

# A Macroeconomic Model with Financially Constrained Producers and Intermediaries

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# Motivation

- Great Recession underscored importance of financial sector for broader economy
  - ▶ Bank insolvencies and government bailouts
  - ▶ High credit spreads and low real interest rates
  - ▶ Disruptions in financial intermediation fed back on the real economy
  - ▶ Investment, output, and consumption all fell substantially and persistently

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- Triggered debate on bank regulation, with majority of work advocating for much higher bank capital requirements
  - ▶ The Minneapolis Plan (Dec 2017): 23.5% common equity/RW assets, or 15% equity/assets
  - ▶ Admati & Hellwig (2013): 25% equity/assets
  - ▶ “For society, there are in fact significant benefits and essentially no cost from much higher equity requirements.”

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- Triggered debate on bank regulation, with majority of work advocating for much higher bank capital requirements
- Quantitatively realistic model to assess costs and benefits still lacking
  - ▶ BIS: “the report should not be viewed as indicating a particular calibration level” and “analysis of the macroeconomic benefits and costs is subject to considerable uncertainty”
  - ▶ Requires explicit role for intermediary sector  $\Rightarrow$  understand importance of intermediation frictions
  - ▶ Nonlinear risk dynamics  $\Rightarrow$  realistic asset prices

# Main Contributions

- Model

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- ▶ Both face financial constraints, can default on their debt
- ▶ Deposit insurance (TBTF guarantee) creates scope for bank regulation

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  - ▶ matches credit spread for realistic amount of credit risk
  - ▶ generates infrequent deep financial recessions
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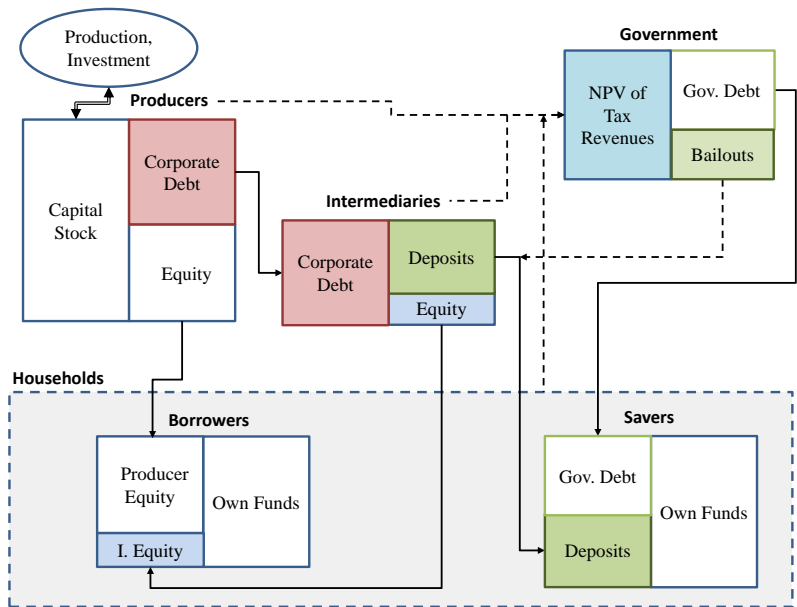
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  - ▶ intermediation frictions account for severity of fin. recessions
- **Macroprudential policy** experiment for bank capital requirement
  - ▶ Higher bank capital requirements benefit equity holders of banks and non-financial firms, but hurt savers: perverse incidence
  - ▶ Tighter policy yields modest aggregate welfare gain
  - ▶ Trade-off between **financial fragility** and **size of economy**
  - ▶ Counter-cyclical capital requirement Pareto improving

## Related Literature

- Asset pricing models with financial intermediaries:
  - ▶ Brunnermeier & Sannikov 14, He & Krishnamurthy 12, 13, 15, Gârleanu & Pedersen 11, Gertler and Karadi 11, Adrian & Boyarchenko 12, Savov & Moreira 16
  - ▶ *Contribution*: split banks and borrowers, add bank bankruptcies, add government
- Quantitative macro models with incomplete markets and macro-prudential policy evaluation
  - ▶ Lorenzoni 08, Mendoza 10, Korinek 12, Bianchi and Mendoza 13, 15, and Guerrieri and Lorenzoni 15: pecuniary externalities
  - ▶ Farhi and Werning 16: demand externalities.
  - ▶ *Contribution*: financial sector with bank default & deposit insurance
- Bank capital regulation:
  - ▶ Maddaloni and Peydro 11, Admati and Hellwig 14, Begeau 15, Begeau and Landvoigt 16
  - ▶ *Contribution*: quantifiable framework, interaction with guarantees



# Model Overview



# Borrower-Entrepreneurs

- Individual entrepreneurs produce  $Y_{i,t} = \omega_{i,t} Z_t^A K_t^{1-\alpha} L_t^\alpha$ 
  1. **Aggregate TFP shock:**  $\log(Z_{t+1}^A) = \rho_A \log(Z_t^A) + \sigma_A \epsilon_{t+1}$
  2. Idiosyncratic TFP shock  $\omega_{i,t}$ :  $\sigma_{\omega,t} = \text{Var}(\omega_{i,t})^{1/2}$  time-varying  
⇒ **uncertainty shock second source of aggregate risk**
- Entrepreneurs obtain corporate loans/bonds to finance investment
  - ▶ Corporate loans/bonds are long-term (perpetuity with decay  $\delta$ )
  - ▶ Each entrepreneur defaults on debt if profit  $\pi(\omega_{i,t}) < \underline{\pi}$ 
    - ★ Model of *liquidity default*, not strategic default
    - ★ Default triggers liquidation: bank seizes bankrupt firm and unwinds it
    - ★ Aggregate implication: fraction of entrepreneurs with  $\omega_{i,t} < \omega_t^*$  defaults
  - ▶ Family of entrepreneurs provides perfect consumption insurance, but each entrepreneur manages debt repayment/default

# Borrower-Entrepreneurs

- Family of entrepreneurs decides jointly on
  - ▶ consumption
  - ▶ labor demand (inelastically supplied by HH)
  - ▶ investment (subject to convex adjustment cost)
  - ▶ total corporate debt
- Debt enjoys a tax shield
- Borrower leverage limited through two forces
  1. Costly bankruptcies: borrower-entrepreneurs internalize effect of time- $t$  choices on next period default rate  $D(\omega_{t+1}^*)$
  2. Hard borrowing constraint with max LTV  $\Phi$  (rarely binding):  
$$\text{FV of debt} \leq \Phi \text{ (MV of depreciated capital of non-defaulting firms)}$$

▶ Complete Problem

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- Portfolio choice
  1. New corporate loans
    - ★ Receive coupon payment on performing loans
    - ★ Recover assets and earnings through liquidation of defaulting firms
    - ★ Fraction  $\zeta$  of bankrupt firms' assets and output lost to banks, fraction  $\eta \times \zeta$  is DWL to society
  2. Deposits for next period

# Intermediaries

- Banks are firms owned by borrower-entrepreneurs, pay dividends subject to convex equity adjustment cost
- Portfolio choice
  1. New corporate loans
  2. Deposits for next period
- Enjoy limited liability & deposit insurance (creditor bailout)
  - ▶ Receive idiosyncratic profit shocks & optimally default
  - ▶ Government assumes all assets and liabilities of defaulting bank
  - ▶ Fraction  $\zeta$  of bankrupt banks' assets lost to government, fraction  $\eta \times \zeta$  is DWL to society

# Intermediaries

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- Portfolio choice
  1. New corporate loans
  2. Deposits for next period
- Enjoy limited liability & deposit insurance (creditor bailout)
- Subject to **regulatory bank capital constraint**:

$$\text{deposits} \leq \xi \text{ (MV of corporate loans)}$$

- Pay for deposit insurance ( $\kappa$ ), taxed on net interest income, tax shield

▶ Complete Problem

# Savers and Government

- **Savers**

- ▶ More patient than borrowers
- ▶ Solve dynamic consumption-savings problem
- ▶ Only invest in risk free bonds (no short sales)

- **Government** follows passive tax and spending rule

- ▶ Revenues  $T_t$ : taxes on labor income, corporate and intermediary profits, and financial income, deposit insurance fees
- ▶ Expenditures  $G_t$ : discretionary ( $GOV_t$ ), transfer, intermediary bailouts
- ▶ Budget constraint (govt. debt policy)

$$T_t + q_t^f B_t^G = B_{t-1}^G + G_t$$

- ▶ Tax rate adjusts at the extremes to ensure  $B^G$  stays bounded
- ▶ Tax rate, discr. and transfer spending are cyclical



# Competitive Equilibrium

- Given prices and government policy parameters, both household types and intermediary firms maximize their value functions subject to their budget and borrowing constraints
- Markets clear
  - ▶ Risky, long-term corporate loan/bond market ( $\rightarrow$  corporate loan rate)
  - ▶ Riskfree bond market: deposits + govmt debt ( $\rightarrow$  riskfree rate)
  - ▶ Capital market ( $\rightarrow$  Tobin's  $q$ )
  - ▶ Labor market for each of two types of households ( $\rightarrow$  wages)
- Resource constraint:

$$Y_t = CONS_t + GOV_t + INV_t + DWL_t$$

# State Variables and Solution Method

- Exogenous states
  - ▶ Persistent aggregate TFP  $Z_t^a$ , discretized
  - ▶ Dispersion of idiosyncr. productivity (*uncertainty*)  $\sigma_{\omega,t}$ , discretized
- Five endogenous states: capital, corp. debt, govt. debt, deposits, intermediary wealth
  - ▶ Wealth distribution matters for asset prices due to incomplete markets
  - ▶ **Intermediary wealth** is a key state variable, as is borrower wealth
- Nonlinear global solution method – policy time iteration
  - ▶ Two collateral constraints occasionally binding
  - ▶ Changing wealth distribution causes time-variation in risk premia
  - ▶ Non-linear dynamics when intermediaries are constrained

# Calibration

- Key parameters
  1. Pop. and inc. shares for stockholders (=borrower-entrepreneurs) and non-stockholders (=savers) from SCF

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  3. Corporate debt: realistic calibration of credit risk
    - ★ Default threshold  $\underline{\pi}$ : non-fin leverage of 37%
    - ★ TS mean of  $\sigma_{\omega,t}$ : corporate default rate of 2.2%
    - ★ LGD  $\zeta$ : severity rates on corporate debt of 44%

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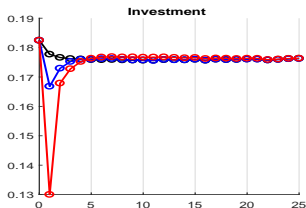
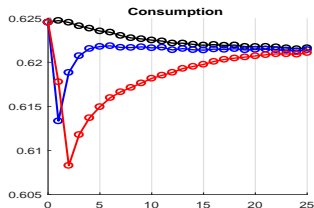
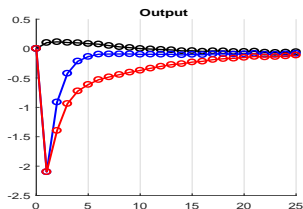
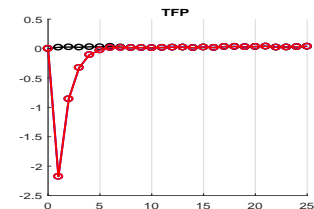
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4. Bank equity issuance cost to match credit spread of 2.05%
5. Preferences: log utility for both HH (robust to EZ utility)
  - ★  $\beta_B = 0.95$ :  $K/Y = 2.24$
  - ★  $\beta_S = 0.982$ : mean  $r^f$  of 2.2%

▶ All parameters

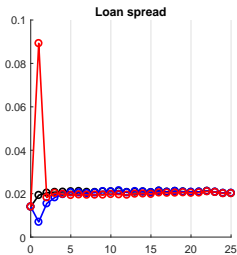
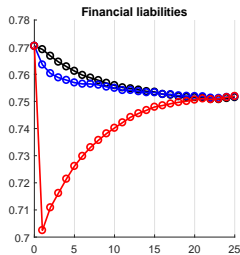
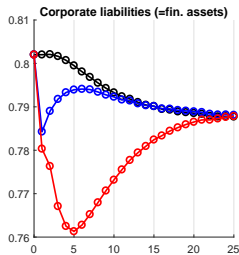
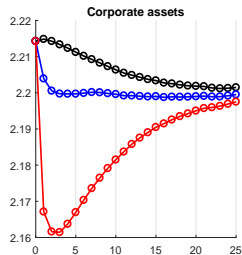
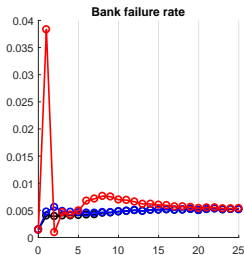
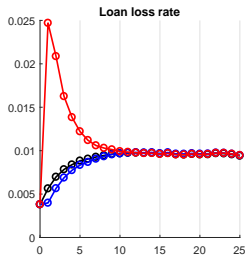
# Results: Macro Quantities

- Period 1: One std shock down in TFP  
+ uncertainty shock (high  $\sigma_\omega$ ) or not (low  $\sigma_\omega$ )
- **Financial** vs. **non-financial** recession vs. unconditional path

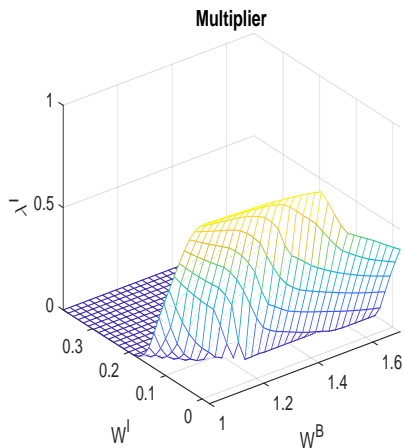
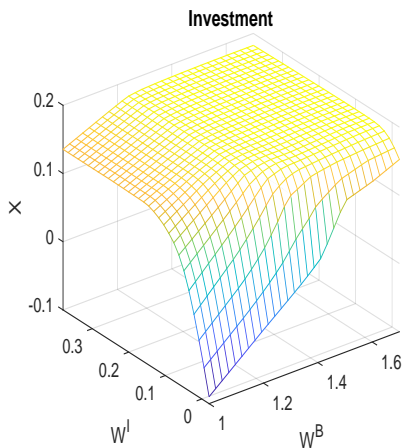




# Results: Prices and Balance Sheets



# Intermediary Constraint and Producer Investment

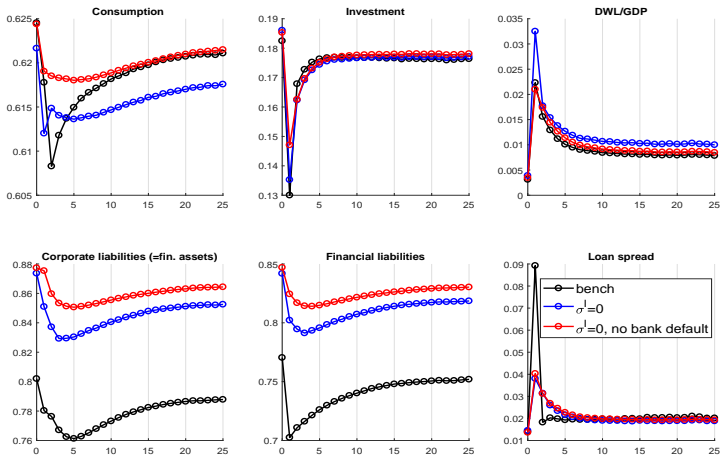


- “Double Accelerator”: investment plummets when firm has little equity and intermediary becomes constrained
- Feedback: low profits  $\Rightarrow$  loan losses for bank  $\Rightarrow$  reduced credit supply  $\Rightarrow$  less investment  $\Rightarrow$  low profits next period

# Key Frictions

- Debt finance in model subject to frictions
  - ① Firms
    - ★ Debt funding cheap due to higher patience of savers
    - ★ But costly liquidity-driven bankruptcies limit benefit
    - ★ Default waves during times of high XS dispersion of productivity
  - ② Banks
    - ★ Moral hazard due to strategic default option and deposit insurance
    - ★ Equity adjustment cost: expensive to recapitalize bank after losses, effectively like risk aversion
- How important are intermediation frictions (point 2) for financial recessions?

# Importance of Intermediation Frictions



- Turning off
  - ▶ equity adjustment cost ( $\sigma^l = 0$ )
  - ▶ and **limited liability** for banks
- leads to larger fin. sector, less severe fin. recessions

# Macro-prudential Policy

- Bank leverage declines with tighter capital requirement

	Bench $\xi = 94\%$	Tighter cap. requ. $\xi = 85\%$ $\xi = 90\%$		Looser $\xi = 97\%$
<b>Financial sector size &amp; profitability</b>				
Fin leverage	93.3%	83.6%	88.9%	97.0%
Fraction intermed. constr. binds	61.3%	43.5%	60.3%	96.0%
EER on loans	1.09%	1.70%	1.44%	0.62%
Corp leverage	35.8%	29.5%	32.4%	38.9%
<b>Financial fragility</b>				
Loss rate	0.96%	-44.8%	-25.0%	+18.8%
Bank failure rate	0.54%	-100.0%	-99.0%	+851.0%
DWL/GDP	0.008	-31.23%	-20.89%	+124.88%
<b>Size of the Economy</b>				
GDP	0.978	-1.1%	-0.6%	+0.9%
Capital stock	2.199	-3.8%	-2.2%	+3.0%
<b>Volatility</b>				
Investment gr	29.56%	+35.2%	+16.4%	-5.5%
Aggr. consumption gr	2.17%	+27.7%	+16.6%	+58.5%

# Macro-prudential Policy

- Tighter constraint binding *less often* as banks become more cautious

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- EER on corporate loans rises, corporate leverage declines

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- Rise in EER despite large drop in loss rate on loans

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- Bank failure rate zero at  $\xi = 85\%$

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- Economy shrinks as cost of capital for firms rises

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# Macro-prudential Policy

- Willingness of banks to absorb aggregate risk decreases

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# Bank Profitability and Tighter Regulation

- Bank AROE

Bank assets  $\times$  EER on loans / Bank equity capital

- EER on loans  $\uparrow$ , bank assets  $\downarrow$ , equity capital  $\uparrow$ ,  $\Rightarrow$  AROE declines as financial sector shrinks

	<b>Bench</b> <b><math>\xi = 94\%</math></b>	<b>Tighter cap. requ.</b>		<b>Looser</b> <b><math>\xi = 97\%</math></b>
		<b><math>\xi = 85\%</math></b>	<b><math>\xi = 90\%</math></b>	
Accounting ROE	15.35	-36.66%	-20.90%	+55.31%
Market ROE	7.73	-2.55%	-1.53%	+7.94%
WACC	2.34	+25.60%	+15.64%	-16.88%
Franchise value	33.9	18.3	33.8	73.7

# Bank Profitability and Tighter Regulation

- Banking becomes less risky when forced to hold more capital  $\Rightarrow$  MROE = required return on equity declines
- Consistent with argument of Admati et al (2013)

	<b>Bench</b> $\xi = 94\%$	<b>Tighter cap. requ.</b>		<b>Looser</b> $\xi = 97\%$
		$\xi = 85\%$	$\xi = 90\%$	
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# Bank Profitability and Tighter Regulation

- But WACC

$$\text{MROE} \times \text{Leverage} + r^f \times (1 - \text{Leverage})$$

rises sharply despite drop in MROE as bank is forced to shift away from cheap deposits

	<b>Bench</b> <b><math>\xi = 94\%</math></b>	<b>Tighter cap. requ.</b>		<b>Looser</b> <b><math>\xi = 97\%</math></b>
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# Bank Profitability and Tighter Regulation

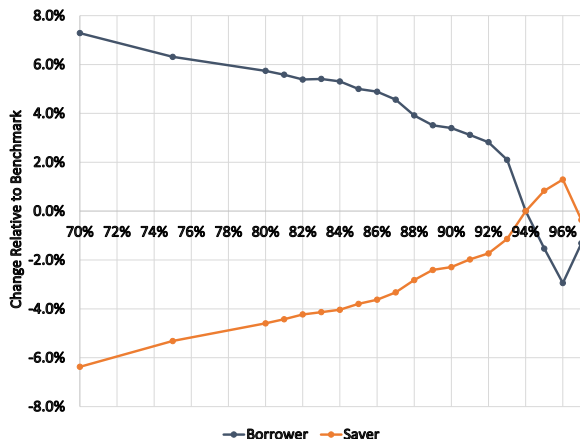
- Franchise value

$$\frac{\text{Market value of equity for shareholders}}{\text{Bank equity capital}} - 1$$

- Net result is decline in franchise value with tighter regulation

	<b>Bench</b> <b>ξ = 94%</b>	<b>Tighter cap. requ.</b>		<b>Looser</b> <b>ξ = 97%</b>
		<b>ξ = 85%</b>	<b>ξ = 90%</b>	
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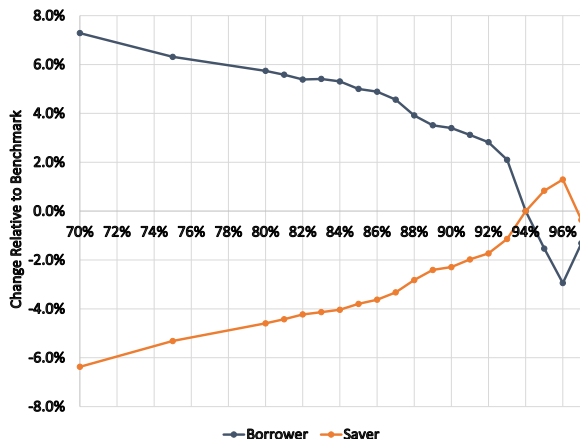
# Macro-prudential Policy: Welfare



- Tighter regulation shifts wealth from savers to entrepreneurs
  - ▶ As debt finance becomes more expensive, firms shift to equity finance
  - ▶ More of firm profits “owned” by B  $\Rightarrow$  their consumption increases

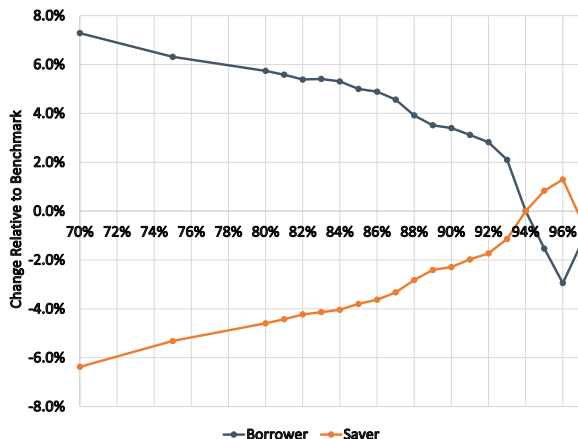


# Macro-prudential Policy: Welfare



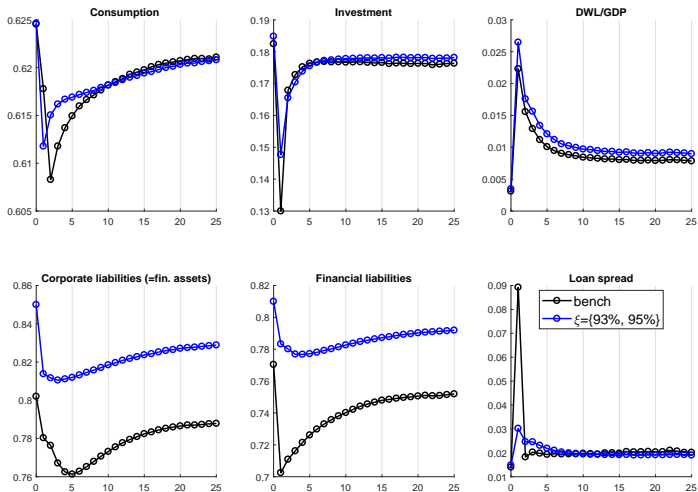
- Tighter regulation shifts wealth from savers to entrepreneurs
- Aggregate welfare
  - 1 Population weighted ex-post welfare:  $\xi_{opt} = 91\%$
  - 2 NPV of compensating transfer scheme:  $\xi_{opt} = 96\%$

# Macro-prudential Policy: Welfare



- Tighter regulation shifts wealth from savers to entrepreneurs
- Aggregate welfare  $\xi_{opt} \in \{91\%, 96\%\}$
- Current capital requirement close to optimal ▶ Both measures

# Macro-prudential Policy: Pro-cyclical Cap Req



- Set  $\xi = 93\%$  when uncertainty is low,  $\xi = 95\%$  when high
  - ▶ Reduces macroeconomic volatility
  - ▶ Largest Pareto improvement

# Conclusion

- Calibrated macro-economic model with financial intermediaries
  - ▶ banks who extend long-term defaultable loans to firms
  - ▶ and raise deposits from risk averse savers
  - ▶ both are subject to leverage restrictions
  - ▶ rich set of fiscal policy rules, including deposit insurance

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- Calibrated macro-economic model with financial intermediaries
- Unconditional macro and asset pricing moments are realistic
- Model generates financial crises where GDP and investment fall considerably and credit spreads are high
- Use model to evaluate quantitatively effects of macro-prudential policy
  - ▶ Intermediary leverage constraint: trade-off between size of economy and financial fragility
  - ▶ Large redistributive effects that depend on policy instrument

# Borrower-Entrepreneurs: Complete Problem

▶ Back

$$\hat{V}^B(\hat{K}_t^B, \hat{A}_t^B, S_t^B) = \max_{\{\hat{C}_t^B, \hat{K}_{t+1}^B, \hat{X}_t, \hat{A}_{t+1}^B, L_t^j\}} \left\{ (1 - \beta_B) (\hat{C}_t^B)^{1-1/\nu} + \right. \\ \left. + \beta_B \text{E}_t \left[ \left( e^{g_{t+1}} \tilde{V}^B(e^{-g_{t+1}} \hat{K}_{t+1}^B, e^{-g_{t+1}} \hat{A}_{t+1}^B, S_{t+1}^B) \right)^{1-\sigma_B} \right]^{\frac{1-1/\nu}{1-\sigma_B}} \right\}^{\frac{1}{1-1/\nu}}$$

subject to

$$\hat{C}_t^B = (1 - \tau_{\Pi}^I) Z_K(\omega_t^*) (\hat{K}_t^B)^{1-\alpha} L_t^\alpha + (1 - \tau_t^B) \hat{w}_t^B \bar{L}^B + \hat{G}_t^{T,B} \\ + p_t [\hat{X}_t + Z_A(\omega_t^*) (1 - (1 - \tau_{\Pi}^B) \delta_K) \hat{K}_t^B] \\ + q_t^m \hat{A}_{t+1}^B - Z_A(\omega_t^*) \hat{A}_t^B (1 - (1 - \theta) \tau_{\Pi}^B + \delta q_t^m) \\ - p_t \hat{K}_{t+1}^B - \hat{X}_t - \Psi(\hat{X}_t, \hat{K}_t^B) - (1 - \tau_{\Pi}^I) Z_A(\omega_t^*) \sum_{j=B,S} \hat{w}_t^j L_t^j + D_t^I$$

$$F \hat{A}_{t+1}^B \leq \Phi p_t Z_A(\omega_t^*) \hat{K}_t^B \\ S_{t+1}^B = h(S_t^B)$$



# Intermediaries: Complete Problem

▶ Back

$$V^l(W_t^l, S_t^l) = \max_{d_t^l, B_t^l, A_{t+1}^l} d_t^l + E_t \left[ \mathcal{M}_{t,t+1}^B \max \left\{ V_{t+1}^l(W_{t+1}^l, S_{t+1}^l) - \epsilon_{t+1}^l, 0 \right\} \right]$$

subject to:

$$W_t^l \geq d_t^l + \Sigma(d_t^l) + q_t^m A_{t+1}^l + (q_t^f + \mathbb{1}_{\{B_t^l < 0\}} \kappa) B_t^l + \tau_{\Pi}^l \Pi_t^l,$$

$$W_t^l = \Omega_A(\omega_t^*) (1 + \delta q_t^m) A_t^l + M_t + B_{t-1}^l,$$

$$-q_t^f B_t^l \leq \xi q_t^m A_{t+1}^l,$$

$$A_{t+1}^l \geq 0,$$

$$S_{t+1}^l = h(S_t^l).$$

with payoff on defaulted bonds:

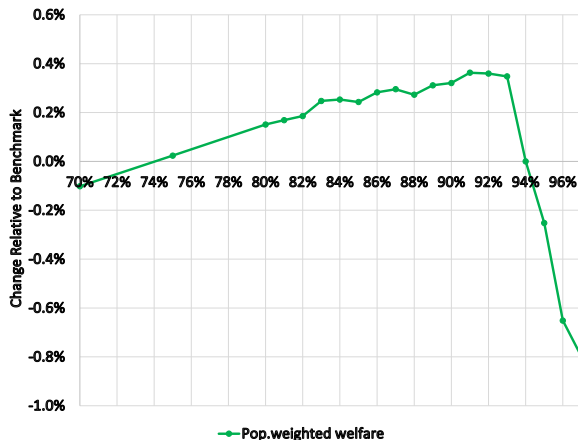
$$M_t = (1 - \zeta) \left[ (1 - \Omega_A(\omega_t^*)) (1 - \delta_K) p_t K_t^B + (1 - \Omega_K(\omega_t^*)) Z_t^A (K_t^B)^{1-\alpha} L_t^\alpha \right] \\ - (1 - \Omega_A(\omega_t^*)) \sum_j w_t^j L_t^j$$

# Calibration Overview

Par	Description	Value	Target
Exogenous Shocks			
$\rho_A$	persistence TFP	0.7	AC(1) HP-detr GDP 53-14 of 0.55
$\sigma_A$	innov. vol. TFP	2.0%	Vol HP-detr GDP 53-14 of 2.56%
$\sigma_{\omega,L}$	low uncertainty	0.095	Avg. corporate default rate of 2%
$\sigma_{\omega,H}$	high uncertainty	0.175	Avg. IQR firm-level productivity (Bloom et al. (2012))
$P_{LL}^{\omega}, P_{HH}^{\omega}$	transition prob	{0.91, 0.80}	Bloom et al. (2012)
Production, Population, Labor Income Shares			
$\psi$	marginal adjustment cost	2	Vol. investment-to-GDP ratio 53-14 of 1.58%
$\alpha$	labor share in prod. fct.	0.71	Labor share of output of 2/3
$\delta_K$	capital depreciation rate	8%	Investment-to-capital ratio, 53-14
$\ell^i$	pop. shares $i \in \{S, B\}$	{69,31}%	Population shares SCF 95-13
$\gamma^i$	inc. shares $i \in \{S, B\}$	{60,40}%	Labor inc. shares SCF 95-13
Corporate loans and Intermediation			
$\delta$	average life loan pool	0.937	Duration fcn. bond index
$\theta$	principal fraction	0.582	Duration fcn. bond index
$\zeta$	Losses in bankruptcy	0.6	Corporate loan and bond severities 81-15 of 44%
$\eta$	% bankr. loss is DWL	0.2	Bris, Welch, & Zhu 2006
$\Phi$	maximum LTV ratio	0.45	Vol. of non-fin sector debt-to-GDP 53-14 of 5.2%
$\pi$	profit default threshold	0.04	FoF non-fin sector leverage 85-14 of 37%
$\sigma_{\epsilon}$	cross-sect. dispersion $\epsilon_t^I$	0.025	FDIC failure rate of deposit. inst. of 0.5%
$\sigma^I$	marg. dividend payout cost	5	avg. credit spread of 2.05%
Government Policy			
$G^o$	discr. spending	17.17%	BEA discr. spending to GDP 53-14 of 17.58%
$G^T$	transfer spending	2.42%	BEA transfer spending to GDP 53-14 of 3.18%
$\tau$	labor income tax rate	29.5%	BEA pers. tax rev. to GDP 53-14 of 17.30%
$\tau_{\Pi}^B = \tau_{\Pi}^I$	corporate tax rate	20.0%	BEA corp. tax rev. to GDP 53-14 of 3.41%
$\tau^D$	interest rate income tax rate	13.2%	tax code; see text
$\kappa$	deposit insurance fee	0.0084	Deposit insurance revenues/bank assets
$\xi$	max. intermediary leverage	0.94	Basel II reg. capital charge for C&I loans & bonds

# Macro-prudential Policy: Welfare

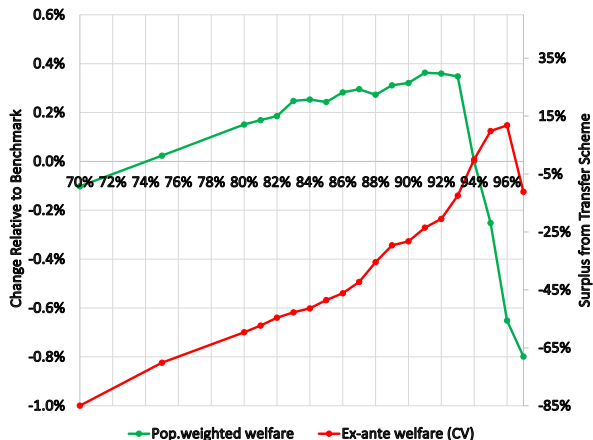
▶ Back



- Small aggregate gain from tighter constraint (max at 91%)

# Macro-prudential Policy: Welfare

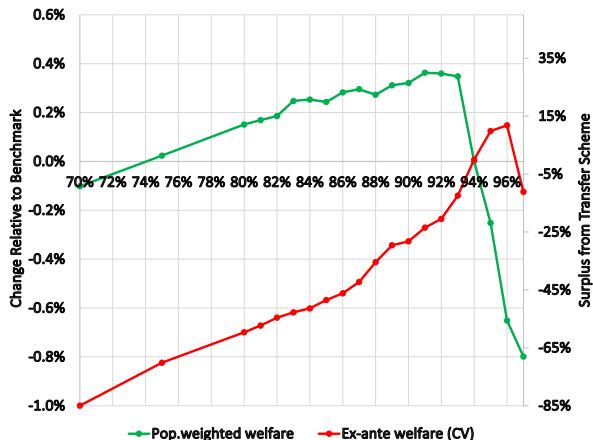
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- Small aggregate gain from tighter constraint (max at 91%)
- Pareto improvement possible for looser constraint (max at 96%)

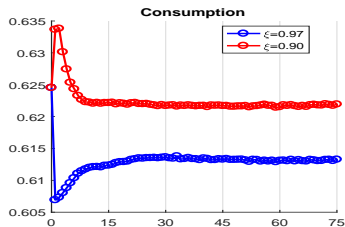
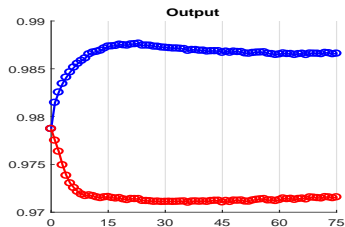
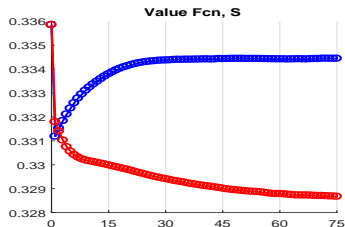
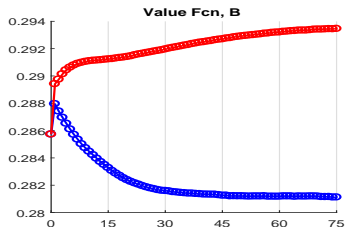
# Macro-prudential Policy: Welfare

▶ Back



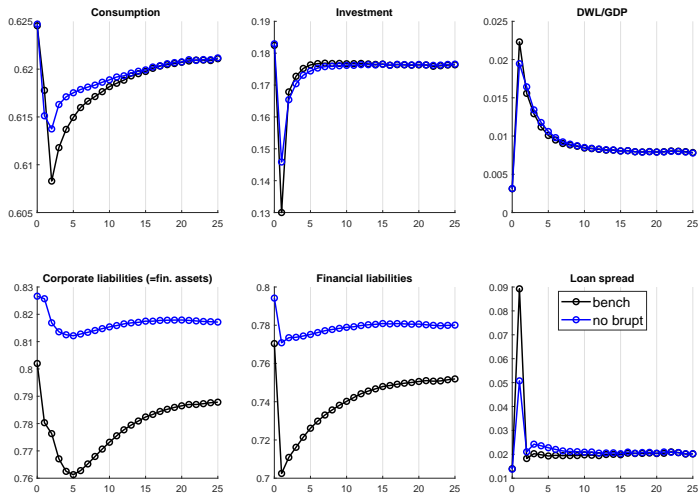
- Small aggregate gain from tighter constraint (max at 91%)
- Pareto improvement possible for looser constraint (max at 96%)
- Status quo close to optimal for either measure

# Transitions



- Tighter capital: Investment overshoots
- Investment drop associated with consumption boom as economy adjusts to lower capital stock

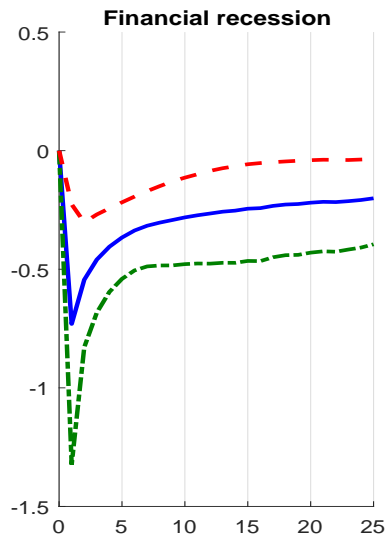
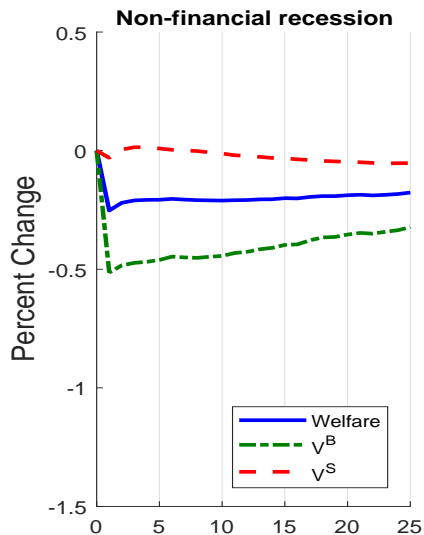
# No Bankruptcy



- Removing bankruptcy option makes banks effectively more risk averse
- Makes financial crises substantially less bad

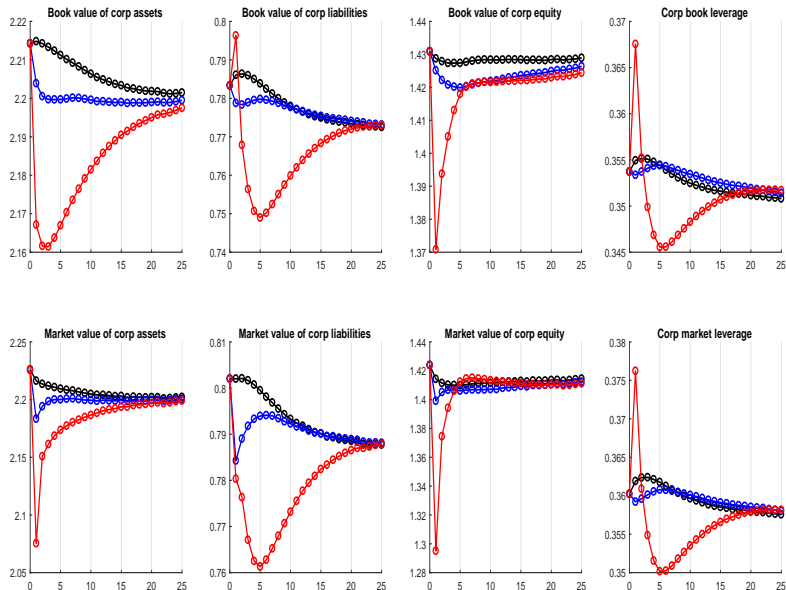
# Boom-Bust: Welfare

- Financial vs. non-financial recession

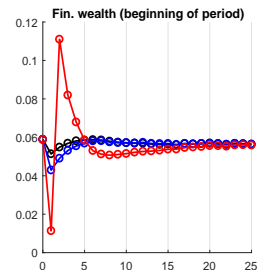
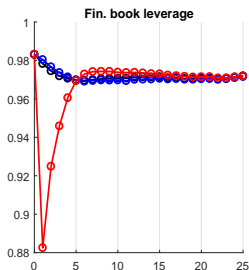
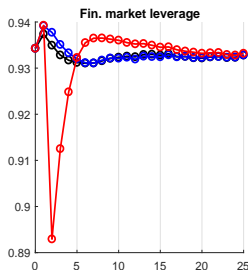
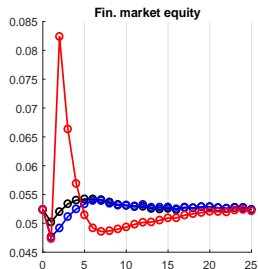
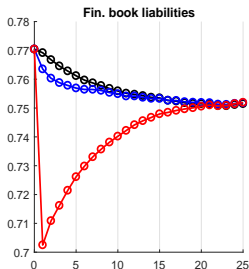
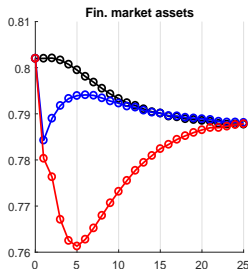




# Boom-Bust: Balance Sheets of Non-financial Corporates



# Boom-Bust: Balance Sheets of Intermediaries



# Boom-Bust: Prices

