Designing Resilient Financial Systems

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What I do

- Study the problem of a policymaker who wants to improve the resilience of a financial system.

- Develop a simple model in which:

    - Large cascading failures may occur in times of economic stress.

    - Policymaker is unsure about how distress propagates among related companies during times of economic stress.

What do we learn?

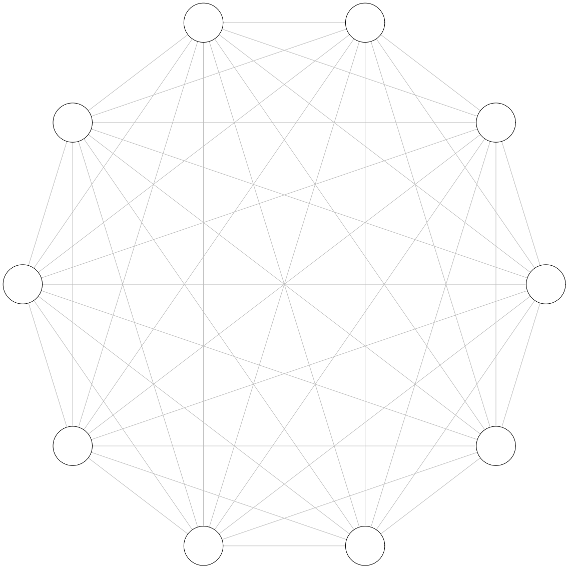
- If policymaker has no information about the set of companies that play an important role in propagating distress during times of economic stress
  - policymaker may be unable to improve the resilience of the system
- If the policymaker knows such a set
  - she can always improve the resilience of the system by restricting a small fraction of companies
  - fraction depends on the ease of implementing restrictions

Model

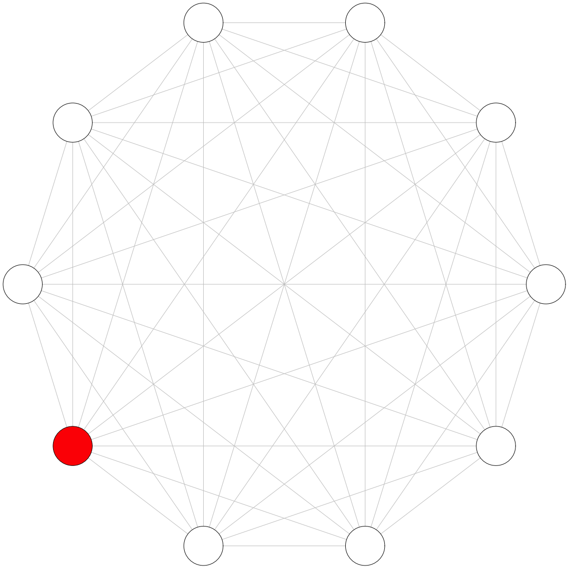
- Financial system with n companies.
- Two periods, $t = \{0, 1\}$.
- At $t = 0$, policymaker designs and implements a policy to minimize the likelihood of large cascading failures at $t = 1$.
- Policymaker's problem at $t = 0$

$$\begin{aligned} \min_{p} \quad & \beta \times \mathbb{P}\left[\text{Large cascading failures occur}|p\right] + (1-\beta) \times C(p) \\ \text{s.t.} \quad & 0 \le p \le 1 \end{aligned}$$

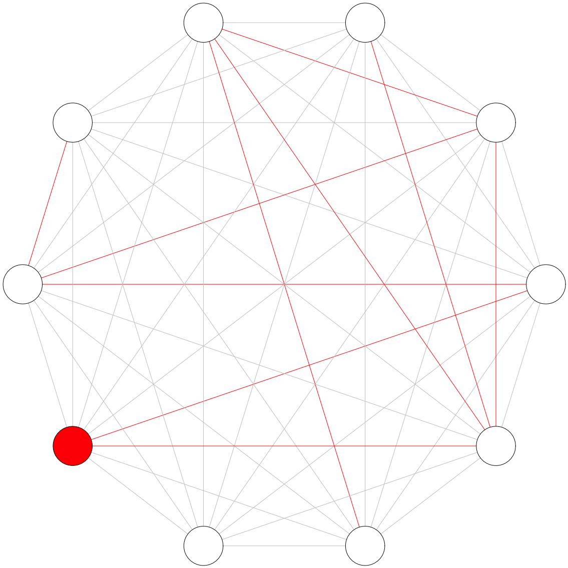
Cascading failures



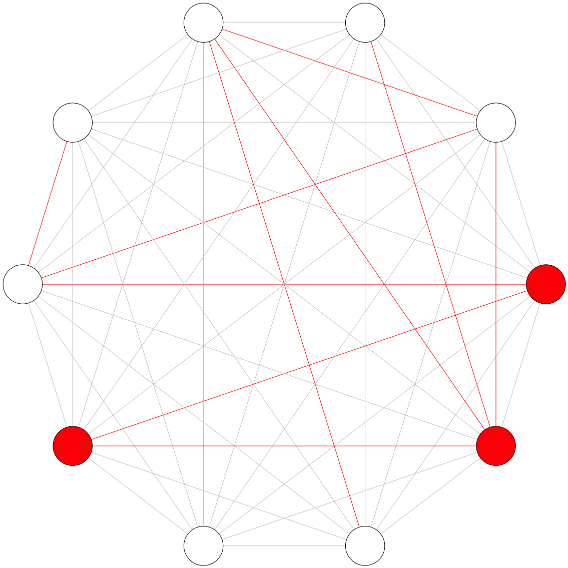
Cascading failures



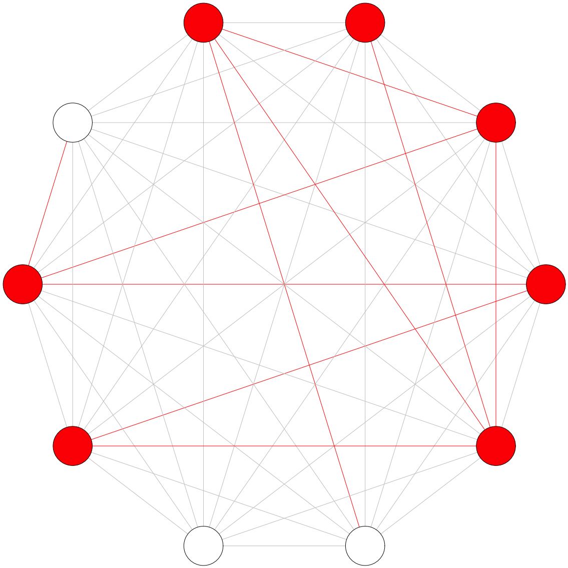
Cascading failures



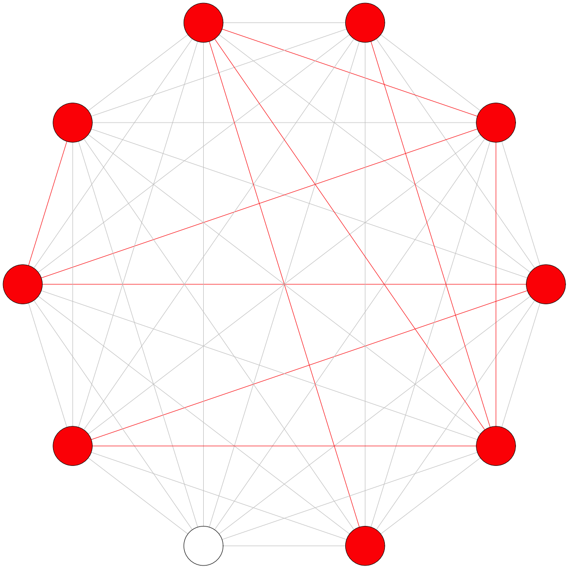
Cascading failures



Cascading failures

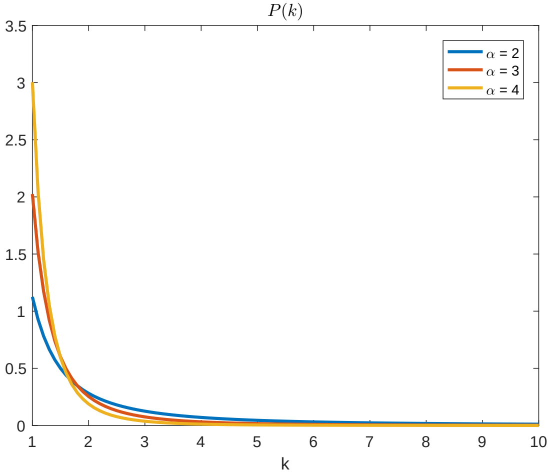


Cascading failures



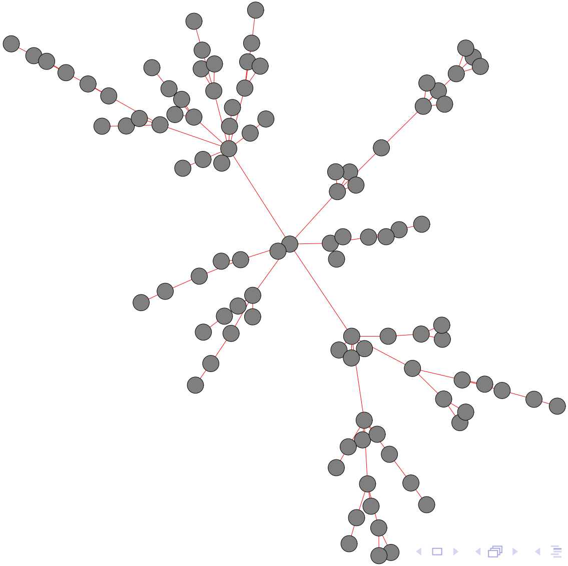
Cascading failures

$$\mathbb{P}_n(k) \quad \propto \quad k^{-\alpha}, \text{with } k = 1, \cdots, n-1.$$



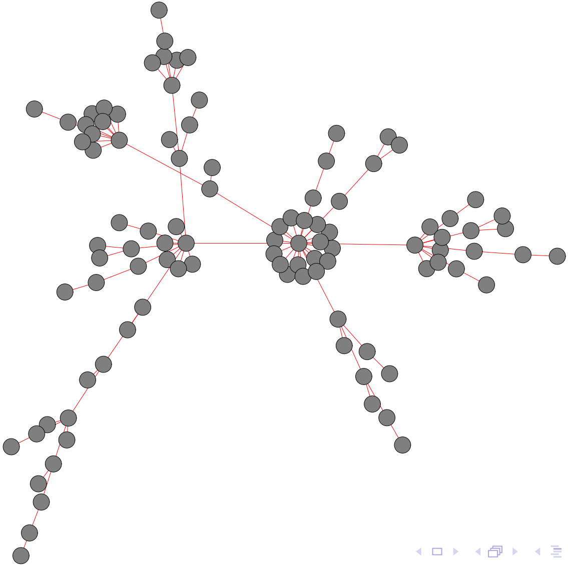
Contagion and α

$n = 100$, $\alpha = 0.5$



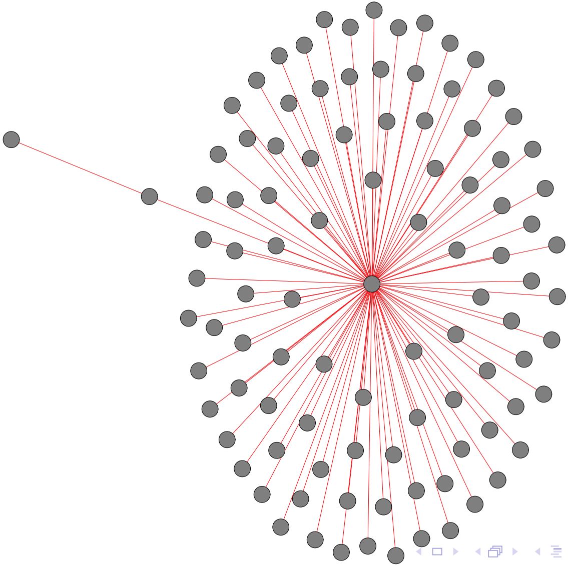
Contagion and α

$n = 100$, $\alpha = 1.5$



Contagion and α

$n = 100$, $\alpha = 3$



The rise of large cascading failures

Large cascading failures occur if

$$\lim_{n\to\infty} \mathbb{E}_n\left[k_i | i \leftrightarrow j\right] = \lim_{n\to\infty} \sum_{k_i} k_i \mathbb{P}_n\left[k_i | i \leftrightarrow j\right] = 2 \qquad (1)$$

Because

$$\mathbb{P}_n\left[k_i | i \leftrightarrow j\right] = \frac{\mathbb{P}_n\left[i \leftrightarrow j | k_i\right] \mathbb{P}_n\left[k_i\right]}{\mathbb{P}_n\left[i \leftrightarrow j\right]}$$

$$\mathbb{P}_n\left[i \leftrightarrow j\right] = \frac{\mathbb{E}_n[k]}{n-1} \quad \text{and} \quad \mathbb{P}_n\left[i \leftrightarrow j | k_i\right] = \frac{k_i}{n-1}$$

Thus, (1) is equivalent to

$$\lim_{n\to\infty} \frac{\mathbb{E}_n[k^2]}{\mathbb{E}_n[k]} = 2$$

Policymaker has no information

After imposing restrictions, the new distribution of susceptible links is

$$\mathbb{P}'_n(k) = \sum_{k \geq k_0} \mathbb{P}_n(k_0) \binom{k_0}{k} (1-p)^k p^{k_0-k}$$

Then, large cascading failures occur if:

$$\lim_{n\to\infty} \frac{\mathbb{E}'_n[k^2]}{\mathbb{E}'_n[k]} = 2 \quad \rightarrow \quad 1-p = \frac{1}{\left|\frac{2-\alpha}{3-\alpha}\right| - 1}$$

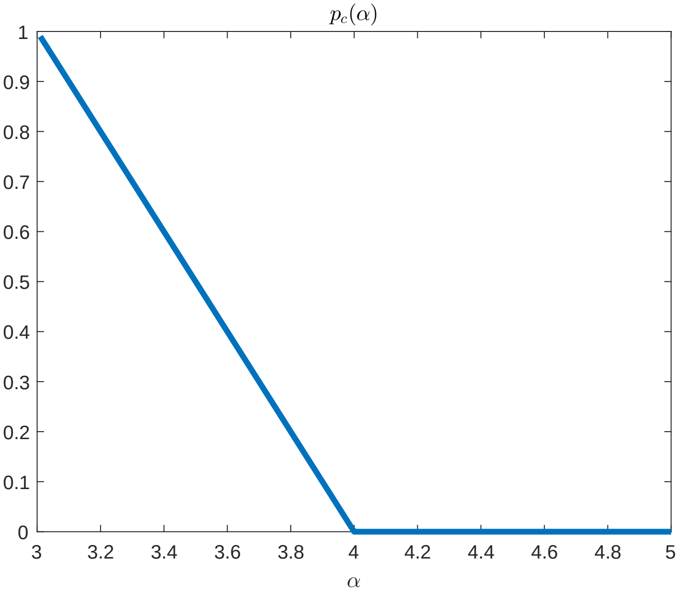
Optimal policy

If the policymaker has no information about the set of most connected companies at $t = 1$, then

$$p = \begin{cases} p_c & \text{if} \quad 3 < \alpha \leq 4 \text{ and } (1-\beta)\, C(p_c) < \beta \\ 0 & \text{otherwise} \end{cases}$$

with

$$p_c = 1 - \frac{1}{\left|\frac{2-\alpha}{3-\alpha}\right| - 1}$$



$p_c(\alpha)$
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
3
3.2
3.4
3.6
3.8
4
4.2
4.4
4.6
4.8
5
α

Policymaker has some information

After the policy is implemented, two things happen:

- Maximum number of susceptible links per company decreases from $n-1$ to K, with $K < n-1$.

$$\lim_{n\to\infty} \sum_{k=K}^{n-1} \mathbb{P}_n(k) = p_K \quad \to \quad K \approx p_K^{1/(1-\alpha)}$$

- Distribution of susceptible links per company changes as a large number of susceptible links are removed.

$$\widetilde{p} = \lim_{n\to\infty} \left(\frac{1}{\mathbb{E}_n[k]}\right) \left(\sum_{k=K}^{n-1} k\mathbb{P}_n(k)\right) \quad \approx \quad K^{2-\alpha}$$

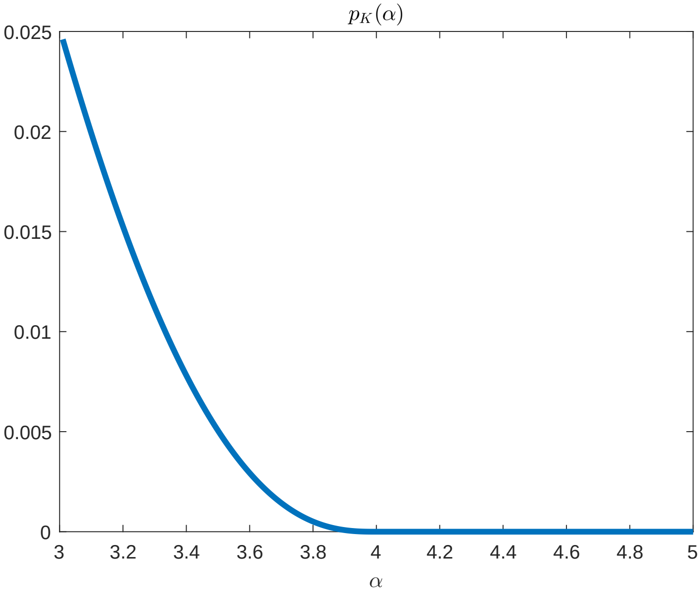
Optimal policy

If policymaker knows the set of most connected companies at $t = 1$, then

$$p = \begin{cases} p_K & \text{if } \beta > (1-\beta)\, C(p_K) \\ 0 & \text{otherwise} \end{cases}$$

with

$$p_K^{\frac{2-\alpha}{1-\alpha}} - \left(\frac{2-\alpha}{3-\alpha}\right) p_K^{\frac{3-\alpha}{1-\alpha}} + \left(\frac{2-\alpha}{3-\alpha}\right) - 2 = 0.$$



$p_K(\alpha)$
0.025
0.02
0.015
0.01
0.005
0
3
3.2
3.4
3.6
3.8
4
4.2
4.4
4.6
4.8
5
α

Concluding Remarks

- Tractable model (potential benchmark to which other models can be compared).
- Results highlight that the ability of a policymaker to prevent large cascading failures heavily depends both on:
  - information about how the system behaves in times of economic stress.
  - ease of implementing restrictions.
- Next step: Explore how parameter and model uncertainty modify results.