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
  - Seven million U.S. home owners lost their homes
  - Large deadweight losses associated with foreclosure

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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.

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- Foreclosure crisis called into question this risk-sharing arrangement
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- But is it safe to shift house price losses to lenders?
- **Broader research question**: What are equilibrium implications of alternative risk sharing arrangements in world where financial intermediaries enjoy deposit insurance and bailout guarantees?

This Paper

- **Concrete question**: how do Shared Appreciation Mortgage (SAM) contracts influence financial stability and risk sharing?

- **Approach**: build a GE model of mortgage and housing market with explicit financial sector that intermediates 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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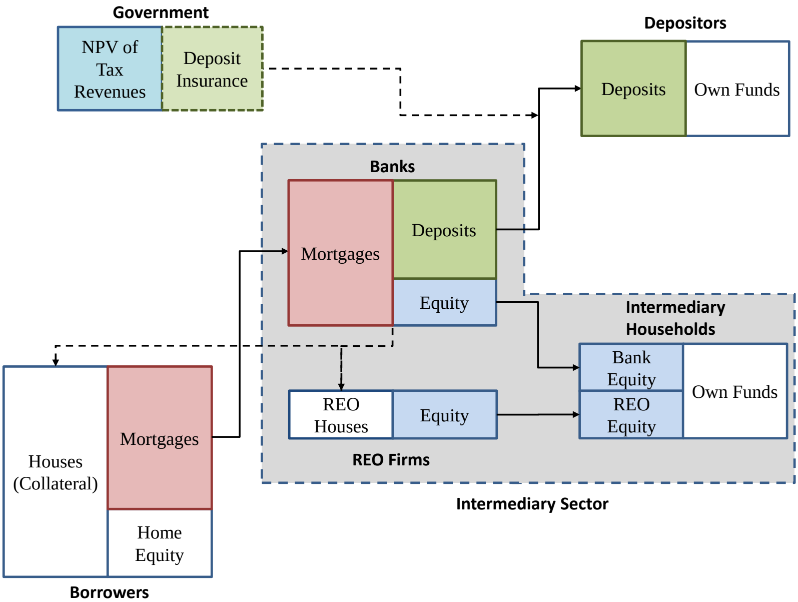
  - Start from realistic mortgage debt contracts: long-term, nominal, prepayable, defaultable
  - Consider different forms of mortgage payment indexation (SAMs)
- **Policy conclusion**: only carefully designed mortgage indexation leads to aggregate stability and risk-sharing benefits.
  - Commonly proposed 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

Model Overview



Model Ingredients

- Borrowers:
  - Choose whether to exercise default option.
  - Realistic long-term mortgages, endogenous refinancing.
- Financial intermediaries/banks:
  - Choose mortgage origination volume and leverage.
  - Can default: bailouts financed by taxpayers (deposit insurance).
  - Face capital requirements (moral hazard).
- Depositors:
  - Final investors with preference for safe assets.
  - Do not participate in risky asset markets.

Demographics, Endowments, Preferences, Inflation

- 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
- Inflation

Demographics, Endowments, Preferences, Inflation

- 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
- Inflation

Demographics, Endowments, Preferences, Inflation

- 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.
- Inflation

Demographics, Endowments, Preferences, Inflation

- Demographics
- Endowments
- Preferences
- Inflation
  - Nominal contracts, constant inflation rate $\bar{\pi}$

Mortgage Contract: Basics

- Mortgages are geometric perpetuities with duration parameter δ
- Example: borrow face amount M_0 at rate r_0^* at $t = 0$
  - Each period, pay off $1 - \delta$ of principal, $M_{t+1} = \delta M_t$.
- Promised repayments to lender:

t	1	2	3	…
Principal (M_t)	$(1-\delta) \cdot M_0$	$(1-\delta) \cdot \delta M_0$	$(1-\delta) \cdot \delta^2 M_0$	…
Interest (A_t)	$r_0^* \cdot M_0$	$r_0^* \cdot \delta M_0$	$r_0^* \cdot \delta^2 M_0$	…

- Payments are tax deductible for borrower.

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Mortgage Contract: Overview

- State variables: principal balance (M_t^B), promised interest payment (A_t^B), borrower-owned housing (K_t^B).
- Transition laws (start simple and build up):

$$
\begin{aligned}
M_{t+1}^B &= \bar{\pi}^{-1} \left[M_t^* + \delta M_t^B \right] \\
A_{t+1}^B &= \bar{\pi}^{-1} \left[r_t^* M_t^* + \delta A_t^B \right] \\
K_{t+1}^B &= K_t^B
\end{aligned}
$$

Mortgages: Refinancing

- Mortgages are geometric perpetuities with duration parameter δ
- Realistic prepayment option allows separate tracking of outstanding principal balance (M_t^B) and promised interest payment (A_t^B)
  - Effective interest rate on old debt: $r_t^B = A_t^B / M_t^B$
- Refinancing and new house purchases
  - Indiv. borrowers draw iid transaction costs for refi $\kappa_{i,t} \sim \Gamma_\kappa(\kappa)$
  - Optimal policy: fraction $Z_{R,t} = \Gamma_\kappa(\bar{\kappa}_t)$ refinance
  - Refinancers choose new mortgage balance M_t^* and house of size K_t^*, subject to LTV constraint $M_t^* \leq \phi^K p_t K_t^*$ at origination (only).

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

1. Costly debt refinancing at endog. rate $Z_{R,t}$.

Mortgages: Defaults

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

$$\log \omega_{i,t} = \log \omega_{i,t}^L + \log \omega_{i,t}^U$$
$$\log \omega_{i,t}^j = (1-\rho_\omega)\mu_j + \rho_\omega \log \omega_{i,t-1}^j + \varepsilon_t^j, \qquad j \in \{L, U\}$$

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

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

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

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

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

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

1. Costly debt renewal at endog. rate $Z_{R,t}$.

2. Default and foreclosure at endog. rate $Z_{D,t}$.

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

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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.
- Rep. borrower chooses consumption (C_t^B, H_t^B), new mortgage balances M_t^* and assoc. houses K_t^*, refinancing rate $Z_{R,t}$, and default rate $Z_{D,t}$ to maximize V_t^B, subject to laws of motion, budget constraint

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

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

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

and loan-to-value constraint on **new** borrowing: $\quad M_t^* \leq \phi^K p_t K_t^*$

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
- Enjoy limited liability and deposit insurance
- Subject to regulatory capital requirement
- **REO firms** maximize SHV, pay dividends to intermediary households

Complete Problem

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
  - 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)
- Enjoy limited liability and deposit insurance
- Subject to regulatory capital requirement
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- **Banks** maximize SHV, pay dividends to intermediary households
- Enjoy limited liability and deposit insurance
  - Receive idiosyncratic profit shocks and optimally default
  - Government assumes all assets and liabilities of defaulting banks
  - Fraction η of bankrupt banks' assets are DWL to society
- Subject to regulatory capital requirement
- **REO firms** maximize SHV, pay dividends to intermediary households

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

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▸ Complete Problem

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- Enjoy limited liability and deposit insurance
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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: $G_t = \tau \underbrace{\left(Y_t - Z_{A,t} A_t^B\right)}_{\text{income net of interest}}$
- Funds deposit shortfall of failing banks through lump-sum taxation, proportional to population shares

$$T_t^j = \chi_j \cdot \text{bailout}_t$$

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

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

Details

State Variables and Solution Method

- Exogenous states
  - Persistent aggregate **income** Y_t
  - Persistent disp. of idio. housing (**uncertainty**) shock: $\sigma_{\omega,t}$ (by regime)
  - Persistent housing (**demand**) shock: ξ_t (by regime)
- Five endogenous states: housing stock, mortgage principal, mortgage payments, deposits, intermediary wealth
  - Wealth distribution matters for asset prices due to incomplete markets
  - Intermediary wealth is a key state variable
- Nonlinear global solution method: policy time iteration
  - Occasionally binding intermediary constraint
  - Risk premia have important implications for welfare results
  - 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.
     - Housing shares = income shares.
  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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1. Demographics (pop., income) from 1998 SCF
2. Exogenous shocks
3. Mortgage debt: realistic calibration of prepayment and credit risk
   - Choose refi 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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Calibration

- Quarterly calibration targeting sample 1991.Q1 - 2016.Q1
  1. Demographics (pop., income) from 1998 SCF
  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

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  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
     - $\beta_B = \beta_I = 0.95$: match borrower VTI
     - $\beta_S = 0.998$: mean r^f of 3% (ann.)
     - $\gamma = 5$: standard value

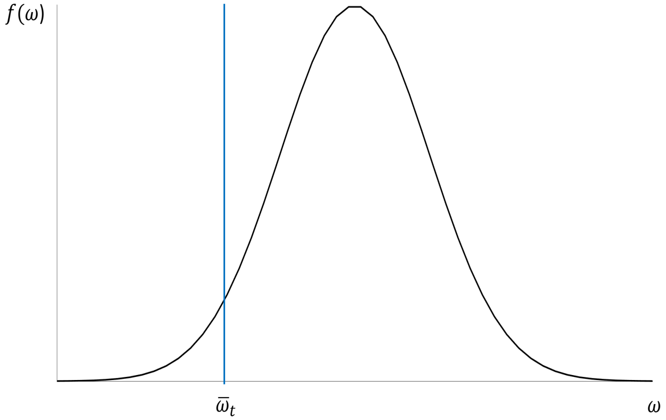
All parameters

RESULTS

Financial Recession Experiment

- Two sources of house price risk for lenders

    1. Fall in aggregate house price p_t (housing utility shock).
    2. Increase in cross-sectional dispersion ("uncertainty") $\sigma_{\omega,t}$



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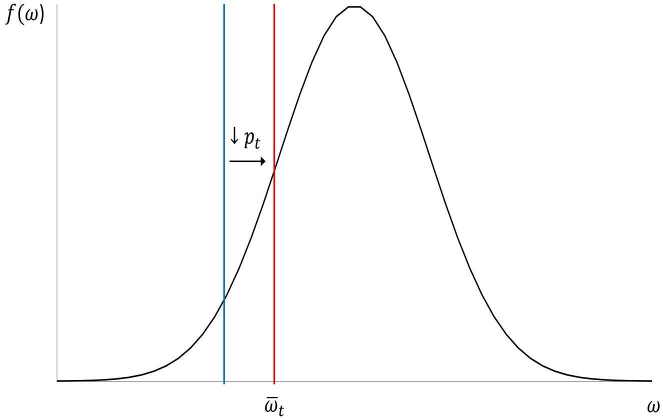

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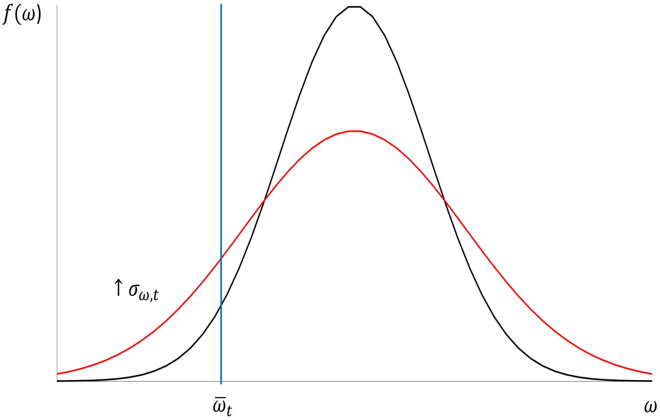
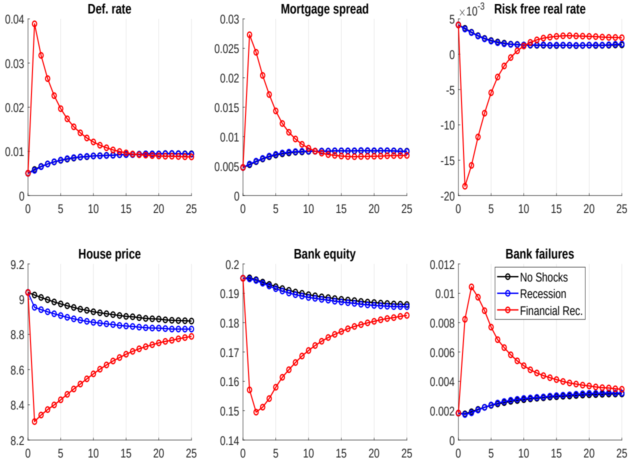


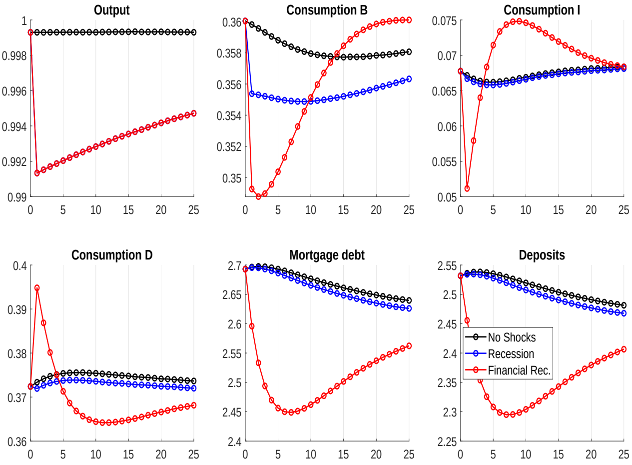
Financial Recession: Prices and Defaults

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



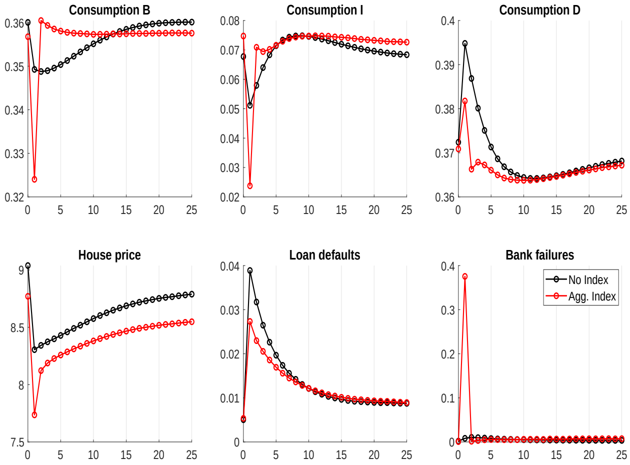
Financial Recession: Allocations

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



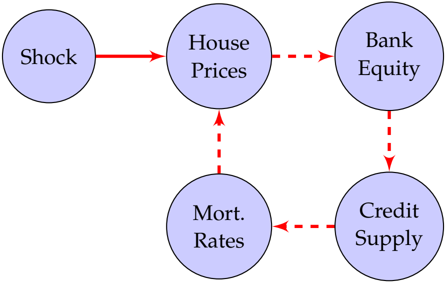
Aggregate Indexation: Financial Fragility

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



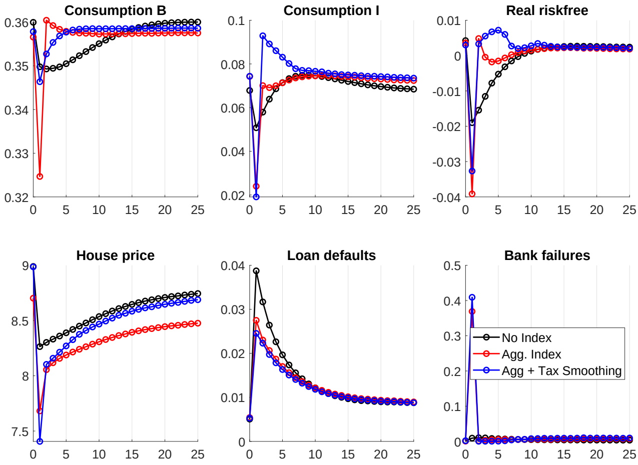
Financial Fragility: Mechanism

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



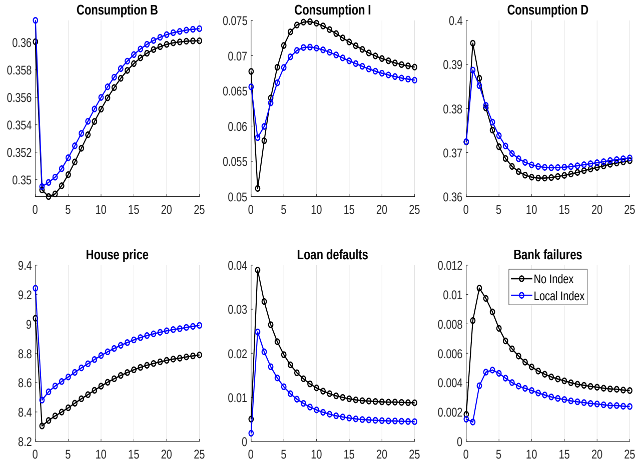
Aggregate Indexation: Financial Fragility

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



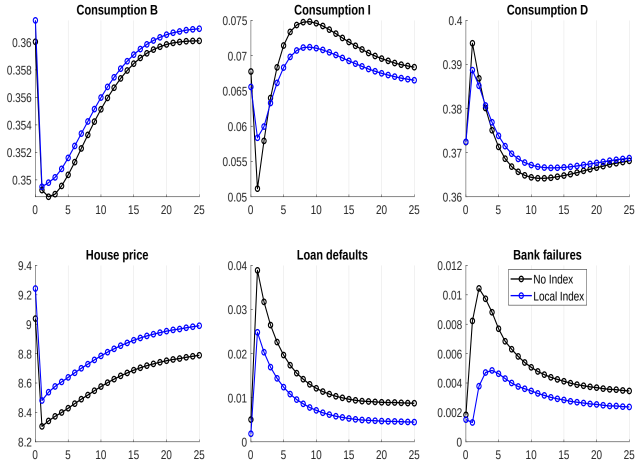
Local Indexation: Financial Stability

- 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: aggregate + local indexation.
- 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%
Risk-free rate	0.71%	0.66%	0.74%	0.75%
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)

- Agg. indexation: extra capital insufficient against higher risk.
- Local indexation: reduced defaults prevent bank failures.

	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%
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Model Moments by Indexation Regime (Quarterly)

- Higher financial fragility $\Longrightarrow$ higher spreads, profits.
- Smaller financial sector + precautionary saving pushes $r^f \downarrow$.

	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%
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Model Moments by Indexation Regime (Quarterly)

- Lower risk/rates $\implies$ higher house prices $\implies$ debt, deposits $\uparrow$.
- Reduced risk under local indexation despite higher debt loads.

	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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Model Moments by Indexation Regime (Quarterly)

- Regional model (agg. + local) has lowest default rates.
- But gives up many of the Local Only stability gains.

	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%
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Comparing Indexation Regimes: Welfare

- Agg. indexation: borrowers lose, intermediaries gain!

	No Index	Aggregate	Local Only	Regional
Aggregate welfare	0.821	+0.17%	+0.06%	+0.32%
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 $\Longrightarrow$ higher intermediary consumption.

	No Index	Aggregate	Local Only	Regional
Aggregate welfare	0.821	+0.17%	+0.06%	+0.32%
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Comparing Indexation Regimes: Welfare

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

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Comparing Indexation Regimes: Welfare

- Improved risk sharing under local indexation.

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Comparison: Interest vs. Principal Indexation

- Some proposals envision only indexing interest payments
- Ganong + Noel (17): principal reductions ineffective in HAMP

	No Index	**Regional**	**Regional IO**	**Regional PO**
Mortgage default rate	0.95%	0.47%	0.80%	0.49%
Bank failure rate	0.33%	0.50%	0.30%	0.31%
Refi Rate	3.84%	3.74%	3.84%	3.76%
Mortgage rate	1.46%	1.35%	1.41%	1.32%
Mortgage excess return	0.34%	0.40%	0.35%	0.38%
House price	8.842	8.784	8.806	8.900
Mortgage debt	259.59%	267.74%	261.60%	270.80%
Household leverage	64.41%	65.80%	65.09%	65.63%
Deposits	2.454	2.526	2.484	2.553
Consumption, B	0.359	+0.1%	+0.1%	+0.3%
Consumption, I	0.068	-0.4%	-1.1%	-1.7%

Comparison: Interest vs. Principal Indexation

- Interest-only indexation has much more modest impact on defaults.
- Why? Interest payments only matter until next refi.

	No Index	Regional	Regional IO	Regional PO
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Comparison: Asymmetric Contracts

- Many SAM proposals are asymmetric, only adjust downward.
- Our implementation: index mortgages by $\min(\zeta, 1)$.

	No Index	Regional	Reg. Asym.	Reg. Asym. IO
Mortgage default rate	0.95%	0.47%	0.12%	0.55%
Bank failure rate	0.33%	0.50%	0.94%	0.34%
Refi Rate	3.84%	3.74%	4.42%	3.56%
Mortgage rate	1.46%	1.35%	2.37%	1.56%
Mortgage excess return	0.34%	0.40%	0.49%	0.35%
House price	8.842	8.784	8.488	8.663
Mortgage debt	259.59%	267.74%	231.85%	260.24%
Household leverage	64.41%	65.80%	58.35%	62.85%
Deposits	2.454	2.526	2.196	2.373
Consumption, B	0.359	+0.1%	+1.9%	+0.5%
Consumption, I	0.068	-0.4%	-1.6%	-2.9%

Comparison: Asymmetric Contracts

- Financial fragility $\uparrow\uparrow$.
- High ω dispersion causes losses in crash.

	No Index	**Regional**	**Reg. Asym.**	**Reg. Asym. IO**
Mortgage default rate	0.95%	0.47%	0.12%	0.55%
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Comparison: Asymmetric Contracts

- House prices, mortgage debt, deposits ↓↓. Mortgage rates ↑↑.
- Forgiveness $\simeq$ shorter maturity. Lower leverage means defaults ↓↓.

	No Index	**Regional**	**Reg. Asym.**	**Reg. Asym. IO**
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Comparison: Asymmetric Contracts

- Asym-IO: same effects (lower leverage) but more moderate.
- Interesting twist: interest forgiveness reduces incentives to refi.

	No Index	**Regional**	**Reg. Asym.**	**Reg. Asym. IO**
Mortgage default rate	0.95%	0.47%	0.12%	0.55%
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Comparison: Asymmetric Contracts

- Asym-IO lowers defaults with little fragility. But need indexation?
- Political economy obstacle: intermediaries hate it.

	No Index	**Regional**	**Reg. Asym.**	**Reg. Asym. IO**
Mortgage default rate	0.95%	0.47%	0.12%	0.55%
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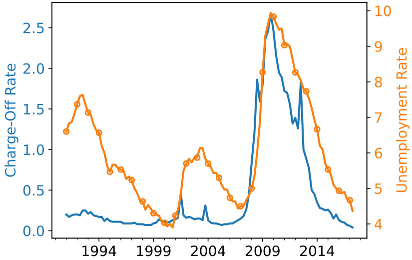
Conclusion

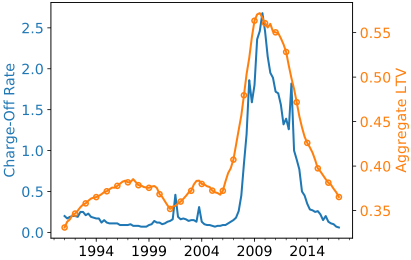
- General equilibrium model of intermediated mortgage market allowing for indexed mortgage contracts.
- Effect depends on type of indexation:
  - Aggregate indexation: amplifies intermediary sector instability.
  - Local indexation: dampens intermediary sector instability.
- Costs of indexation partly 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.



(a) Charge-Offs vs. Unemp.



(b) Charge-Offs vs. LTV

Incorporating Liquidity Defaults

- Our implementation: receive liquidity shock with probability θ, need to leave house.
  - If home equity is positive, sell.
  - If home equity is negative, default.
- Add utility cost of default to reduce number of strategic defaults.
- Results with over 50% liquidity defaults nearly identical to baseline.

Equilibrium: Details

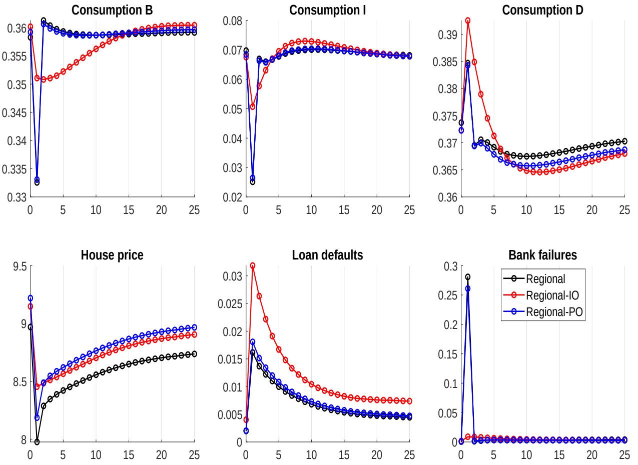
Optimizing allocation and price vector $(r_t^*, q_t^A, q_t^M, q_t^f, p_t, p_t^{REO}, \rho_t)$ such that markets clear:

$$\begin{aligned}
\text{New mortgages:} \quad & Z_{R,t} Z_{N,t} M_t^* = L_t^* \\
\text{PO strips:} \quad & \tilde{M}_t^I = \hat{M}_t^I \\
\text{IO strips:} \quad & \tilde{A}_t^I = \hat{A}_t^I \\
\text{Deposits:} \quad & B_{t+1}^I = B_{t+1}^D \\
\text{Housing Purchases:} \quad & Z_{R,t} Z_{N,t} K_t^* = S^{REO} K_t^{REO} + Z_{R,t} Z_{K,t} K_t^B \\
\text{REO Purchases:} \quad & I_t^{REO} = (1 - Z_{K,t}) K_t^B \\
\text{Housing Services:} \quad & H_t^B = K_t^B + K_t^{REO} = \bar{K}^B \\
\text{Resources:} \quad & Y_t = C_t^B + C_t^I + C_t^D + G_t + \underbrace{\eta \delta (1 - Z_{R,t}) Z_{A,t} \left(q_t^A A_t^I + q_t^M M_t^I \right)}_{\text{DWL from bank failures}} \\
& + \underbrace{\nu^K p_t (Z_{K,t} K_t^B + \bar{K}^I + \bar{K}^D) + \nu^{REO} p_t \left[K_t^{REO} + (1 - Z_{K,t}) K_t^B \right]}_{\text{housing maintenance expenditure}}
\end{aligned}$$

Back

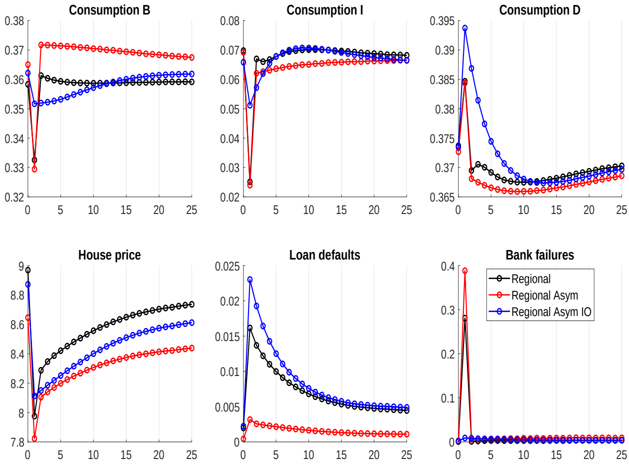
Interest vs. Principal Indexation

- 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