Endogenous Financial Networks: Diversification and Intermediation

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The Paper in a Nutshell

How to explain the core-periphery structures of financial networks?

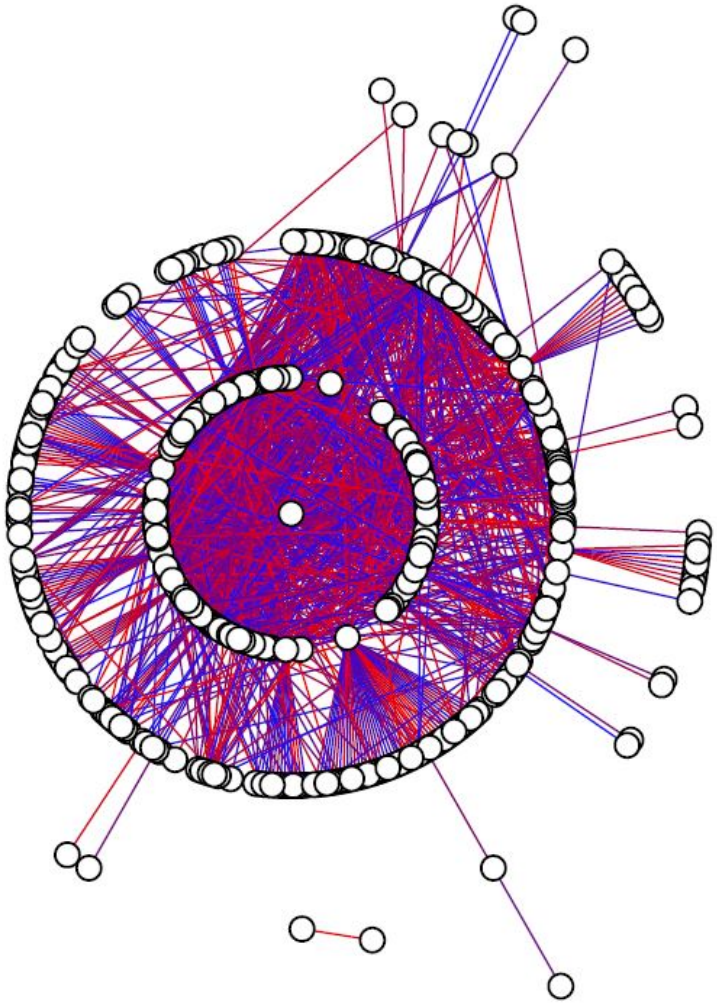
- **Method:**
  - Strongly stable equilibria of a network formation game
  - Intuitive structural interpretation of value and allocation rule
- **Contribution:** Endogenous weighted, directed networks
  - Links represent actual flows of funds, not just binary relationships
- **Answer:** Diversification and Intermediation
  - Banks want to spread investment across many counterparties
  - Core banks give peripheral banks access to a diversified portfolio ...
  - in exchange for intermediation rents.

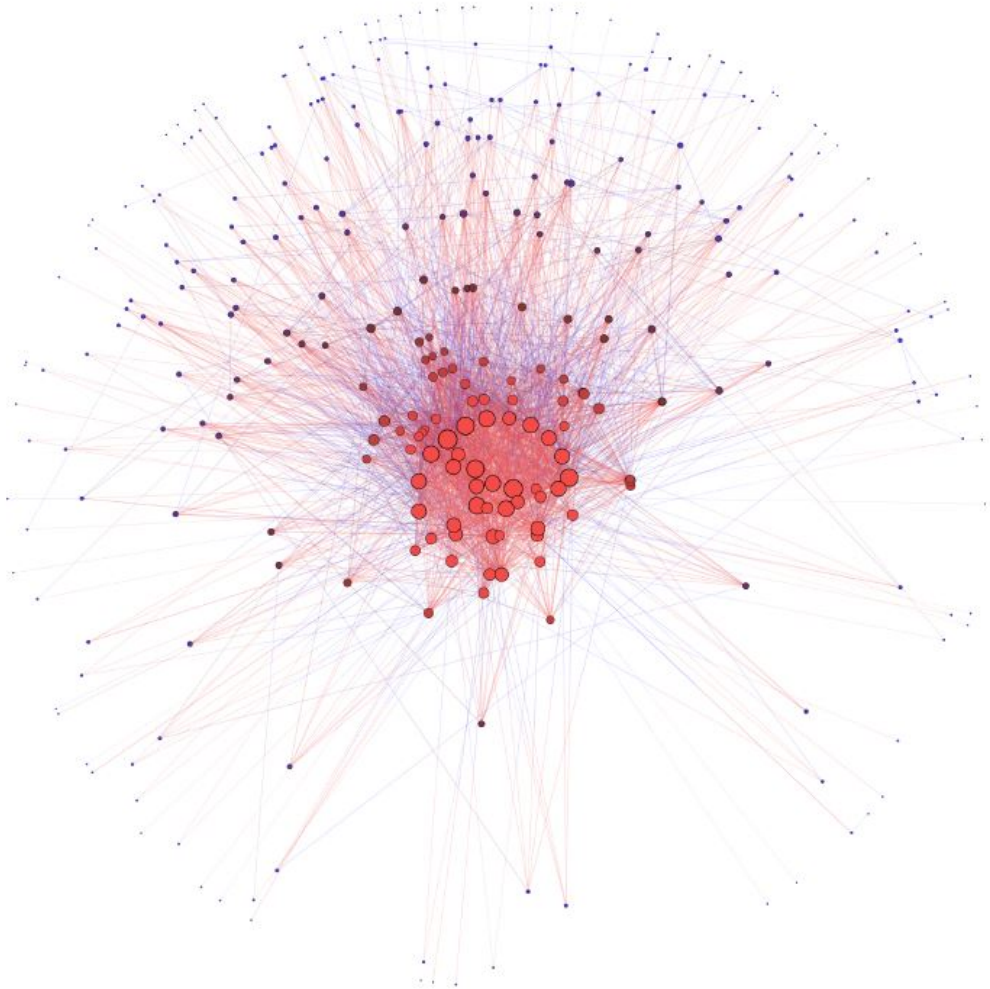
Outline

Motivation

- Network approaches became popular after the financial crisis
- Many problems cannot be analyzed in representative bank models
- Real-world (OTC) interbank networks ...
  - are formed **endogenously**,
  - feature (**directed**) borrowing/lending contracts, ...
  - specifying heterogenous credit amounts (**weights**) along each link
- Network architecture has strong implications for financial stability
- We need a theory of how these networks form
  - Predict endogenous reaction to policy changes (regulation, bailouts, ...)

Implicit Requirement: Core-periphery Structure





Sources: Bech and Atalay (2010), Hollifield et al. (2016)

Literature Gap

- Financial networks literature mostly takes network structure as given
- Resilience to shocks, risk-sharing properties, economic efficiency
  - Allen and Gale (2000), Eisenberg and Noe (2001), Rogers and Veraart (2013)
    Acemoglu et al. (2015a), Elliott et al. (2014), Gai and Kapadia (2010), ...
- Endogenous networks: *Undirected/-weighted* trading relationships
  - Babus (2016), Di Maggio and Tahbaz-Salehi (2014), **?**, Wang (2018)
- Notable exceptions:
  - Farboodi (2017), Acemoglu et al. (2015b)
- This paper combines ...
  - *intermediation* à la Farboodi (2017) with the
  - *diversification* motive of Cabrales et al. (2017)

Additional Literature

- Robust empirical finding: Core-periphery networks
  - Bech and Atalay (2010), Hollifield et al. (2016), Craig and Von Peter (2014), in 't Veld and van Lelyveld (2014), ...
- Trading/Bargaining in (non-financial) networks
  - Choi et al. (2017), Condorelli et al. (2016), Goyal and Vega-Redondo (2007), Manea (2018) ...
- Endogenous (non-financial) core-periphery networks
  - Hojman and Szeidl (2008)
- Delegated monitoring
  - Diamond (1984)

Environment

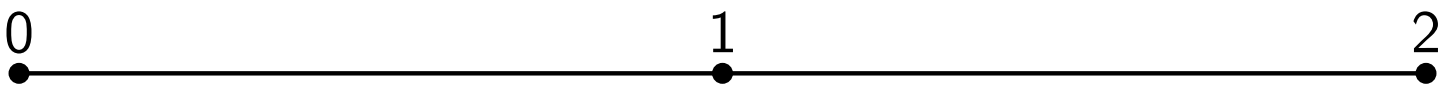
- Three periods $t = 0, 1, 2$
- Set of banks N, risk-neutral, profit-maximizing
- N partitioned into (ex ante known) subsets $\mathbb{I}$ and $\mathbb{D}$
- $\mathbb{I}$ banks receive risky, proprietary investment project in $t = 1$
- $\mathbb{D}$ banks raise funds d from depositors in $t = 0$ ($r_D = 0$ w.l.o.g.)
- In $t = 2$, projects (linearly scalable) yield i.i.d. per-unit return

$$\begin{cases} R > 1 & \text{with probability} \quad p \\ 0 & \text{with probability} \quad 1 - p \end{cases} \tag{1}$$

Network Formation Game

- **Network formation:** In $t = 0$ banks open credit lines $b_{ij} \geq 0$
  - *Feasibility*: $\sum_{j \neq i} b_{ij} \leq \sum_{j \neq i} b_{ji} + d \times \mathbb{1}_{i \in \mathbb{D}} \quad \forall i \in N$
  - For each link, lending bank pays fixed *management utility cost* κ
  - Volume of outflowing funds is spread *equally* across lending links
- **Bargaining:** In $t = 1$ counterparties bargain over interest rates r_{ij}
  - For now: Symmetric Nash bargaining
  - Outside options depend on position in network
  - Complete information about bank types and network structure
- **Payoffs:** In $t = 2$ asset returns realize, debt is paid back (if possible)
- In case of insolvency:
  - Bankruptcy (utility) cost δ per unit of defaulted *principle*
  - Pro-rata repayment of creditors

Timing



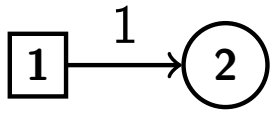
Credit lines are formed

Bargaining about interest rates
Lending/borrowing takes place
Investment in projects

Returns realize
Banks repay/default

Bargaining Stage I

- Not the main topic of the paper, but an important ingredient
- In simple bilateral relationship ($|\mathbb{D}| = |\mathbb{I}| = 1,\ d = 1$)



$$\mathbb{E}\pi_1 = pr - (1-p)\delta - \kappa$$
$$\mathbb{E}\pi_2 = p(R-1-r) - (1-p)\delta$$

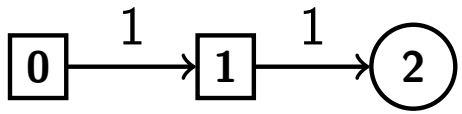
- Without deal both earn zero, maximizing Nash product w.r.t. r yields

$$r = \frac{1}{2}\left(R - 1 + \frac{\kappa}{p}\right)$$

- Trade only happens if $p(R-1) \geq 2(1-p)\delta + \kappa$

Bargaining Stage II

- With an *intermediary* $\mathbb{D}$-bank ($d_1 = 0$ for simplicity)



$$\mathbb{E}\pi_0 = pr_1 - (1-p)\delta - \kappa$$
$$\mathbb{E}\pi_1 = p(r_2 - r_1) - (1-p)\delta - \kappa$$
$$\mathbb{E}\pi_2 = p(R - 1 - r_2) - (1-p)\delta$$

- Outside options are zero, Nash bargaining yields

$$r_1 = \frac{1}{3}\left(R - 1 + \frac{\kappa}{p}\right), \quad r_2 = \frac{2}{3}\left(R - 1 + \frac{\kappa}{p}\right)$$

- Trade only happens if $p(R-1) \geq 3(1-p)\delta + 2\kappa$

  $\Longrightarrow$ Parameters pin down maximal length of intermediation chain

Equilibrium Concept: Strong Stability

- Credit lines require consent of *both* contracting parties
  $\rightarrow$ Nash equilibria not appropriate

Definition

A deviation from network g to g' by a coalition $S \subseteq N$ is *feasible* if

1. $b_{ij}^{g'} > 0$ and $b_{ij}^{g'} \neq b_{ij}^{g}$ implies $\{i,j\} \subseteq S$, and
2. $b_{ij}^{g} > 0$ and $b_{ij}^{g'} = 0$ implies $\{i,j\} \cap S \neq \emptyset$

A network g is *strongly stable* if no coalition of banks $S \subseteq N$ has a *feasible* deviation that makes all banks in S strictly better off.

- Dutta and Mutuswami (1997), Jackson and Van den Nouweland (2005)

Diversification I

- Project returns are i.i.d. $\Longrightarrow$ Scope for diversification
- Example: Compare the following two situations ($d = 1,\ \kappa = 0$)

- If *one* $\mathbb{I}$-bank's repayment is sufficient for $\mathbb{D}$'s survival ($\frac{1}{2}(1+r) \geq 1$):

$$\mathbb{E}\pi_{\mathbb{D}} = p^2 r + 2p(1-p)\left[\frac{1}{2}(1+r) - 1\right] - (1-p)^2\delta > pr - (1-p)\delta$$

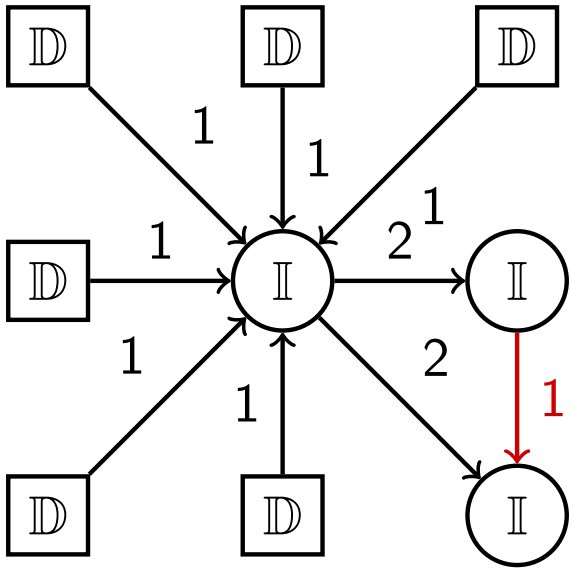
  as long as $\delta > 1$
- Reduce probability of states in which the lender becomes insolvent

Diversification II

- *Optimal* degree of diversification, decreasing in κ
- Principle also applies to $\mathbb{I}$-banks (see Cabrales et al. (2017))
- A well-diversified bank is an attractive investment for other banks
  - Low default probability
  - Pay κ only once ("delegated diversification")
- Rationale for core-periphery networks in equilibrium
  - Core intermediaries give peripheral banks access to diversification

Core-periphery Networks

Figure: The star as a special CP network



- No incentive to deviate for $\mathbb{D}$-banks
- Core $\mathbb{I}$-bank is optimally diversified
- Intermediation margin compensates for management cost 2κ

Summary and Outlook

- **Key idea**
  - Diversification motive + intermediation rents = CP financial network
  - Endogenous, weighted, directed network
  - Strongly stable equilibrium of network formation game
- **Limitations**
  - Integer/divisibility problems as in many endogenous network models
  - Equilibrium will probably not be unique
  - Ex ante heterogeneous banks
- **Next steps**
  - Connect bargaining and network formation problem properly
  - Welfare properties + comparative statics (e.g. size of core/periphery)
  - What happens with anticipated bailouts?
  - Interbank data (ECB? SRB? Bundesbank?) for empirical counterparts

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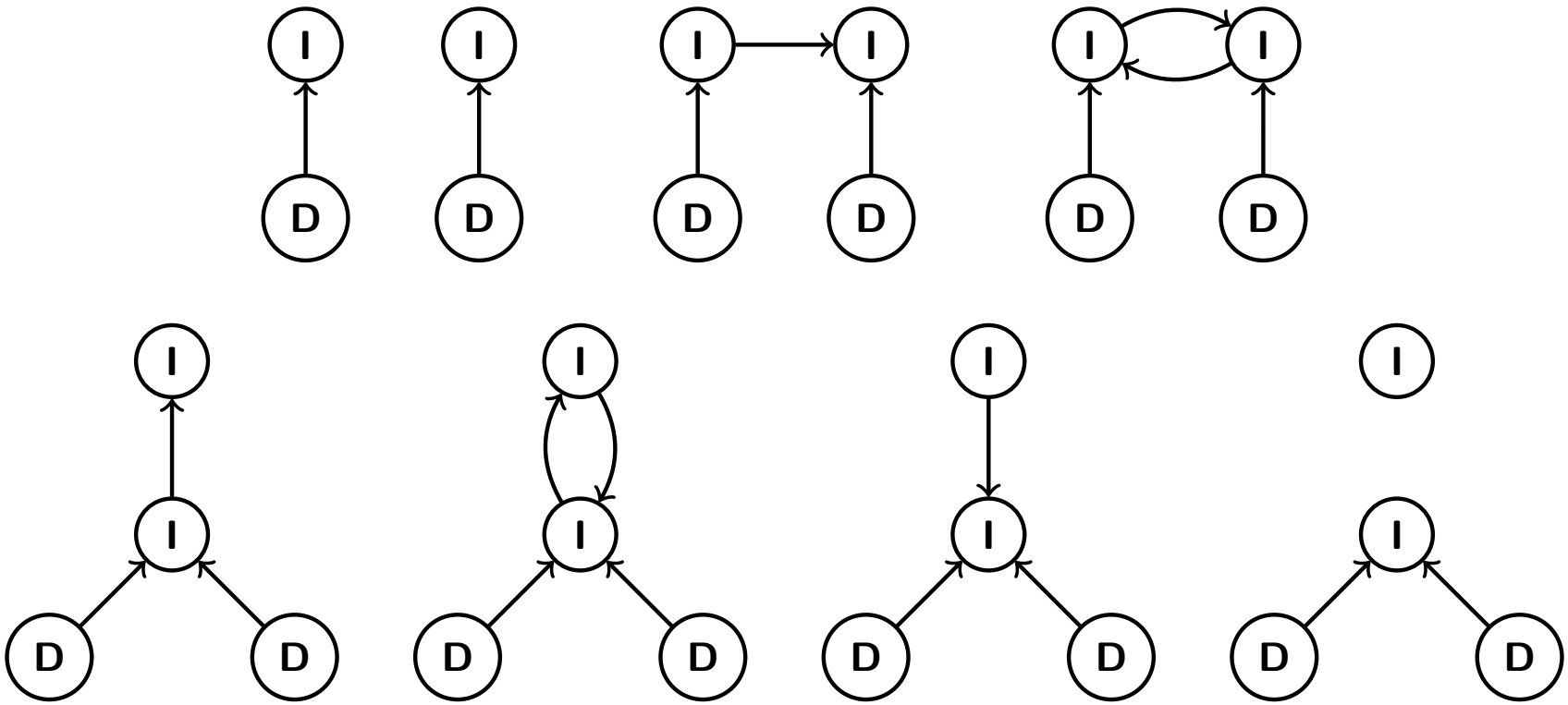
This Paper vs. Farboodi (2017)

- Endogenous surplus sharing rule (bargaining)
- No random allocation of all funds along *just one link*
- Diversification: Funds don't have to flow through *shortest path* from lenders to projects

Example with 4 Banks: Possible Configurations

When $\mathbb{D}$ banks *don't* diversify:



Example with 4 Banks: Possible Configurations

When $\mathbb{D}$ banks *do* diversify: