Risk-Sharing and the Creation of Systemic Risk

Viral Acharya — NYU Stern & NBER
Aaditya Iyer — NYU Stern
Rangarajan Sundaram — NYU Stern

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Introduction

- The last several decades have seen explosive growth in financial innovation.
- New contracts were designed to facilitate risk sharing ((eg.) markets in securitization, credit derivatives).
- Simultaneously, there has been a fall in bank liquidity holdings, and increased financial fragility.
- Alessandri and Haldane - Bank capital ratios have fallen over the last several decades.

Introduction-Paper Intuition

- In a world without risk-sharing, agents choose to hold sufficient liquidity to withstand both idiosyncratic and aggregate shocks.
- Risk-sharing arrangements such as clearinghouses are most effective in hedging against (uncorrelated) idiosyncratic shocks.
- With risk-sharing, agents increase risky investment, while lowering liquidity in the system.
- Risk sharing can improve welfare and lead to efficient holdings of liquidity.
- However, in the presence of a Lender of Last Resort, risk sharing can also lead to liquidity shortfalls and increased systemic risk.

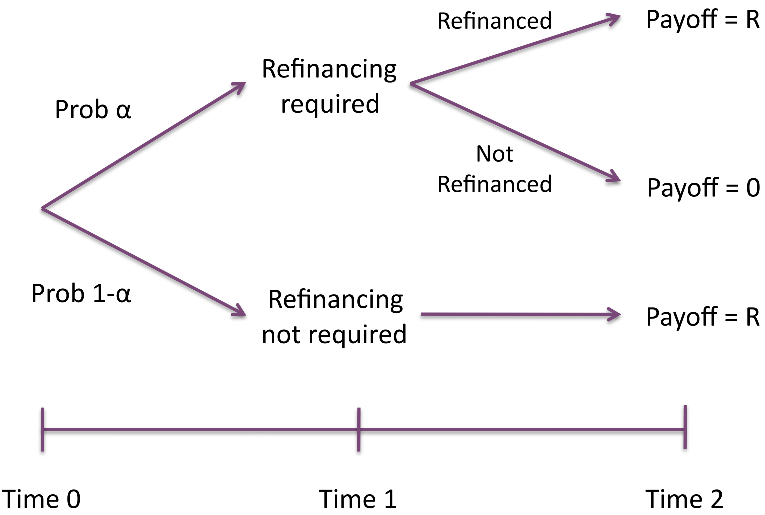
This paper

- Builds a model of risk-sharing leading to increased systemic risk.
- Intuition expressed in one-bank and many-bank framework.
- 1 bank model - optimal risk taking for a bank in autarky.
- Many bank model.
  - Banks share risks and co-insure each other by forming a mutually owned clearinghouse.
  - Banks are better off ex-ante and hold first-best levels of liquidity
  - In the presence of a Lender of Last Resort, banks are still better off, but there is a liquidity shortfall and they are more vulnerable to bad aggregate shocks through clearinghouse failure.

Model - One Bank Setting

- There are three periods and two assets - a risky and a riskfree asset.
- Risky asset returns $R > 1$.
- Risky project may need refinancing with probability α.
- The riskfree portfolio can fund this refinancing requirement.
- There is only one bank, so there is no pooling of risk.

Model - One Bank Setting



One Bank Setting - Optimization Problem

- Let bank invest amount ℓ in riskless asset and $(1-\ell)$ in risky project.
- Bank optimizes over ℓ.
- If $\ell < 1/2$, refinancing of risky project not possible.

$$E\Pi(\ell) = \ell + (1-\alpha)(1-\ell)R$$

- If $\ell > 1/2$, bank always refinances if shock hits.

$$E\Pi(\ell) = \ell + (1-\ell)R - \alpha(1-\ell)$$

One Bank - Optimal Investment Decision

- Bank chooses ℓ to optimize over expected payoff described above.
- Investment in riskless asset (ℓ) is governed by α and R and is intuitive.
- When refinancing is unlikely, bank chooses maximal risky investment.
- But optimally self-hedges when refinancing is more probable.

$$\alpha < \frac{R-1}{2R-1} \implies \ell = 0$$

$$\alpha \in [\frac{R-1}{2R-1}, R-1] \implies \ell = \frac{1}{2}$$

$$\alpha > R-1 \implies \ell = 1$$

Clearinghouse: A Co-Insurance Model

- Now, we model several banks sharing risk by owning a clearinghouse.
- A clearinghouse allows mutualization of returns and risk, and allows transfers from successful to failed banks.
- Banks choose amount of margin they deposit into clearinghouse, and liquidity carried over.
- If clearinghouse fails, insolvent banks sell assets in fire sale. Solvent banks can pledge future earnings to purchase these assets.

Many Banks - A Co-Insurance Model

- Continuum of banks (of measure 1) pay premium k to the clearinghouse.
- Bank i is exposed to an idiosyncratic shock ($\epsilon_i \sim N(0,1)$) and an aggregate shock ($a \sim N(0,1)$).
- Total shock to bank i, $z_i = \sqrt{\rho}a + \sqrt{1-\rho}\epsilon_i$
- Bank i needs refinancing if $z_i < c$; it is bailed out if clearinghouse survives; $\alpha = N(c)$ is the autarkic probability of failure.

Clearinghouse: A Co-Insurance Model

- The clearinghouse collects up-front margin and can make capital calls on solvent banks.
- Clearinghouse can call on liquidity held by banks, and pledge fraction τ of banks' future revenues to make transfers from solvent to insolvent banks.
- Size of the transfer is contingent on the number of failures.
- The clearinghouse becomes insolvent when the required bailout exceeds available revenue, and a fire sale takes place.

Clearinghouse: A Co-Insurance Model

- Banks contribute margin k to the clearinghouse and carry over liquidity ℓ.
- Let f be the number of banks requiring refinancing $\implies$ total refinancing need $= f(1-k-\ell)$.
- Revenue of banks not requiring refinancing $= R(1-f)(1-k-\ell)$.
- Define $\eta(f)$ as the portion of revenue transferred by successful banks to refinance failed firms.

$$\eta(f) = \frac{f(1-k-\ell) - k - \ell}{\tau R(1-k-\ell)(1-f)}$$

- Clearing house fails if

$$\eta(f) > 1 \iff f > \frac{\tau R(1-k-\ell) + k + \ell}{(\tau R + 1)(1-k-\ell)} \iff a < a_0(k,\ell)$$

$$a_0(k,\ell) = \frac{c - \sqrt{1-\rho}N^{-1}[\tau R/(1+\tau R) + (k+\ell)/(1+\tau R)(1-k-\ell)]}{\sqrt{\rho}}$$

Clearinghouse failure and fire sale

- If the clearinghouse fails, margin in the clearinghouse is rebated (randomly) to insolvent banks to bail them out.
- Those banks which do not get bailed out sell assets in fire sale, which is then purchased by solvent banks.
- Solvent banks take prices as given, and submit demand functions to purchase assets.
- Solvent banks can use liquidity carried over and pledge fraction τ of future payoffs. These banks only generate a return of $(R - \Delta)$ from acquired assets.

Fire sale demand functions and prices

- As before, denote the number of banks that have failed by $f(k, \ell)$.
- Clearinghouse uses margins to bail out $g(k, \ell)$ banks before declaring insolvency. $g(k, \ell) = k/(1 - k - \ell)$.
- $y(p, k, \ell)$ is demand function submitted by each bank in the fire sale.
- Market clearing:

$$y(p, k, \ell)[1 - f(a)] = (1 - k - \ell)[f(a) - g(k, \ell)]$$

Also,

$$y(p, k, \ell) = \frac{(\ell + \tau R(1 - k - \ell) - y(p, k, \ell))^+}{p} \quad \text{where} \quad x^+ = max(x, 0)$$

Fire sale demand functions and prices

$$p(k,\ell) = max(0, -1 + [\ell + \tau R(1-k-\ell)] \frac{(1-f(a))}{(1-k-\ell)(f(a)-g(k,\ell))})$$

- Fire sale price $p(k,\ell)$ decreases with number of failures f.
- If number of failures is low enough ($f < f_1$), price is $(R - \Delta - 1)$, and acquiring banks do not make a profit on purchased assets.
- If number of failures is high ($f > \underline{f}$), price is zero

Region	Fire sale price	Fire sale demand	Profits (for acquiring firms)
$f \in [f_0, f_1)$	$(R - \Delta - 1)$	$y(R - \Delta - 1, k, \ell)$	0
$f \in [f_1, \underline{f}]$	$p(k,\ell)$	$y(p,k,\ell)$	$(R - \Delta - 1 - p)y(p,k,\ell)$
$f \in [\underline{f}, 1]$	0	$y(0,k,\ell)$	$(R - \Delta - 1)y(0,k,\ell)$

Equilibrium:

- Clearinghouse sets margin level, k, paid by each bank. Banks choose liquidity ℓ taking as given liquidity $\bar{\ell}$ carried over by other banks.
- We focus on symmetric equilibria where all banks carry the same liquidity.
- The equilibrium quantities k^* and ℓ^* solve the following system:

$$\ell^*(k) = \arg\max_{\ell} \; \mathbf{E}\Pi(k, \ell, \bar{\ell}) \quad \text{and} \quad \ell^* = \bar{\ell}$$

$$k^* = \arg\max_{k} \; \mathbf{E}\Pi(k, \ell^*(k), \ell^*(k))$$

Properties of Equilibrium:

- Expected profits $\mathbf{E}\Pi(k, \ell, \bar{\ell})$ is linear in ℓ.

$$\mathbf{E}\Pi(k, \ell, \bar{\ell}) = \alpha_0(k, \bar{\ell}) + \alpha_1(k, \bar{\ell})\ell$$

There is a bang-bang solution to the bank's choice of ℓ.

Case 1: $\alpha_1(k, \bar{\ell}) < 0$. Then, $\ell^*(k, \bar{\ell}) = 0$. For a symmetric equilibrium to exist, $\bar{\ell} = 0$, and for consistency, $\alpha_1(k, 0) < 0$. This situation corresponds to the case where the bank carries over no liquidity from time 0.

Case 2: $\alpha_1(k, \bar{\ell}) = 0$ Bank is indifferent to the choice of ℓ. For a symmetric equilibrium, the bank chooses $\ell^*(k, \bar{\ell}) = \bar{\ell}$.

Case 3: $\alpha_1(k, \bar{\ell}) > 0$ In this case, the bank chooses $\ell^*(k, \bar{\ell}) = 1$ and in equilibrium, $\ell^* = \bar{\ell} = 1$. There is no systemic risk or investment in the risky asset and the clearing house never fails.

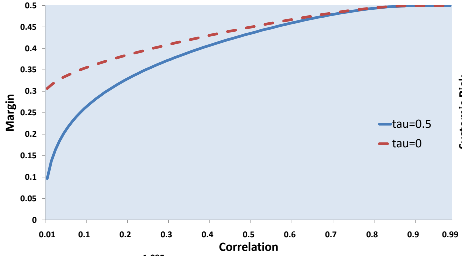
Properties of Equilibrium:

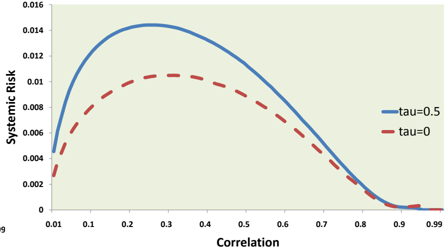
- For every ρ and for every k, there exists a unique $\ell^*(k)$ such that $(k, \ell^*(k))$ is an equilibrium.
- For every ρ, $\ell^*(k^*) = 0$, where $k^* = \arg\max_k \quad \mathbf{E}\Pi(k, \ell^*(k))$
- In the absence of the clearinghouse, banks choose to carry over enough liquidity to always be able to refinance themselves if required, i.e. $\tilde{\ell} = 1/2$.
- In the absence of the clearinghouse, profit is the same as under autarky, and equals $\Pi^{aut} = (1 + R - \alpha)/2$.
- $\mathbf{E}\Pi(k^*, 0) > \Pi^{aut}$, so expected payoffs under the clearing house always dominates autarky.
- In the presence of the clearinghouse, there is always systemic risk.

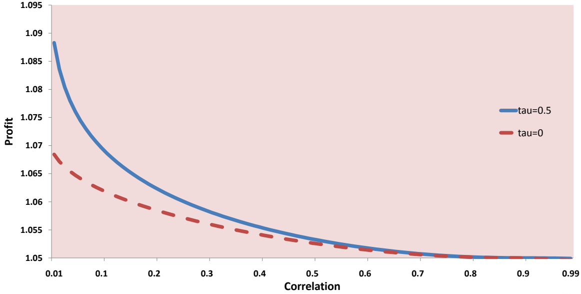
Asymmetric Equilibria

- So far, we have focused on the outcomes of symmetric equilibria where all banks carry same liquidity ℓ^*.
- We can generalize framework to allow for asymmetric equilibria, where there are n "types" of banks.
- In particular, let w_i banks carry liquidity $\bar{\ell}_i$, where $\Sigma_{i=1}^{n} w_i = 1$.
- Bank chooses liquidity ℓ taking as given weights (w_i) and liquidity holdings $(\bar{\ell}_i)$.
- **Claim:** For any asymmetric equilibrium $(\mathbf{w}, \bar{\boldsymbol{\ell}})$, $\exists$ a unique symmetric equilibrium $\ell^*(\mathbf{w}, \bar{\boldsymbol{\ell}})$ which delivers the same profits and systemic risk for all the banks.

Equilibrium under coinsurance and fire sale



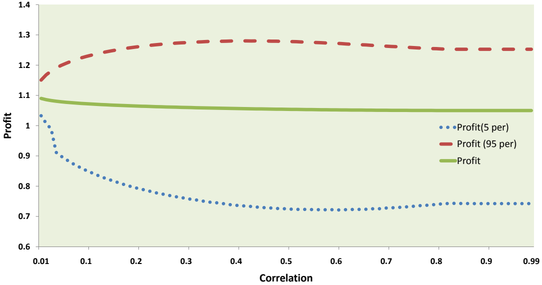


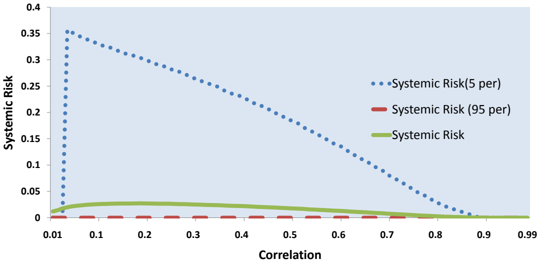


Results

- Margins rise with correlation, converging to autarkic levels.
- Systemic risk first rises with correlation, and then decreases.
- An increase in τ, the amount of future income that can be pledged in a fire sale increases systemic risk for all values of ρ.
- Under autarky, banks continue to self-hedge and there is no aggregate risk.

Dependence of profits and systemic risk on aggregate shock





Regulation and First-best outcomes

- How efficient is the clearinghouse in raising profits for banks? Is it possible for a regulator to do better?

- Regulator sets margin (k^{FB}) and liquidity (ℓ^{FB}) levels for all banks to maximize expected profits.

$$(k^{FB}, \ell^{FB}) = \arg\max_{k,\ell} \quad \mathbf{E}\Pi^{FB}(k, \ell)$$

- For every value of correlation ρ, $k^{FB}(\rho) = k^*(\rho)$ and $\ell^{FB}(\rho) = \ell^*(k^*, \rho) = 0$

- For every value of ρ, $\mathbf{E}\Pi^{FB}(\rho) = \mathbf{E}\Pi(\rho)$, and systemic risk is as large under the first-best outcome as under equilibrium.

Lender of Last Resort

- Without external intervention, the clearinghouse is able to deliver first-best welfare and liquidity outcomes.
- In practice, however, there is a Lender of Last Resort that injects liquidity into a clearinghouse in the case of an emergency.
- The Federal Reserve extended credit to the CME following the 1987 crash.
- We extend the model allowing for the presence of a Lender of Last Resort.
- This can lead to liquidity shortfalls and lower welfare.

Model with Lender of Last Resort

- Assume that the Lender of Last Resort (LoLR) injects funds $g(a)$ into the economy at cost $c(g) = a_{gov}g^2$
- The LoLR refinances $g(a)/(1-k-\bar{\ell})$ banks, and the total benefit to the economy through liquidity injections is $\Delta g(a)$.
- The maximal LoLR injection g^* satisfies $c'(g^*) = \Delta$.
- Clearinghouse and banks take LoLR injection as given, and choose margins k^* and liquidity $\bar{\ell}$.
- There is a fire sale if not all banks can be refinanced even if $g = g^*$.

Model with Lender of Last Resort

- Assume that the LoLR injects $g = g^*$ if $a < a_g$.
- If $a \in (a_g, a_0)$, the clearinghouse fails, but the LoLR injects $g < g^*$ and there is no fire sale.
- If $(a > a_0)$, then the clearinghouse survives and $g = 0$.
- Welfare is given by

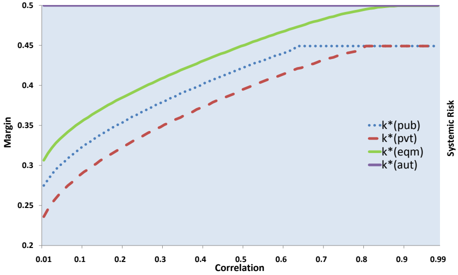
$$W(k, \ell, \bar{\ell}) = \mathbf{E}\Pi(k, \ell, \bar{\ell}) - c(g^*)P(a < a_g(k, \bar{\ell}) - \int_{a_g}^{a_0} c(g(a))\phi(a)da$$

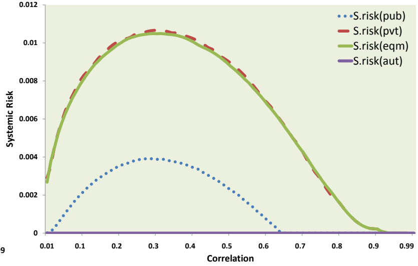
Let us define

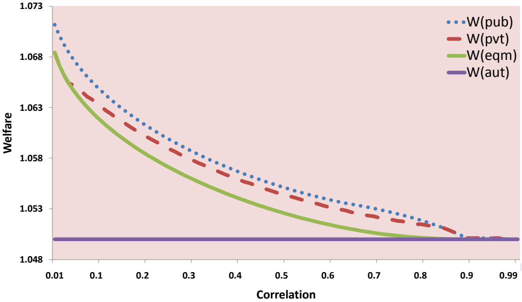
$$k^*_{pub} = \arg\max_k W(k, \ell, \bar{\ell}(k)) \; ; \; k^*_{pvt} = \arg\max_k \mathbf{E}\Pi(k, \ell, \bar{\ell}(k))|g^*$$

$$k^*_{eqm} = \arg\max_k \mathbf{E}\Pi(k, \ell, \bar{\ell}(k))|g^* = 0$$

Outcomes with Lender of last resort







Conclusions

- This paper builds a model showing how risk sharing can increase systemic risk in a framework where there are several banks mutually owning a clearinghouse.
- However, the presence of risk sharing while increasing systemic risk can also generate first-best outcomes.
- In the presence of Lender of Last Resort provisions, however, a clearinghouse can lead to inefficiently high systemic risk and lower welfare.
- This provides a rationale for regulation in the form of margin requirements for clearinghouses.