Endogenous Market Making and Network Formation

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Core-Periphery Structure in OTC

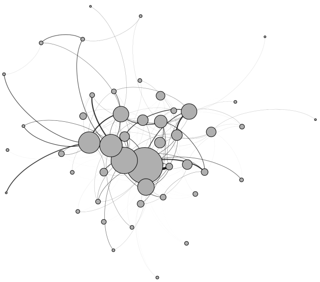


Figure: Observed Interbank Network (Blasques et al. 2015)

- Stylized Facts (Li & Schurhoff (2011), Bech & Atalay (2010)...)
  - “Customers” trade through "Dealers”
  - Heterogeneity in dealers’ connectedness
    - A few highly interconnected banks (Implications on financial stability)

Core-Periphery Structure in OTC

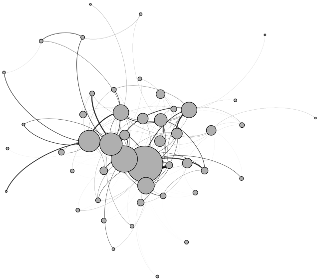


Figure: Observed Interbank Network (Blasques et al. 2015)

"In the current crisis, ... financial firms ... become too interconnected to fail .... Due to the complexity and interconnectivity of today's financial markets, the failure of a major counterparty has the potential to severely disrupt many other financial institutions, their customers, and other markets."
– Charles Plosser, 03/06/09

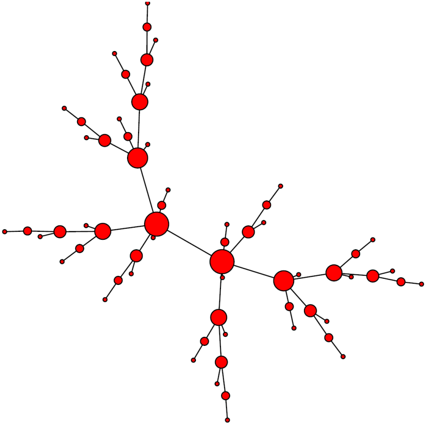
Core-Periphery Structure in OTC

- Q: Why is this the equilibrium structure?
- Existing approaches:
    - Random Search (non-directional)
    - Network *(mostly* exogenous links)
- This paper:
    - We model information frictions motivating search frictions
    - All trading links are formed *optimally*

Basic Ingredients

- Agents are exposed to uncertainty about asset value.
- Market makers insure customers against the uncertainty.
- Traders with less exposure to uncertainty have *comparative advantage* to be market makers.

Result



1. Volatile types trade through stable types
2. Stable types have most connections & highest gross trading volume
3. Implications on prices and systemic risk

Roadmap

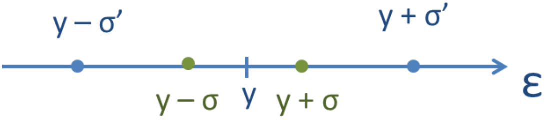
- Basic Model: One Round of Trade
- Full Model: Multiple Rounds of Trade
- Implications for
  - trading structures, prices, allocation
  - systemic risk in unsecured credit markets

Model

A continuum of traders

- Endowment: A units of asset, unlimited numeraire goods
- Capacity constraint: asset holding $a \in [0, 2A]$.
- Preference: $u(a, T) = \varepsilon_\sigma a + T$.
  - σ: volatility of preference, $\sigma \sim G(\cdot)$.
  - ε_σ^v: i.i.d. shocks, $\Pr(v = H) = 1/2$.

$$\varepsilon_\sigma^v = \begin{cases} y + \sigma, & \text{if } v = H, \\ y - \sigma, & \text{if } v = L, \end{cases}$$



More generally,
$p \equiv$prob of two traders that have the opposite preferences

- T: transfer of numeraire goods

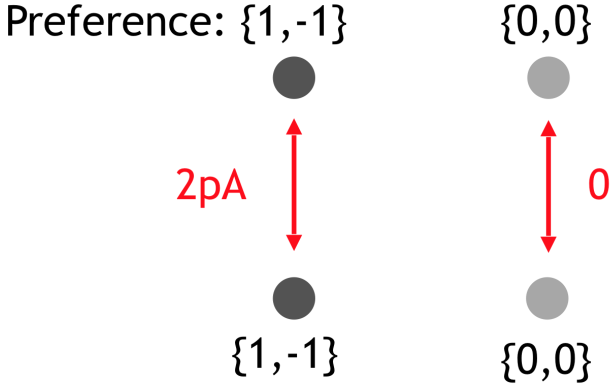
Market Structure

- $t = 0$: **bilateral matching**
  - Choose counterparty based on *observables* z

$$z = (\text{volatility type } \sigma, \ \text{asset holding } a)$$

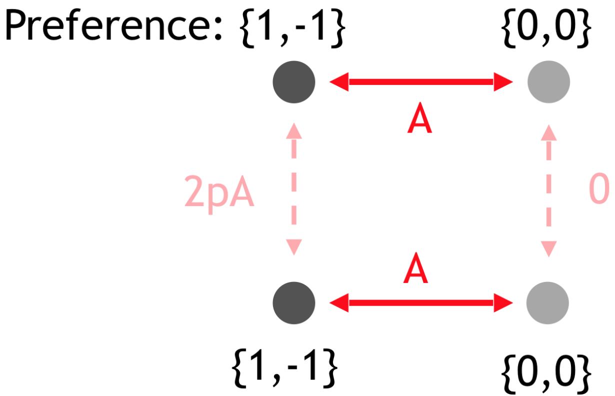
  - Agree on feasible asset allocation & transfer contingent on the realization of preference type of traders in a match
  - Preference shocks are realized
- $t = 1$: **bilateral trade** takes place according to the agreement

Constrained Efficiency: an Example



Total gain from trade: 2pA

Constrained Efficiency: an Example

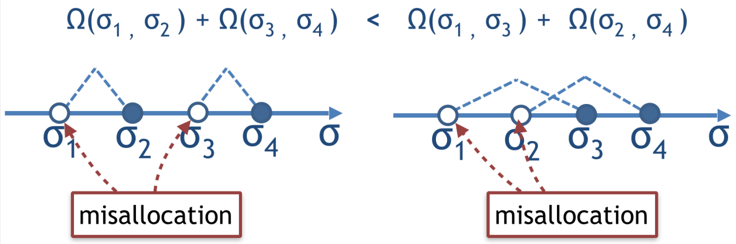


Total gain from trade: 2A

Constrained Efficiency: Matching Based on Volatility Types

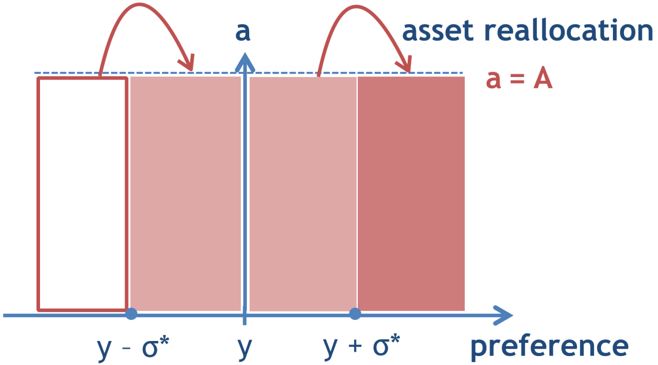
Lemma

Total value from matching, $\Omega(\sigma, \sigma')$, shows weak submodularity



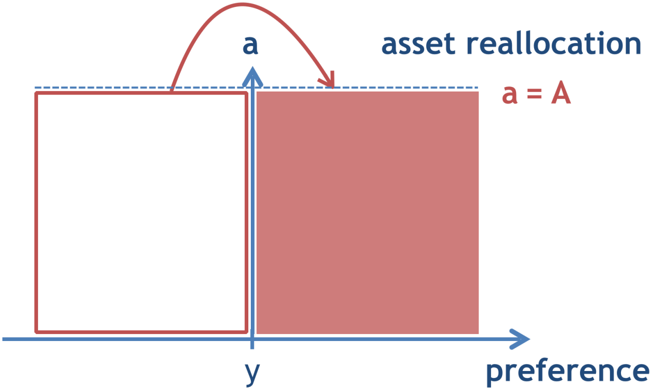
- Within a pair, the trader of more stable type "makes market" and may not receive efficient allocation
- Trading through stable types minimizes the overall misallocation
- Stable types have comparative advantages at making the market

Constrained Efficient Allocation



Weak submodularity of matching surplus
$\Rightarrow \exists$ a cutoff type σ^*, such that $G(\sigma^*) = 1/2$,
$\sigma > \sigma^*$ match with $\sigma \leq \sigma^*$.

Comparison with First Best Allocation



Implementation

- Centralized Walrasian market, with an auctioneer (multilateral clearing)
- Bilateral matching based on realized preferences

Equilibrium

Definition

An equilibrium is an allocation function $f : \mathbb{Z}\times\mathbb{Z} \to R_+$ and equilibrium payoff $W^*(\cdot) : \ \mathbb{Z} \to R_+$ satisfying the following conditions:
1) Optimality for Traders:

$$W^*(z) = \max_{\tilde{z}\in\mathbb{Z}} \Omega(z, \tilde{z}) - W^*(\tilde{z})$$

and for any $f(z, z') > 0$, $z' \in \arg\max_{z\in\mathbb{Z}}\{\Omega(z, z') - W^*(z)\}$.
2) Feasibility constraint:

$$\int f(z, \tilde{z})d\tilde{z} = h(z) \text{ for } \forall z,$$

where $h(z)$ is the density function of z.

The solution concept is related to pair-wise stability.

Decentralization of Constrained Efficient Allocation

- Customers' payoff depends on
  - gain from asset reallocation
  - payment to market makers
- Competition across market makers: they charge the same expected transfer T
- Traders with volatility type below σ^*:

$$\text{Gain from asset reallocation} < T$$

- Traders with volatility type above σ^*:

$$\text{Gain from asset reallocation} > T$$

- Expected transfer $T \propto$ Bid-Ask Spread

Takeaway

- Trading through stable types minimizes the cost of misallocation
- Stable types
  - act as market makers
  - are compensated by a bid-ask spread

Setup: Multiple Rounds of Trade

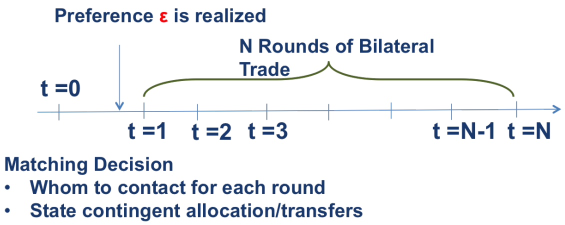
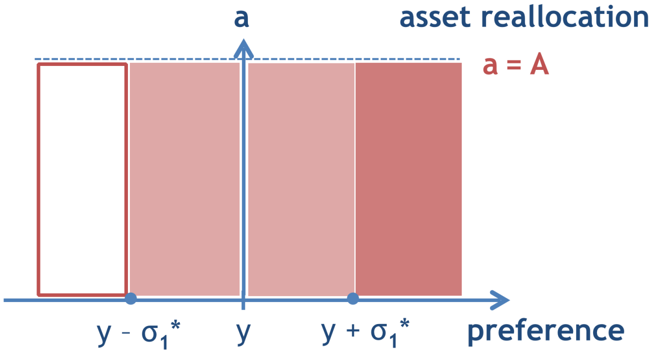


Figure: Timeline: $t = 0, 1, \ldots N$

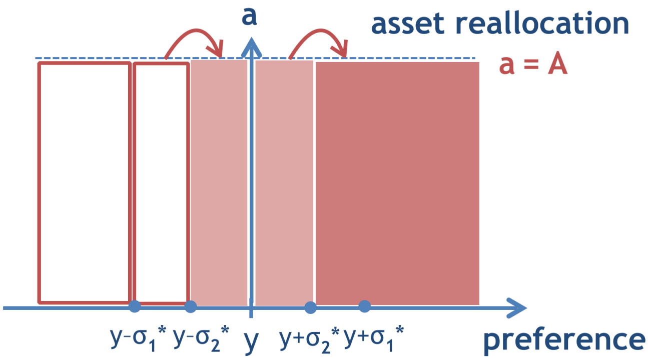
- Flow value of holding the asset: $\tilde{\varepsilon}_\sigma \kappa_t a_t$ (and $\sum_{t=1}^{N} \kappa_t = 1$)
- Matching Decision at $t = 0$:
  - volatility type
  - **contingent on** asset holding $a_t \in \{0, A\}$

Constrained Efficient Allocation



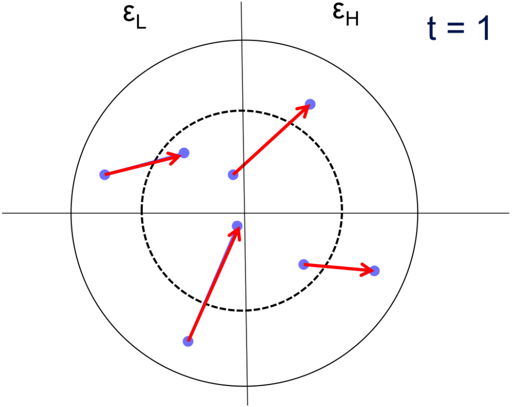
- σ^* is such that $G(\sigma^*) = 1/2$.

Constrained Efficient Allocation



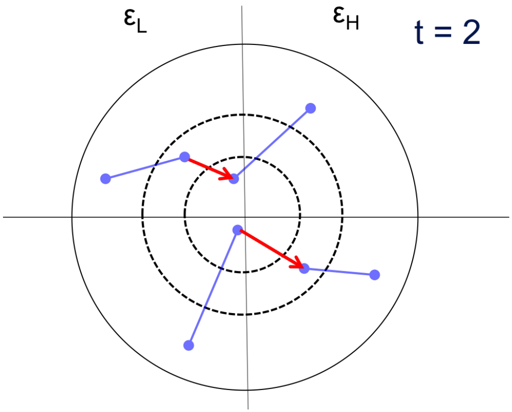
- σ_1^* is such that $G(\sigma_1^*) = \frac{1}{2}$, σ_2^* is such that $G(\sigma_2^*) = \left(\frac{1}{2}\right)^2$.
- The constrained efficient solution follows a recursive structure

Market Making and Network Formation ($N = 3$)



- Volatile types ($\sigma > \sigma_1^*$) match with stable types ($\sigma \leq \sigma_1^*$)
- Volatile types have reached their efficient allocation

Market Making and Network Formation ($N = 3$)



- "Customers" last period ($\sigma > \sigma_1^*$) do not trade
- Volatile types ($\sigma > \sigma_2^*$) match with remaining stable types ($\sigma \leq \sigma_2^*$)

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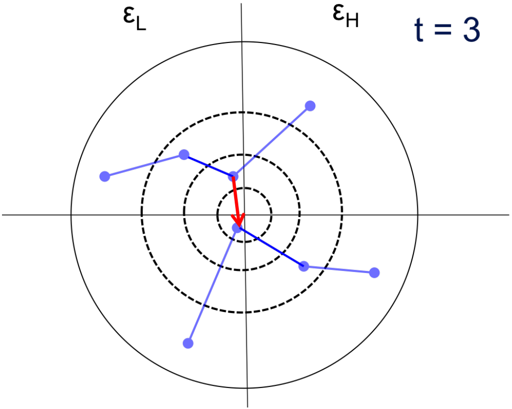


- "Customers" last period ($\sigma > \sigma_2^*$) do not trade
- Volatile types ($\sigma > \sigma_3^*$) match with remaining stable types($\sigma \leq \sigma_3^*$)

Network Structure with N rounds of Trade

- $\sigma > \sigma_1^*$: "customers"
  - receive efficient allocation by trading once
- $\sigma \leq \sigma_N^*$: "central dealers"
  - build most links
  - have highest gross trading volume
- $\sigma_t^* < \sigma \leq \sigma_{t-1}^*$: "peripheral dealers"
  - make the market until $t-1$
  - trade with more central dealers at t

Equilibrium

Definition

Given the initial distribution $\pi_1^v(a, \sigma, k)$, an equilibrium is a payoff function $W_t^*(\cdot) : \mathbb{Z} \to \mathbb{R}^+$, an allocation function $f_t(z, z') : \mathbb{Z} \times \mathbb{Z} \to \mathbb{R}^+$, terms of trade $\psi_t^*(\cdot, \cdot) : \mathbb{Z} \times \mathbb{Z} \to \mathcal{C}$ for all $t \in \{1, \ldots, N\}$, probability of preferences $\pi_t^v(\cdot) : \mathbb{Z} \to [0, 1]$, such that the following conditions are satisfied:

1) Optimality of traders' matching decisions. For any $z \in \mathbb{Z}$ and $z' \in \mathbb{Z} \cup \{\emptyset\}$ such that $f_t(z, z') > 0$,

$$z' \in \arg\max_{z \in \mathbb{Z}} \Omega_t(z, \tilde{z}) - W_t^*(z),$$

$$W_t^*(z) = \max_{\tilde{z} \in \mathbb{Z}} \Omega_t(z, \tilde{z}) - W_t^*(\tilde{z}).$$

with $\psi_t^*(z, z') \in \arg\max_{\psi \in \mathcal{C}(z,z')} W_t(z, \psi) + W_t(z', \psi)$, if $z' \neq \{\emptyset\}$.

2) The laws of motion of $\pi_t^v(z)$.

3) Feasibility of the allocation function.

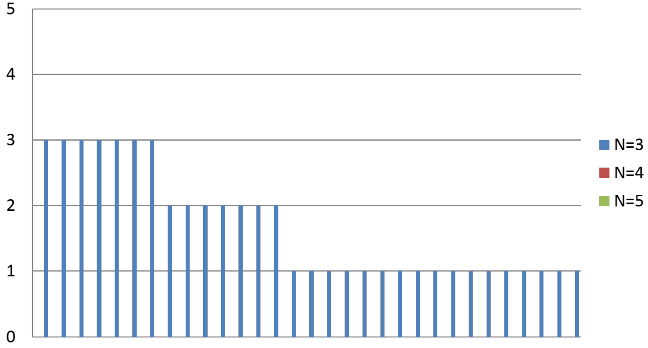
Equilibrium Construction: Payoff

- Cutoff type at period t: $G(\sigma_t^*) = 2^{-t}$
- Indifference condition for the cutoff type:

$$\underbrace{\kappa_t \sigma_t^* - S_t}_{\text{gaining immediacy}} = \underbrace{S_t - \beta S_{t+1}}_{\text{saving trading cost by delay}}$$

- S_t: the expected bid-ask spread at period t.

Distribution of Links



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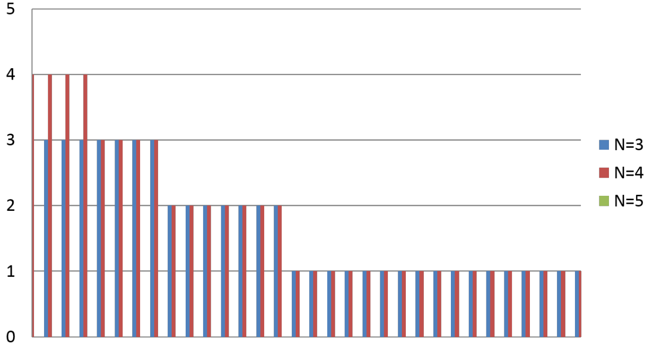
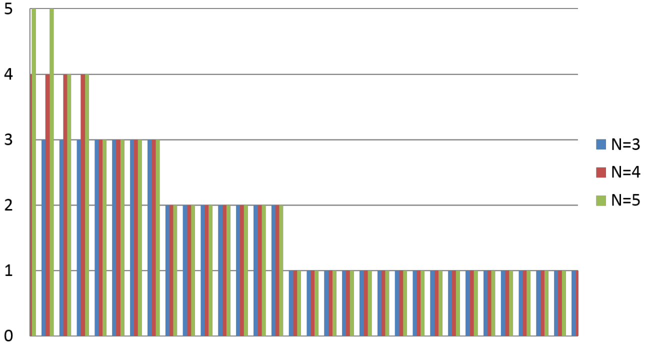
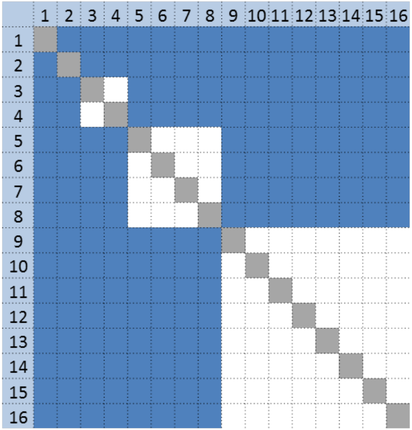


Market structure: Distribution of Links



Tiered Trading Structure



- Traders within a tier, $\sigma \in (\sigma_t^*, \sigma_{t-1}^*]$ does not trade with each other
  - In contrast to random search: Afonso and Lagos (2014), Hugonnier et al (2014)

Expected Bid-Ask Spread S_t

$$\underbrace{\kappa_t \sigma_t^* - S_t}_{\text{gaining immediacy}} = \underbrace{S_t - \beta S_{t+1}}_{\text{saving trading cost by delay}}$$

- Without needs for Immediacy: Increasing Spread ($S_{t+1} - S_t > 0$)
  - dividends payout at the end $\kappa_t \to 0 \ \forall t < N$ and $\kappa_N \to 1$
- Benefit from immediacy: Decreasing Spread ($S_{t+1} - S_t < 0$)
  - e.g. constant dividend $\kappa_t = \kappa \ \forall t$

Expected Bid-Ask Spread S_t

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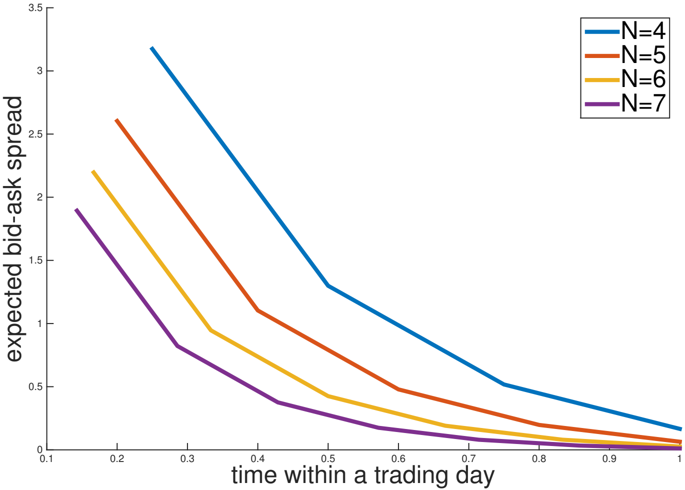
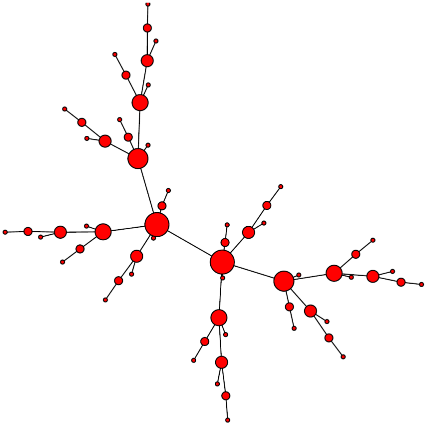
  - e.g. constant dividend $\kappa_t = \kappa\ \forall t$
- Cross sectional Predictions
  - "Inter-dealer" spread vs "dealer-customer" spread
  - Does spread increase with centrality?
  - Li & Schurhoff (2011), Hollifield et al (2014)

Spread and Trading Capacity of the Market



Network Structure



1. Maximum Connections: 2^N nodes with N rounds of trade
2. No Loop.

Systemic Risk in the Unsecured Credit Market

"The risk of failure of large, interconnected firms must be reduced, whether by reducing their size, curtailing their interconnections, or limiting their activities" (Volcker 2012).

- Does a more densely connected network enhance "stability" ?
  - Current theoretical models focus on simple/symmetric network
    - e.g., Allen and Gale (2000), Acemoglu et al (2015), etc
  - "Too-Interconnected-to-Fail" Institutions
    - e.g., Gofman (2014)

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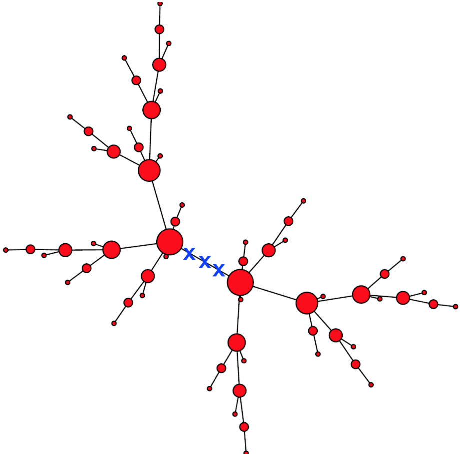
  - "Too-Interconnected-to-Fail" Institutions
    - e.g., Gofman (2014)
- The extent of contagion in the core-periphery network?

How does interconnectedness matter?

"The risk of failure of large, interconnected firms must be reduced, whether by reducing their size, curtailing their interconnections, or limiting their activities" (Volcker 2012).

A simple exercise: $N' = N - 1$

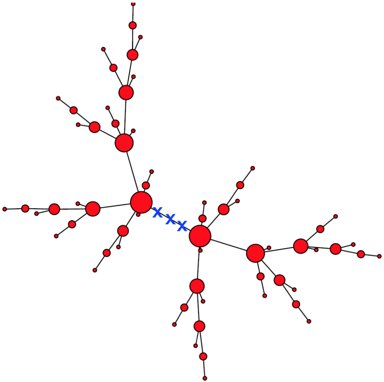


How does interconnectedness matter?

- Consider the effect of the default of one financial institution
- Two standard effects of interconnectedness
  - Dilution effect: creditors share default cost

    Stronger for more interconnected institutions
  - Contagion effect: spread of default through network
- Acemoglu et al (2015): a convex combination of the ring and complete networks
  - symmetric networks

How does interconnectedness matter?



- Cost: reduce allocation efficiency
- Potential benefit?
  - If the dilution effect is strong enough, NO.
  - Otherwise, YES. Contagion effect is reduced.

Related Literature

- Random Search:
  - Duffie, et al (2005), Afonso and Lagos (2014), Hugonnier et al (2014)
- Networks:
  - Gofman (2011), Babus and Kondor (2012), Malamud and Rostek (2012)
- Network Formation:
  - Hojman and Szeidl (2008), Babus and Hu (2015), Farboodi (2014)

Methodology: A dynamic matching model of network formation

Predictions: Hierarchical Core-periphery Structure (Li & Schurhoff (2011))

- The core: the ones with lower needs for trade (less exposure to uncertainty shocks)

Conclusion

- Contribution: a dynamic matching model of network formation
  - Existence of (highly connected) intermediaries
  - Implications for price, volume, allocations
  - Implications for systemic risk

Setup of the Unsecured Lending Market

- Applying to unsecured lending markets:
  - FIs different in their investment returns: ε_{σ}^{v}
  - borrow or lend "liquid" capital (with initial position $a_0 \in \{0, A\}$)
  - All payments (i.e., interests) are made at the end of period N
  - All FIs start the same net worth e (with some outside debt obligation)
- The net worth of FI i after the trading

$$e' = \varepsilon_{\sigma}^{v} a_N + \sum_{k=1}^{n_s} \tau_{ki} A - \sum_{j=1}^{n_b} \tau_{ij} A + e \to e$$

Setup of the Unsecured Lending Market

- Assumptions on Default:
  - One FI is hit by an exogenous shock
  - A FI defaults iff the loss > net worth ($l > e$)
  - z: deadweight loss from default (liquidation or bankruptcy cost)
  - If the FI has n creditors, each creditor takes a loss of $\frac{1}{n}(l + z - e)$

Equilibrium Construction: Payoff

- Traders' expected payoff :

$$W_0^*(\sigma) = \max_t \vartheta(\sigma, t) + \tau(t).$$

$$\vartheta(\sigma, t) \equiv \underbrace{\sum_{s=1}^{t-1} \kappa_s y A}_{misallocation} + \underbrace{\sum_{s=t}^{N} \kappa_s (y+\sigma) A}_{efficient}$$

$$\tau(t) \equiv \sum_{s=1}^{t-1} T_s - T_t$$

- "reaching efficient earlier" v.s "net payment"