Financial Networks

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Motivation: Why do we care?

- Degree of interconnectedness among financial institution
  - Systemic risk and contagion
  - Too-connected-to-fail
  - Bailout and regulation

Motivation: Why do we care?

- Degree of interconnectedness among financial institution
  - Systemic risk and contagion
  - Too-connected-to-fail
  - Bailout and regulation
- Take the structure of interbank network as given
  - Implications for prices, quantities, information (positive)
  - For systemic risk and contagion (normative)
- Network formation
  - Bank incentives to form connections in the first place
  - Resource allocation, risk sharing, information aggregation

Outline

1. Overview of Literature
   - Contagion and Systemic Risk
   - Network Formation
   - Intermediation
   - OTC Markets
   - Others
2. Intermediation and Voluntary Exposure to Counterparty Risk
3. Meeting Technologies in Decentralized Asset Markets
4. Concluding Remarks

My Subjective Classification!

- Question
  - Contagion and Systemic Risk properties of given network structure
  - Network formation
- Basic Model
  - Allen and Gale (2000): Liquidity shocks
  - Eisenberg and Noe (2001): Fix point payment vector

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- Intermediation (often OTC)
  - Pricing, efficiency, collateralized lending, network formation
- OTC markets
  - Risk sharing, price dispersion, information diffusion
- Useful tool
  - Search

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- Useful tool
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- Others: Complexity, disclosure

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Allen and Gale (2000)

- 3 date model with intermediate liquidity shocks, a la Diamond-Dybvig (1983)
- 4 regions, pairwise complementary liquidity shock (A, B), (C, D)

$$\lambda = \frac{\lambda_L + \lambda_H}{2}$$

- 3 networks: complete, ring, two disconnected components
- **Base model, no aggregate shock**: Regardless of the network structure $\rightarrow$ incentive-efficient risk sharing, no contagion
- **MIT shock** ϵ
  - ϵ sufficiently small: No contagion
  - ϵ intermediate: complete $>$ two components $>$ ring
  - ϵ sufficiently large: two components $>$ complete $=$ ring

Eisenberg and Noe (2001)

- N banks, their arbitrary interbank obligations, and obligations to/cash flow from outsiders
- Shock realization vector
- For some bank(s) i, total assets $<$ total liabilities $\rightarrow$ i cannot pay $\rightarrow$ i defaults $\rightarrow$ i creditors get proportional, partial repayment (in order of seniority)
- Assets (and so liabilities) of other banks affected $\rightarrow$ iterate until convergence: **clearing payment vector**
- Fix point exists

Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015)

- Interbank lending model a la Eisenberg and Noe (2001), with junior outside claims
- Ring network always perform terrible
- **Phase Transition**: Robust-yet-fragile interconnected networks
  - Small/few shocks: Symmetric complete network is absorbing, no contagion
  - Large/many shocks: Complete network is as bad as ring.
    - "weakly connected" financial networks perform better

Others

- Elliott, Golub and Jackson (2014)
  - Model of cascade and contagion
  - Financial institutions *cross-hold* each other (equity claims) + outside equity holders
  - Minimum value requirements +cost of default: **debt-like** contracts
  - Diversification: contagion non-monotonic $\rightarrow$ increase and then fall
  - Integration: contagion monotonically increases (unless already very high)
- Gai and Kapadia (2010), Gai, Haldane, and Kapadia (2011), Freixas, Parigi, and Rochet (2000), Wagner (2011), Upper (2011), Gofman (2011), Gourieroux, Heam, and Monfort (2014), Dasgupta (2004), Furfine (1999).

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Preamble

- General network formation literature
  - Bala and Goyal (2000), Hojman and Szeidl (2006, 2008)
- Financial network caveat
  - Connections between banks (interbank loans, overlapping asset portfolios, derivative exposures) very complex
  - High level of abstraction!

Babus (2015): Risk-sharing and contagion

- Model of network of interbank deposits with two types of links, based on Allen and Gale (2000)
  - Liquidity links between banks in different regions to smooth liquidity shocks (complete and exogenous);
  - Solvency links between banks in the same region to provide insurance against contagion risk (endogenous).

Babus (2015): Risk-sharing and contagion

- Contagion: systemic effects of a shock that makes one bank insolvent depends on the number of his links
  - solvency links $> \bar{\eta}$: neighbors incur a loss, but no contagion;
  - solvency links $< \bar{\eta}$: all banks default by contagion.
- Link formation incentives:
  - Banks willing to incur a small loss on their deposits, if they can avoid default.
  - Free-riding on others links: they are better off if contagion is averted without incurring any loss.
- Main results:
  - In a stable network, at least half the banks have $\bar{\eta}$ solvency links;
  - There exist stable networks in which there is no contagion;
  - In interbank networks in which contagion does not occur, welfare is not necessarily increasing in the number of links

Others

- Zawadowski (2013)
  - Banks on a ring
  - Network formation: a bank can enter into credit derivatives with neighbors
  - Banks choose **not** to hedge counterparty risk → systemic risk
  - Inefficiency: banks don't internalize contagion externality and under-insure
- Babus and Hu (2015), Kiyotaki and Moore (1997), Elliott and Hazel (2016), Allen, Babus and Carletti (2012), Moore (2011), Rotemberg (2008), Zawadowski (2011), Zawadowski (2013), Blume et al (2011), and Cabrales, Gottardi, and Vega-Redondo (2015), Heam and Koch (2013), Craig and Von Peter (2014), Castiglionesi and Navarro (2016), Hommes, in 't Veld and van del Leij (2016), Erol and Vohra (2014).

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Intermediation 1: OTC Markets

- Babus and Hu (2015)
  - Traders are connected through an exogenous *informational* network
  - Limited enforcements: collateralized and uncollteralized trade
  - Opportunity cost for one-shot, collateralized trade
  - Intermediation provides agents that meet infrequently more favorable terms of trade than one-shot interactions
  - **Network of intermediaries** used to **sustain unsecured trade**
    - Large market size, sufficiently concentrated network
  - Incentive compatibility requires intermediation fees
  - Star networks are the constrained efficient and stable, and feature higher intermediation fees

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- Gofman (2011)
  - Trade probability and prices for exogenous trade networks
  - Trade efficiency
  - Inefficient trade: **trade-break down due to bargaining frictions**
  - Dense networks help and hurt: how bad are interconnected financial institutions?

Intermediation 2

- Glode and Opp (2015)
  - What is **good about long intermediation chains**?
  - Bilateral trade with asymmetric information
  - Chain of moderately informed intermediaries facilitate efficient trade by reducing the adverse selection problem within each trade
  - Avoid trade break-down due to aggressive price quotes

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- DiMaggio and Tahbaz-Salehi (2014)
  - What is **bad about long intermediation chains**?
  - Intermediation chain with moral hazard (fund diversion)
  - Collateralized lending to overcome moral hazard
  - Moral hazard cumulative: haircuts increasing in chain length
  - Abundant collateral asset → first best
  - Scarce collateral → *intermediation capacity*: collateral's liquidity, volatility and availability

Intersection: Farboodi (2015)

- Network formation focusing on intermediation!
  1. Which types of networks endogenously arise?
     - Do they qualitatively match the patterns we observe?
  2. Are some more efficient than others?
  3. Are there policies to improve equilibrium efficiency?

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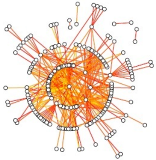
- Equilibria:
  - Type 1: *core-periphery* equilibrium
    - Set of highly connected banks at core
    - Excessive exposure to counterparty risk
  - Type 2: under-investment equilibrium
    - Savings trapped in a subset of banks



- Efficiency
  - Centralized clearing house

Honorable Mention

- Manea (2014)
    - Model of general intermediation
    - Takes the network as given and characterizes prices
    - Where do intermediation rents come from
        - **Layers of intermediation**
        - Within layer: seller intermediary extracts all the rents due to competition
        - Across layers: hold-up generates intermediation rent for buyer intermediary

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Preamble

- Information diffusion, pricing, risk sharing, entry
- Externalities when agents involve in multiple concurrent trades
- Complementary approach to search-based models

Networks and OTC Markets

- Babus and Kondor (2014)
  - Model of information diffusion with private info
  - Exogenous trade network
  - Strategies trade by submitting quantity-price schedules
  - Dealers involved in multiple concurrent trades
  - Strategic trading motives do **not** affect information revelation
    - **Information diffusion is substantial**
    - Each bilateral price partially aggregates private info of **all** agents
  - **Inefficient learning**: distorted by the structure of trading links.

Networks and OTC Markets 2

- Atkeson, Eisfeldt and Weill (2013)
  - Model of entry, trade pattern, price formation
  - Risk sharing subject to frictions
    - Entry costs and limited positions
  - *Large* banks become dealers (middlemen), average banks costumers and small banks stay out
  - Efficient market size (conditional on composition)
  - **Inefficient composition**: Too much concentration → too many middlemen and too few costumers

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- Search Models: directed versus random search
    - Neklyudov (2012), Chang and Zhang (2015), Uslu (2015), Chaojun (2016), Farboodi, Jarosch and Shimer (2016), Farboodi, Jarosch and Menzio (2016).

Farboodi, Jarosch and Shimer (2016)

- Random search model a la Duffie, Garleanu, Pederson (2005)
- Theory of intermediation in decentralized asset markets
  - Consequence of heterogeneity in market access
- But why is there dispersion in market access?
  - Arises naturally to leverage the gains from intermediation
  - Consistent with both equilibrium and efficient allocations
- And there is heterogeneity *only* if there is intermediation!

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What Else?

- Caballero and Simsek (2013)
  - Model of **complexity (network uncertainty)**
  - Banks located on a ring
  - Uncertainty about financial network and the identity of distressed banks leads to excess liquidity hoarding, lower profitability and more failures
  - Balance sheet contagion, fire sales and credit crunch

What Else?

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  - Banks located on a ring
  - Uncertainty about financial network and the identity of distressed banks leads to excess liquidity hoarding, lower profitability and more failures
  - Balance sheet contagion, fire sales and credit crunch
- Alvarez and Barlevy (2015)
  - Does mandatory disclosure of bank balance sheet info improve welfare?
  - Banks endowed by *equity* which depends on other bank types through symmetric patterns (possible contagion)
  - Disclosure must be forbidden if in the absence of balance sheet information investors would fund banks
  - **Mandatory disclosure** can increase welfare if banks engage in moral hazard, only if **contagion is sufficiently large**

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Environment

- I: banks who can invest
  - Potential to make risky investment
- NI: banks who can never invest
  - Have raised one unit on competitive market (debt)
- Value of other businesses for each bank: V_i
- All contracts are debt
- Maximize expected return net of expected cost of failure
- Universal risk neutrality, no discounting

Risky Technology

- Date 1
  - Investment opportunity arrives with iid probability q at each I
- Date 2
  - iid return across investors $\tilde{R}$

$$\tilde{R} = \begin{cases} R & \text{with probability } p \\ 0 & \text{otherwise} \end{cases}$$

- Scalable

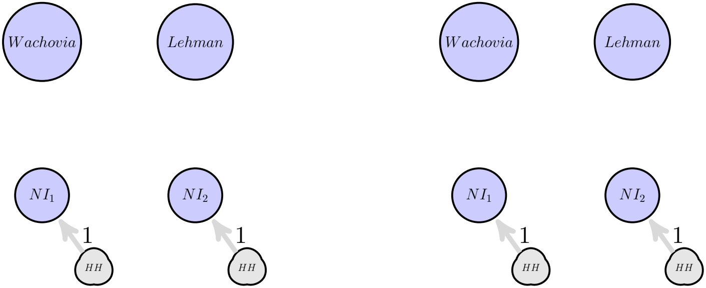
Frictions

- Contracting friction
  - Surplus allocation depends on network structure
  - Intermediators get positive share
  - Rents cannot be negotiated away
- Lending friction
  - Minimum size of lending contract
  - Intermediation required
  - Endogenous limit on number of counterparties
- Solution concept: Group Stability

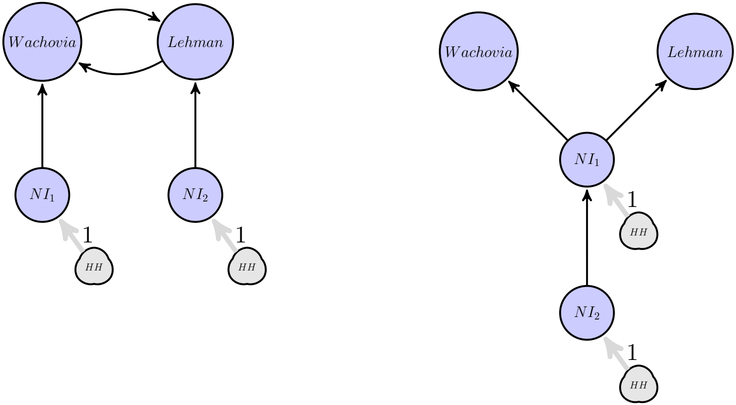
Timing

- Date 0
  - Funding raised from households
  - Network formation: banks enter *potential* lending relationships
- Date 1
  - Risky investment opportunities arrive
  - Loans made
- Date 2
  - Return realized
  - Debt payed back
  - Bank fails and looses V_i if unable to pay back obligation

Example ($t = 0$)


Wachovia
Lehman
NI_1
NI_2
1
1
HH
HH
Wachovia
Lehman
NI_1
NI_2
1
1
HH
HH

Example ($t = 0$)


Wachovia
Lehman
NI_1
NI_2
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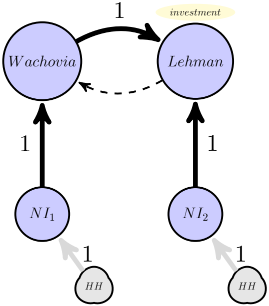
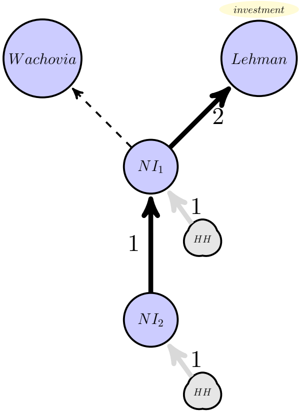
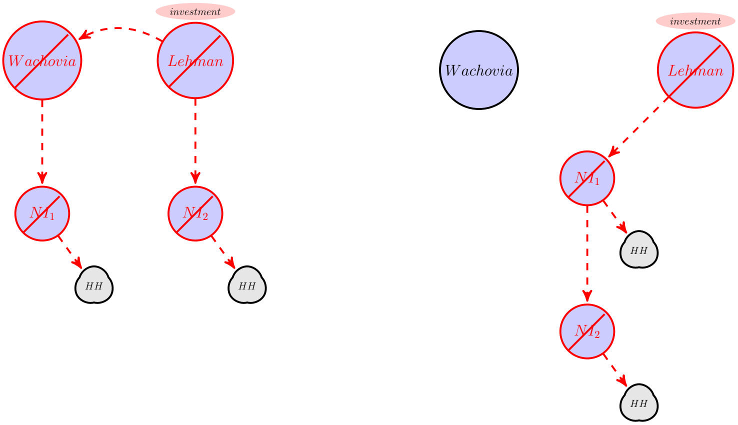
1
HH
HH
Wachovia
Lehman
NI_1
1
HH
NI_2
1
HH

Example ($t = 1$): Only Lehman has Investment

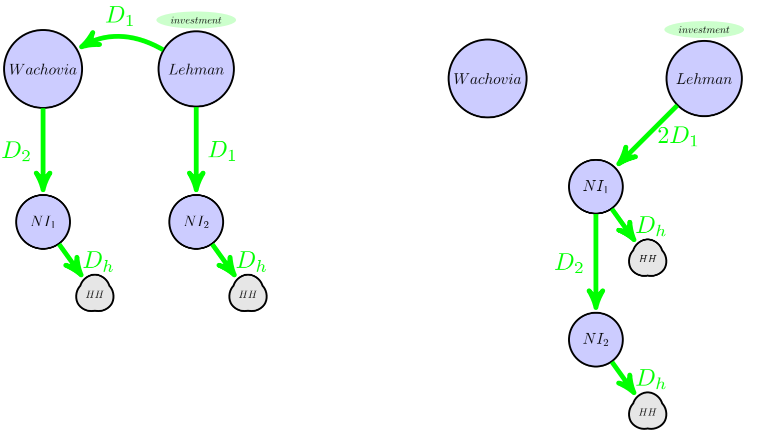




Example $(t = 2)$: Project Fails

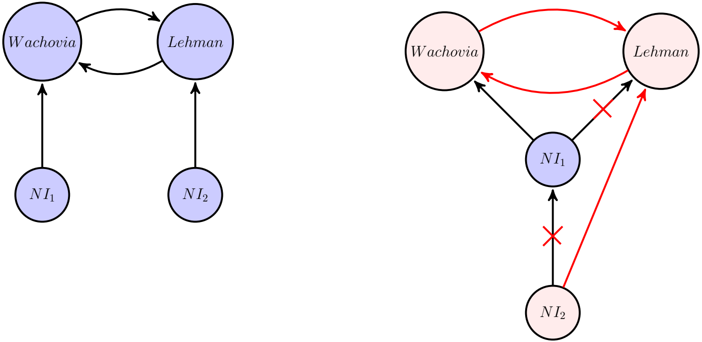


Example $(t = 2)$: Project Succeeds



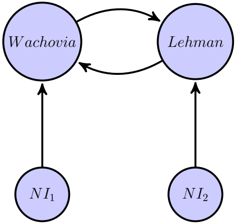
- $D_1 > D_2$: Return to lender
- $p(D_1 - D_2) \lesseqgtr (1-p)V_I$: Intermediation spread versus cost of failure

Equilibrium

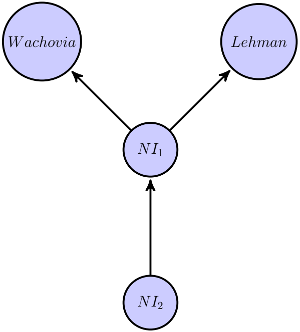


Detail

Stability versus Efficiency



(A) Inefficient Stable



(B) Efficient Unstable

- $\frac{\text{Intermediation Rent}}{\text{Cost of Failure}} > Z$

Misaligned Incentives

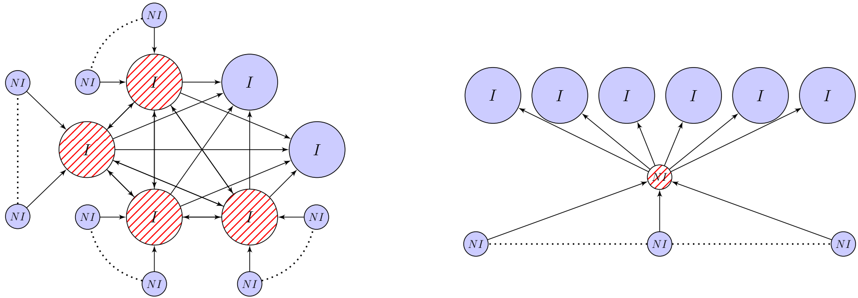
- Efficiency: scale of investment versus loss in the event of failure
  - *Efficient Intermediator*: imposes minimal extra cost of failure
- Individual incentives: return versus loss of failure
  - ***Intermediation spread*** versus ***cost of default***

    Redistribution (Intermediation spread) — Social Loss (cost of default)
  - *Equilibrium Intermediator*: offers highest rate of return
  - Does he minimize the cost?

General Result

Proposition

When intermediation rents are sufficiently high, there is a family of equilibria that consist of a subset of I banks at the core, forming a digraph. Each I bank at the core borrows from a subset of NI banks, and lends to every I bank outside the core. These equilibria are all inefficient.



(A) Equilibrium (B) Efficient

▸ Conclusion

Final Notes

- Endogenous formation of financial network has implications
  - Overall structure of inter-bank network
    - Core-periphery
  - Inter-bank exposures
    - High gross and low net exposure among banks with risky investment at the core
  - Efficiency
    - Excessive exposure to counterpart risk
    - Inefficient intermediation (and dis-intermediation)

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Model

- Measure one of risk-neutral investors, discount rate $r \to 0$
- Two preference states, $\{A, B\}$
  - Switch at exogenous rate $\gamma > 0$
- Two asset holdings, $\{a, b\}$, equal supply of each
  - Trading opportunities at endogenous rate λ
- λ chosen irrevocably at time 0, cost $c(\lambda)$ per meeting
- Payoffs
  - Well-matched: flow payoff 1
  - Mismatched: flow payoff -1
  - (symmetric) Nash bargaining in meetings using an outside good

Meeting Technology

- $G(\lambda)$: population distribution of λ
- Λ: average contact rate
- $m(\lambda)$: fraction of type λ who are mismatched
- The probability of meeting someone is proportional to her contact rate
    - It does not depend on the agents' mismatch status

Types of Meetings

- Both individuals have the same asset holding
  ⇒ no gains from trade
- Individuals have different asset holdings
  - both are mismatched
    ⇒ gains from trade
  - both are well-matched
    ⇒ no gains from trade
  - one is well-matched, the other is mismatched
    ⇒ there is a possibility of "intermediation"
    - take advantage of different contact rates λ

Value Functions

- Take an individual with contact rate λ
  - $v_0(\lambda)$: value when mismatched
  - $v_1(\lambda)$: value when well-matched
  - $s(\lambda) \equiv v_1(\lambda) - v_0(\lambda)$: *net* gain from being well-matched

$$(\rho + 2\gamma)s\left(\lambda\right) = \frac{1}{2} + \frac{\lambda}{2} O\left(\lambda\right)$$

- Net gain from being well-matched
  - Expected flow value of holding the asset
  - *Speed-weighted* net option value of search, $O\left(\lambda\right)$
  - Determines the equilibrium pattern of trade

Equilibrium Trading Pattern

Proposition

In any equilibrium:

- *two mismatched agents always trade;*
- *two well-matched agents never trade; and*
- *a mismatched and well-matched agent trade if and only if the well-matched agent has the higher contact rate.*

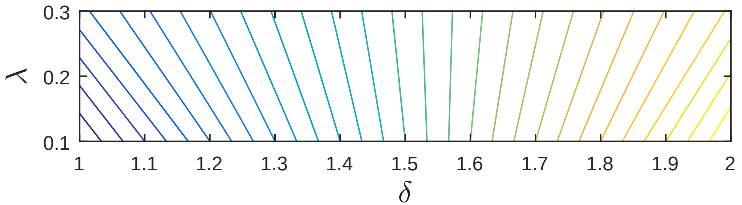


Figure: Iso-Net-Value Curves

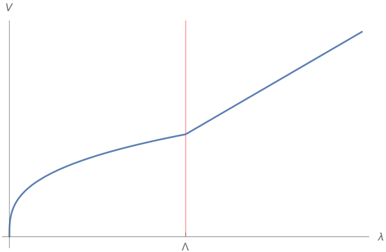
- Fast types are intermediators
- Endogenous multi-tier Core-Periphery structure

Equilibrium Distribution: Symmetric-λ Eq?

Proposition

No symmetric equilibrium exists.

- $\lambda > \Lambda$: linear
- $\lambda < \Lambda$: concave
- *Convex kink* at $\lambda = \Lambda$



- For any continuous, increasing, differentiable cost function, there is no symmetric equilibrium!

Characterization. Equilibrium and Optimal Distributions

Proposition

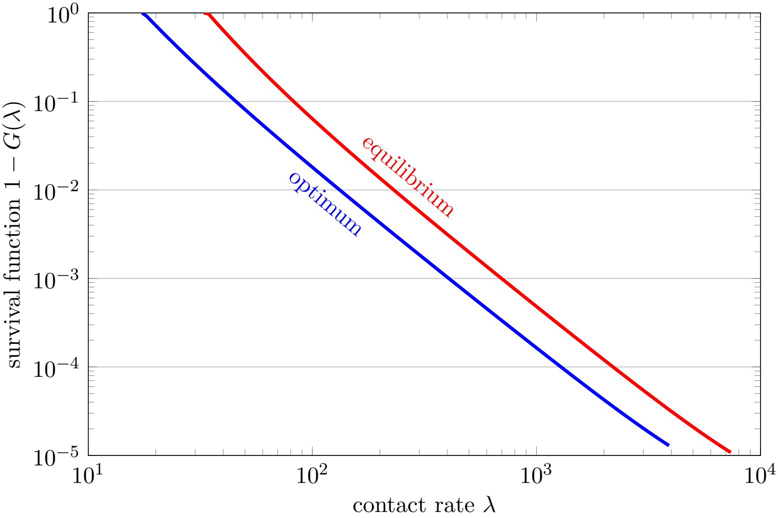
Assume $c(\lambda)$ is differentiable. There are no mass points in equilibrium or optimal in any equilibrium.

Proposition

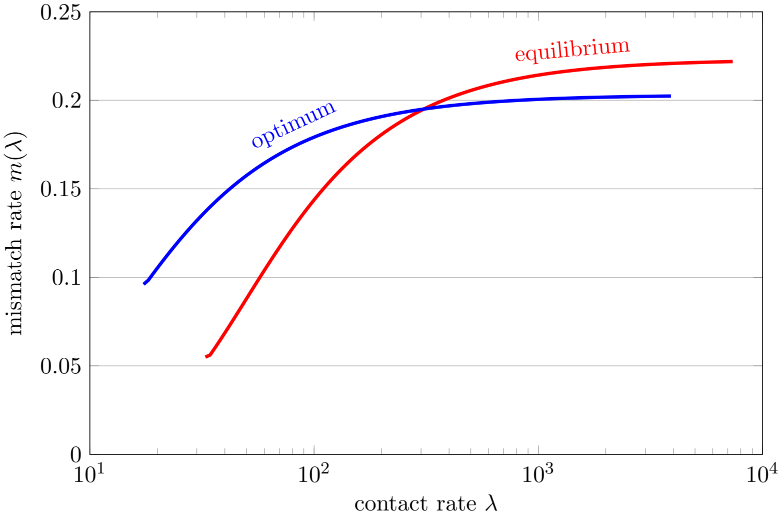
Assume $c(\lambda) = c$. The equilibrium and optimal distribution G has a positive lower bound $\underline{\lambda}$ and is unbounded above.

- Pattern of trade is the same in equilibrium and efficient outcome
- But the distributions are **not** the same!

Contact Distribution, $c(\lambda) = 0.004$



Mismatch Rates, $c(\lambda) = 0.004$



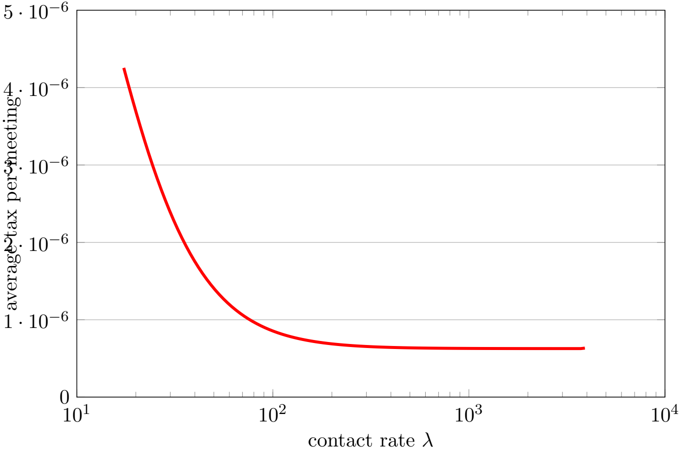
Inefficiency

- Describe equilibrium inefficiency using Pigouvian taxes:
  - Constant tax on every meeting (independent of λ)

$$\frac{\gamma}{\Lambda}\int_0^\infty S(\lambda')(1-2m(\lambda'))dG(\lambda')$$

  - Transfer that doubles the surplus in every meeting
    - Equates private and social surplus

Pigouvian Tax, $c(\lambda) = 0.004$



Intermediation and Heterogeneity

- Assume agents with the same preferences cannot trade
  - For example, the meetings do not happen
  - Only two mismatched (or two well-matched) agents can trade
- Redefine equilibrium and optimal allocation
- **Proposition:** in equilibrium all agents choose the same λ
- **Proposition:** all agents optimally choose the same λ
- substantial welfare loss
  - Optimal search intensity $\lambda = 35.96$ (compared to $\Lambda = 41.6$)
  - Welfare 0.483 (compared to 0.594)

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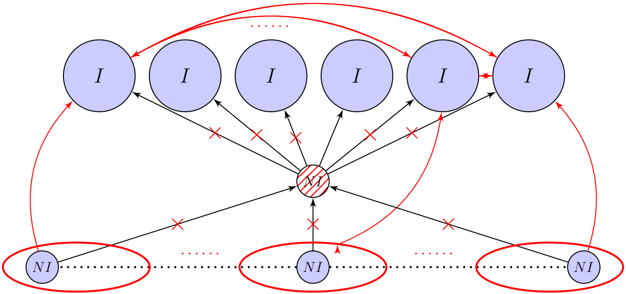
Conclusion

- Networks, as well as search, are tools to model the interaction among financial institutions
- These interactions are complex. How do we adapt this tool without missing too much economics?
- Does the actual network structure matter beyond some aggregate, or redistributional factors?

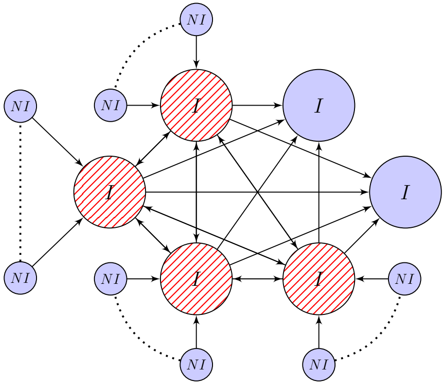
Intuition

- Joint deviation

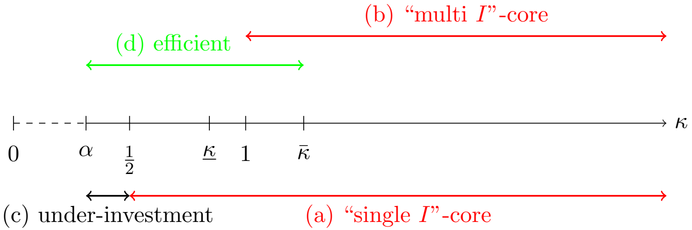


Intuition

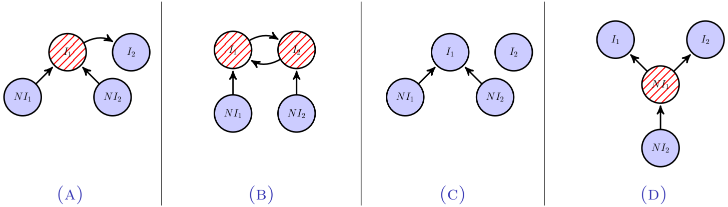
- No joint deviation to networks with I banks at the core



Economy with Four Banks Revisited

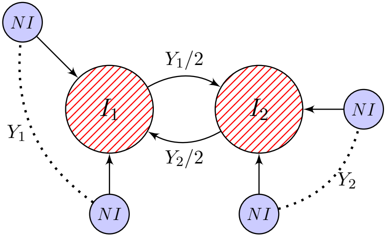


- $\kappa = \frac{\text{intermediation rent}}{\text{expected cost of default}} = \frac{(1-\alpha)\alpha X}{(1-p)V_I}$



Back Deviation Policy

Diversification, noframenumbering



Assets	Liabilities
$\frac{Y_1+Y_2}{2}\tilde{R}$	$Y_1 D_{11}$
$\frac{Y_1-Y_2}{2}D_{21}$	

(A) Net Lender (I_1)

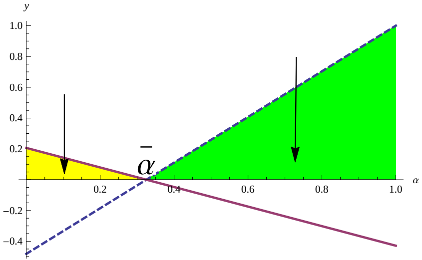
Assets	Liabilities
$\frac{Y_1+Y_2}{2}\tilde{R}$	$Y_2 D_{22}$
	$\frac{Y_1-Y_2}{2}D_{21}$

(B) Net Borrower (I_2)

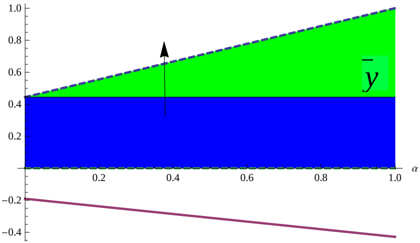
- $Y_1 > Y_2$
- $y = \frac{Y_2}{Y_1}$, $0 < y \leq 1$

Diversification, noframenumbering

- Net lender



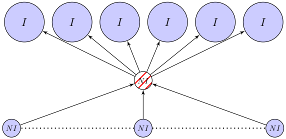
(A) $R > \frac{2}{p(2-p)}$



(B) $R < \frac{2}{p(2-p)}$

Policy

- Central Clearing Party (CCP)
  - Prevents exposure to counterparty risk among banks with investment opportunity
  - Fully funds all the projects



- Cap on Number of Counterparties a bank can lend to
  - Increases the length of intermediation chains
  - Shifts the composition of equilibrium family towards larger cores
  - Larger loss in the event of melt down

Equilibrium

Exposure to Counterparty Risk in the Financial Crisis

- September 15: Lehman filed for bankruptcy
- First wave: holders of unsecured CP and lenders in tri-party repo
  - Wachovia (Evergreens Investment)
  - Reserve Management Company (Reserve Primary Fund)

Exposure to Counterparty Risk in the Financial Crisis

- September 15: Lehman filed for bankruptcy
- First wave: holders of unsecured CP and lenders in tri-party repo
  - Wachovia (Evergreens Investment)
  - Reserve Management Company (Reserve Primary Fund)
- Havenrock
  - IKB ABCP conduit (Rhineland): RMBS and CDO investment
  - CaLyon: liquidity backstop; FGIC: senior credit risk protection
- CDO crashed → FGIC unable to honor guarantee → CaLyon significant credit loss → capital injection by French government

▸ Back

Stylized Facts

- Liability structure among banks looks like a core-periphery graph
  - Federal funds market
  - International inter-bank markets
    - Germany, Austria, Netherlands, Brazil
  - Municipal bond market
- OTC derivative exposures
  - Dealer: High gross and small net positions
  - Aggregate trade quantity:
    - Dealer-to-dealer: $\sim 60\%$
    - Customer-to-dealer: $\sim 40\%$
    - Customer-to-customer: $< 1\%$

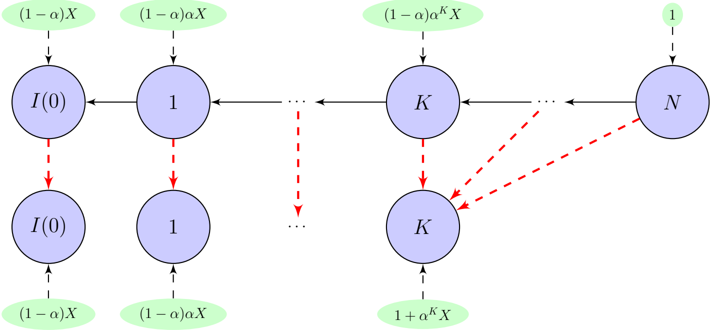
Back

General Rule for Division of Surplus

- Every member of intermediation chain gets strictly positive share
- Elimination of each intermediary
  - Weakly increase every other bank's share (along the chain)
  - Strictly increase lender's share
- Anonymous and depends only on the chain
- Special case (α-rule)
  - Each bank only cares about distance to final borrower

▸ Eq ▸ α-rule

General α-Rule

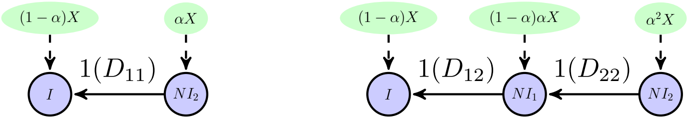


- $j < K$ gets $(1-\alpha)\alpha^j X$
- K gets $1 + \alpha^K X$
- Shares only depend on distance from final borrower
- Face value of debt set to reflect shares
  - $D_j - D_k$ = intermediation spread between k and j

Eq α-rule

Date 1: Payoff Example

- $X = pR - 1$: expected net surplus of investing one unit



- $D_1 = D_{11} = D_{12} = \frac{\alpha X + 1}{p}$
- $D_2 = D_{22} = \frac{\alpha^2 X + 1}{p}$
- Intermediation spread $= D_1 - D_2$
  - Expected intermediation rent $= p(D_1 - D_2) = \alpha(1-\alpha)X$

Back

Long Term Relationship Lending

- Theory
  - Switching costs
  - Monitoring costs: costly information acquisition
- Empirical evidence
  - Fed fund market: %60 of inter-bank borrowing comes from the same lender over one month
  - Hedge funds: maintain at most two prime brokers and rarely switch

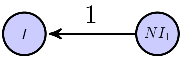
Back

Disabling Diversification

- j has multiple active commitments
  - All of its funding allocated randomly to exactly one of them
- An I bank with an active investment opportunity
  - Invests only in own project

▸ Flow of Funds ▸ Debt Payoff

Efficient Direct Lending



- Efficiency

$$pR - 1 > (1 - p)(V_I + V_{NI})$$

- Borrower and lender participation constraint

$$(1 - \alpha)(pR - 1) > (1 - p)V_I$$
$$\alpha(pR - 1) > (1 - p)V_{NI}$$

Bank Maximization

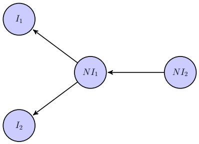
Robustness

- Division of surplus
  - Partial renegotiation and side payments as long as not fully competitive
  - Default cost taken into account
- Market incompleteness
  - No minimum size constraint but loans made prior to realization of investment opportunities
- Correlated returns

General Result

Date 1: Flow of Funds

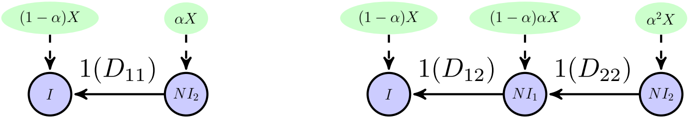
- When does j make a loan to k over potential lending relationship $j \to k$?
- At $t = 1$
  - k has received an investment opportunity
  - k has a potential lending relationship to a bank l who has received an investment opportunity
    - j does not have a potential lending relationship to l



- *Active lending* $j \to k$
  - k is on the shortest path of j to $l \in \mathbb{I}_R$ ▸ Note

Date 1: Debt Contract Payoff

- Division of surplus
  - $X = pR - 1$: expected net surplus of investing one unit
  - For funds lent over any link, the lender(s) get α share of the benefit



- D_{jK}: face value paid to position j of chain length K
  - $D_{jK} = D_j \quad j < K$
  - $D_{KK} = D_K$
  - $D_1 - D_2 =$ Intermediation Spread > 0

▸ General α-rule ▸ General Surplus Division ▸ Example ▸ Note

Date 0: Lending Contracts

- Project return not contractible: unobservable
- Face values contingent on
  - Lending network
  - Set of realized investment opportunities
- **Contingent lending**

Date 0: Bank j Maximization Problem

- Maximizes expected return net of expected cost of default
- Choice set: $E^j = \{e_0^{jk}, e_0^{kj}\}_{k \in \mathbb{N}}$
  - e_0^{jk}: potential lending relationship from j to k established at $t = 0$
- $E = \bigcup_{j \in \mathbb{N}} E^j$

Date 0: Bank j Maximization Problem

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  - e_0^{jk}: potential lending relationship from j to k established at $t = 0$
- $E = \bigcup_{j \in \mathbb{N}} E^j$
- Date 1 variables
  - $m_1^{jk}(E, \mathbb{I}_R)$: amount lent from j to k at $t = 1$
  - $D_1^{kj}(E, \mathbb{I}_R)$: face value of debt at $t = 1$
- Date 2 variables
  - $d_2^{kj}(.)$: realized payment from k to j at $t = 2$

Date 0: Bank j Maximization Problem

- Maximizes expected return net of expected cost of default
- Choice set: $E^j = \{e_0^{jk}, e_0^{kj}\}_{k\in\mathbb{N}}$
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- $E = \bigcup_{j\in\mathbb{N}} E^j$
- Date 1 variables
  - $m_1^{jk}(E, \mathbb{I}_R)$: amount lent from j to k at $t = 1$
  - $D_1^{kj}(E, \mathbb{I}_R)$: face value of debt at $t = 1$
- Date 2 variables
  - $d_2^{kj}(.)$: realized payment from k to j at $t = 2$
- *Intuition*: bank j chooses his lending and borrowing based on
  - Expected share received for each realization of $\mathbb{I}_R$ given E
  - Default probability for each realization of $\mathbb{I}_R$ given E

Bank j Maximization Problem

- Interim value function

$$\hat{\mathcal{V}}_1^j(E, \mathbb{I}_R) = \mathbb{1}[j \in \mathbb{I}_R]\big(\sum_{k \in \mathbb{N}} m_1^{kj}\big)\mathbb{E}_{\tilde{R}}[\tilde{R}] + \mathbb{E}_{\tilde{R}}\big[\sum_{k \in \mathbb{N}} m_1^{jk} d_2^{kj} - \sum_{k \in \mathbb{N}} m_1^{kj} d_2^{jk}\big] + P(j \text{ does not fail}|E, \mathbb{I}_R)V_j$$

Bank j Maximization Problem

- Interim value function

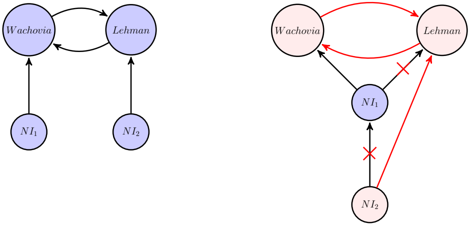
$$\hat{\mathcal{V}}_1^j(E, \mathbb{I}_R) = \mathbb{1}[j \in \mathbb{I}_R]\Big(\sum_{k \in \mathbb{N}} m_1^{kj}\Big)\mathbb{E}_{\tilde{R}}[\tilde{R}] + \mathbb{E}_{\tilde{R}}\Big[\sum_{k \in \mathbb{N}} m_1^{jk} d_2^{kj} - \sum_{k \in \mathbb{N}} m_1^{kj} d_2^{jk}\Big] + P(j \text{ does not fail} | E, \mathbb{I}_R) V_j$$

- Ex-ante value function

$$\max_{E_j} \quad \hat{\mathcal{V}}_0^j(E^j; E) = \mathbb{E}_{\tilde{\mathbb{I}}_R}\Big[\hat{\mathcal{V}}_1^j(E, \tilde{\mathbb{I}}_R)\Big]$$
$$\text{s.t.} \quad m_{jk}, m_{kj} \geq 1 \;\; \forall\, \mathbb{I}_R, k$$
$$\text{Participation Constraint} \;\; \forall\, \mathbb{I}_R$$

▸ More ▸ Timing

Equilibrium

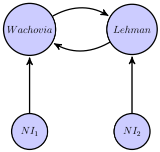


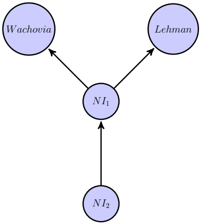
Probability			
$(1-q)^2$	V_{NI}	V_{NI}	
q^2	$p(V_{NI}+D_1)-1$	$p(V_{NI}+D_2)-1$	NI_2
$q(1-q)$	$p(V_{NI}+D_2)-1$	$p(V_{NI}+D_2)-1$	
$(1-q)q$	$p(V_{NI}+D_1)-1$	$p(V_{NI}+D_2)-1$	
$(1-q)^2$	V_I	V_I	
q^2	$pV_I+p(R-D_1)$	$\frac{1}{2}(1+p)V_I+p(R-D_1)$	*Wachovia*
$q(1-q)$	$p\big(V_I+2(R-D_1)\big)$	$p\big(V_I+2(R-D)\big)$	*(Lehman)*
$(1-q)q$	$p\big(V_I+(D_1-D_2)\big)$	V_I	

- $\frac{p(D_1-D_2)}{(1-p)V_I} > 1+\frac{q}{2(1-q)}$ ▸ Four Bank Economy ▸ Back

Social Planner Solution

- Maximizes total surplus $\sum_{i \in \mathbb{N}} \hat{\mathcal{V}}_i$

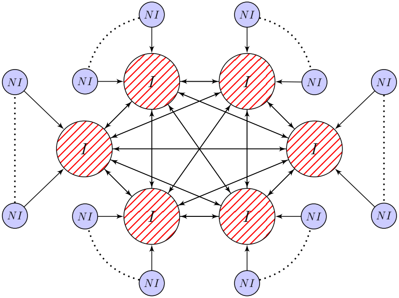




Probability		
$(1-q)^2$	$2(V_I + V_{NI})$	$2(V_I + V_{NI})$
q^2	$2p(V_I + V_{NI} + R) - 2$	$V_I + p(V_I + 2V_{NI} + 2R) - 2$
$2q(1-q)$	$2p(V_I + V_{NI} + R) - 2$	$V_I + p(V_I + 2V_{NI} + 2R) - 2$

Back

Equilibrium versus RMBS Observed Network



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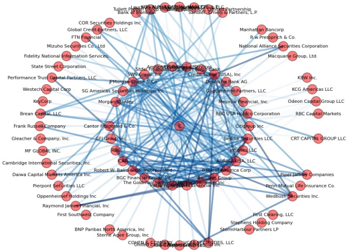
(A) Model Equilibrium



(B) RMBS Network

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