FINANCIAL NETWORKS AND INTERMEDIATION: NETWORK AND SEARCH MODELS

Maryam Farboodi
Princeton University

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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
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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 → incentive-efficient risk sharing, no contagion
- **MIT shock** \(\epsilon\)
  - \(\epsilon\) sufficiently small: No contagion
  - \(\epsilon\) intermediate: complete \(>\) two components \(>\) ring
  - \(\epsilon\) sufficiently large: two components \(>\) complete \(=\) ring
$N$ banks, their arbitrary interbank obligations, and obligations to/cash flow from outsiders

- Shock realization vector
- For some bank(s) $i$, total assets $< \text{total liabilities} \rightarrow i$ 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 à 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 \( \rightarrow \) 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 $\geq \bar{\eta}$: 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 → 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
Glode and Opp (2015)
- What is **good about long intermediation chains**?
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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
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 type of banks ($\mathbb{N}$)
- $N$: 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 $l$, investment opportunity arrives with iid probability $q$
  - *Active investing bank*: $l \in \mathbb{I}_R$
- 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 ($t = 0$)

\[ (D_1 - D_2) \geq (1 - p) \]

\( V \): Intermediation spread versus cost of failure
**Example** \((t = 0)\)

\[
Wachovia \quad \overset{1}{\longrightarrow} \quad Lehman \quad \overset{1}{\longrightarrow} \quad NI_1 \quad \overset{1}{\longrightarrow} \quad NI_2 \quad \overset{HH}{\longrightarrow} \quad HH
\]

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\[
V_{II} : \text{Intermediation spread versus cost of failure}
\]
**Example (t = 1): Only Lehman has Investment**

- Return to lender: $\text{D}_1 - \text{D}_2 \geq (1 - p) \text{V}_I$
- Intermediation spread versus cost of failure
Example ($t = 2$): Project Fails
Example ($t = 2$): Project Succeeds

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

(A) Inefficient Stable

- Intermediation Rent
  - Cost of Failure
  - \( Z \)

(B) Efficient Unstable
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?
**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
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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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    - 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**

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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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- Common theme in all search-based models
  - Agents with *moderate* taste are central dealers
  - How to generate moderate taste?
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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
Meeting Technology

- 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: $\mathbb{E}(f(\lambda')) \equiv \int_{0}^{\infty} \frac{\lambda'}{\Lambda} f(\lambda') dG(\lambda') + \left(1 - \int_{0}^{\infty} \frac{\lambda'}{\Lambda} dG(\lambda')\right) f(\infty)$
Does a Symmetric-$\lambda$ 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

- Medium
  - 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 \( \alpha \) 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
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- Each agent 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, Jaroch 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?