Systemic Credit Freezes in Financial Lending Networks

James Siderius joint with **Daron Acemoglu**, **Asu Ozdaglar**, and **Alireza Tahbaz-Salehi**

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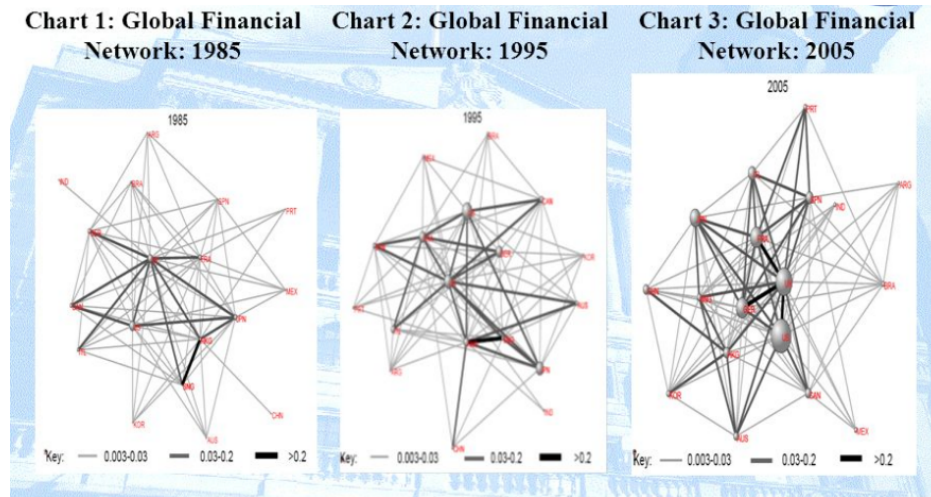
Motivation

- By the onset of the financial crisis of 2008, the US financial system had become increasingly more interconnected.
  - Complex lending relations: interbank and overnight lending, securitized lending such as repo market.



- Failure of an institution may trigger financial distress for its counterparties or those holding its shares.
- Lenders need to also assess creditworthiness of borrowers of the borrower, and so on.

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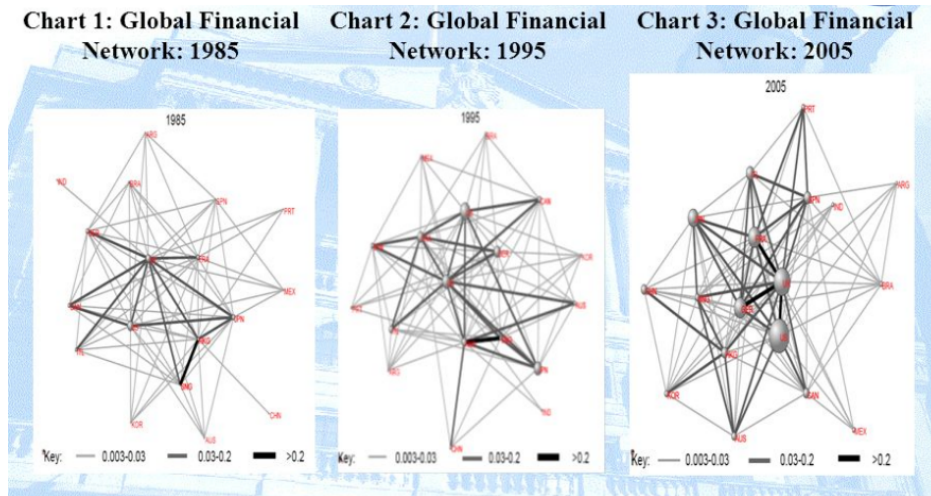

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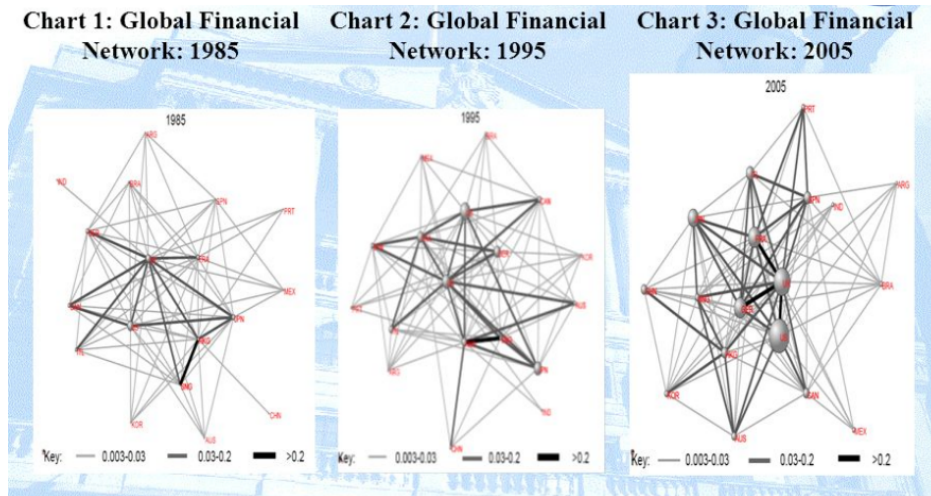

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- Ex-Post Contagion: The failure of one institution can cause other institutions to fail.
- Ex-Ante Considerations: Credit freezes induced by the fear of future liquidity problems, ex-ante. Profitability of loans might be compromised because of additional perceived *systemic* risk.

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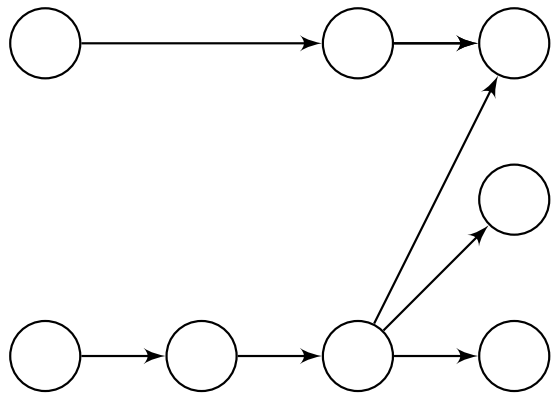
Ex-Post Analysis

- Basic setup: n banks, survival of bank i *depends* on both (1) an idiosyncratic shock at i, and (2) the survival of other banks.
- We model the dependence structure in (2) using a financial network $\mathbf{G}_*$:



  - Dependence may capture unsecured debt contracts, collateralized lending, common asset holdings, among others.

- Main point: A negative shock can spread to the rest of the network, causing systemic trouble.
- Studied extensively in previous literature: Acemoglu, Ozdaglar and Tahbaz-Salehi (2015), Cabrales, Gale and Gottardi (2015), Elliott, Golub and Jackson (2014), Gai and Kapadia (2010), Jorian and Zhang (2010)

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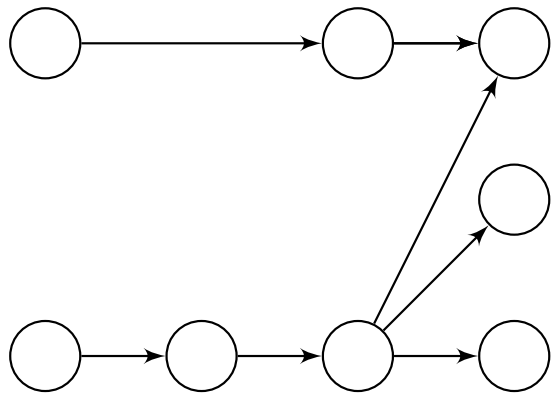

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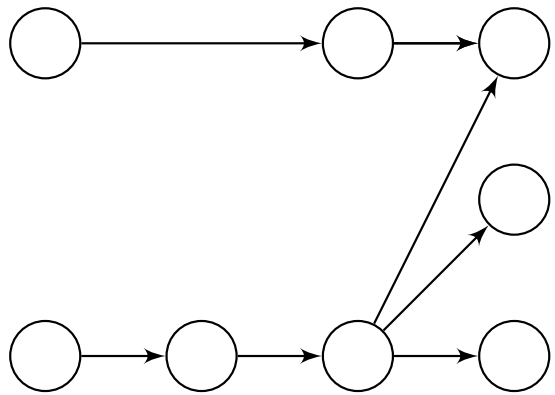

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- A bank-level model of financial intermediation
  - ex-ante incentives of the banks to make profitable loans
  - endogenous lending contracts and financial network
  - endogenous risk and defaults

- Banks' fear of future default determines network of financial lending.
- System-wide credit freezes may arise for small changes to risk in the network.
- Freezes may arise in parts of the network unaffected directly by changes in the risk profile, because of interconnectivity.

- Today:
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This Talk

- More importantly than ex-post contagion, banks fear systemic problems ex-ante, can lead to systemic credit freeze.

- We develop a stylized model of ex-ante credit freezes in a financial network:
  - Banks have outside known liabilities (e.g., senior debt, employee wages, operational costs) and also hold assets with random value.
  - Some banks can lend to entrepreneurs located at the leaves of the network with a fixed demand for funds.
  - Lending contracts determined by potential lenders who offer an interest rate and borrowers decide to borrow as much as desired.
  - Potential lenders can always freeze credit by offering no contract and avoiding any subsequent losses.

- Introduce risk shifts that increase the likelihood and severity of future liquidity problems for certain banks in the network. Risk shifts correspond to anticipated shocks in the future.
- Characterize the subgame perfect equilibria of this financial network.

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Main Results

- Properties of the equilibrium:
  - Existence of a pure strategy equilibrium, and uniqueness of a stronger equilibrium notion.
  - Financial network is always a directed-tree between ultimate cash lenders and borrowers.

- Comparative statics for the economies with a single entrepreneur. Freeze occurs when:
  - Many layers of financial intermediation or gains from trade are small.
  - Asset markets are weak and/or unstable.
  - Portfolios of assets across banks are independent or anti-correlated.

- In single-entrepreneur economies or tree networks (where each bank can borrow from at most one other bank) with multiple entrepreneurs, freezes are "simple" in the sense that:
  (a) They always originate with the affected bank (the bank with added risk).
  (b) The set of banks experiencing a credit freeze is a connected set.

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Main Results, cont.

- For general networks with multiple entrepreneurs, new risks can affect the equilibrium in nuanced ways and freezes may "complex."
  - Non-monotone: increase in the risk of some bank i leads to increase in lending.
  - Two types of complexity: (i) bank with increased risk does not lose credit but some other bank does, and (ii) increase in risk of one part of network causes some other distinct segment of the network to lose access to credit.

- Because systemic credit freeze can occur from a small, isolated shock to risk, (relatively) inexpensive rescue policy can restore large amounts of lending.

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Related Literature

- Empirical evidence of credit freezes in interbank lending
  - Adrian et al. (2013); Alfonso, Kovner and Schoar (2010); Brunnermeier (2009)
- Endogenous network formation
  - Leitner (2004); Babus (2006); Blume et al. (2011)
- Single bank or pair of banks accessing credit market
  - Gorton and Metrik (2012); Diamond and Rajan (2011); Caballero and Simsek (2013)
- Ex-ante fears captured through coordination game
  - Allen and Babus (2009); Anand et al. (2012); building off global games literature of Shin and Morris (2001)
  - No ex-post trigger
- To the best of our knowledge none of this literature studies ex-ante credit freezes in financial networks.

Banks, Depositors, and Entrepreneurs

(a) Entrepreneurs ($\mathcal{E}$): Non-financial "bulky" project with return r^* for one unit of investment ($1).

(b) Depositor ($\mathcal{D} = \{0\}$): Competitive market of depositors with access to outside risk-free technology with return r_0.

(c) Banks ($\mathcal{B} = \{1, \ldots, n\}$): Intermediaries between depositors and entrepreneurs, and each other.

Figure: Opportunity Network **G**.

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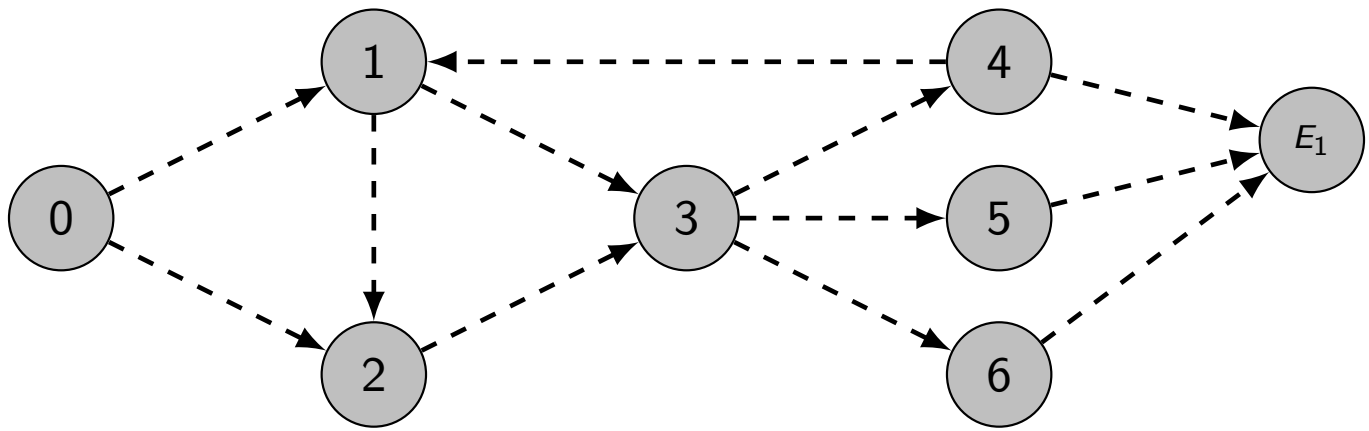
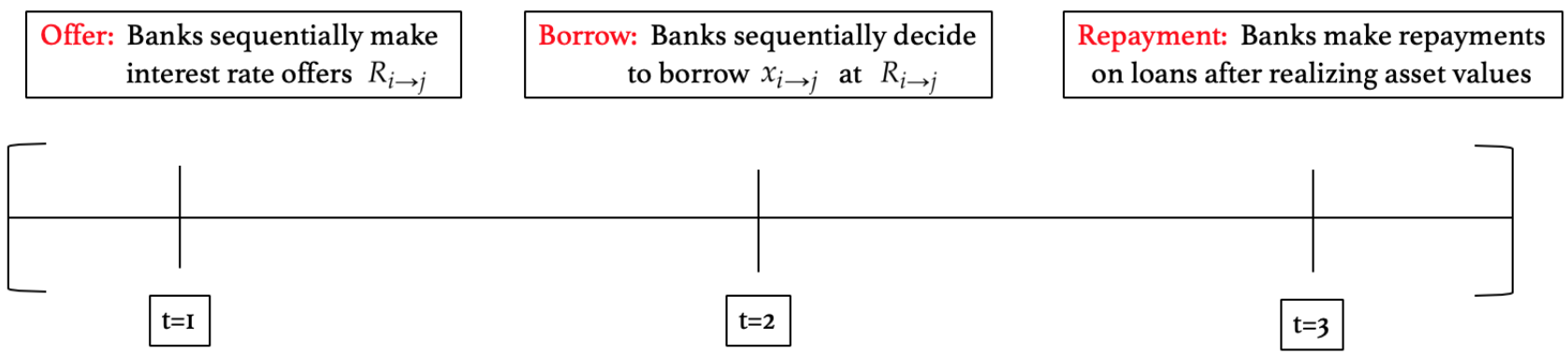


Figure: Opportunity Network **G**.

Timing of Interbank Lending

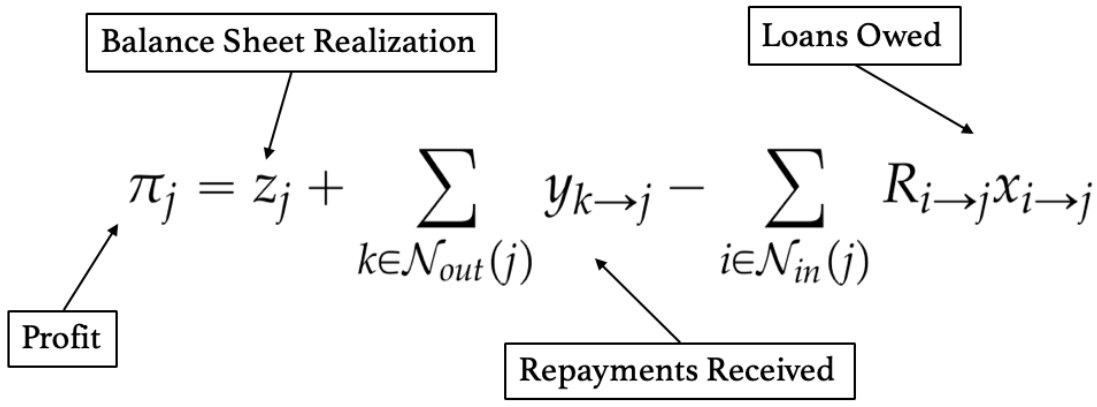
- Take directed, opportunity network **G** as given. Let $\mathcal{N}_{in}(i)$ and $\mathcal{N}_{out}(i)$ denote the in and out-neighborhood of i, respectively.

- Lending model consists of three stages:



Repayment Equilibrium

- Take financial network $\mathbf{G}_* = (\mathbf{R}, \mathbf{x})$ as given.
- The (realized) profit of bank j is



- If $\pi_j \geq 0$, the bank is *solvent* and makes full repayment on all its loans, $y_{j \to i} = R_{i \to j} x_{i \to j}$.
- If a bank defaults, it repays nothing. This is known as the total failure model, where bankruptcy liquidation proceeds are zero.

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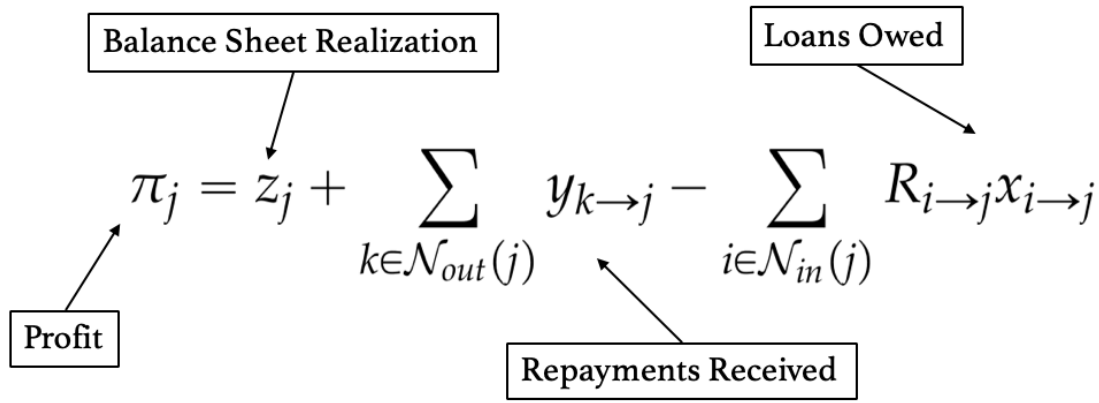

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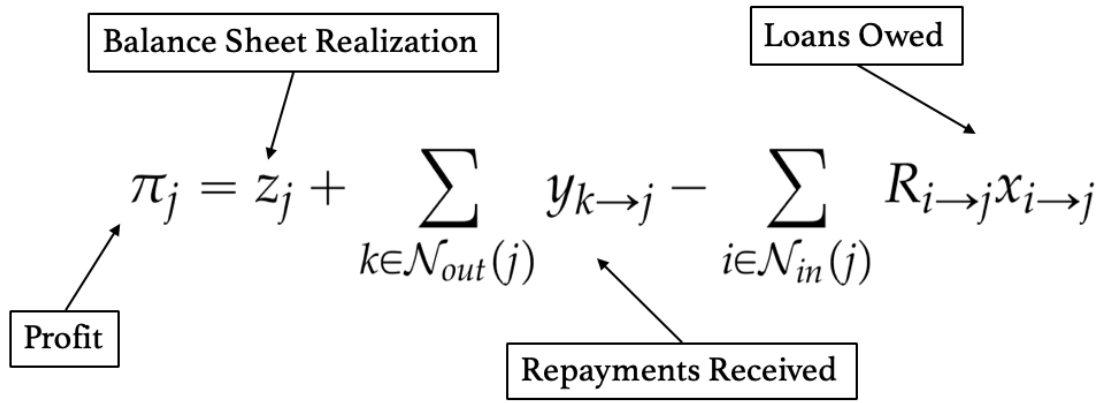

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Lending Equilibrium

- Every bank j maximizes expected upside profit minus a default cost ($F \geq 0$) from bankruptcy, $\mathbb{E}[(\pi_j)_+ - F \cdot d_j]$, subject to the borrowing constraint:

$$\sum_{i \in \mathcal{N}_{in}(j)} x_{i \to j} \geq \sum_{k \in \mathcal{N}_{out}(j)} x_{j \to k}$$

- Weak solution concept: subgame perfect equilibria.

- Strong solution concept: refine subgame perfection to eliminate indifferences; trembling-hand perfect equilibrium for interest rate offers.

- Essential uniqueness: two financial networks $\mathbf{G}_*, \mathbf{G}'_*$ are equivalent if $\mathbf{x} = \mathbf{x}'$ and $R_{i \to j} = R'_{i \to j}$ agree wherever $x_{i \to j} > 0$.

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Theorem

For any opportunity network $\mathbf{G}$*:*

(i) *There exists a strong lending equilibrium in pure strategies.*

(ii) *For a generic probability distribution over* $\mathbf{z}$*, the strong lending equilibrium is essentially unique.*

(iii) *Financial network* $\mathbf{G}_*$ *is a directed tree.*

Figure: Opportunity Network $\mathbf{G}$ (dashed) and Financial Network $\mathbf{G}_*$ (solid).

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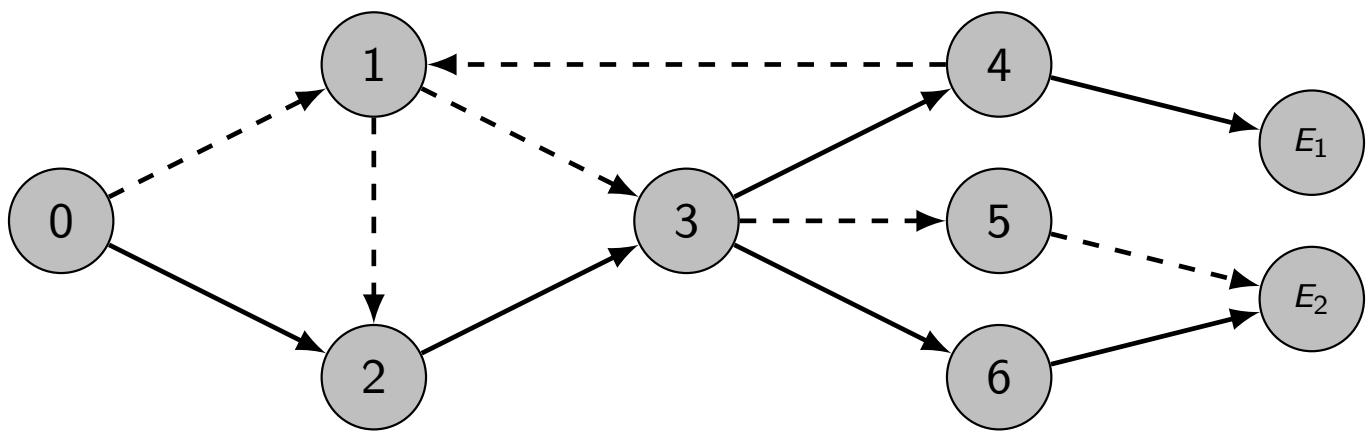

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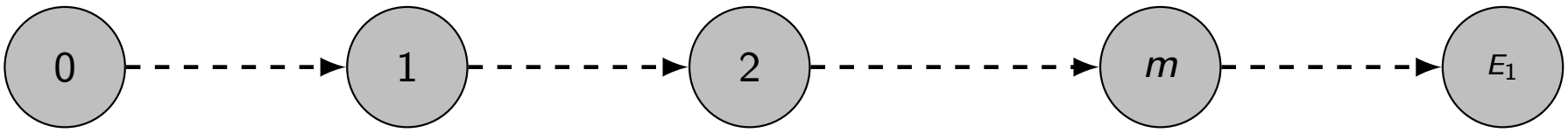
Intermediation Chain Example



- Single depositor 0, single client $m+1$.
- Every bank has iid returns $z_i \in \{-\infty, \sigma\}$ where $\sigma \in (0,1)$ and return $z_i = \sigma$ occurs with probability $p_i = 1-\varepsilon$ for small ε.
- Increasing risk premia as you move up the chain because of greater default risk:

$$R_{(m-k)\to(m-k+1)} - R_{(m-k-1)\to(m-k)} = \frac{1-p^k}{p^k}\sigma \approx k\varepsilon\sigma$$

- Interest rates in equilibrium given by $R_{(m-k-1)\to(m-k)} \approx r^* - \frac{1}{2}k^2\varepsilon\sigma$.
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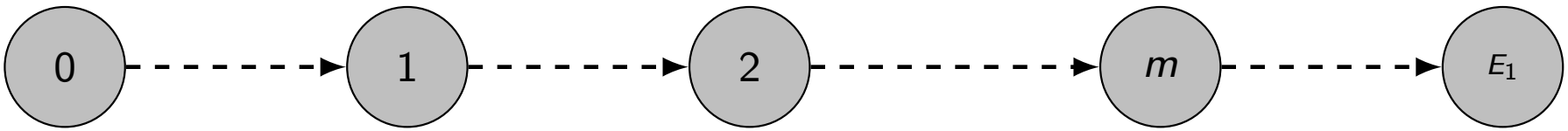
Intermediation Chain Example



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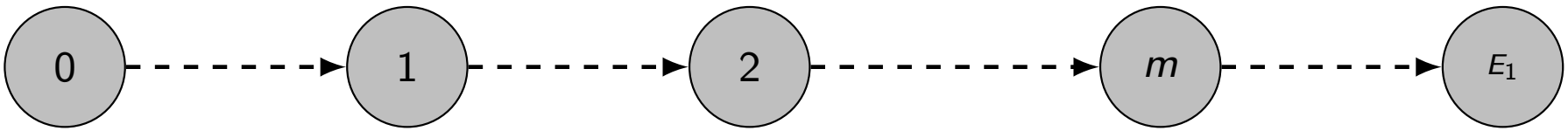

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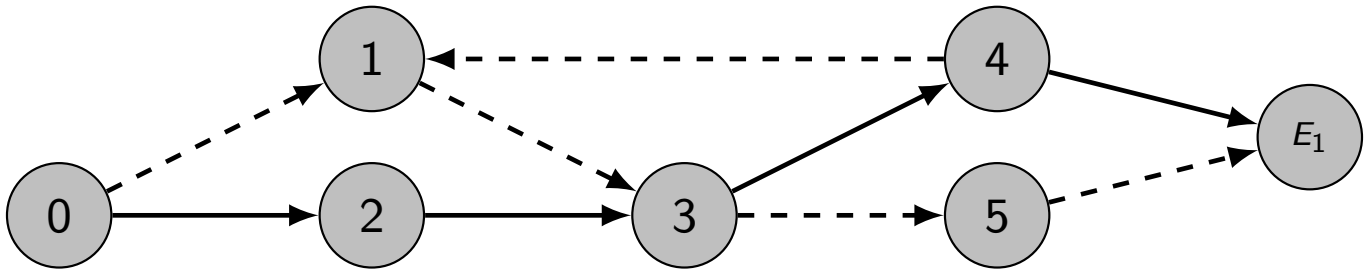

Proposition

Let $\mathbf{G}$ *contain a single entrepreneur. The entrepreneur experiences a credit freeze if and only if it experiences a credit freeze for all opportunity subnetworks* $\mathbf{H} \subset \mathbf{G}$.

Corollary

Let $\underline{\mathbf{G}} \subset \overline{\mathbf{G}}$ *denote two opportunity networks, each consisting of a single entrepreneur. If the entrepreneur experiences a credit freeze in* $\overline{\mathbf{G}}$*, then it also experiences a credit freeze in* $\underline{\mathbf{G}}$.

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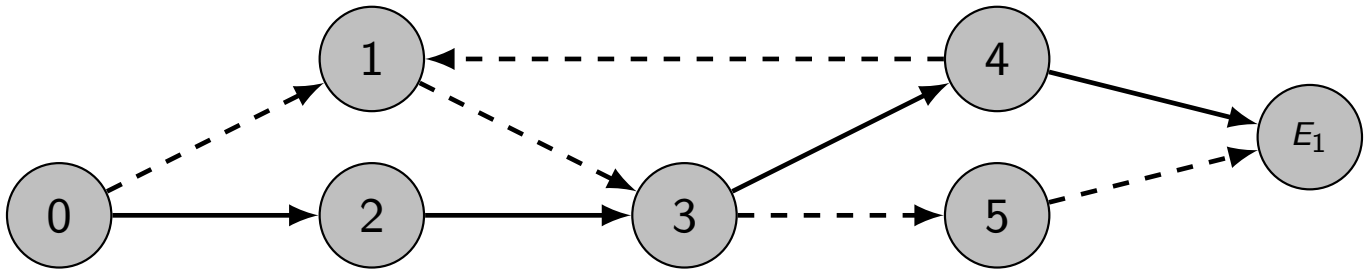

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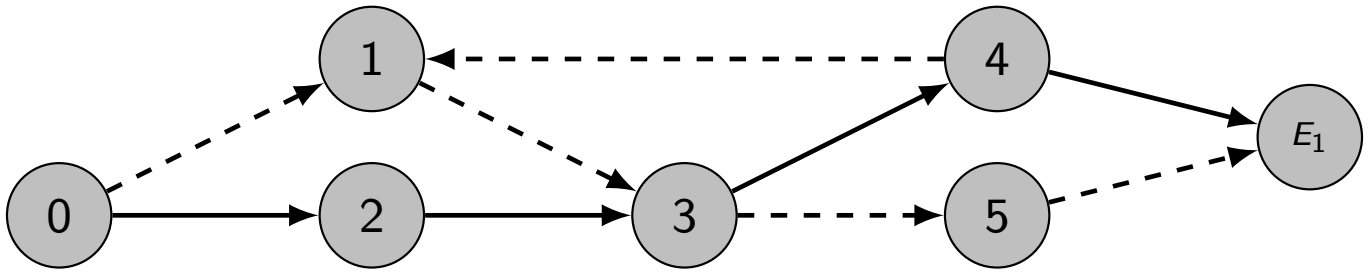

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Intermediation and Gains from Trade

- We say bank j has a credit freeze if $R_{i \to j} = \varnothing$ for all $i \in \mathcal{N}_{in}(j)$ in the equilibrium financial network $\mathbf{G}_*$.
- A credit freeze is systemic if all banks experience a credit freeze.
- If $\mathbf{G}$ is a chain, then every credit freeze is systemic.

Theorem

If $\mathbf{G}$ is a chain network, then:

(a) *there exists $\bar{n}$ such that the economy experiences a systemic freeze if and only if $n \geq \bar{n}$;*

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- Recall $r^* - r_0$ are gains from trade. As banks face possible ex-post cascades from downstream defaults, will only lend if loans are sufficiently profitable ex-ante.
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Shocks to Asset Distribution

Definition

Say that $\mathbf{z}$ first-order stochastic dominates $\mathbf{z}'$ if $z_i|\mathbf{z}_{-i}$ FOSD $z_i'|\mathbf{z}_{-i}$ for all banks i and all realizations $\mathbf{z}_{-i}$. If $\mathbf{z}$ FOSD $\mathbf{z}'$, and $z_i \nsim z_i'$, then there is a risk shift to bank i.

- *Stronger condition*: In every state of the world, asset $\mathbf{z}'$ pays no more than $\mathbf{z}$ for all banks. For banks with a risk shift, there is also some state of the world where $\mathbf{z}'$ pays less than $\mathbf{z}$.

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There exists $\bar{F} > 0$ such that for all $F > \bar{F}$, whenever $\mathbf{z}$ FOSD $\mathbf{z}'$, there is no systemic credit freeze in $\mathbf{z}$ if there is no systemic freeze in $\mathbf{z}'$.

- Negative shocks to the distribution of asset returns cause freezes.
- Two competing effects: systemic risk and risk appetite.
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- Similar result for a special case of second-order stochastic dominance (see paper).

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Portfolio Correlation

- For simplicity, assume asset returns are normally distributed with mean $\boldsymbol{\mu} > \mathbf{0}$, variance σ^2, and correlation ρ.

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For a fixed chain network $\mathbf{G}$*, there exists* $\rho^* < 1$ *such that if* $\rho > \rho^*$ *there is no credit freeze.*

- As $\rho \to 1$, lending becomes "riskless" because all banks default in the same state of the world.

- As returns become more independent (or anti-correlated), bank i gets a positive return when some other bank might default, which makes lending riskier.

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Simple Freezes

- Beyond intermediation chains...
- We say a freeze is simple if for all banks $\mathcal{R} \subset \mathcal{B}$ experiencing a risk shift:

  (i) if a bank $j \notin \mathcal{R}$ experiences a credit freeze after the shift(s), then some bank $i \in \mathcal{R}$ does too;

  (ii) the set of banks that experience a credit freeze form at most $|\mathcal{R}|$ connected subcomponents of $\mathbf{G}$, each of which contains a bank in $\mathcal{R}$.

Proposition

In a single-entrepreneur economy, or if $\mathbf{G}$ *is a directed tree and the default cost* F *is not too large, then any FOSD shift induces only simple freezes.*

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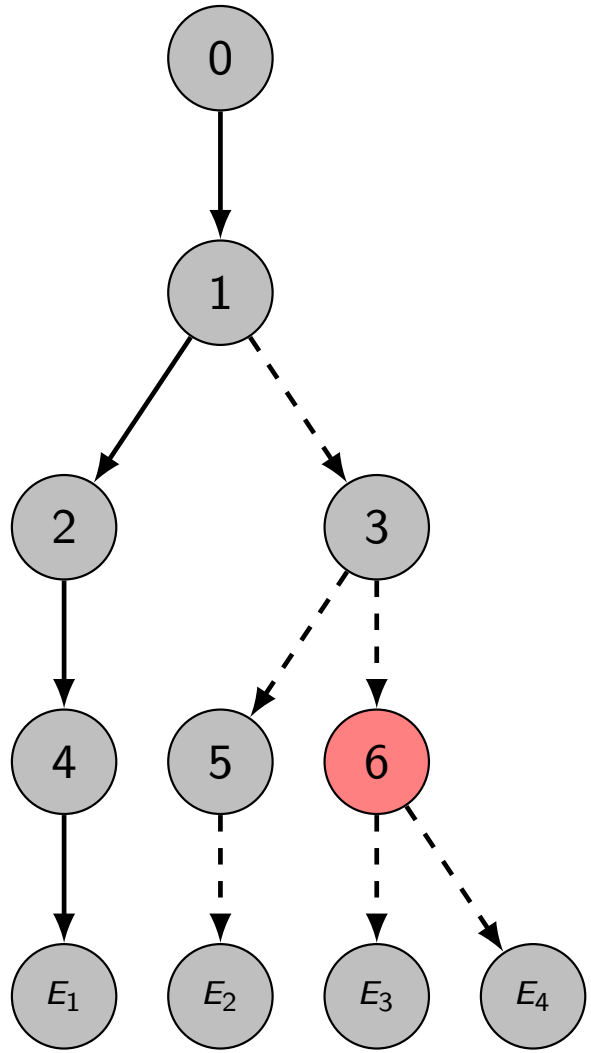

Non-Monotonicity: Before Risk Shift

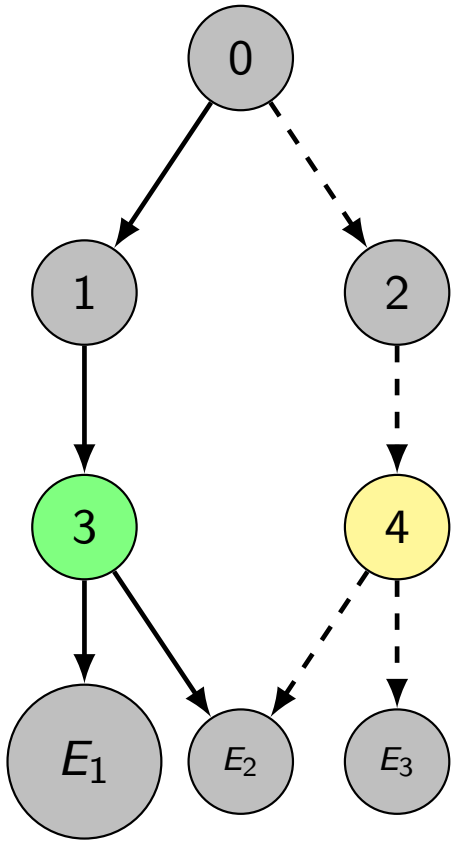

Figure: Before Shift.

- Bank 3 has unique access to a big project, bank 4 has unique access to a small project, and banks 3 and 4 compete over another project.
- Bank 3 has lower risk of default than bank 4.
- Intermediation chain $2 \to 4$ cannot compete with $1 \to 3$ because of added risk.
- Bank 2 may find the \$1 loan to bank 4 unprofitable given default risk of bank 4.
  - Entrepreneur 3 has a credit freeze.

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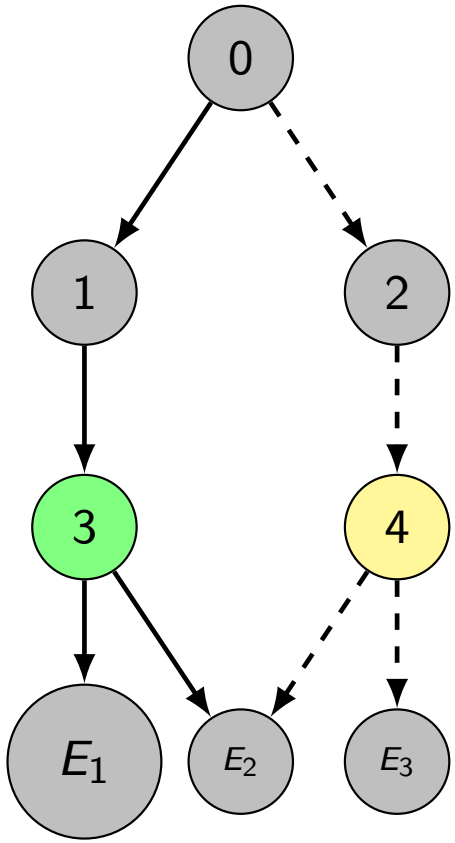

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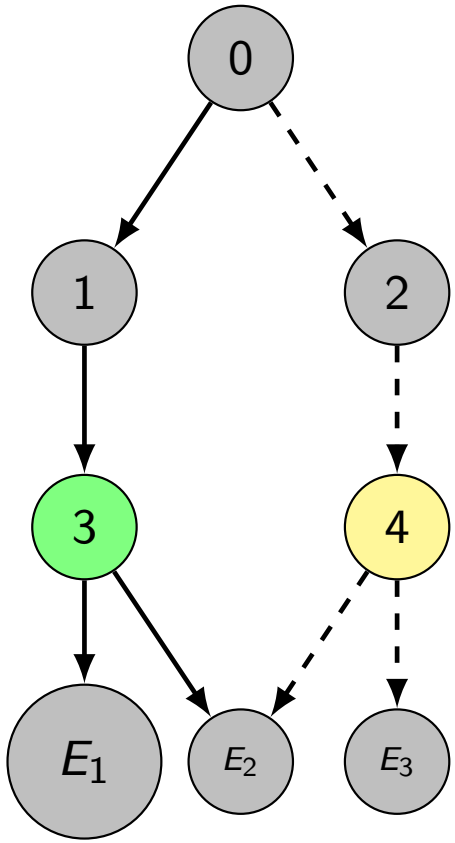

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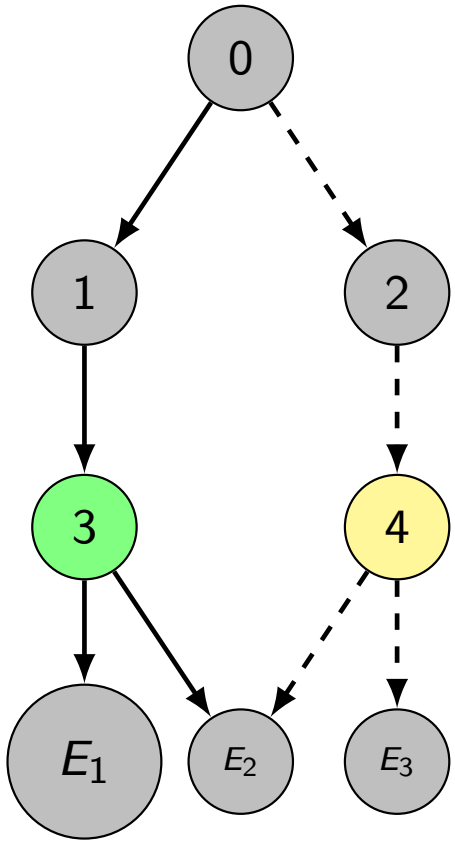

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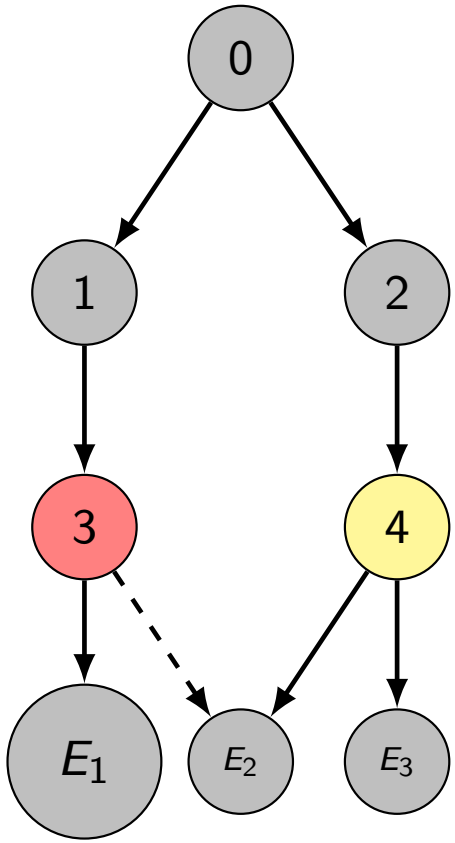

Figure: After Shift.

- Bank 3 is now riskier than bank 4. Intermediation chain $1 \to 3$ cannot compete with $2 \to 4$ because must bank 1 must demand a higher interest rate.
- Chain $2 \to 4$ now has two projects, and bank 2 makes positive expected profits on a loan of \$2.
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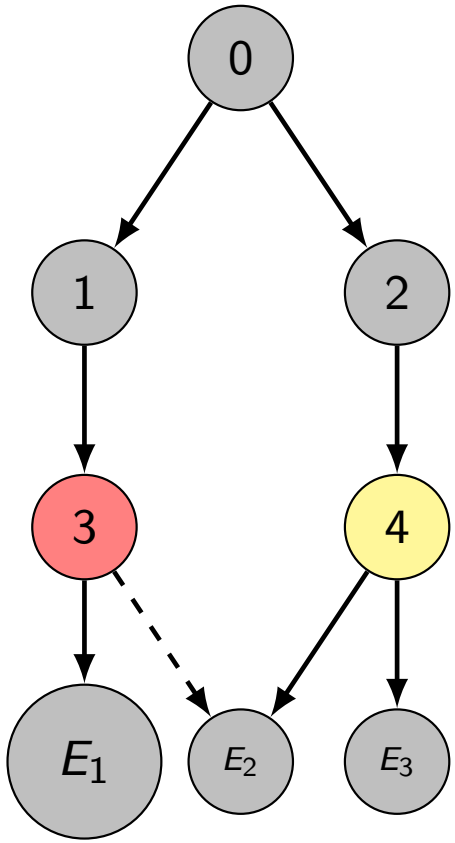

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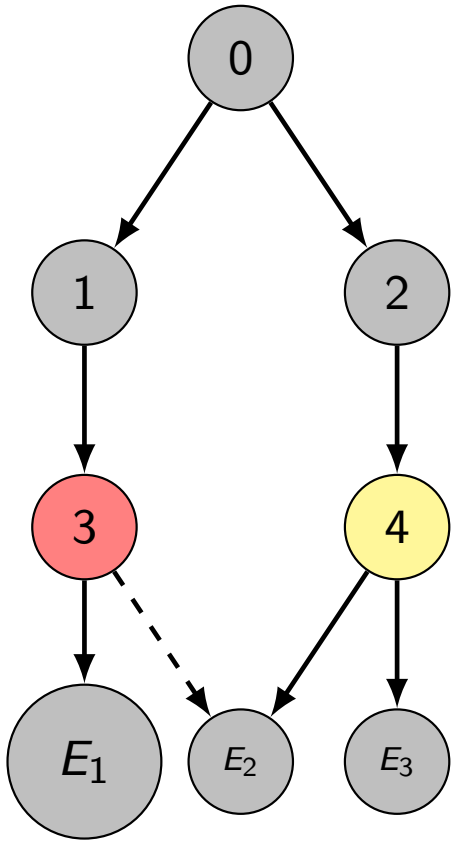

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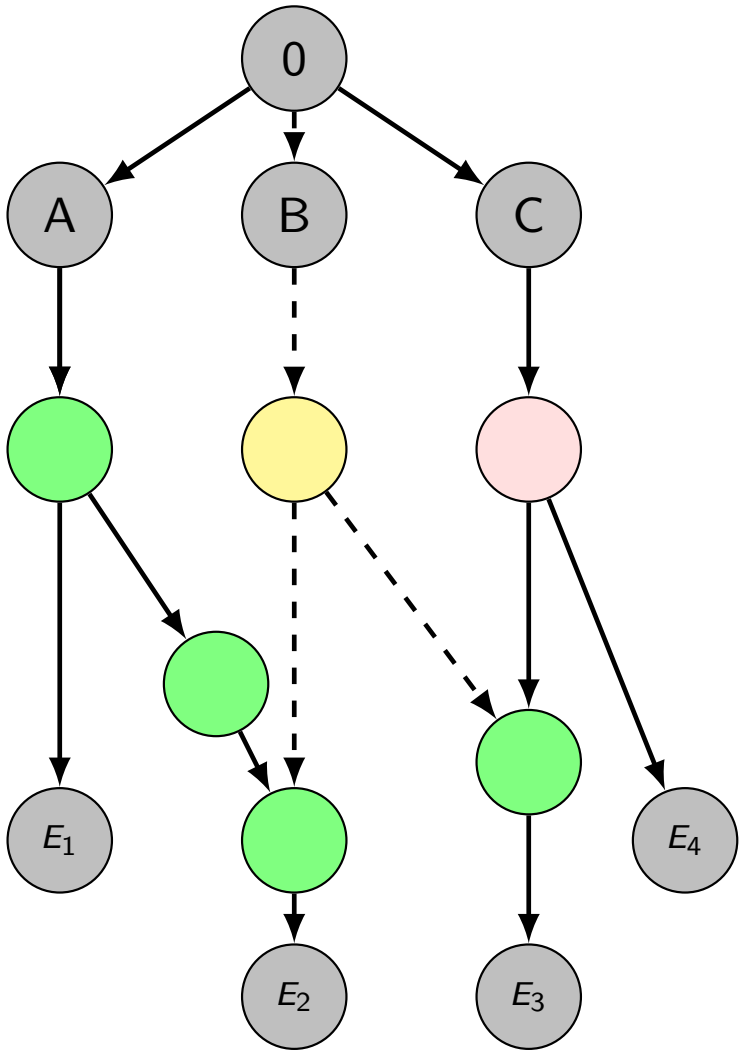

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- Each bank has independent returns: **G(ood)** or **B(ad)**
- **B**: toxic asset wipes the bank out
- Green banks are always safe (realize state **G** with probability 1)
- Small chance yellow and pink banks get **B** return. Assume pink bank is slightly riskier.
- Branch A to E_2 is riskless so is more competitive than branch B.
- Branch C has two clients as opposed to one, so branch C can compete with branch B over E_3.

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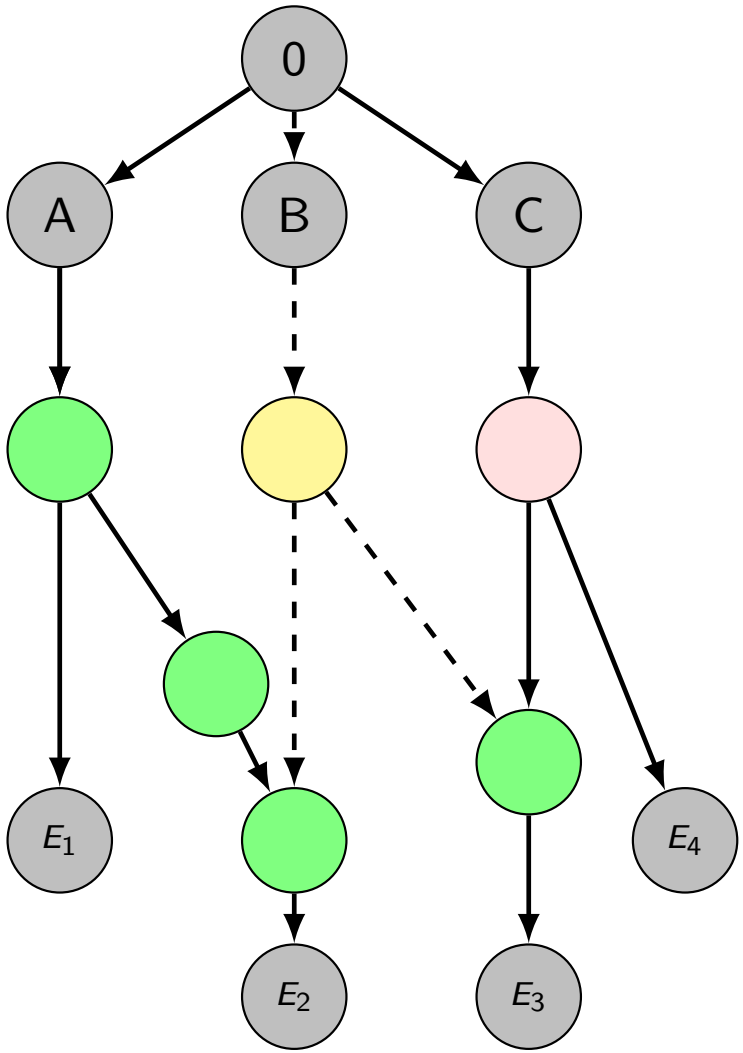

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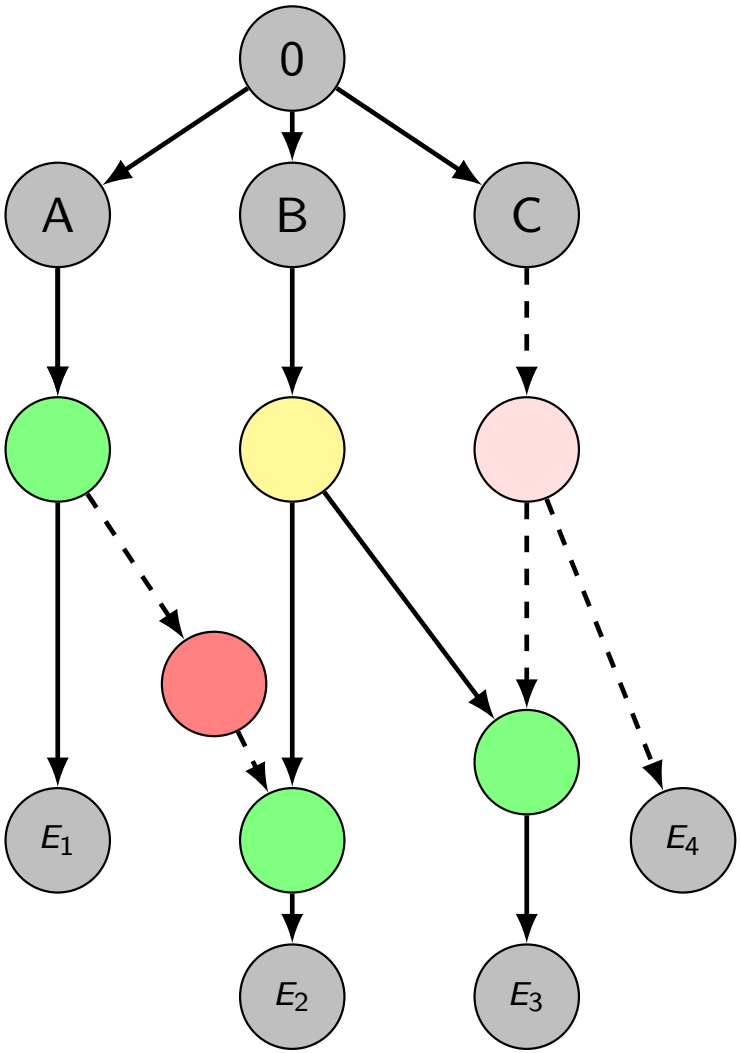

Figure: After Shift.

- Shift risk of bank in branch A (red): realizes state **B** with probability 1 (for simplicity).
- Clearly branch A will not lend to E_2, so branch B has monopolistic access over E_2.
- Bank 3 is less risky than bank 5, and both branch B and C have access to two clients.
- Branch B is now competitive for client 3, so branch C can only have access to E_4.
- Profits from client E_4 not sufficient to compensate for pink bank's risk.
  - Entrepreneur 4 loses access to credit, despite a shock to a separate part of the network.

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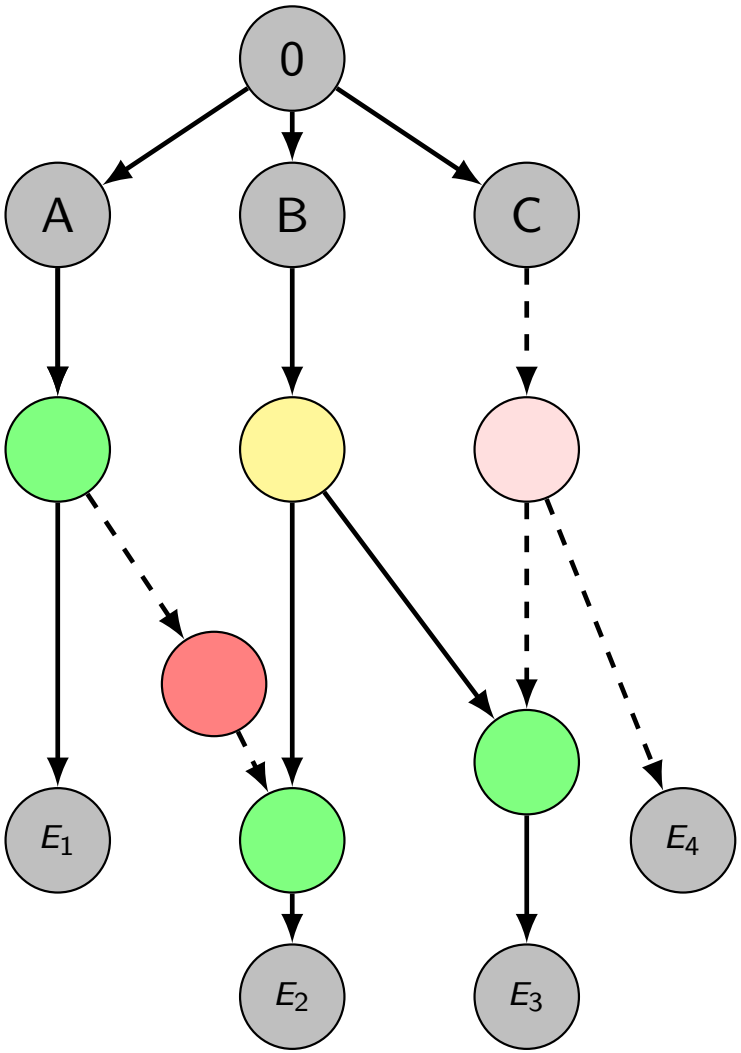

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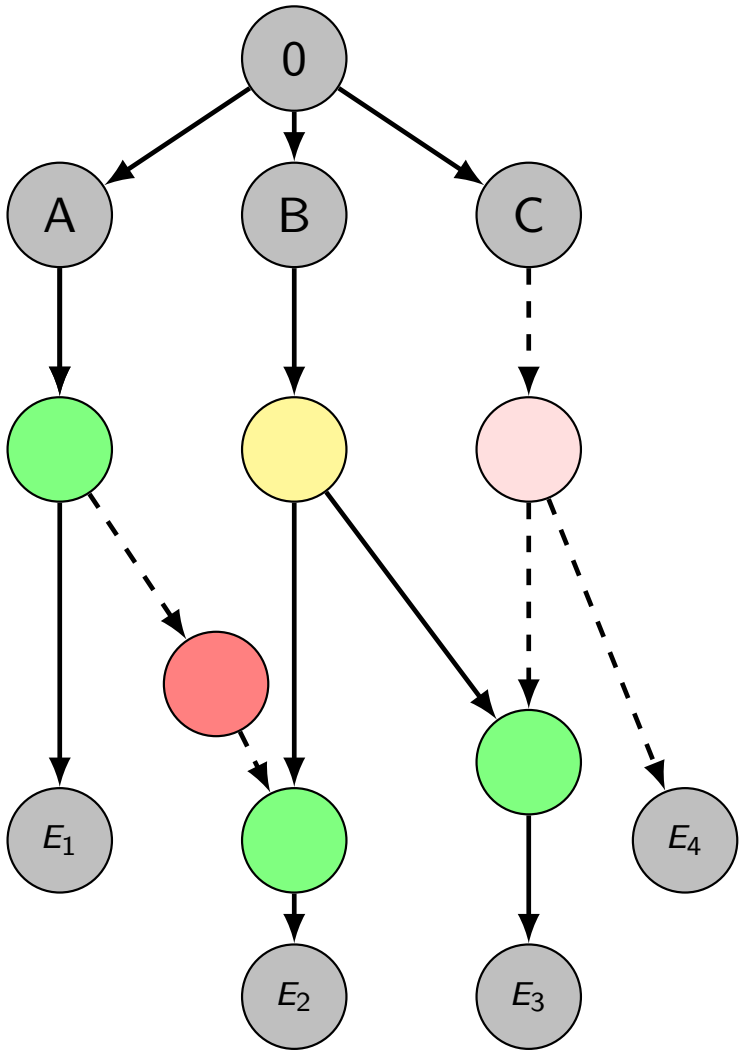

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Central Bank Policy

- Central bank has a budget B and can intervene with a vector of rescue policies $\epsilon = \{\epsilon_0, \ldots, \epsilon_n\}$.
  - These may be interpreted as asset purchases (boost risk profile of some banks) or lending at the discount window (to be facilitate lending or isolate against default).
  - We assume such an intervention is equivalent to a positive risk shift $z_i' = z_i + \epsilon_i$ for bank i.

- Space of feasible policies ϵ for budget B: $\sum_{i=1}^{n} \epsilon_i \leq B$.
  - Untargeted policy: Use the entire budget on the depositor, $\epsilon_0 = B$, instead of providing funds to any bank directly in the network.
  - Targeted policy: No restriction on ϵ except the budget constraint.

- Optimal policy: maximize total lending to entrepreneurs.

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Main Policy Findings

- For freezes in a single-entrepreneur economy, an untargeted policy is optimal. Such a policy may even be strictly preferred to a targeted policy that has $\epsilon_i > 0$ for some bank i.
  - Funds provided at the beginning of a chain can be redistributed downstream using the interest rate as an instrument. Because of potential defaults, the same is not true for redistributing upstream.

- Suppose that a financial network $\mathbf{G}_*$ faces a FOSD shift such that a single bank receives a risk shift and the freeze is simple. Then there exists a budget B^* and a bank i with its credit frozen such that:
  - The targeted policy which targets bank i in its entirety (i.e., $\epsilon_i = B^*$) restores all lending without introducing additional credit freezes.
  - An untargeted policy which restores lending requires some budget $B^{**} > B^*$ (unless in a degenerate freeze).

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Other Policy Features

- Even with an unlimited budget, there may be no untargeted or targeted policy that targets a bank in distress (i.e., a bank which lost credit from a risk shift) that completely alleviates all freezes (if freeze is complex).
  - Increasing the profitability of all lending paths might not relieve competition effects that cause credit freezes.
- If policymakers are misinformed of the financial network, targeting policies can exacerbate the problem.
  - A rescue policy that only targets banks in distress can lead to more credit freezes because of network effects.
- In some cases, costless policies that absorb liquidity (i.e., $\epsilon_i < 0$) will eliminate credit freezes (because of non-monotonicity).

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Conclusion

- Extend current work on financial networks: link between ex-post defaults and ex-ante lending considerations.

- Lack of funding because of banks' uncertainty about future solvency:
  - Bear Stearns was in trouble (March 2008) months before the collapse of Lehman Brothers (September 2008).
  - Increasing interconnectedness of financial system caused tightening of credit, as early as August 2007 (Allen and Babus (2008)). Affected large financial institutions and small business alike.

- Extent of credit freeze is highly sensitive to the structure of lending. Ex-ante credit freeze "contagion" can affect remote parts of the network.

- Rescue policy can be effective if the cause of the freezes is well-understood. Policy becomes increasingly more complex as financial system becomes more complex.

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