Optimal liquidity control and systemic risk in an interbank network with liquidity shocks and regime-dependent interconnectedness*

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*The authors gratefully acknowledge financial support from the Puey Ungphakorn Institute for Economic Research. The opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the Puey Ungphakorn Institute for Economic Research.

Motivations

- The interbank market is an important but fragile source of financing for banks (Craig and Ma (2022)).
- Connectivity in financial network: risk sharing vs contagion.
  - Diversification for small shocks, but risk propagation for large shocks
  - Gai and Kapadia (2010), Stiglitz (2010), and Acemoglu et al. (2015)
- Marked reduction in interconnectedness after global financial crisis.
  - Martinez-Jaramillo et al. (2014), Affinito and Pozzolo (2017), and Brunetti et al. (2019)
- Interconnectedness restriction vs interbank relationship.
  - Gofman (2017): restriction reduces trading efficiency but increases stability.
  - Chiu et al. (2020): relationship reduces trading cost and insures against liquidity shocks.

Key questions

- How should banks manage liquidity under the normal and crisis regimes given a reduction in interconnectedness during crises?
- Given banks optimally manage their liquidity, does the reduction increase or decrease systemic liquidity risk?
- Are there policies for the regulators that can reduce systemic risk?

Main contributions

- Novel interbank network model that allows:
  - Changes in the interconnectedness between market regimes (e.g. collapse of interbank markets during crises)
  - Systemic liquidity shocks (e.g. bank runs)
  - Panic-triggered liquidity flows during crises (e.g. flight-to-quality effect)

- Optimal liquidity control policy under the new network model
  - Single-regime with jumps in the mean-field framework without optimal control (Bo and Capponi (2015) and Borovykh et al. (2018))
  - Single-regime without jump framework with optimal control (Carmona et al. (2015, 2018), and Sun (2017, 2018))

Interbank model

- M banks in the network
  - $X_i(t)$ is the liquidity level of bank i at time t.
  - θ_i is the ideal liquidity target of bank i.

- Regime shifts (e.g. normal and crisis regimes)
  - $Y(t)$ is the market regime at time t.
  - It is modelled by a time-homogeneous Markov chain with finite-state space.

Interbank model

$$dX_i(t) = \alpha_i(t)dt$$

Bank's own control

α_i: rate of adding liquidity

$$+\zeta\big(Y(t)\big)\sum_{j=1}^{M}\pi_{ij}(Y(t))\Big(\big[X_j(t)-\theta_j(Y(t))\big]-\big[X_i(t)-\theta_i(Y(t))\big]\Big)\,dt$$

Interbank relationship

π_{ij}: lending preference

ζ : overall exposure

$x_i - \theta_i$: excess liquidity

$$+\,\sigma_i\big(Y(t)\big)\sqrt{X_i(t)}\,dW_i(t)$$

Idiosyncratic shocks (daily deposit/withdrawal)

σ_i: volatility

W_i: Brownian motion

$$+\sum_{z=1}^{K}\eta(Y(t^-),z)\,X_i(t^-)\,dN_z(t)$$

Systemic shocks (bank run)

η: shock size

N: Poisson process

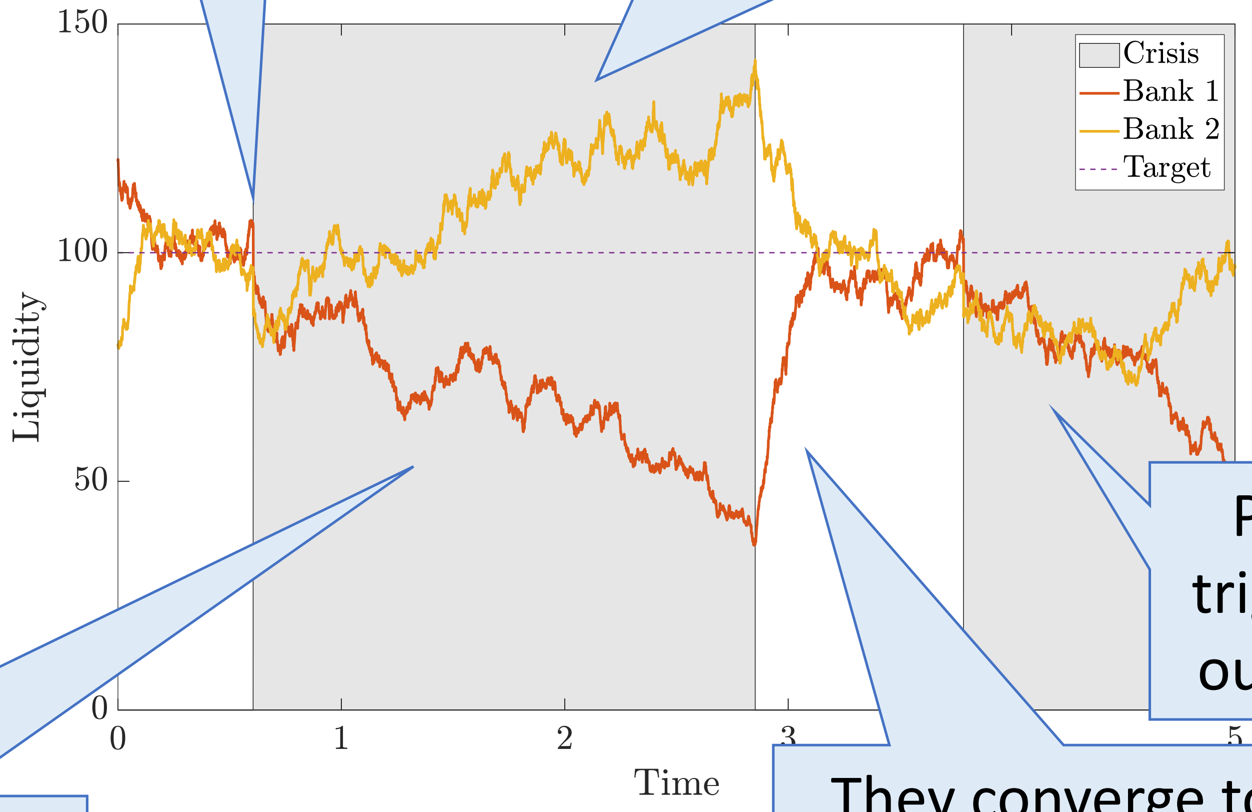
$$+\mu_i\big(Y(t)\big)\Big(X_i(t)-\theta_i\big(Y(t)\big)\Big)\,dt$$

Flight-to-quality (panic-triggered flows)

μ_i: degree of flight-to-quality

Interbank model

- Example:
  - Strongly interconnected during the normal regime.
  - Interbank market collapses during crises.
  - Systemic shock of -10% when transition to a crisis.
  - Flight-to-quality in crises.
  - Liquidity target at 100.
  - No bank's own control.



Negative 10% shock

No interbank market: Liquidity inflows for Bank 2 as its liquidity is above the target

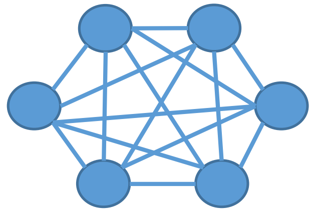
Liquidity outflows for Bank 1 as its liquidity is below the target

They converge to each other once the interbank market functions again

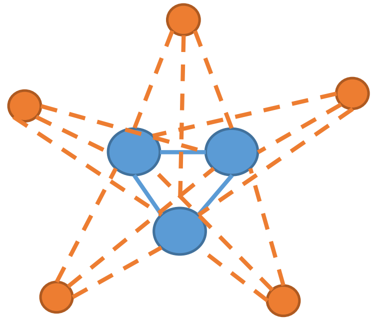
Panic-triggered outflows

Interbank model

- Large homogeneous complete network with single regime
  - All banks are homogeneous and connected to each other.
  - Infinite number of banks.
  - Theoretical results (not presented here).



- Core-peripheral network with group homogeneity and multiple regimes
  - Core banks are important banks in the network and are connected to each other.
  - Peripheral banks are smaller banks and are connected to core banks, but not any other peripheral banks.
  - Banks of the same type are homogeneous.
  - Numerical results (to be presented here).



Optimal control problem

- Objective function: $\min_{\alpha} \int_0^\infty e^{-\delta(Y(t))t} f_i(\alpha_i(t), X_i(t), Y(t))dt$

where

$$f_i(\alpha_i, x_i, y) = \frac{1}{2}\alpha_i^2 - b_i(y)\alpha_i(\theta_i(y) - x_i) + \frac{1}{2}q_i(y)(\theta_i(y) - x_i)^2$$

Controlling Cost
Cost of adding/removing liquidity through borrowing from/lending to a party outside the interbank market

Incentive
Incentive to control liquidity towards the target $\theta_i(y)$. (e.g. low lending rate with the central bank)

Penalty
Loss of profit from holding too much (less ability to extend credit) or too less (high bankruptcy cost) liquidity

Optimal control problem

- Optimal control under the Markov-Nash equilibrium: (core bank i)

Adjustment speed
b_C: incentive
$\gamma_1^C > 0$: non-incentive

Precautionary liquidity
(to buffer future losses)
$\Delta\theta_C$

$$\alpha_i^*(x_i, \bar{x}_{C_{-i}}, \bar{x}_P, y) = \left(b_C(y) + \gamma_1^C(y)\right)(\theta_C(y) + \Delta\theta_C(y) - x_i)$$

$$+\gamma_2^C(y)\left(\bar{x}_{C_{-i}} - x_i\right)$$

$$+\gamma_2^{CP}(y)([\bar{x}_P - \theta_P(y)] - [x_i - \theta_C(y)])$$

Interbank liquidity provision
(to gain more control)
$\gamma_2^C < 0$: within core group
$\gamma_2^{CP} < 0$: between groups
$\bar{x}_{C_{-i}}$: liquidity average of core except i
$\bar{x}_P$: liquidity average of peripheral

Main parameters

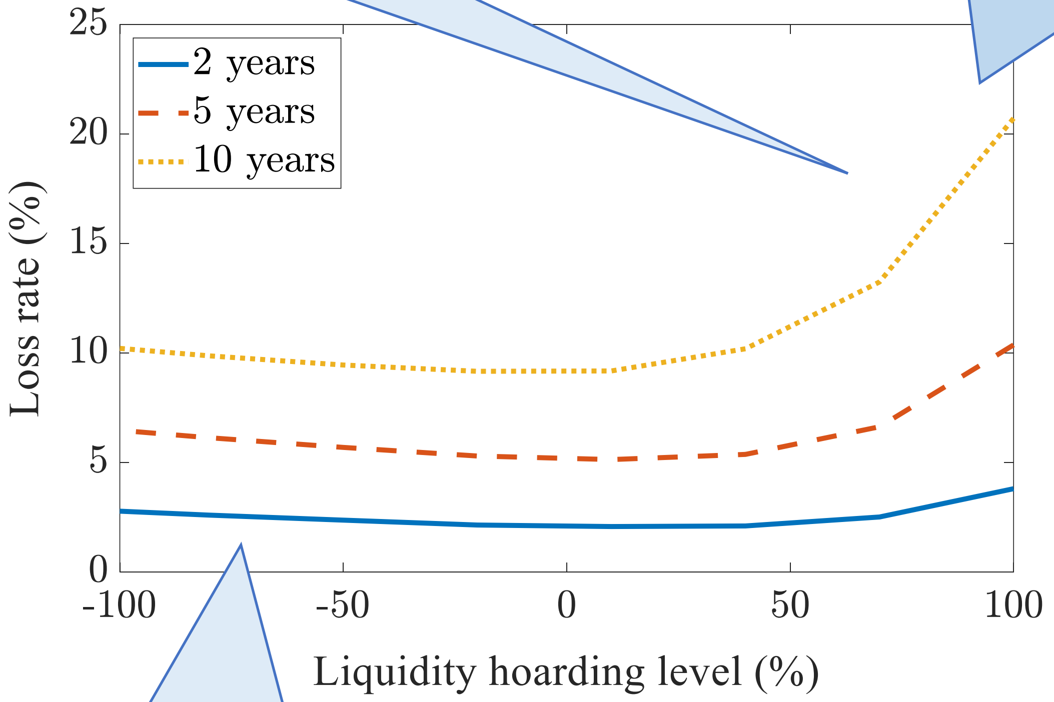
- Number of banks
  - 4 core + 24 peripheral
- Liquidity target θ
  - Large banks account for 85% of the banking sector ($\sim$ total asset).
- Lending preference π_{ij}
  - Average interbank exposure of a core bank $\approx 100 \times$ that of a peripheral bank (Craig and Ma (2022) and Lin and Zhang (2021)).
- Overall network exposure ζ
  - Core bank reduces 80% of liquidity gap by one quarter.
- Normal-to-crisis shocks η
  - -30% for peripheral and -10% for core banks.

Key results: Liquidity hoarding during crises

- Banks:
  - Potential borrowers (lenders) during crises tend to set higher (lower) precautionary liquidity targets during the normal regime.
- Regulators:
  - Motivate potential borrowers to hold more precautionary liquidity with higher adjustment speed.
  - Ensure that interbank network can function as usual during crises.

Higher default rate from borrowers

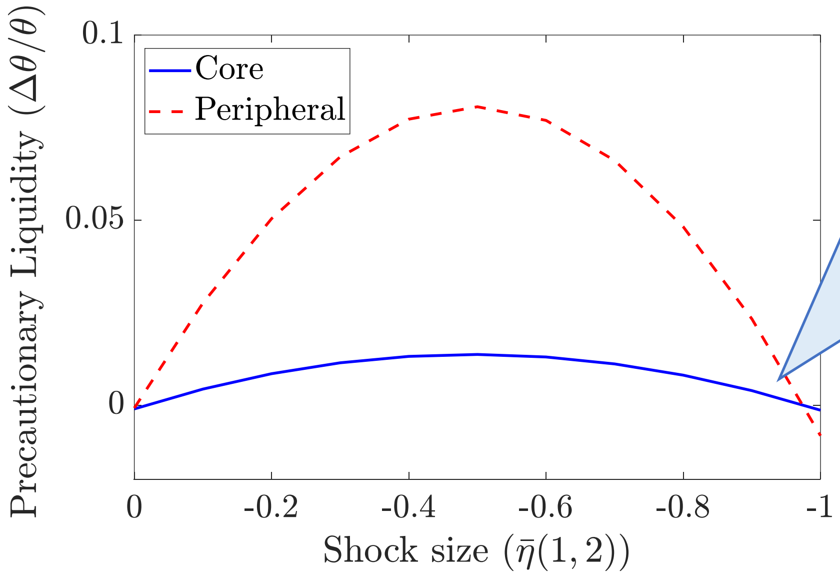
Worst when interbank market collapses



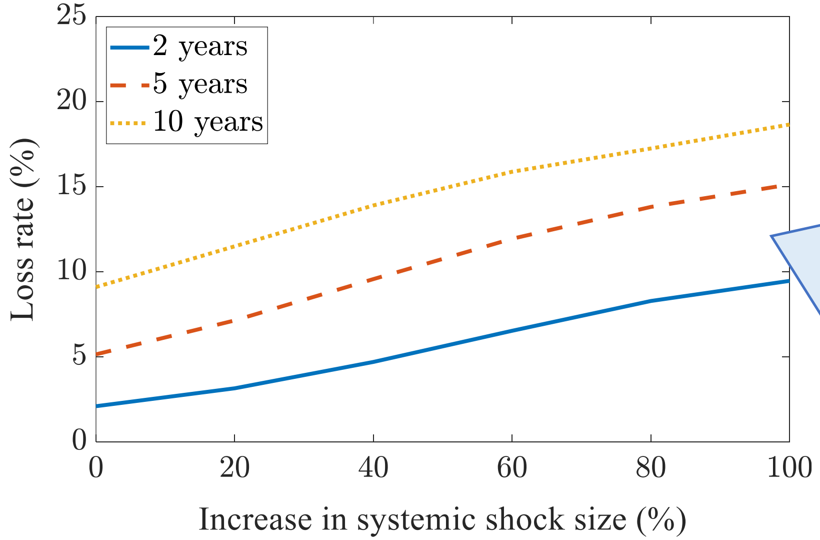
Higher default rate from lenders

Key results: Normal-to-crisis systemic shocks

- Banks:
  - Non-monotone response for the precautionary liquidity targets during the normal regime.
  - Reduce adjustment speed and interbank provision in the normal regime.
- Regulators:
  - Avoid large shock size (e.g. severe bank run).
- If interbank market collapses:
  - Even worst.



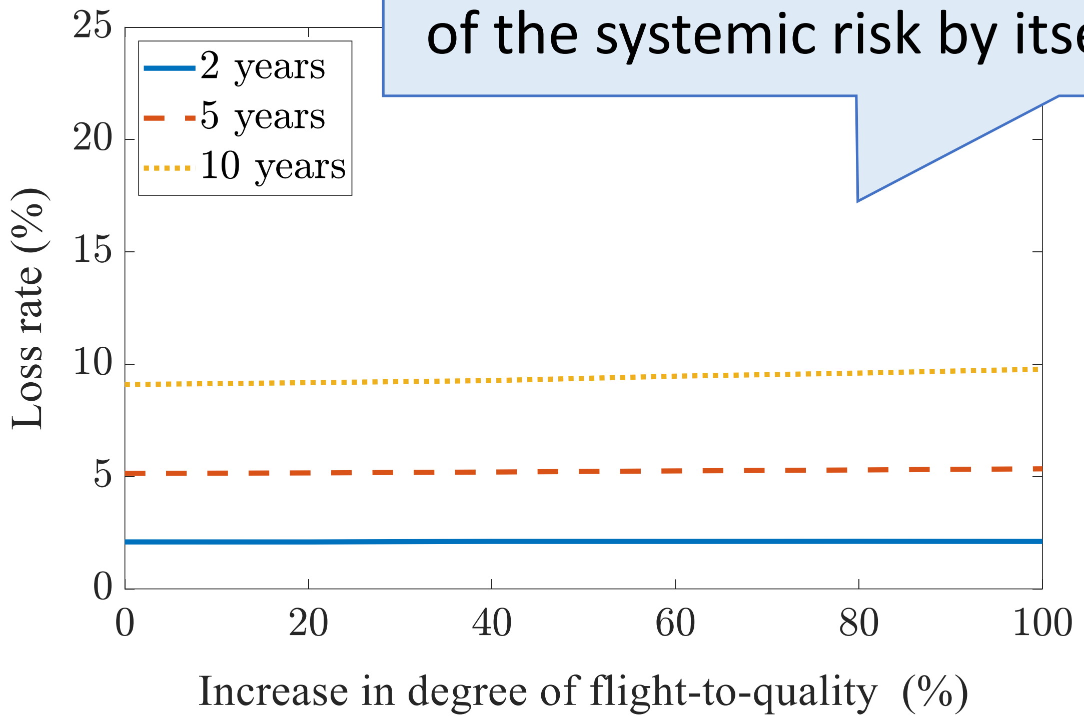
Most of precautionary liquidity will be lost once a shock occurs



Systemic risk increases significantly due to less prudential risk management

Key results: Flight-to-quality effect during crises

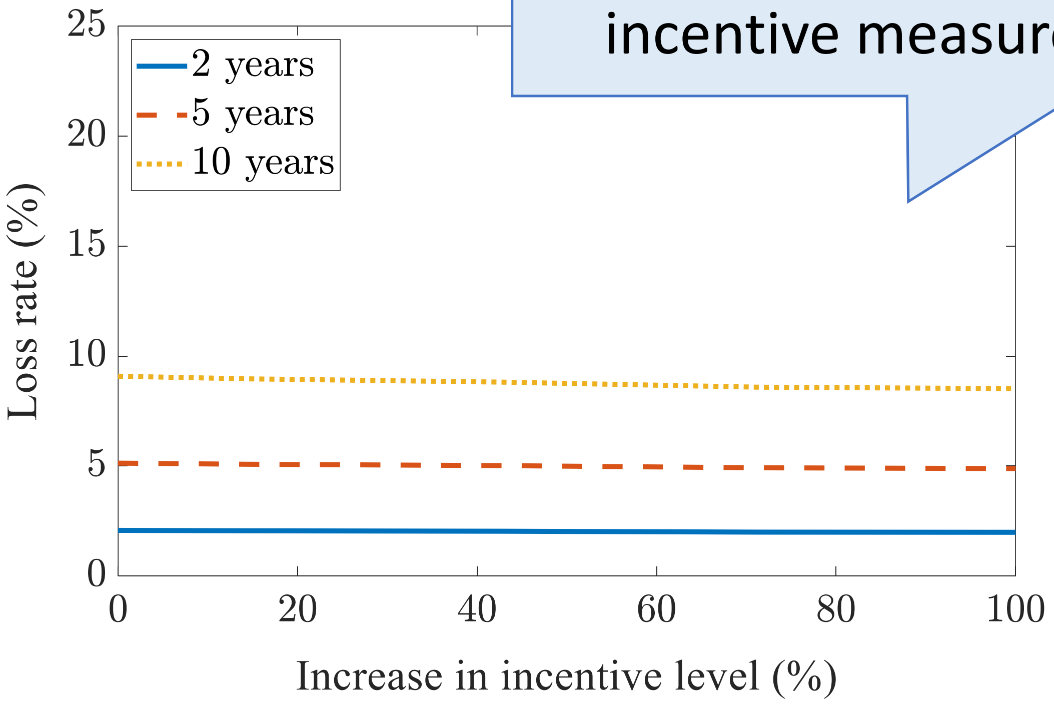
- Banks:
  - Set higher precautionary liquidity targets during the normal regime.
  - Increase the interbank liquidity provisions during the crisis regime.
- Regulators:
  - Ensure that banks understand the benefits of prudential policy.
  - Low additional regulatory cost.
- If interbank market collapses:
  - Worse loss rates for strong flight-to-quality effect can be observed.



Banks' prudential liquidity risk management takes care of the systemic risk by itself.

Key results: High incentive during crises

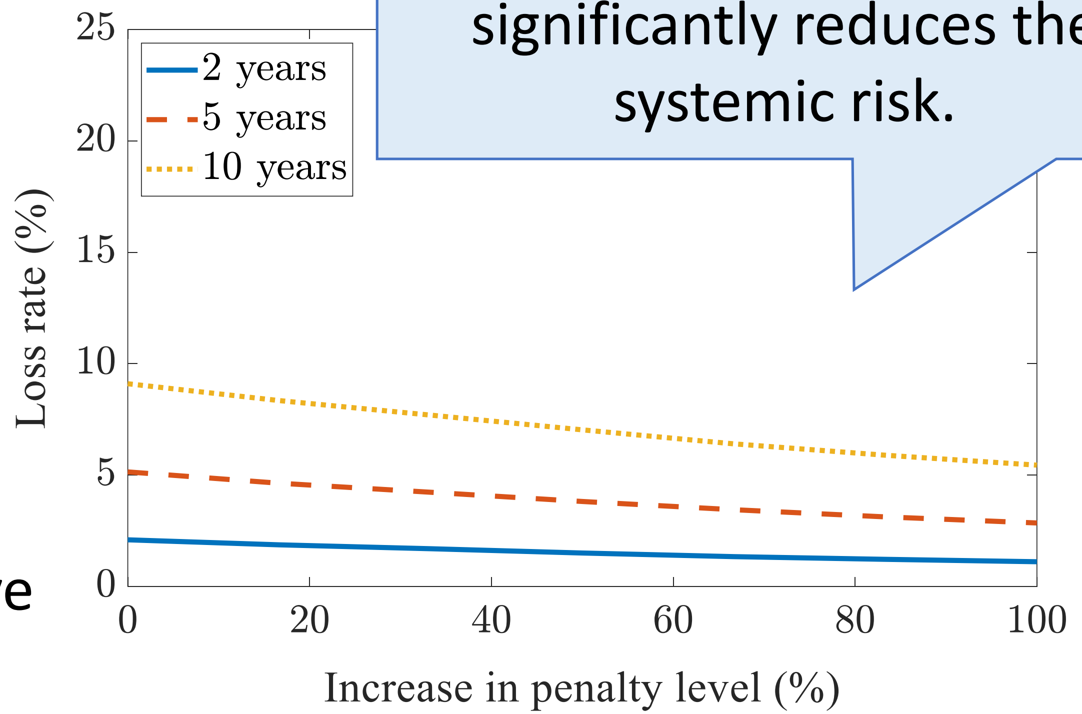
- Banks:
  - Reduce the precautionary liquidity targets during the normal regime.
  - Reduce the interbank liquidity provision and non-incentive component of the adjustment speed during the crisis regime.
  - Utilize lending facilities during crises.
- Regulators:
  - Direct and indirect costs.
- If interbank market collapses:
  - Similar results with higher loss rates.



Moral hazard reduces the effectiveness of the incentive measure.

Key results: High penalty during crises

- Banks:
  - Increase the precautionary liquidity targets during the normal regime.
  - Increase the interbank liquidity provision and adjustment speed during the crisis regime.
- Regulators:
  - Additional cost of banks' prudential risk management may lead to negative indirect effect on systemic risk.
- If interbank market collapses:
  - Similar results with higher loss rates.



Banks' more prudential liquidity risk management significantly reduces the systemic risk.

Conclusions and extensions

- Banks respond to each type of liquidity risk differently, and their responses may contribute positively or negatively to systemic risk.

- An explicit help during crises from the regulators creates moral hazard problems, while an explicit penalty leads to more prudential risk management. But costs associated with each type of policy need to be investigated further.

- Extensions:
  - Core banks act as intermediaries in the interbank markets.
  - Seeking for data for model fitting.