Financial Networks and Intermediation: Network and Search Models

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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, investment

Outline

My Subjective Classification!

- Question
  - Contagion and Systemic Risk properties of given network structure
  - Network formation
- Tool
  - Explicit network theory
  - Search
- Basic Model
  - Network framework
    - Allen and Gale (2000): Liquidity shocks
    - Eisenberg and Noe (2001): Fix point payment vector
  - Search models
    - Duffie, Garleanu, Pederson (2005), Rubinstein and Wolinsky (1987)

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  - Search models
    - Duffie, Garleanu, Pederson (2005), Rubinstein and Wolinsky (1987)
- Intermediation (often OTC)
  - Pricing, efficiency, collateralized lending, network formation
- OTC markets
  - Risk sharing, price dispersion, information diffusion
- Others: Complexity, disclosure

Outline

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), Aymanns, Georg, And Golub (2017)

Outline

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 $\rightarrow$ 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).

Outline

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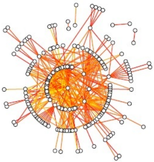
- Equilibria:
  - Type 1: *core-periphery* equilibrium
    - Set of highly connected banks at core
    - Excessive exposure to counterparty risk
  - Type 2: under-investment equilibrium
    - Savings trapped in a subset of banks



- Efficiency
  - Centralized clearing house

Environment

- Three dates: $t = 0, 1, 2$
- Two type of banks ($\mathbb{N}$)
  - NI: banks who can never invest
    - Raise one unit from a continuum of households (debt)
    - Each household matched to a single bank
  - I: banks who can invest
    - Potential to make risky investment
    - Borrow on the inter-bank market
- Value of other businesses for each bank: V_j
  - Non-pledgable
  - Lost in case of default
- Risk neutrality, no discounting

Risky Technology

- Date 1
  - At each I, investment opportunity arrives with iid probability q
    - *Active investing bank:* $I \in \mathbb{I}_R$
  - Initial investment made
- Date 2
  - Per-unit iid return across investing banks $\tilde{R}$

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

- Scalable

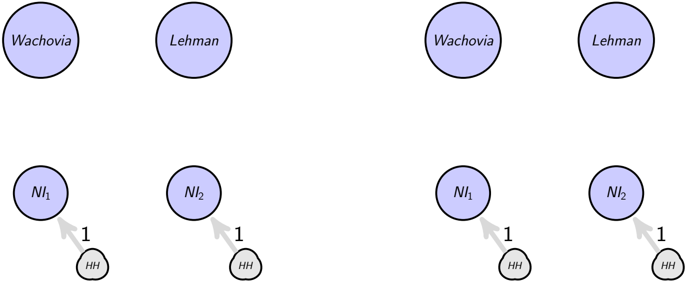
Frictions

- Market incompleteness
  - Segmented markets
  - Potential lending relationship established at $t = 0$
    - **Financial network** $G = (\mathbb{N}, E)$: Collection of banks and their lending relationships
  - All contracts are debt
- Feasibility
  - Minimum size constraint
- Surplus division
  - Depends on endogenous network structure
  - Intermediators get positive share
  - Rents cannot be negotiated away

Timing

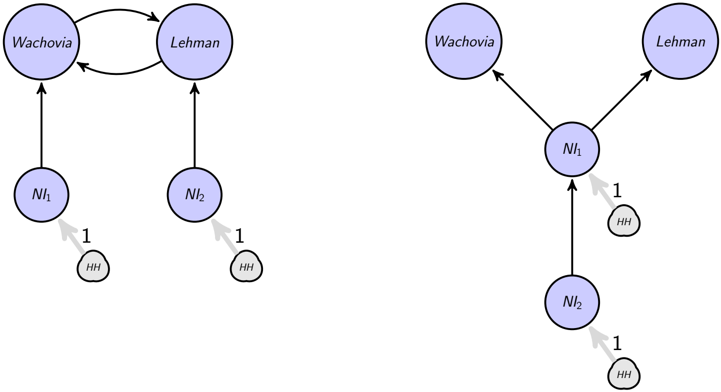
- Date 0
  - Funding raised from households
  - Network forms: banks establish potential lending relationships (*Subject to feasibility*)
    - Equilibrium Concept: **Group Stability**
- Date 1
  - Risky investment opportunities arrive
  - Loans made
- Date 2
  - Return realized
  - Debt paid back
  - Bank fails and loses V_j 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
1
HH
1
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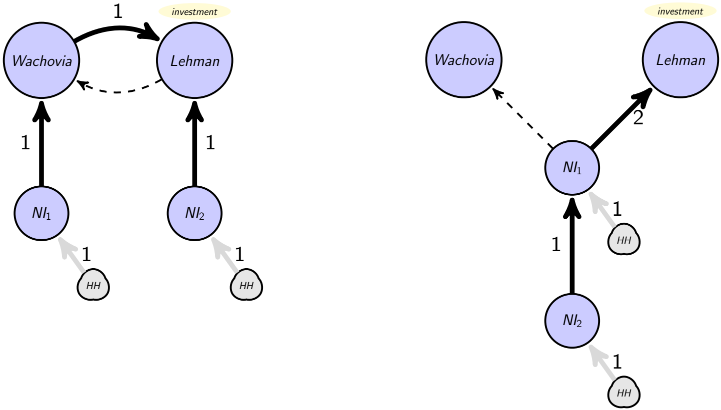
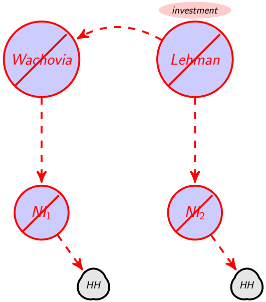
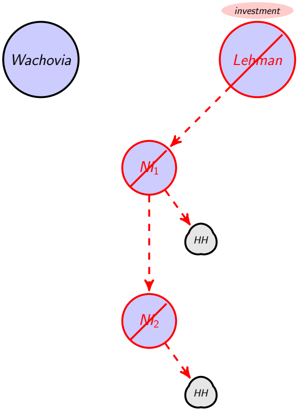
Wachovia
Lehman
NI_1
1
HH
NI_2
1
HH

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

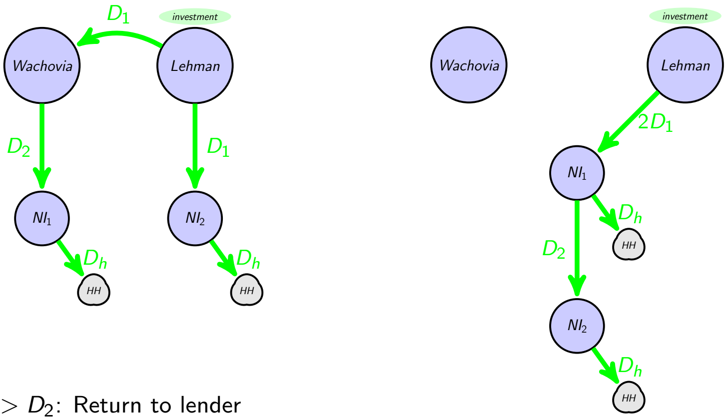


Example ($t = 2$): Project Fails



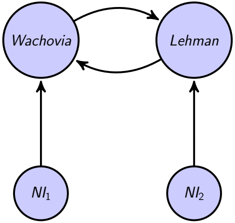


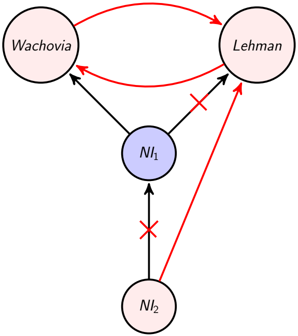
Example ($t = 2$): Project Succeeds



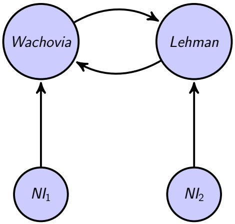
- $D_1 > D_2$: Return to lender
- $p(D_1 - D_2) \lesseqgtr (1-p)V_I$: Intermediation spread versus cost of failure

Equilibrium

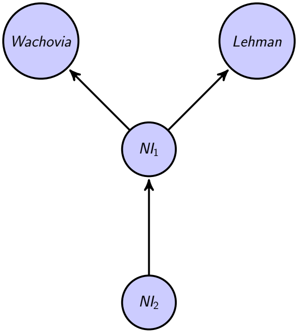




Stability versus Efficiency



(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**

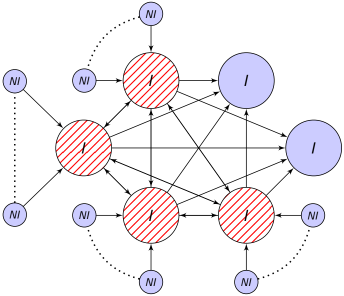
    Redistribution   Social Loss

  - *Equilibrium Intermediator*: offers highest rate of return
  - Does he minimize the cost?

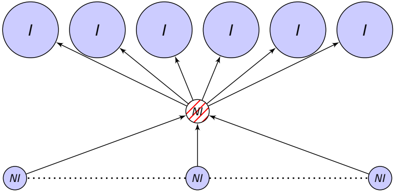
General Result

Theorem

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

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

Outline

- Overview of Literature
- Contagion and Systemic Risk
- Network Formation
- Intermediation
- Search and Intermediation
- Concluding Remarks

Ex-post Dealer Heterogeneity

- Ex-ante dealer heterogeneity
  - Atkeson, Eisfeldt, Weill (2015)
    - Dealers heterogeneous in exposure to aggregate risk
    - Agents with average exposure intermediate
  - Chang and Zhang (2016)
    - Dealers heterogeneous in taste volatility
    - Agents with lower volatility intermediate

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- Neklyudov and Sambalaibat (2016)
  - Micro-found heterogeneity among dealers using customer heterogeneity
- Others
  - Neklyudov (2014) (jmp), Uslu (2016) (jmp)
    - Ex-ante heterogeneity in meeting rate: fast agents intermediate
  - Hugonnier, Lester, Weill (2016)
    - Agent with close-to-average taste intermediate

Ex-post Dealer Heterogeneity

- Some ex-ante heterogeneity, no ex-ante designated dealers
  - My jmp!
  - Rent-seeking versus counterparty risk
  - *Wrong* intermediators
- No ex-ante heterogeneity at all
  - Wang (2016) jmp
  - Trade-off: competition among core dealers to give favorable quotes versus ability to offset inventory and avoid cost
  - Periphery *too-connected* to the core

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  - Agents with *moderate* taste are central dealers
  - How to generate moderate taste?

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- **Where does heterogeneity come from?**

Farboodi, Jarosch, Shimer (2016)

- Market participants can choose the rate at which they contact others
- Traders who choose a higher contact rate emerge as intermediaries
- Endogenous distribution of contact rates has no mass points
- **Middlemen.** constant contact with other traders
- Linear Cost
  - Pareto tail with parameter 2
  - Middlemen emerge endogenously
- Search costs $\rightarrow 0$
  - Heterogeneity and intermediation persists
  - Trade occurs in intermediation chains
  - Economy does **not** converge to a centralized market
- Equilibrium inefficient: too much and too heterogeneous investment
- Intermediation is the key!

Model

- Measure one of risk-neutral investors, discount rate $r \to 0$
- Two preference states, $\{l, h\}$
  - Switch at exogenous rate $\gamma > 0$
- One asset, supply $\frac{1}{2}$
  - Asset holding restricted to $\{0, 1\}$
  - Trading opportunities at endogenous rate λ
- λ chosen irrevocably at time 0, cost $c(\lambda)$ per meeting
- Payoffs
  - Well-aligned $(h, 1)$, $(l, 0)$: flow payoff $\frac{\Delta}{2}$
  - Misaligned $(h, 0)$, $(l, 1)$: flow payoff $-\frac{\Delta}{2}$
  - (Symmetric) Nash bargaining in meetings using an outside good

Meeting Technology

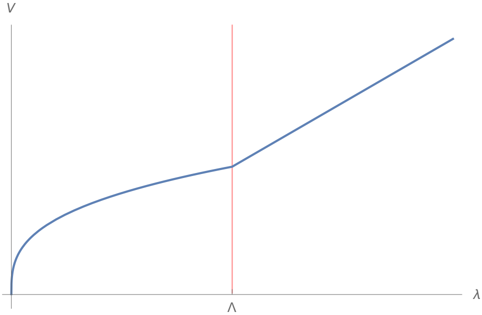
- Let $G(\lambda)$ denote the population distribution of λ
- Let Λ denote the average contact rate
- Let m_λ denote the fraction of type λ who are misaligned
- The probability of meeting someone is proportional to her contact rate
  - Does not depend on the agents' alignment status
  - *Random* search
    - Individual with meeting intensity λ meets an individual with $a \leq \lambda' \leq b$ at rate

$$\lambda \int_a^b \frac{\lambda'}{\Lambda} dG(\lambda')$$

- *Zero measure* of agents may account for a positive fraction of meetings
  - $1 - \int_0^\infty \frac{\lambda}{\Lambda} dG(\lambda)$
  - notation: $\mathbb{E}(f(\lambda')) \equiv \int_0^\infty \frac{\lambda'}{\Lambda} f(\lambda') dG(\lambda') + \left(1 - \int_0^\infty \frac{\lambda'}{\Lambda} dG(\lambda')\right) f(\infty)$

DOES A SYMMETRIC-λ EQUILIBRIUM EXIST?

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



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

Middlemen. Linear cost function

- *Middlemen*
  - Zero measure of agents, who do strictly positive fraction of trade
  - Infinitely fast agents, in continuous contact with everyone

$$\alpha = 1 - \int_0^\infty \frac{\lambda'}{\Lambda} dG(\lambda') = \frac{2\bar{v}}{1-\bar{v}} \int_0^\infty \frac{\lambda'}{\Lambda} m_{\lambda'} dG(\lambda'),$$

- $\bar{v} \equiv$ equilibrium trading profits
- When there are positive profits to be made, *yes!*
- Each agents does α fraction of his meetings with middlemen and $1-\alpha$ fraction of his meetings with agents with finite speed

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- $\bar{v} \equiv$ equilibrium trading profits
- When there are positive profits to be made, *yes!*
- Each agents does α fraction of his meetings with middlemen and $1-\alpha$ fraction of his meetings with agents with finite speed
- Marginal cost $\to 0$
  - Strictly positive fraction of meetings are with middlemen and strictly positive fraction are with finite traders
  - Does not converge to a symmetric/centralized market!

An alternative view. heterogeneity in bargaining power

- Farboodi, Jarosch and Menzio (2017), Nosal, Wong, Wright (2016)
- Agents with higher bargaining power emerge as intermediaries
- No welfare gain, pure *rent seeking* motives
  - Option value of expropriating future trading partners
- Initial investment
  - Behavior in frictionless limit

Outline

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?