers, risk sharing with multiple contract types
- Quantitative macro models of mortgage markets:
  - Favilukis, Ludvigson, Van Nieuwerburgh 17, Corbae + Quintin 14, Elenev, Landvoigt, Van Nieuwerburgh 16, Landvoigt 15, Garriga, Kydland, Sustek 15, Greenwald 16, Wong 15
  - Contribution: realistic mortgages and intermediation in GE
- Alternative mortgage contracts/SAMs:
  - Eberly + Krishnamurthy 14, Hall 15, Kung 15, Mian 13, Mian + Sufi 14, Piskorski + Tchistyi 17, Guren, Krishnamurthy, McQuade 17
  - Contribution: effect on risk sharing, housing/mortgage markets with levered intermediaries

Model Overview



Demographics, Endowments, Preferences

- Demographics
  - Three types of agents: Borrowers, Depositors, Intermediaries
  - Population mass χ_j for $j \in \{B, D, I\}$
  - Perfect consumption insurance within, but not across types (aggregation).
- Endowments
- Preferences

Demographics, Endowments, Preferences

- Demographics
- Endowments
  - Non-durable endowment, income shock:

$$\log Y_t = (1-\rho_y)\log \bar{Y} + \rho_y \log Y_{t-1} + \sigma_y \varepsilon_{y,t}, \quad \varepsilon_{y,t} \sim N(0,1)$$

  - Agent $j \in \{B, D, I\}$ receives share s_j of Y_t, taxed at rate τ.
  - Housing tree provides services in fixed supply ($\bar{K} = H_t^B + H_t^D + H_t^I$).
- Preferences

Demographics, Endowments, Preferences

- Demographics
- Endowments
- Preferences
  - Epstein-Zin:

$$U_t^j = \left\{ (1-\beta_j) \left(u_t^j\right)^{1-1/\psi} + \beta_j \left(\mathbb{E}_t \left[\left(U_{t+1}^j \right)^{1-\gamma_j} \right] \right)^{\frac{1-1/\psi}{1-\gamma_j}} \right\}^{\frac{1}{1-1/\psi}}$$

$$u_t^j = (C_t^j)^{1-\xi_t} (H_t^j)^{\xi_t}$$

  - Borrowers, intermediaries more impatient: $\beta_b = \beta_i < \beta_d$
  - Fixed intermediary/depositor housing demand: $H_t^I = \bar{K}^I, H_t^D = \bar{K}^D$.
  - **Housing demand** shock ξ_t.

Mortgage Contract

- Mortgages are geometric perpetuities with duration parameter δ
- Example: borrow face value M_0 at rate r_0^* at $t = 0$
  - Each period, pay off $1 - \delta$ of principal, $M_{t+1} = \delta M_t$.
  - Fixed rate: interest payment of $r_0^* M_t$ in each period (tax deductible).
- Costly debt renewal at endogenous rate
  - Renewers choose new mortgage balance M_t^* and house size K_t^*, subject to borrowing constraint at origination: $M_t^* \leq \phi^K p_t K_t^*$.
- Default and foreclosure
  - Indiv. borrowers draw idiosyncratic house value shocks $\omega_{i,t} \overset{iid}{\sim} \Gamma_{\omega,t}$. Endogenous fraction with worst shocks default.

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Idiosyncratic Shocks and Mortgage Default

- At start of t, all borrowers have same housing capital K_t^B, debt (M_t^B, A_t^B)
- Draw idiosyncratic/local home valuation shock $\omega_{i,t} \overset{iid}{\sim} \Gamma_{\omega,t}$.
  - Local (insurable) component ($\omega_{i,t}^L$) + uninsurable indiv. component ($\omega_{i,t}^U$):

$$\log \omega_{i,t} = \log \omega_{i,t}^L + \log \omega_{i,t}^U$$

  - Constant local share of variation (α), time-varying XS variance:

$$\mathrm{Var}_t(\log \omega_{i,t}^L) = \alpha \sigma_{\omega,t}^2 \qquad \mathrm{Var}_t(\log \omega_{i,t}^U) = (1-\alpha)\sigma_{\omega,t}^2$$

- Borrowers with $\omega_{i,t} < \bar{\omega}_t$ optimally default. Banks seize housing capital and erase debt of defaulting borrowers.
  - Default rate: $Z_{D,t} = \Gamma_{\omega,t}(\bar{\omega}_t)$.
  - Frac. housing retained: $Z_{K,t} = \int_{\omega_{i,t} > \bar{\omega}_t} \omega_{i,t} \, d\Gamma_{\omega,t}$.

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Mortgage Contract: Summary

- State variables for borrower: principal balance (M_t^B), promised interest payment (A_t^B), borrower-owned housing (K_t^B).
  1. Costly debt renewal at endog. rate $Z_{R,t}$.
  2. Default and foreclosure at endog. rate $Z_{D,t}$.

- Transition laws:

$$M_{t+1}^B = \bar{\pi}^{-1} \left[Z_{R,t}(1 - Z_{D,t})M_t^* + \delta(1 - Z_{R,t})(1 - Z_{D,t})M_t^B \right]$$

$$A_{t+1}^B = \bar{\pi}^{-1} \left[Z_{R,t}(1 - Z_{D,t})r_t^* M_t^* + \delta(1 - Z_{R,t})(1 - Z_{D,t})A_t^B \right]$$

$$K_{t+1}^B = Z_{R,t}(1 - Z_{D,t})K_t^* + (1 - Z_{R,t})Z_{K,t}K_t^B$$

Indexation: Basics

- Define a borrower's initial leverage as $\lambda = M/p\omega K$, where p is national house price, and ω is relative value of individual house.

- Housing wealth hit by two forces that shift leverage:

$$p\omega K \rightarrow \left(\frac{p'}{p}\right) \cdot \left(\frac{\omega'}{\omega}\right) \cdot p\omega K, \qquad \lambda' = \left(\frac{1}{p'/p}\right) \cdot \left(\frac{1}{\omega'/\omega}\right) \lambda$$

  for idiosyncratic shock ω.

- Indexation scales mortgage debt, dampening shocks to leverage:

$$M \rightarrow \zeta_p \cdot \zeta_\omega \cdot M, \qquad \lambda' = \left(\frac{\zeta_p}{p'/p}\right) \cdot \left(\frac{\zeta_\omega}{\omega'/\omega}\right) \lambda$$

- Full indexation ($\zeta_p = p'/p,\ \zeta_\omega = \omega'/\omega$) implies $\lambda' = \lambda$.

Indexation: Implementation

- **SAM**: index by scaling both principal balance and payment

  1. Aggregate: $\zeta_{p,t} = \frac{p_t}{p_{t-1}}$
  2. Individual/local: $\zeta_\omega(\omega_{i,t}) = \frac{\omega^L_{i,t}}{\omega^L_{i,t-1}}$

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$$M^B_{t+1} = \bar{\pi}^{-1} \left[Z_{R,t}(1 - Z_{D,t})M^*_t + \delta(1 - Z_{R,t})(1 - Z_{D,t})M^B_t \right]$$

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- Default threshold ("Q" terms are average continuation values/costs):

$$\bar{\omega}^U_{i,t} = \frac{1}{\omega^L_{i,t}} \cdot \frac{Q_{A,t}A_t + Q_{M,t}M_t}{Q_{K,t}K^B_t}$$

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Borrowers

- Perfect sharing of nondurable consumption and housing services risk *within* borrower family $\implies$ aggregation.
- Representative borrower chooses
  - housing and non-housing consumption
  - refinancing rate
  - for refinancers only: $\begin{cases} \text{new mortgage balance} \\ \text{new housing purchases} \end{cases}$
  - default rate

  to maximize utility subject to budget constraint and loan-to-value constraint on **new** borrowing

Intermediaries

- Intermediary sector consists of **banks**, **REO firms**, and **households**
- Intermediary **households** receive endowment income and hold equity of banks and REO firms
- **Banks** maximize SHV, pay dividends to intermediary households
- Limited liability and deposit insurance s.t. capital requirement
- **REO firms** maximize SHV, pay dividends to intermediary households

Complete Problem

Intermediaries

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- Intermediary **households** receive endowment income and hold equity of banks and REO firms
- **Banks** maximize SHV, pay dividends to intermediary households
  - Issue new loans to borrowers
  - Take deposits from depositors
  - Seize foreclosed properties and sell to REO firms at price $p_t^{REO} < p_t$
  - Trade mortgages on the secondary market (IO + PO strips)
- Limited liability and deposit insurance s.t. capital requirement
- **REO firms** maximize SHV, pay dividends to intermediary households

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- **Banks** maximize SHV, pay dividends to intermediary households
- Limited liability and deposit insurance s.t. capital requirement
  - Receive idiosyncratic profit shocks and default if optimal
  - Government assumes all assets and liabilities of defaulting banks
  - Fraction η of bankrupt banks' assets are DWL to society
  - Capital requirement:

$$\text{deposits} \leq \phi^I(\text{MV of mortgage securities})$$

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- **REO firms** maximize SHV, pay dividends to intermediary households
  - Buy foreclosed houses from banks
  - Maintain REO housing stock ($\nu^{REO} > \nu$)
  - Rent current REO stock to borrowers
  - Slowly sell REO properties back to borrowers

Complete Problem

Depositors and Government

Depositors:

- More patient than borrowers and intermediaries
- Only invest in deposits

Government:

- Discretionary spending from income tax net of mortgage deduction
- Funds fraction τ_L of deposit shortfall of failing banks through lump-sum taxation, the remainder by issuing debt

$$q_t^f B_{t+1}^G = (1 - \tau_L) \left(B_t^G + \text{bailout}_t \right)$$

- Benchmark case: immediate full taxation ($\tau_L = 1, B_t^G = 0 \; \forall t$)
- Results robust to partial debt funding with $\tau_L < 1$

Equilibrium

- Given prices and parameters, three households, banks, and REO firms maximize their value functions subject to budget and borrowing constraints
- Markets clear
  - New mortgages ($\rightarrow$ mortgage rate)
  - Secondary mortgage market ($\rightarrow$ mortgage bond price)
  - Housing purchases ($\rightarrow$ house price)
  - REO purchases ($\rightarrow$ REO house price)
  - Housing services ($\rightarrow$ rental rate)
  - Deposits and government debt ($\rightarrow$ riskfree rate)
- Resource constraint

$$Y_t = CONS_t + GOV_t + \underbrace{\nu^K p_t(\bar{K} - K_t^{REO})}_{\text{regular housing maint.}} + \underbrace{\nu^{REO} p_t K_t^{REO}}_{\text{REO housing maint.}} + \underbrace{DWL_t}_{\text{bank failures}}$$

State Variables and Solution Method

- Exogenous states
  - Persistent aggregate **income** Y_t, discretized
  - Persistent disp. of idio. housing (**uncertainty**) shock: $\sigma_{\omega,t}$
  - Persistent housing (**demand**) shock: ξ_t
- Six endogenous states: housing stock, mortgage principal, mortgage payments, deposits, intermediary wealth, government debt
  - Wealth distribution matters for asset prices due to incomplete markets
  - Intermediary wealth is a key state variable
- Nonlinear global solution method: policy time iteration
  - Risk premia have important implications for welfare results
  - Occasionally binding intermediary constraint
  - Non-linear dynamics when intermediaries are constrained

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Calibration

- Quarterly calibration targeting sample 1991.Q1 - 2016.Q1
  1. Demographics (pop., income) from 1998 SCF
     - "Borrower" is mortgagor with LTV $\geq$ 30% (hold 89% of debt).
     - Intermediary income based on FIRE sector.
  2. Exogenous shocks
  3. Mortgage debt: realistic calibration of prepayment and credit risk
  4. Banks: match average FDIC bank failure rate, receivership costs
  5. Preferences: EZ utility with EIS 1

All parameters

Calibration

- Quarterly calibration targeting sample 1991.Q1 - 2016.Q1

  1. Demographics (pop., income) from 1998 SCF
  2. Exogenous shocks
     - **Income**: AR(1), match detrended labor income persistence, vol.
     - **Uncertainty**: two regimes, transition probs match fraction of time in foreclosure crisis, vols to match conditional default rates.
     - **Housing demand**: same two regimes, match average expenditure share, house price vol.
  3. Mortgage debt: realistic calibration of prepayment and credit risk
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Calibration

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3. Mortgage debt: realistic calibration of prepayment and credit risk
   - Choose renewal cost parameters following Greenwald (2018)
   - Max LTV at origination 85%
   - REO maint. ν^{REO} to match loss given default on mortgages of 40%
4. Banks: match average FDIC bank failure rate, receivership costs
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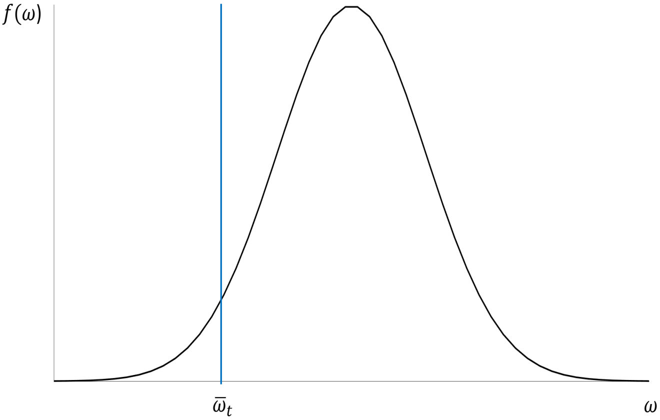
5. Preferences: EZ utility with EIS 1
   - $\beta_B = \beta_I = 0.95$: match borrower VTI
   - $\beta_S = 0.998$: mean r^f of 3% (ann.)
   - $\gamma = 5$: standard value

All parameters

Financial Recession Experiment

- Two sources of house price risk for lenders
  1. Fall in aggregate house price p_t
  2. Increase in cross-sectional dispersion ("uncertainty") $\sigma_{\omega,t}$



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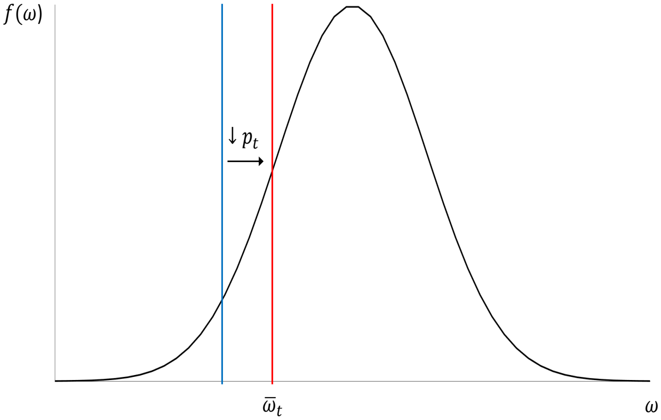

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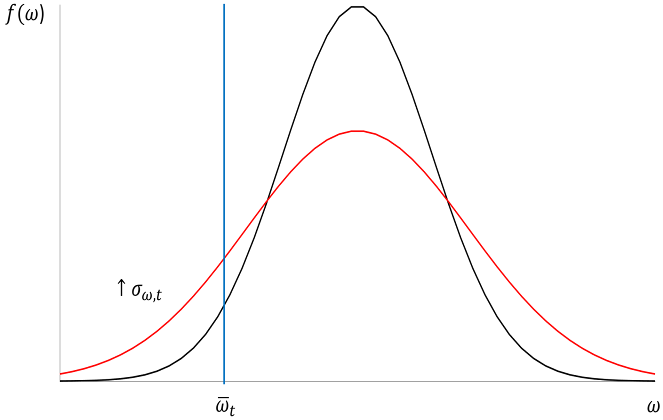
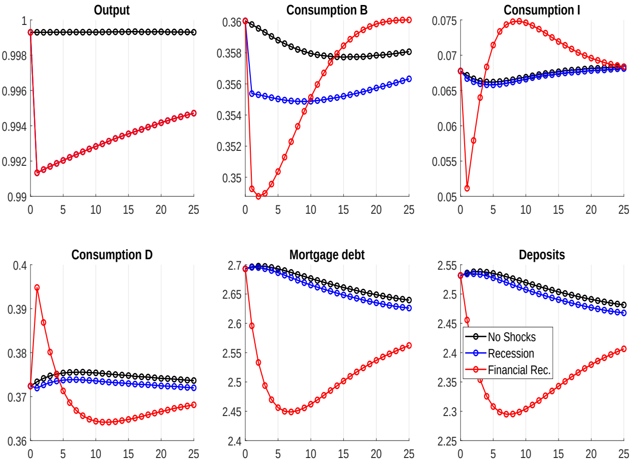


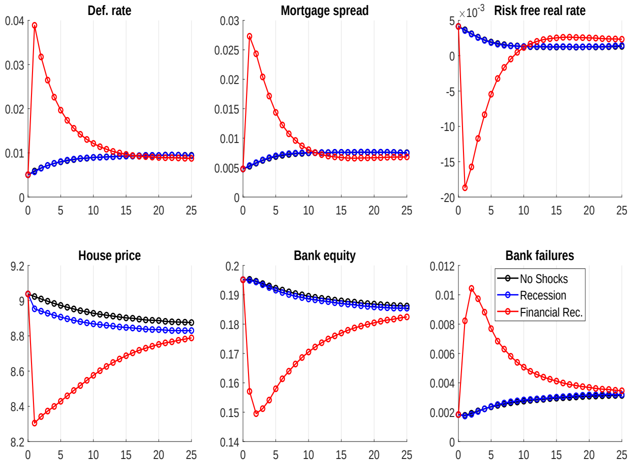
Financial Recession: Allocations

- Consumption shifts from $B, I \to D$ as financial sector contracts.



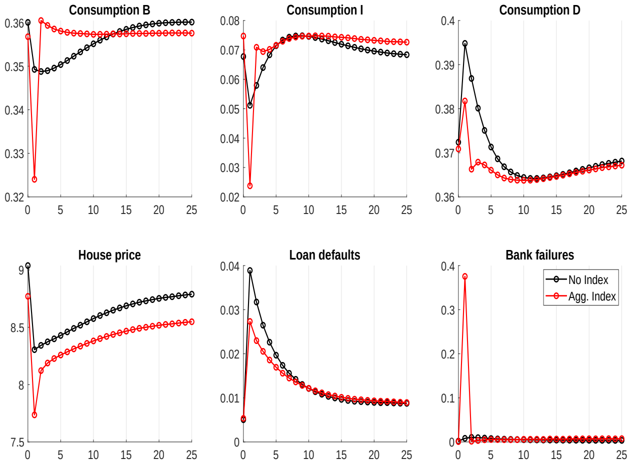
Financial Recession: Prices and Defaults

- Drop in house prices and short rate, spreads + defaults up.
- Sharp reduction in bank equity and spike in bank failures



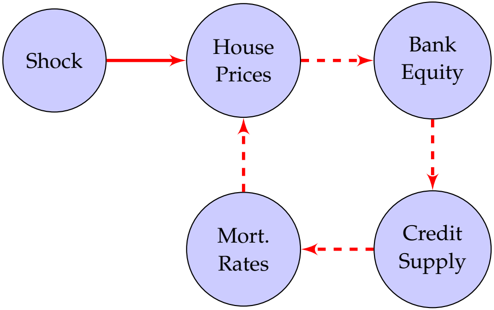
Aggregate Indexation: Financial Fragility

- Comparison: baseline vs. full aggregate indexation ($\zeta_p = p'/p$)
- Foreclosures $\downarrow$ (indiscriminate debt relief), bank failures $\uparrow\uparrow$.



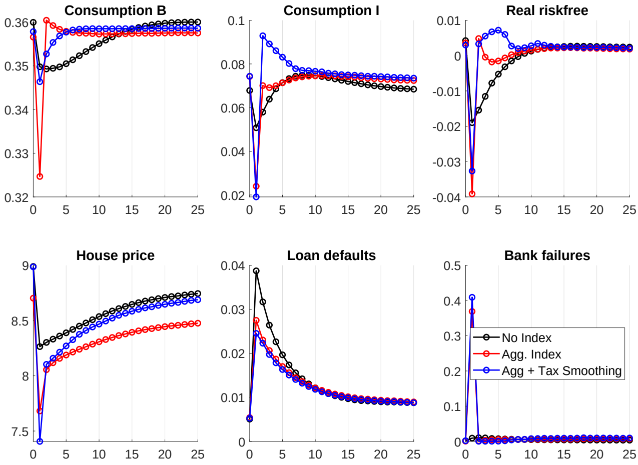
Financial Fragility: Mechanism

- Capital requirements: bank losses $\implies$ credit contraction.
- Feedback: larger losses $\implies$ higher rates $\implies$ lower house prices.
- Traditional mortgage: no forced delevering $\implies$ much less feedback.



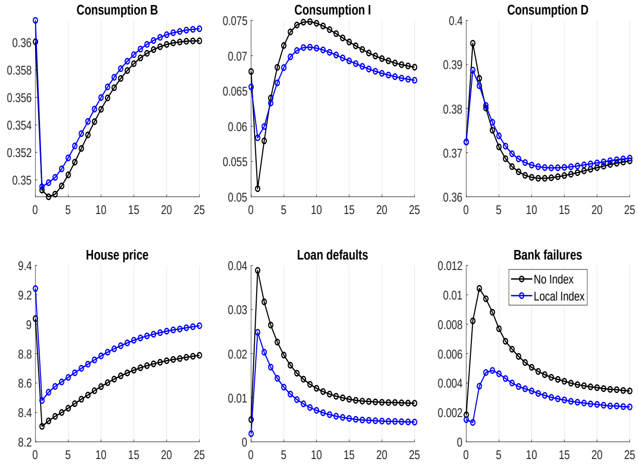
Aggregate Indexation: Financial Fragility

- Immediate financing of bailouts $\implies$ sharp consumption drops.
- Would tax smoothing help? No! Gov't debt crowds out deposits.



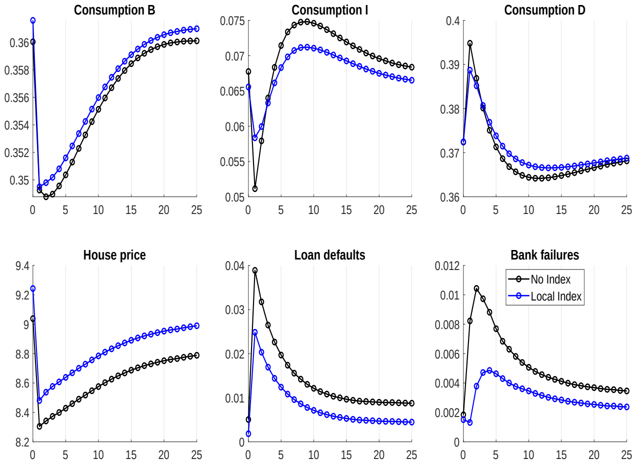
Local Indexation: Financial Stability

- Comparison: baseline vs. full local indexation ($\zeta_\omega = \omega_L' / \omega_L$)
- Local share of variance (α): 25%.



Local Indexation: Financial Stability

- Foreclosures ↓↓ (targeted debt relief)
- Bank failures ↓↓, financial fragility reduced



Model Moments by Indexation Regime (Quarterly)

- Regional model: indexation at aggregate and local levels.

	No Index	Aggregate	Local Only	Regional
Mortgage default rate	0.95%	0.92%	0.49%	0.47%
Bank equity ratio	7.09%	7.33%	7.13%	7.25%
Fraction leverage constr. binds	99.35%	90.16%	99.90%	90.92%
Bank failure rate	0.33%	0.84%	0.22%	0.50%
Mortgage rate	1.46%	1.54%	1.30%	1.35%
Credit spread	0.75%	0.87%	0.56%	0.60%
Mortgage excess return	0.34%	0.49%	0.35%	0.40%
House price	8.842	8.595	9.042	8.784
Mortgage debt	259.59%	252.53%	274.88%	267.74%
Deposits	2.454	2.381	2.599	2.526

Model Moments by Indexation Regime (Quarterly)

- Defaults: no indexation $>$ agg. indexation $>>$ local indexation.

	No Index	Aggregate	Local Only	Regional
Mortgage default rate	0.95%	0.92%	0.49%	0.47%
Bank equity ratio	7.09%	7.33%	7.13%	7.25%
Fraction leverage constr. binds	99.35%	90.16%	99.90%	90.92%
Bank failure rate	0.33%	0.84%	0.22%	0.50%
Mortgage rate	1.46%	1.54%	1.30%	1.35%
Credit spread	0.75%	0.87%	0.56%	0.60%
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Deposits	2.454	2.381	2.599	2.526

Model Moments by Indexation Regime (Quarterly)

- Agg. indexation: extra capital insufficient against higher risk.

	No Index	Aggregate	Local Only	Regional
Mortgage default rate	0.95%	0.92%	0.49%	0.47%
Bank equity ratio	7.09%	7.33%	7.13%	7.25%
Fraction leverage constr. binds	99.35%	90.16%	99.90%	90.92%
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Deposits	2.454	2.381	2.599	2.526

Model Moments by Indexation Regime (Quarterly)

- Higher financial fragility $\Longrightarrow$ higher spreads, profits.

	No Index	Aggregate	Local Only	Regional
Mortgage default rate	0.95%	0.92%	0.49%	0.47%
Bank equity ratio	7.09%	7.33%	7.13%	7.25%
Fraction leverage constr. binds	99.35%	90.16%	99.90%	90.92%
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Deposits	2.454	2.381	2.599	2.526

Model Moments by Indexation Regime (Quarterly)

- Lower risk/rates $\Longrightarrow$ higher house prices $\Longrightarrow$ debt, deposits $\uparrow$.

	No Index	**Aggregate**	**Local Only**	**Regional**
Mortgage default rate	0.95%	0.92%	0.49%	0.47%
Bank equity ratio	7.09%	7.33%	7.13%	7.25%
Fraction leverage constr. binds	99.35%	90.16%	99.90%	90.92%
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House price	8.842	8.595	9.042	8.784
Mortgage debt	259.59%	252.53%	274.88%	267.74%
Deposits	2.454	2.381	2.599	2.526

Comparing Indexation Regimes: Welfare

- Agg. indexation: borrowers lose, intermediaries gain!

	No Index	Aggregate	Local Only	Regional
Value function, B	0.379	-0.57%	+0.43%	+0.27%
Value function, D	0.374	-0.07%	+0.07%	+0.47%
Value function, I	0.068	+5.66%	-2.11%	-0.21%
Consumption, B	0.359	-0.3%	+0.3%	+0.1%
Consumption, D	0.372	-0.6%	+0.1%	+0.3%
Consumption, I	0.068	+6.1%	-2.9%	-0.4%
Consumption gr vol, B	0.42%	+351.3%	+15.9%	+189.0%
Consumption gr vol, D	1.11%	-10.4%	-26.5%	-15.4%
Consumption gr vol, I	4.47%	+392.9%	-54.1%	+282.5%
Wealth gr vol, I	0.035	+1366.8%	-1.8%	+679.3%
log (MU B / MU D) vol	0.025	-4.6%	-10.4%	-21.5%
log (MU B / MU I) vol	0.061	+145.7%	-36.8%	+101.8%

Comparing Indexation Regimes: Welfare

- Higher spreads, bailouts $\implies$ higher intermediary consumption.

	No Index	Aggregate	Local Only	Regional
Value function, B	0.379	-0.57%	+0.43%	+0.27%
Value function, D	0.374	-0.07%	+0.07%	+0.47%
Value function, I	0.068	+5.66%	-2.11%	-0.21%
Consumption, B	0.359	-0.3%	+0.3%	+0.1%
Consumption, D	0.372	-0.6%	+0.1%	+0.3%
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log (MU B / MU I) vol	0.061	+145.7%	-36.8%	+101.8%

Comparing Indexation Regimes: Welfare

- Agg. indexation sharply increases consumption vol for B, I.

	No Index	Aggregate	Local Only	Regional
Value function, B	0.379	-0.57%	+0.43%	+0.27%
Value function, D	0.374	-0.07%	+0.07%	+0.47%
Value function, I	0.068	+5.66%	-2.11%	-0.21%
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log (MU B / MU D) vol	0.025	-4.6%	-10.4%	-21.5%
log (MU B / MU I) vol	0.061	+145.7%	-36.8%	+101.8%

Comparing Indexation Regimes: Welfare

- Improved risk sharing under local indexation.

	No Index	Aggregate	Local Only	Regional
Value function, B	0.379	-0.57%	+0.43%	+0.27%
Value function, D	0.374	-0.07%	+0.07%	+0.47%
Value function, I	0.068	+5.66%	-2.11%	-0.21%
Consumption, B	0.359	-0.3%	+0.3%	+0.1%
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log (MU B / MU I) vol	0.061	+145.7%	-36.8%	+101.8%

Comparison: Alternative Contracts

- Indexation of interest only ("IO"): effects much weaker since only last until next renewal.

	No Index	Regional	Reg. IO	Reg. Asym.
Deposits	2.454	2.526	2.484	2.196
House Price	8.842	8.784	8.806	8.488
Mortgage Debt	259.59%	267.74%	261.60%	231.85%
Mortgage Rate	1.46%	1.35%	1.41%	2.37%
Refi Rate	3.84%	3.74%	3.84%	4.42%
Default Rate	0.95%	0.47%	0.80%	0.12%
Bank Failure Rate	0.33%	0.50%	0.30%	0.94%
Value Function, B	0.379	+0.27%	+0.30%	+1.85%
Value Function, D	0.374	+0.47%	+0.25%	+0.07%
Value Function, I	0.068	-0.21%	-0.61%	-1.91%

Comparison: Alternative Contracts

- Asymmetric indexation where payments can only fall ("Asym"): increases financial fragility, shrinks mortgage balances

	No Index	Regional	Reg. IO	Reg. Asym.
Deposits	2.454	2.526	2.484	2.196
House Price	8.842	8.784	8.806	8.488
Mortgage Debt	259.59%	267.74%	261.60%	231.85%
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Refi Rate	3.84%	3.74%	3.84%	4.42%
Default Rate	0.95%	0.47%	0.80%	0.12%
Bank Failure Rate	0.33%	0.50%	0.30%	0.94%
Value Function, B	0.379	+0.27%	+0.30%	+1.85%
Value Function, D	0.374	+0.47%	+0.25%	+0.07%
Value Function, I	0.068	-0.21%	-0.61%	-1.91%

Comparison: Alternative Contracts

- Eliminates most foreclosures, but does so by shrinking leverage, not improving insurance $\implies$ banks dislike.

	No Index	**Regional**	**Reg. IO**	**Reg. Asym.**
Deposits	2.454	2.526	2.484	2.196
House Price	8.842	8.784	8.806	8.488
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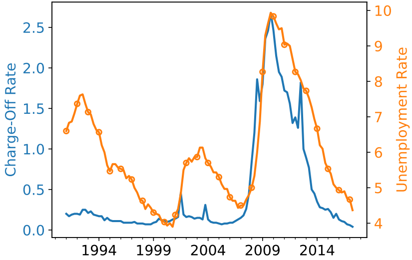
Bank Failure Rate	0.33%	0.50%	0.30%	0.94%
Value Function, B	0.379	+0.27%	+0.30%	+1.85%
Value Function, D	0.374	+0.47%	+0.25%	+0.07%
Value Function, I	0.068	-0.21%	-0.61%	-1.91%

Conclusion

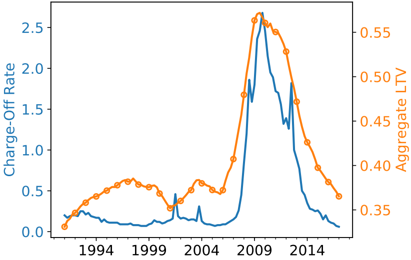
- General equilibrium model of intermediated mortgage market allowing for indexed mortgage contracts.
- Effect depends on type of indexation:
  - Aggregate indexation: amplifies intermediary sector instability.
  - Local indexation: dampens intermediary sector instability.
- Costs of indexation partly born by taxpayer
- Nature of indexation matters for macro implications
  - Indexing principal more effective than interest.
  - Asymmetric indexation has potent effects, but largely through leverage.
  - Misalignment between bank, social incentives may be major obstacle.

Strategic vs. Liquidity Defaults

- Liquidity shocks only turn into defaults when borrower is underwater (double trigger).
- Reducing principal burden may be most effective way to prevent liquidity defaults.
- Extension including liquidity defaults yields very similar results.



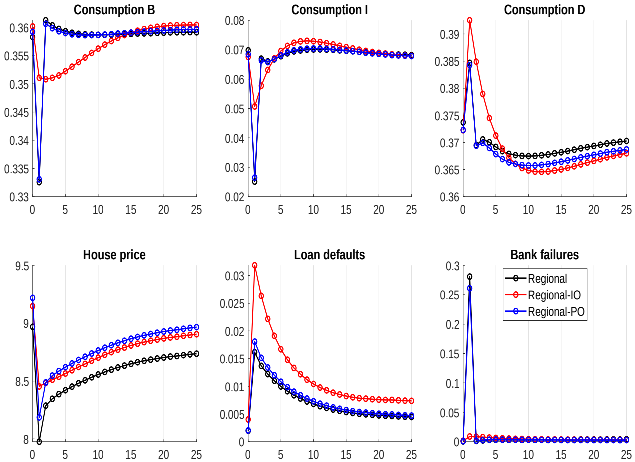
(a) Charge-Offs vs. Unemp.



(b) Charge-Offs vs. LTV

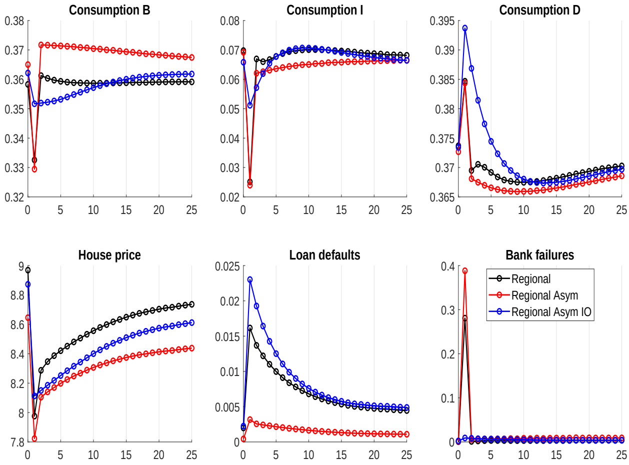
Interest vs. Principal Indexation

- Comparison: regional indexation vs. regional interest-only indexation vs. regional principal-only indexation.



Asymmetric Indexation

- Asymmetric indexation: cap upward indexation at 20% for each component.



Transition Comparison: Asymmetric Contracts

- Black: response on impact. Blue: steady state response.

	No Index	Regional	Reg. Asym.	Reg. Asym. IO
Welfare	0.821	+0.61% (+0.32%)	+0.90% (+0.73%)	+0.28% (+0.25%)
V^B	0.379	+0.68% (+0.27%)	+1.76% (+1.85%)	+0.36% (+0.53%)
V^D	0.374	+0.54% (+0.47%)	+0.11% (+0.07%)	+0.47% (+0.37%)
V^I	0.068	+0.53% (-0.21%)	+0.51% (-1.91%)	-1.25% (-2.02%)
C^B	0.359	+0.50% (+0.08%)	-1.00% (+1.92%)	-0.18% (+0.51%)
C^D	0.372	+0.82% (+0.26%)	+0.47% (+0.05%)	+2.42% (+0.44%)
C^I	0.068	+4.63% (-0.40%)	+18.26% (-1.65%)	+0.35% (-2.88%)
Deposits	2.454	+5.98% (+2.90%)	-8.34% (-10.52%)	+3.79% (-3.31%)
p	8.842	+2.30% (-0.66%)	-2.11% (-4.01%)	+0.73% (-2.03%)
M^B	2.596	+4.76% (+3.14%)	+4.76% (-10.69%)	+4.76% (+0.25%)
r^*	1.46%	-0.04pp (-0.11pp)	+0.80pp (+0.91pp)	+0.06pp (+0.09pp)
Refi Rate	3.84%	-0.00pp (-0.09pp)	-0.82pp (+0.59pp)	-0.15pp (-0.27pp)
Loss Rate	0.40%	-0.33pp (-0.20pp)	+0.42pp (+0.51pp)	-0.11pp (-0.05pp)
Failures	0.33%	-0.24pp (+0.16pp)	-0.29pp (+0.60pp)	-0.20pp (+0.01pp)

Transition Comparison: Interest vs. Principal

- Black: response on impact. Blue: steady state response.

	No Index	Regional	Regional IO	Regional PO
Welfare	0.821	+0.61% (+0.32%)	+0.36% (+0.20%)	+0.51% (+0.18%)
V^B	0.379	+0.68% (+0.27%)	+0.61% (+0.30%)	+0.83% (+0.33%)
V^D	0.374	+0.54% (+0.47%)	+0.34% (+0.25%)	+0.28% (+0.21%)
V^I	0.068	+0.53% (-0.21%)	-0.95% (-0.61%)	-0.03% (-0.75%)
C^B	0.359	+0.50% (+0.08%)	+0.78% (+0.11%)	+1.11% (+0.29%)
C^D	0.372	+0.82% (+0.26%)	+1.49% (+0.28%)	+0.32% (+0.17%)
C^I	0.068	+4.63% (-0.40%)	-1.09% (-1.07%)	+3.00% (-1.65%)
Deposits	2.454	+5.98% (+2.90%)	+5.84% (+1.20%)	+6.52% (+4.02%)
p	8.842	+2.30% (-0.66%)	+2.58% (-0.40%)	+3.55% (+0.66%)
M^B	2.596	+4.76% (+3.14%)	+4.76% (+0.77%)	+4.76% (+4.32%)
r^*	1.46%	-0.04pp (-0.11pp)	-0.05pp (-0.05pp)	-0.07pp (-0.14pp)
Refi Rate	3.84%	-0.00pp (-0.09pp)	+0.07pp (+0.01pp)	+0.10pp (-0.08pp)
Loss Rate	0.40%	-0.33pp (-0.20pp)	-0.24pp (-0.08pp)	-0.33pp (-0.20pp)
Failures	0.33%	-0.24pp (+0.16pp)	-0.19pp (-0.03pp)	-0.21pp (-0.02pp)

Borrower Complete Problem ▸ Back

$$\max_{C_t^B, H_t^B, M_t^*, K_t^*, Z_{D,t}, Z_{R,t}} \quad V^B(K_t^B, A_t^B, M_t^B)$$

subject to

$$C_t^B = \underbrace{(1-\tau_t)Y_t^B}_{\text{income}} + \underbrace{Z_{R,t}\left((1-Z_{D,t})M_t^* - \delta Z_{M,t}M_t^B\right)}_{\text{net new borrowing}} - \underbrace{(1-\delta)Z_{M,t}M_t^B}_{\text{principal payment}}$$

$$- \underbrace{(1-\tau)Z_{M,t}A_t^B}_{\text{interest payment}} - \underbrace{p_t\left[Z_{R,t}(1-Z_{D,t})K_t^* + \left(\nu^K - Z_{R,t}\right)Z_{K,t}K_t^B\right]}_{\text{owned housing}}$$

$$- \underbrace{\rho_t\left(H_t^B - K_t^B\right)}_{\text{rental housing}} - \underbrace{\left(\Psi(Z_{R,t}) - \bar{\Psi}_t\right)(1-Z_{D,t})M_t^*}_{\text{net transaction costs}} - \underbrace{T_t^B}_{\text{lump-sum taxes}}$$

and

$$M_{t+1}^B = \bar{\pi}^{-1}\zeta_{p,t+1}\left[Z_{R,t}(1-Z_{D,t})M_t^* + \delta(1-Z_{R,t})Z_{M,t}M_t^B\right]$$

$$A_{t+1}^B = \bar{\pi}^{-1}\zeta_{p,t+1}\left[Z_{R,t}(1-Z_{D,t})r_t^* M_t^* + \delta(1-Z_{R,t})Z_{M,t}A_t^B\right]$$

$$K_{t+1}^B = Z_{R,t}(1-Z_{D,t})K_t^* + (1-Z_{R,t})Z_{K,t}K_t^B$$

$$M_t^* \le \phi^K p_t K_t^*$$

Bank Complete Problem ▸ Back

$$V^I(W_t^I, \mathcal{S}_t^I) = \max_{L_t^*, \tilde{M}_t^I, \tilde{A}_t^I, B_{t+1}^I} \quad W_t^I - J_t^I$$
$$+ \mathrm{E}_t \left[\Lambda_{t,t+1}^I \, F_\epsilon^I \left(V^I(W_{t+1}^I, \mathcal{S}_{t+1}^I) \right) \left(V^I(W_{t+1}^I, \mathcal{S}_{t+1}^I) - \epsilon_{t+1}^{I,-} \right) \right]$$

subject to

$$B_{t+1}^I \leq \phi^I \left(q_t^A \tilde{A}_t^I + q_t^M \tilde{M}_t^I \right)$$
$$J_t^I = \underbrace{(1 - r_t^* q_t^A - q_t^M) L_t^*}_{\text{net new debt}} + \underbrace{q_t^A \tilde{A}_t^I}_{\text{IO strips}} + \underbrace{q_t^M \tilde{M}_t^I}_{\text{PO strips}} - \underbrace{q_t^f B_{t+1}^I}_{\text{new deposits}}$$
$$W_{t+1}^I = \underbrace{\left[X_{t+1} + Z_{A,t+1} \Big((1-\delta) + \delta Z_{R,t+1} \Big) \right] M_{t+1}^I + Z_{A,t+1} A_{t+1}^I}_{\text{payments on existing debt}}$$
$$+ \underbrace{\delta (1 - Z_{R,t+1}) Z_{A,t+1} \left(q_{t+1}^A A_{t+1}^I + q_{t+1}^M M_{t+1}^I \right)}_{\text{sales of IO and PO strips}} - \underbrace{\pi_{t+1}^{-1} B_{t+1}^I}_{\text{deposit redemptions}}$$

where $X_t = \frac{(1 - Z_{K,t}) K_t^B (p_t^{REO} - \nu^{REO} p_t)}{M_t^B}$

Calibration: All Parameters ▸ Back

Parameter	Name	Value	Target/Source
Agg. income persistence	ρ_{TFP}	0.977	Real per capita labor income BEA
Agg. income st. dev.	σ_{TFP}	0.008	Real per capita labor income BEA
Housing st. dev. (Normal)	$\bar{\sigma}_{\omega,L}$	0.200	Mortg. delinq. rate US banks, no crisis
Housing st. dev. (Crisis)	$\bar{\sigma}_{\omega,H}$	0.250	Mortg. delinq. rate US banks, crisis
Profit shock st. dev.	σ_ϵ	0.070	FDIC bank failure rate
Fraction of borrowers	χ_B	0.343	SCF 1998 population share LTV>.30
Fraction of intermediaries	χ_I	0.020	Stock market cap. share of finance sector
Borr. inc. and housing share	s_B	0.470	SCF 1998 income share LTV>.30
Intermediary inc. and housing share	s_I	0.067	Employment share in finance
Tax rate	τ	0.147	Personal tax rate BEA
Housing stock	$\bar{K}$	1	Normalization
Inflation rate	$\bar{\pi}$	1.006	2.29% CPI inflation
Mortgage duration	δ	0.996	Duration of 30-yr FRM
Prepayment cost mean	μ_κ	0.370	Greenwald (2018)
Prepayment cost scale	s_κ	0.152	Greenwald (2018)
LTV limit	ϕ^K	0.850	LTV at origination
Maint. cost (owner)	ν^K	0.006	BEA Fixed Asset Tables
Bank regulatory capital limit	ϕ^I	0.940	Financial sector leverage
Deadweight cost of bank failures	ζ	0.085	Bank receivership expense rate
Maint. cost (REO)	ν^{REO}	0.024	REO discount: $p^{REO}_{ss}/p_{ss} = 0.725$
REO sale rate	S^{REO}	0.167	Length of foreclosure crisis
Borr. discount factor	β_B	0.950	Borrower debt/value, SCF
Intermediary discount factor	β_I	0.950	Equal to β_B
Depositor discount factor	β_D	0.998	2% real rate
Risk aversion	γ	5.000	Standard value
EIS	ψ	1.000	Standard value
Housing preference	ξ	0.220	Borrower value/income, SCF