Bank Runs, Prudential Tools and Social Welfare in a Global Game General Equilibrium Model

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Need a simple model of prudential tools

- 10 years since the crisis
- Financial regulatory reforms such as Basel III
- No consensus about a model that can guide policymakers
- We are looking for a simple model
- Three essential ingredients:
  1. Systemic risk event
  2. Financial system resilience
  3. Sources of inefficiencies

Bank runs as a systemic risk event

- Most of the crises feature bank runs (Gorton 2012)
- Financial panics as the culprit of the Great Recession (Bernanke 2018)

What I did

- Developed a two-period general equilibrium model that features
  1. Bank runs in a global game framework (systemic risk event)
  2. Endogenous probability of bank runs (banking system resilience)
  3. Some sources of inefficiencies
- Conducted welfare analyses and studied prudential instruments:
  - Leverage restriction (capital requirement)
  - Liquidity requirement
  - Bank-specific/sectoral capital requirement
  - Restriction on concentration risk

Main results

1. Excessive bank leverage and insufficient liquidity

   $\Longrightarrow$ Too high systemic risk

2. Two sources of inefficiencies

   1. Risk shifting (Jensen and Meckling 1976)
   2. Pecuniary externalities (Christiano and Ikeda 2016)

3. Multiple tools needed; otherwise, risk migration

4. General equilibrium effect: which tool is more effective?

5. Applications

   - Bank-specific/sectoral capital requirements and risk weights
   - Concentration risk
   - Deposit insurance

Today's presentation

- Two-period model with leverage only (Ikeda 2019)
- Infinite horizon dynamic model of leverage (work in progress)

Related literature

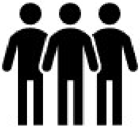
- Global game bank run models
  - **Rochet and Vives (2004)**
  - Goldstein and Pauzner (2005)
- A two-period general equilibrium model with financial frictions
  - **Christiano and Ikeda (2013, 2016)**
- Closely related papers
  - **Gertler and Kiyotaki (2015)**
  - Kashyap et al. (2017); Vives (2014); Kara and Ozsoy (2016)
  - Allen and Gale (2017)
    'The literature on liquidity regulation is still at an early stage.'

Outline

1. Two-period model with leverage only
2. Analytical results
3. Dynamic model
4. Numerical results
5. (Supplementary material)

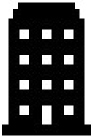
The two-period model: Overview

Households



- Consume
- Save

Banks

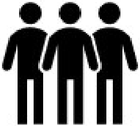


- Take in deposits
- Risky lending

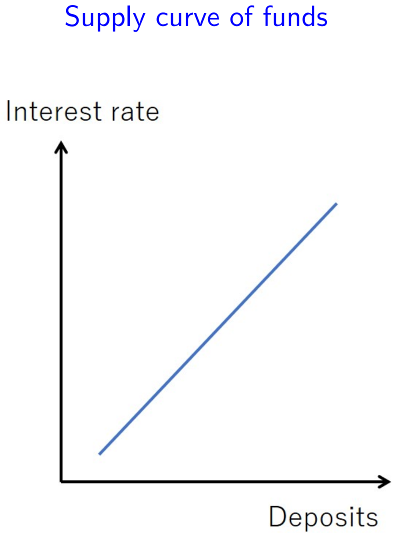
Fund managers

- Decide run or not
- Have private info

Households



- Price taker
- Exogenous income
- Utility over consumption in periods 1 and 2
- Deposit contract
- Aware of bank default risk
- Owner of banks



Households: analytical expression

$$\max_{\{c_1, c_2, d\}} u(c_1) + \mathbb{E}(c_2),$$

s.t.

$$c_1 + d \leq y, \qquad c_2 \leq vRd + \pi,$$

where

$$v = \begin{cases} 1 & \text{with prob. } 1 - P \text{ (no bank default)} \\ < 1 & \text{with prob. } P \text{ (bank default)} \end{cases}$$

Solution: supply curve of funds:

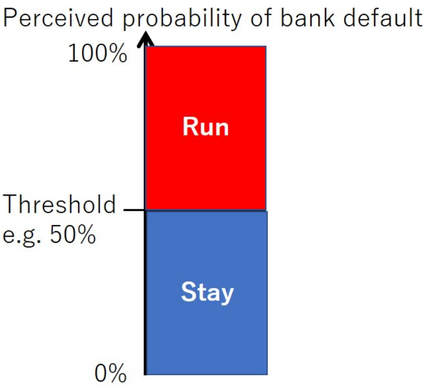
$$R = \frac{u'(y - d)}{1 - P + \mathbb{E}(v|\text{default})P}$$

Fund managers

- Risk neutral
- Private info about bank return (normally distributed)
- Decide run or not following a behavioral rule (Rochet and Vives 2004)
- Run iff perceived probability $> \gamma$

Link

Fund managers' behaviour



How do they form perceived probability of bank default?

- $x = \#$ of fund managers who run; $R^k =$ bank return; $L =$ leverage
- Early withdrawal of xRd
- Costly liquidation: banks have to sell $(1+\lambda)xRd/R^k$ units of assets
- After the liquidation, the bank has $R^k(n+d) - (1+\lambda)xRd$ in hand
- The banks still has to pay $(1-x)Rd$ to remaining depositors
- The bank defaults iff $R^k < R^{k*}$ where

$$R^{k*} = R\left(1 - \frac{1}{L}\right)(1 + \lambda x)$$

Fund managers: analytical expression

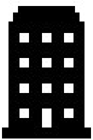
- Withdraw iff $P_i > \gamma$
- R^k = bank return; L = leverage; x = # of fund managers who run
- Private information: $s_i = R^k + \epsilon_i$
- Threshold strategy: withdraw if private info $s_i < \bar{s}$
- Equilibrium threshold $\bar{s} = \bar{s}^*$:

$$
\begin{aligned}
Pr(R^k < R^{k*} | \bar{s}^*) &= \gamma, \\
R^{k*} &= R\left(1 - \frac{1}{L}\right)\left[1 + \lambda x(R^{k*}, \bar{s}^*)\right], \\
x(R^{k*}, \bar{s}^*) &= Pr(R^{k*} + \epsilon_i < \bar{s}^*)
\end{aligned}
$$

- Limit case in which private info becomes infinitely accurate:

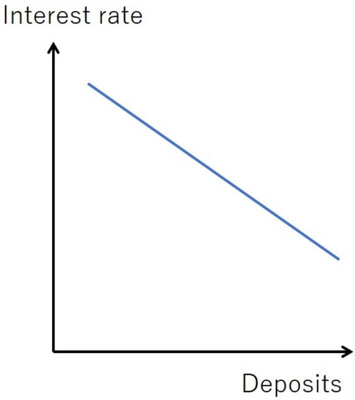
$$
\bar{s}^* = R^{k*} = R\left(1 - \frac{1}{L}\right)[1 + \lambda(1 - \gamma)]
$$

Banks



- Exogenous bank capital
- Simple debt contract; deposit interest rate independent of leverage or liquidity (Acharya 2009)
- Tradeoff: higher leverage
  - Higher return on equity
  - Higher default probability

Demand curve for funds



Banks: analytical expression

- Bank defaults iff $R^k < R^{k*}(L)$
- Deposits $d = (L-1)n$, where n is bank capital
- Bank's problem:

$$\mathbb{E}(\pi) = \max_{\{L\}} \int_{R^{k*}(L)}^{\infty} \left\{ R^k L - R\left[1 + \lambda x\left(R^k, \bar{s}^*(L)\right)\right](L-1)\right\} n dF(R^k).$$

- Optimality condition:

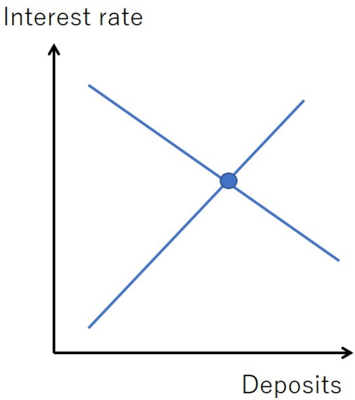
$$0 = \int_{R^{k*}}^{\infty} (R^k - R) dF(R^k) - R\lambda \int_{R^{k*}}^{\infty} x\left(R^k, \bar{s}^*(L)\right) dF(R^k),$$
$$-R\lambda (L-1) \int_{R^{k*}}^{\infty} \frac{\partial x\left(R^k, \bar{s}^*\right)}{\partial \bar{s}^*} \frac{\partial \bar{s}^*(L)}{\partial L} dF(R^k)$$

Competitive equilibrium

Endogenous variables

- Consumption c_1, c_2
- Deposits d
- Leverage L
- Interest rate R
- Recovery rate v
- **Bank run probability** P

Demand and supply curve for funds



Market clearing:

$$d = (L - 1)n$$

Competitive equilibrium: analytical expression

- Household optimality condition:

$$R = \frac{u'(y - (L-1)n)}{1 - P + \mathbb{E}(v|\text{default})P}$$

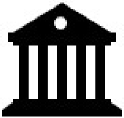
- Bank optimality condition:

$$0 = \int_{R^{k*}}^{\infty} (R^k - R) dF(R^k) - R\lambda \int_{R^{k*}}^{\infty} x\left(R^k, \bar{s}^*(L)\right) dF(R^k),$$
$$-R\lambda (L-1) \int_{R^{k*}}^{\infty} \frac{\partial x\left(R^k, \bar{s}^*\right)}{\partial \bar{s}^*} \frac{\partial \bar{s}^*(L)}{\partial L} dF(R^k)$$

- Recovery rate

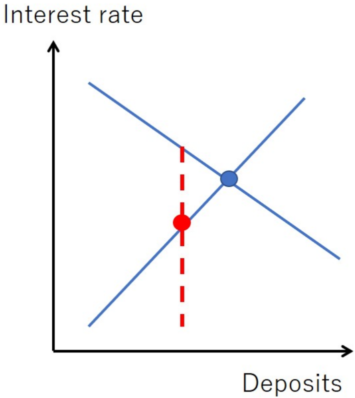
$$v = \min\left\{1, \max\left\{\frac{R^k}{R}\frac{L}{L-1} - \lambda x(R^k, \bar{s}^*), \frac{1}{1+\lambda}\frac{R^k}{R}\frac{L}{L-1}\right\}\right\}$$

Regulator's problem



- Leverage too high?
- Liquidity too low?
- Bank run probability too high?
- Improve social welfare?
- Sources of inefficiencies?

Leverage restriction



Regulator's problem: analytical expression

- Regulator sets leverage and liquidity (liquidity-deposit ratio)
- Otherwise, everything is the same as competitive equilibrium
- Regulator does so to maximize social welfare:

$$\max_{\{L,m\}} SW = u(c_1) + \mathbb{E}(c_2),$$

subject to

Household optimality conditions

Bank run risk (fund managers' behaviour)

Outline

Analytical result 1: Elevated bank run probability

Proposition

In a competitive equilibrium:

- *Leverage is excessive, given any choice of liquidity*
- *(Liquidity is insufficient, given any choice of leverage)*
- *Consequently, bank run probability is too high*

Policy implications

- Need leverage restriction
- (Need liquidity requirement)
- (**Need both**)

Analytical results 2: Sources of inefficiencies

Proposition

There are two sources of inefficiencies:

1. *Bank risk shifting: affects both leverage and liquidity*
2. *Pecuniary externalities: affect only leverage*

Intuition

1. Risk shifting: banks do not internalize the effects of their choice of riskiness (leverage and liquidity) on the (risky) interest rate
2. Pecuniary externalities: costs associated with bank runs depend on the (risk-neutral) interest rate (households' willingness to supply funds)

Outline

Overview: dynamic model

- Real business cycle model with banks
- Banks intermediate funds from households to firms

$$k_{t+1} = n_t + d_t \qquad \text{(Demand for capital)}$$

- Bank runs as in the two-period model
- Capital depreciation (quality) shock

$$k_{t+1} = (1-\delta)\xi_t k_t + i_t \qquad \text{(Supply of capital)}$$

Households

- GHH preferences

$$E_0 \sum_{t=0}^{\infty} \beta \log \left(c_t - \psi \frac{h_t^{1+1/\nu}}{1+1/\nu} \right), \qquad \psi, \nu > 0$$

- Budget constraint

$$c_t + d_t \leq R_t d_{t-1} + w_t h_t + \Theta_t,$$

- Deposit interest rate

$$R_t = \begin{cases} \bar{R}_{t-1} & \text{if banks do not default} \\ v_t \bar{R}_{t-1} & \text{if banks default} \end{cases}$$

where $0 \leq v_t < 1$ is the recovery rate.

Firms

- Cobb-Douglas production function

$$y_t = k_t^{\alpha} h_t^{1-\alpha}, \quad 0 < \alpha < 1$$

- Factor prices

$$\begin{aligned} r_t^k =& \alpha y_t / k_t, \\ w_t =& (1-\alpha) y_t / h_t \end{aligned}$$

- Law of motion for capital

$$k_{t+1} = (1-\delta)\xi_t k_t + i_t, \quad 0 < \delta < 1$$

- Capital depreciation (quality) shock

$$\xi_t - \xi = \rho_{\xi}(\xi_{t-1} - \xi) + \epsilon_{\xi,t}, \quad 0 < \rho_{\xi} < 1$$

- Good market clearing

$$y_t = c_t + i_t$$

Fund managers

- Risk neutral fund managers
- Private information $s_{i,t+1}$ about bank asset return R^k_{t+1}

$$s_{i,t+1} = R^k_{t+1} + \epsilon_{i,t+1}, \quad \epsilon_{i,t+1} \sim N(0, \sigma^2_\epsilon)$$

- $P(s_{i,t+1})$: probability of bank default perceived by fund manager i
- Fund managers withdraw funds iff

$$P(s_{i,t+1}) > \gamma, \quad 0 < \gamma < 1$$

Banks

- Bank balance sheet

$$k_{t+1} = n_t + d_t$$

- Bank asset return

$$R^k_{t+1} = \underbrace{r^k_{t+1}}_{\text{pre-determined}} + (1-\delta)\xi_{t+1}$$

- Expected bank asset return: $R^k_{t+1|t} = r^k_{t+1} + (1-\delta)E_t\xi_{t+1}$

- $R^k_{t+1} \sim N(R^k_{t+1|t}, \sigma^2_{R^k})$ where $\sigma_{R^k} = (1-\delta)\sigma_\xi$

- Early liquidation: banks sell assets to households at discounted prices

- Bank problem is the same as in the two-period model

Banks (cont'd)

- Bank net profits

$$\pi_t^b = R_t^k L_{t-1} n_{t-1} - \bar{R}_{t-1}(L_{t-1} - 1) n_{t-1} - n_{t-1}$$

- Banks remit a fraction $1 - \chi_0$ of net profits to households
- After the remittance, a fraction $1 - \chi_1$ of bankers become workers
- The same number of workers becomes bankers with net worth n_0
- If banks have defaulted, the government injects bank capital $\bar{n}$, financed by lump-sum taxes on households
- Law of motion for bank net worth

$$n_t = \begin{cases} \chi_1 \left\{ \chi_0 \pi_t^b + (1 - \chi_0) \pi_t^b \mathbf{1}_{\{\pi_t^b < 0\}} + n_{t-1} \right\} + n_0 & \text{if no default} \\ \bar{n} & \text{if default} \end{cases}$$

Limit equilibrium

- Limit equilibrium $\sigma_\epsilon \to 0$
- Bank run (default) iff $R^k_{t+1} < R^{k*}_{t+1}$

$$R^{k*}_{t+1} = \bar{R}_t \left(1 - \frac{1}{L_t}\right) [1 + \lambda(1 - \gamma)]$$

- Probability of bank default

$$P_t = \Phi\left(\frac{R^{k*}_{t+1} - R^k_{t+1|t}}{\sigma_{R^k}}\right)$$

Outline

1. Two-period model with leverage only
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5. (Supplementary material)

Numerical solution

- Target values in stochastic SS

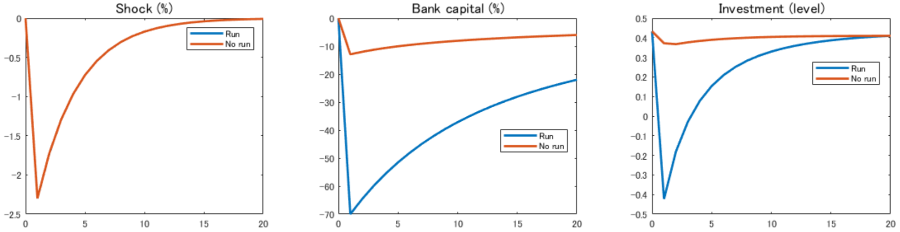
$$L = 15,\ \sigma_{R^k} = 0.01,\ P = 0.05/4,\ h = 1.$$

- Other parameters

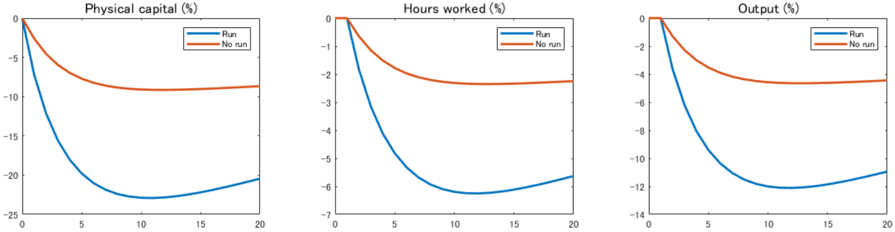
$$\beta = 0.995,\ \nu = 1,\ \alpha = 0.33,\ \delta = 0.025,$$
$$\lambda = 0.5,\ \chi_0 = 0.05,\ \chi_1 = 0.95,\ \rho_\xi = 0.75$$

- Four state variables: $k_t, \bar{R}_{t-1}, n_{t-1}, \xi_t$
- Solution method: parameterized expectations
- Simulate $T = 5000$ periods; $\mathcal{R}^2 = 0.9995$.

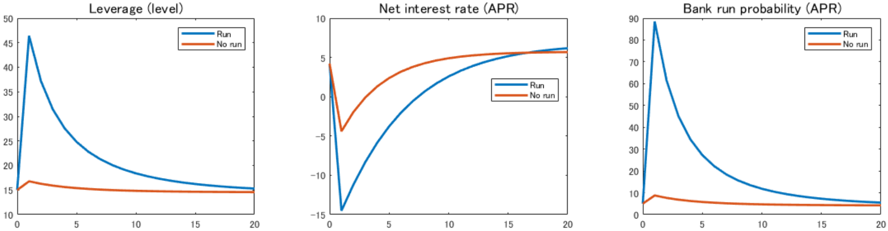
Impulse responses: shock, bank capital, and investment



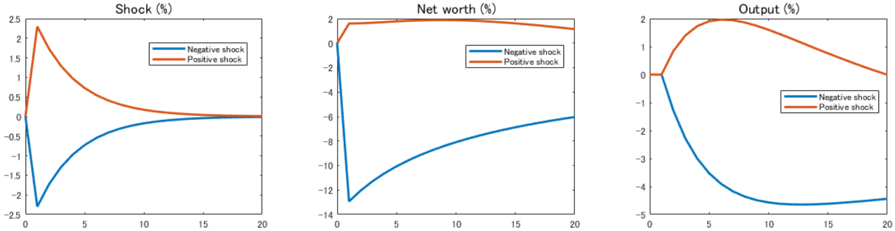
Impulse responses: capital, hours, and output



Impulse responses: leverage, interest rate, and crisis Pr



Asymmetric responses: no bank run



Conclusion: future work

- More micro-foundations for the bank's problem (Mendicino et al. forthcoming)
- Introduce adverse selection and an idiosyncratic shock to endogenize λ (fire sale parameter) and the number of defaulted banks
- More numerical results on the dynamic model
- Macroprudential policy: capital requirements; CCyB

Thank you

Outline

Interpretation of γ

- Fund manager's action and payoff

Action \ States	No bank default	Bank default
Not withdraw	R	$vR - \Gamma_1$
Withdraw	$R - \Gamma_0$	$vR - \Gamma_0$

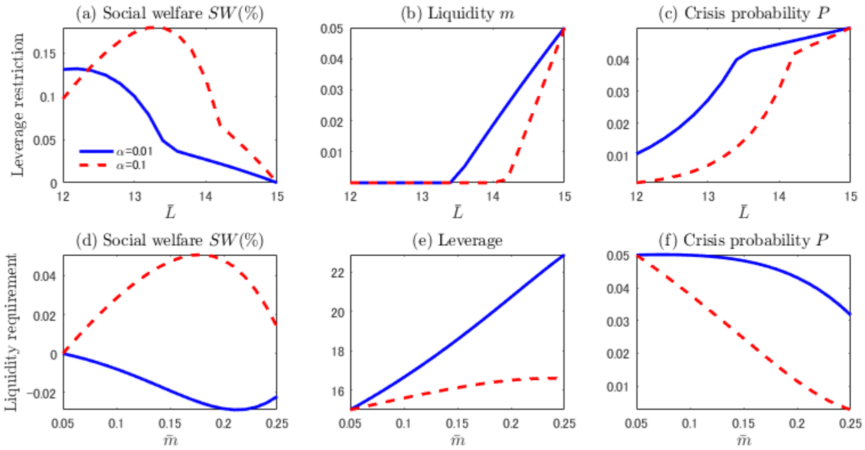
- Not withdraw: $(1 - P_i)R + P_i(vR - \Gamma_1)$
- Withdraw: $(1 - P_i)(R - \Gamma_0) + P_i(vR - \Gamma_0)$
- Withdraw iff $P_i > \Gamma_0/\Gamma_1 \equiv \gamma$
- Costs $\Gamma_0, \Gamma_1 \to 0$

Return

Parameterization for numerical analyses

- US banks 2008-2017 (Miller and Sowerbutts 2018)
- Target values
  - Leverage $= 15$
  - Liquidity ratio relative to deposits $= 5\%$
  - Crisis probability $= 5\%$ (BCBS 2010)
  - Deposit interest rate $= 2\%$
- Average bank asset return $= 3.5\%$ (after-taxed RoE $= 15\%$)
- Standard deviation of bank asset return $= 2.5\%$
- Supply curve of funds: relatively flat or steep

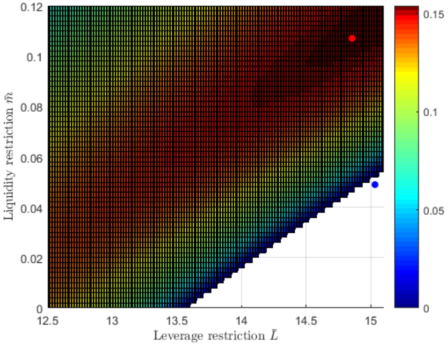
Risk migration: leverage or liquidity requirements only



- Risk migrates from one area to another
- Tightening liquidity requirement worsens welfare when the supply curve is relatively flat ($\alpha = 0.01$).

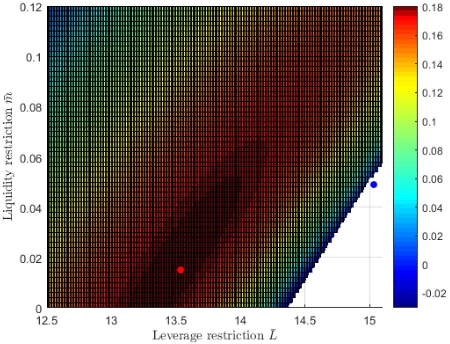
Joint effects of leverage and liquidity requirements on social welfare

$\alpha = 0.01$ (flat supply curve)



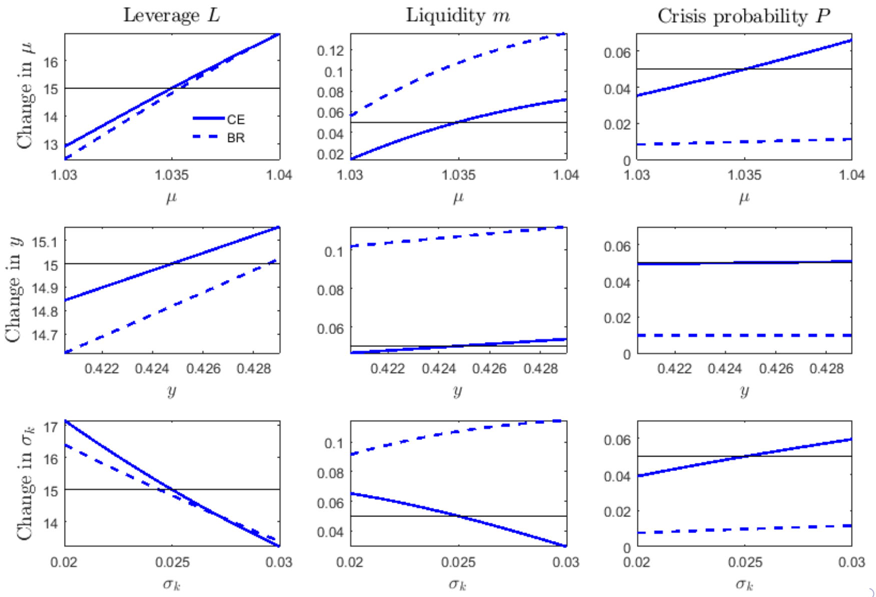
- Liquidity requirement is more tightened.

$\alpha = 0.1$ (steep supply curve)



- Leverage restriction is more tightened.

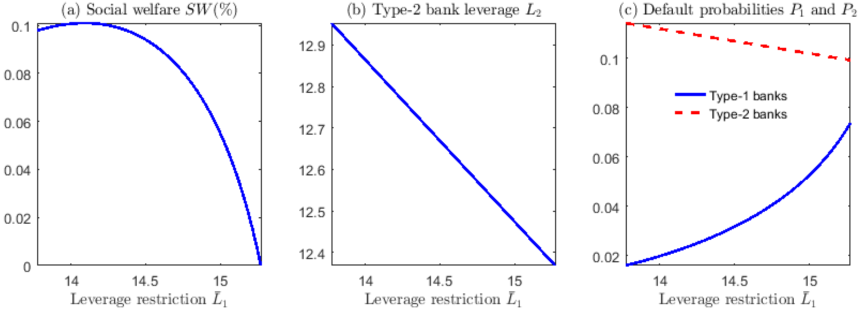
Comparative statics: constrained optimal allocation



Application 1: Regulated banks and shadow banks

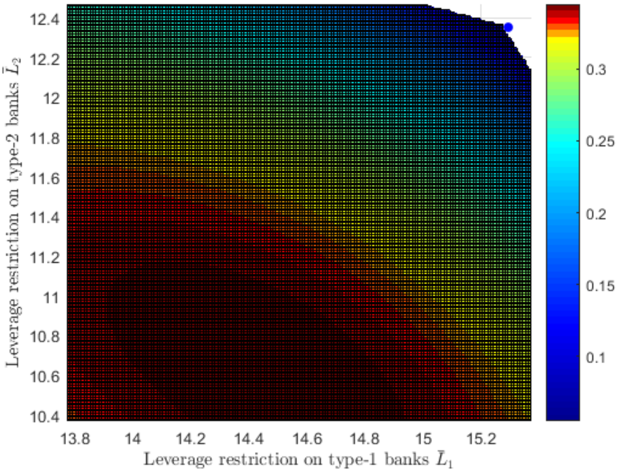
- Two types of banks; leverage choice only
- Type-j bank specializes in lending to sector $j \in \{1, 2\}$
- Sector 2 is risker than sector 1

Risk migration: leverage restriction on type-1 banks only



Application 1 (cont'd): Bank-specific/sectoral capital requirements

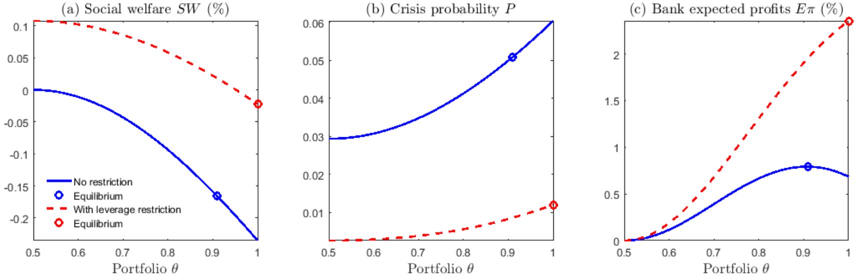
Joint effects of type-specific leverage restrictions



Application 2: Concentration risk

- One type of banks; leverage and portfolio choices
- Identical and independent two types of lending
- Portfolio $[0.5, 0.5]$ minimizes the riskiness of bank assets

Risk migration: leverage restriction and portfolio choice



Recap: macroprudential perspective

- Leverage and liquidity
- Regulated banks and shadow banks
- Leverage and portfolio choice