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 institutions
  - 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

Overview of Literature

Contagion and Systemic Risk

Network Formation

Intermediation

Search and Intermediation

Concluding Remarks
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)
Question
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Intermediation (often OTC)
- Pricing, efficiency, collateralized lending, network formation

OTC markets
- Risk sharing, price dispersion, information diffusion

Others: Complexity, disclosure
OUTLINE

OVERVIEW OF LITERATURE

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CONCLUDING REMARKS
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 → incentive-efficient risk sharing, no contagion
- **MIT shock** \(\epsilon\)
  - \(\epsilon\) sufficiently small: No contagion
  - \(\epsilon\) intermediate: complete \(\succ\) two components \(\succ\) ring
  - \(\epsilon\) sufficiently large: two components \(\succ\) complete \(\equiv\) 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
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
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 → increase and then fall
  ▶ Integration: contagion monotonically increases (unless already very high)

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CONCLUDING REMARKS
PREAMBLE

- General network formation literature
- 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).
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.
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

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Intermediation 1: OTC Markets

- Babus and Hu (2015)
  - Traders are connected through an exogenous informational network
  - Limited enforcements: collateralized and uncollateralized 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
Intermediation 1: OTC Markets

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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?
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
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
Three dates: $t = 0, 1, 2$

Two types 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
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
    
    \[ \text{(Subject to feasibility)} \]
  - 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 \((t = 0)\)
**Example \((t = 0)\)**
**Example (t = 1): Only Lehman has Investment**

![Diagram showing the flow of investment and failure costs with Wachovia and Lehman.]
Example ($t = 2$): Project Fails

Return to lender

$\sum (D_1 - D_2) \geq (1 - p) V$

Intermediation spread versus cost of failure
Example \((t = 2)\): Project Succeeds

- \(D_1 > D_2\): Return to lender
- \(p(D_1 - D_2) \leq (1 - p)V_l\): Intermediation spread versus cost of failure
EQUILIBRIUM

Graph 1:
- Vertex: Wachovia
- Vertex: Lehman
- Edges: Wachovia to Lehman, Lehman to Wachovia
- Vertices: NI1, NI2

Graph 2:
- Vertex: Wachovia
- Vertex: Lehman
- Edges: Wachovia to Lehman, Lehman to Wachovia
- Vertices: NI1, NI2
- Additional edge: NI1 to NI2

Crossed edges indicate non-existent connections.

Note: The graphs represent interactions or relationships between entities labeled as Wachovia and Lehman, with additional vertices and connections indicated by arrows.
**Stability versus Efficiency**

(A) Inefficient Stable

(B) Efficient Unstable

\[
\text{Intermediation Rent} \quad \frac{\text{Cost of Failure}}{Z} > Z
\]
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* versus *Social Loss*
  - *Equilibrium Intermediator:* offers highest rate of return
  - Does he minimize the cost?
**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
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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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
**Ex-post Dealer Heterogeneity**

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    - Micro-found heterogeneity among dealers using customer heterogeneity
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    - 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
Some ex-ante heterogeneity, no ex-ante designated dealers

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Common theme in all search-based models

- Agents with *moderate* taste are central dealers
- How to generate moderate taste?
Ex-post Dealer Heterogeneity

- Some ex-ante heterogeneity, no ex-ante designated dealers
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- Common theme in all search-based models
  - Agents with moderate taste are central dealers
  - How to generate moderate taste?
- Where does heterogeneity come from?
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 → 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 $\lambda$
- $\lambda$ chosen irrevocably at time 0, cost $c(\lambda)$ per meeting
- Payoffs
  - Well-aligned $(h, 1), (l, 0)$: flow payoff $\frac{A}{2}$
  - Misaligned $(h, 0), (l, 1)$: flow payoff $-\frac{A}{2}$
  - (Symmetric) Nash bargaining in meetings using an outside good
Let $G(\lambda)$ denote the population distribution of $\lambda$

Let $\Lambda$ denote the average contact rate

Let $m_\lambda$ denote the fraction of type $\lambda$ 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 $\lambda$ 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: $E(f(\lambda')) = \int_0^\infty \frac{\lambda'}{\Lambda} f(\lambda') dG(\lambda') + \left(1 - \int_0^\infty \frac{\lambda'}{\Lambda} dG(\lambda')\right) f(\infty)$
Does a Symmetric-$\lambda$ 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

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

- \(\bar{\nu} \equiv\) equilibrium trading profits
- When there are positive profits to be made, yes!
- Each agent does \(\alpha\) fraction of his meetings with middlemen and \(1 - \alpha\) fraction of his meetings with agents with finite speed
**Middlemen. Linear cost function**

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

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

- \( \bar{v} \equiv \text{equilibrium trading profits} \)
- When there are positive profits to be made, yes!
- Each agents does \( \alpha \) 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
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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?