Relational Theory and Models for Financial Networks

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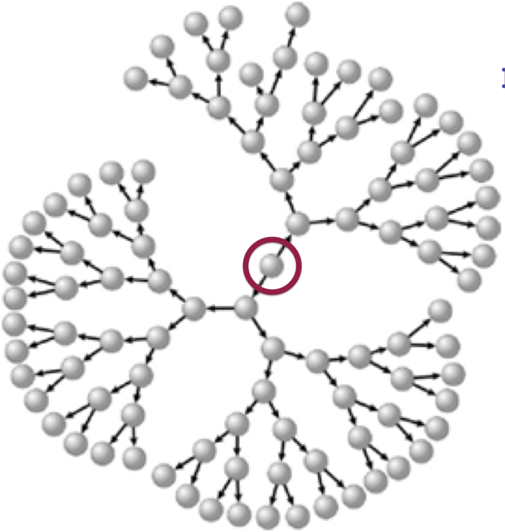
The Relational Structure of Finance

- **Contagion** – Who will be affected by the collapse of a bank or a major loan default?
- **Systemic Risk** – Some structures are more prone to contagion.
- **Market Power** – Some firms occupy a *privileged position.*
- **Politics** – Co-Ownership.
- **Financialization** – Deeper connectivity?

More Than the Sum of its Parts



Efficiency

Fault
Tollerance

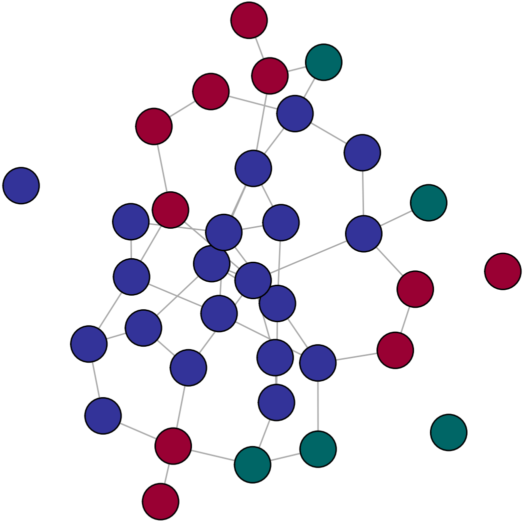
Plan for the Talk

- **Relational Theory for Financial Networks**
- **Statistical Models for Network Structure and Dynamics**
- **Applications to Financial Networks**
- **Data Challenges and Future Directions**

Relational Theory

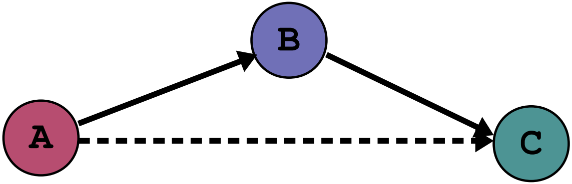
The Network

Nodes and **Edges**



Transitivity and Reciprocity

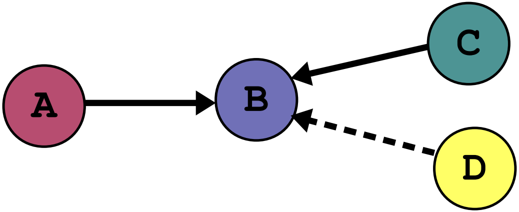
Transitivity – Clustering



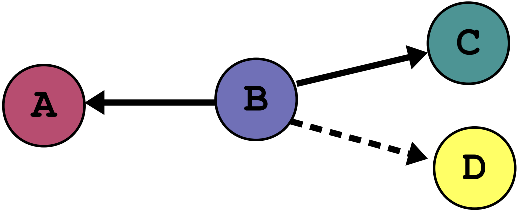
Reciprocity – Collaboration, Stability

Preferential Attachment

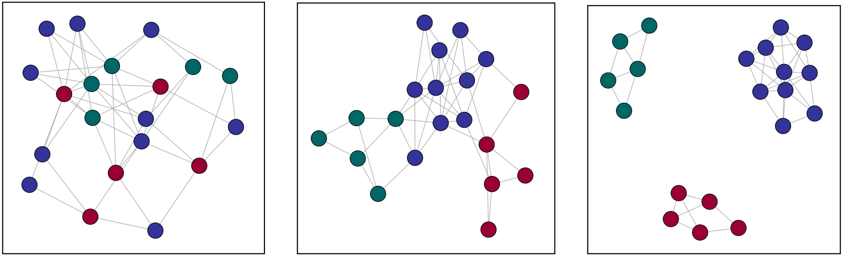
Popularity – Power, Path Dependence



Sociality – Economies of Scale



Compartmentalization



M. Denny. "Graph Compartmentalization", 2014.
http://arxiv.org/abs/1407.2854

Data Format – Sociomatrix

	Manager	Receiver
Sender	1	0 1 0 1 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 0 0
	2	1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 1
	3	0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 1 0 0
	4	1 1 0 0 0 0 0 1 0 0 0 1 0 0 0 1 1 0 0 0 0
	5	0 1 0 0 0 0 0 0 1 0 1 0 0 1 0 0 1 0 1 0 1
	6	0 1 0 0 0 0 1 0 1 0 0 1 0 0 0 0 1 0 0 0 1
	7	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
	8	0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
	9	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
	10	0 0 1 0 1 0 0 1 1 0 0 1 0 0 0 1 0 0 0 1 0
	11	1 1 1 1 1 0 0 1 1 0 0 1 1 0 1 0 1 1 1 0 0
	12	1 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 1
	13	0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0
	14	0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0
	15	1 0 1 0 1 1 0 0 1 0 1 0 0 1 0 0 0 0 1 0 0
	16	1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
	17	1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 1 0 0 1 1 1
	18	0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
	19	1 1 1 0 1 0 0 0 0 0 1 1 0 1 1 0 0 0 0 1 0
	20	0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0
	21	0 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0 1 1 0 0 0

Statistical Models for Network Structure and Dynamics

The Exponential Random Graph Model

- Let Y be a n-vertex network
- An ERGM is specified as:

$$\mathcal{P}(Y, \boldsymbol{\theta}) = \frac{\exp\{\boldsymbol{\theta}' \mathbf{h}(Y)\}}{\sum_{\text{all } Y^* \in \mathcal{Y}} \exp\{\boldsymbol{\theta}' \mathbf{h}(Y^*)\}}$$

- $\boldsymbol{\theta}$ is a parameter vector
- $\mathbf{h}(Y)$ is a vector of statistics on the network
- Object of inference: the probability of Y among all possible permutations of Y given the network statistics.
- **Only defined for binary networks.**

The Generalized ERGM

- Transform unbounded continuous edges onto the [0,1] interval.

- $\boldsymbol{\lambda}_{ij}$ parameterizes the transformation to capture marginal features of Y_{ij}

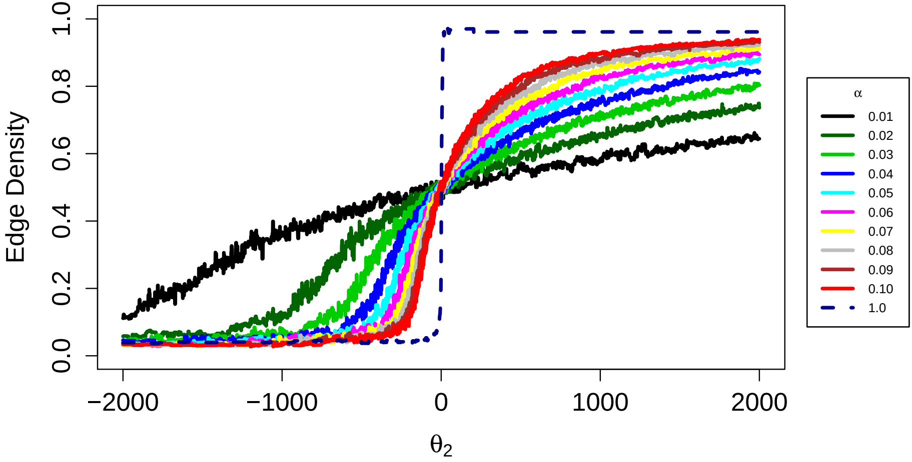
- We write the GERGM PDF of Y as

$$f_Y(Y, \boldsymbol{\theta}, \boldsymbol{\Lambda}) = \frac{\exp\left[\boldsymbol{\theta}' \mathbf{h}(\boldsymbol{G}(Y, \boldsymbol{\Lambda}))\right]}{\int_{[0,1]^m} \exp\left[\boldsymbol{\theta}' \mathbf{h}(Z)\right] dZ} \prod_{ij} g(Y_{ij}, \boldsymbol{\lambda}_{ij})$$

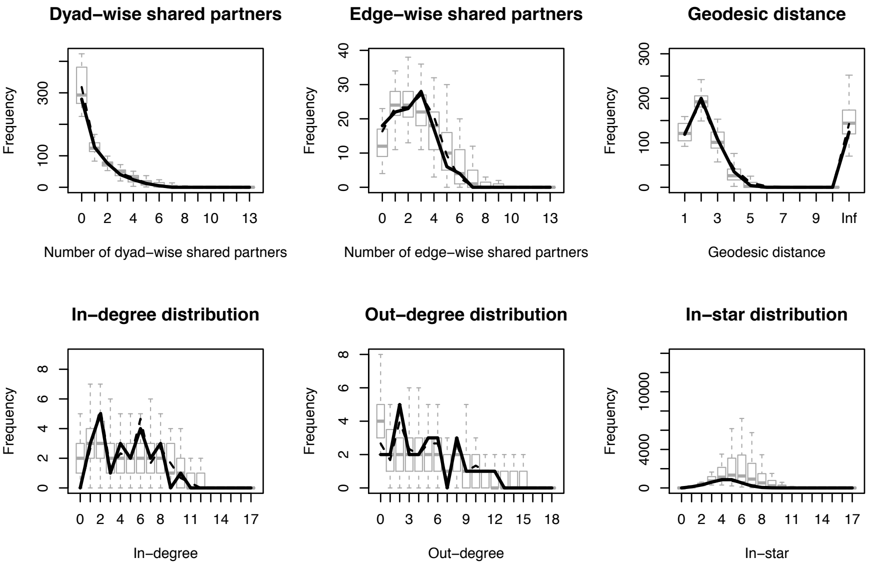
Estimation

- Start with MPLE parameter estimates.
- Use Metropolis-Hastings or Gibbs sampling to update parameters.
  1. Simulate networks using current parameters.
  2. Optimize over parameters.
- When parameters converge, stop algorithm.
- Check for degeneracy and model fit.

Model Degeneracy



Assessing Model Convergence



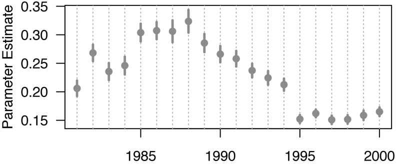
Applications to Financial Network Data

Beyond "Gravity" in International Trade

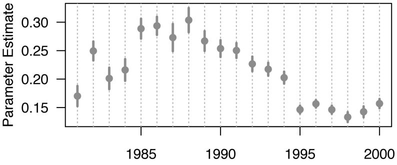
- Ward & Hoff. "Persistent Patterns of International Commerce". *Journal of Peace Research*, 2007.
- Yearly data on international trade flows from the UN Commodity Trade Statistics Database (1980-2001)
- Use of ERGM (thresholding data) and GERGM leads to substantively different results.

GERGM Results

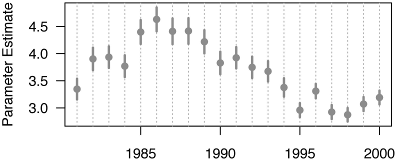
Sociality – (Exporters)



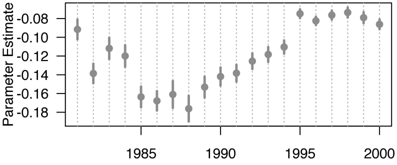
Popularity – (Importers)



Reciprocity



Transitivity



Structure of International Lending

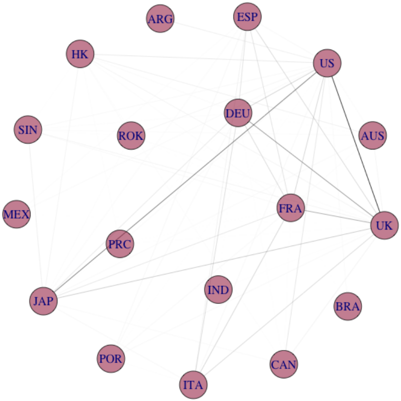
- Oatley et al. "The Political Economy of Global Finance: A Network Model", *Perspectives on Politics*, 2013.

- Aggregate yearly lending volumes between banks in 18 countries from Bank for International Settlements (1980-2005).

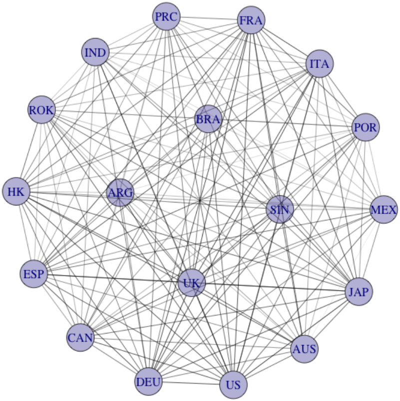
- Authors suggest this network is highly hierarchical. Our analysis draws this into question.

International Lending Network – 2005

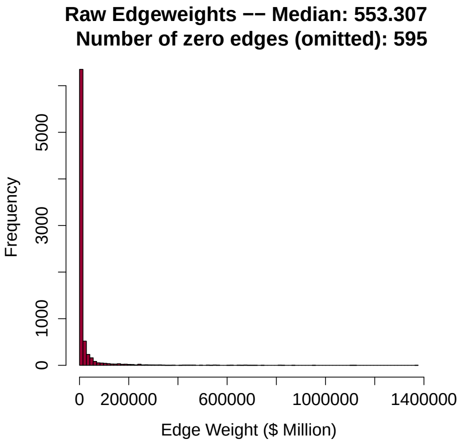
Raw



Logged

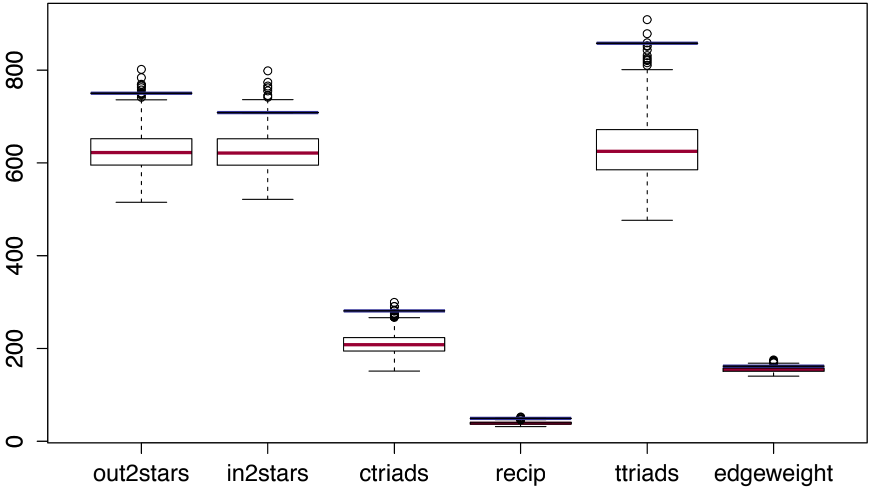


Edge Transformation For Heavy-Tailed Financial Data



Log data and normalize by maximum.

Observed 2005 Network vs. Random Network

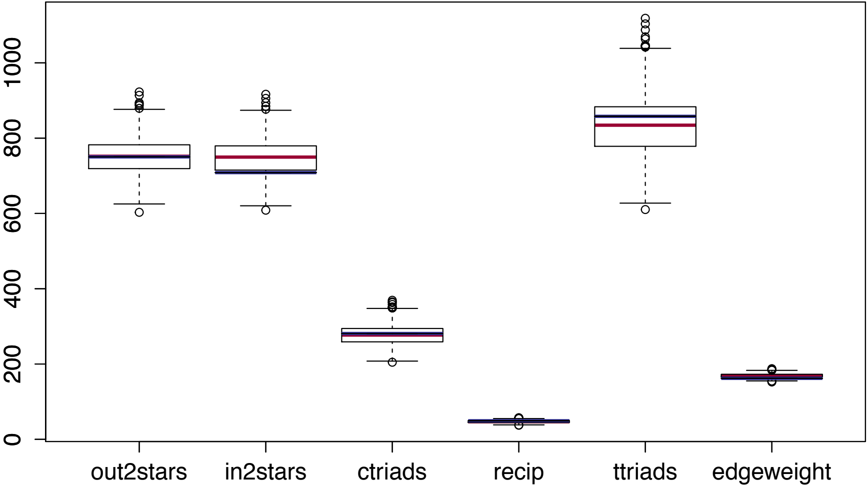


Model Specification – 2005 BIS Data

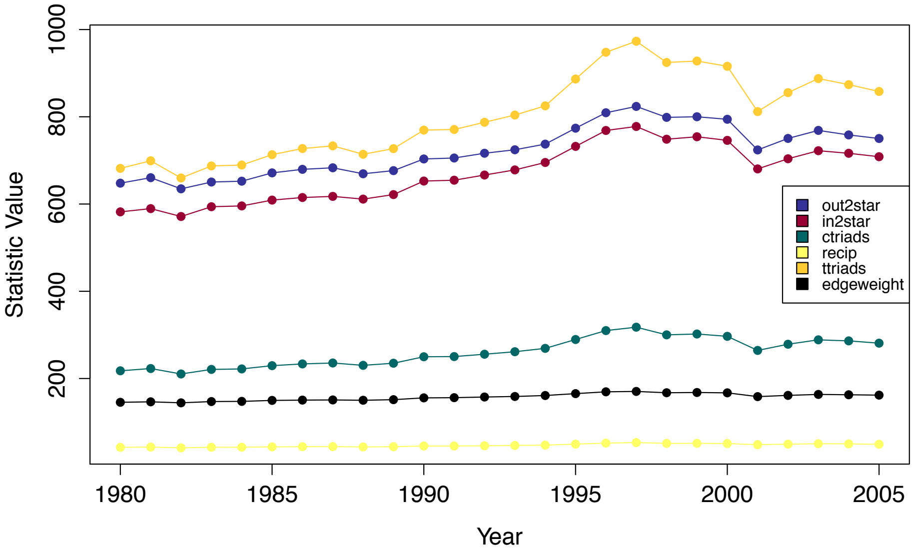
- Net $\sim$ Popularity + Sociality + Transitivity
- Hypotheses
  - **Popularity (+)** a few major borrowers.
  - **Sociality (?)** a few major lenders?
  - **Transitivity (+)** financial clustering.
- Because data are normalized ($\mu \approx 0.5$), do not need intercept.

Preliminary Results

Significant Transitivity, Anti-Popularity



Trends Over Time



Data Challenges and Future Directions

Data Challenges

- **Dealogic LoanAnalytics**: $\$12,000/\text{yr}$ – all syndicated loans since 1980.
- **BVD Bank Scope**: $\$25,000/\text{yr}$ – Ballance sheet data back to 2000.
- **FedWire** – Need government collaborator, 100M+ large inter-bank transfers.
- **Tri-Party Repo** – NY Fed has the data, need to get access.

Future Directions

- **More Theory**: Unique features of financial networks?
- **R Package**: GERGM estimation implementation in `xergm` package
- **Applications** – systemic risk, 2008 financial crisis.