Regulating Financial Networks Under Uncertainty

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Research Question

- How can policymakers regulate a financial system when they are fundamentally uncertain about its precise structure?

What I do

- Develop a framework to understand the behavior of such policymakers. Within my framework:
  - institutions are linked via an opaque network of exposures.
  - cascades of distress may occur as a result of contagion.
  - policymaker—who imposes preemptive restrictions on certain institutions to maximize expected output—is uncertain about the precise structure of the network.

What do we learn?

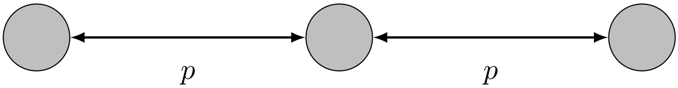
- Uncertainty about the precise structure of the network reduces the scope for welfare improving regulations.

- While improving network transparency potentially reduces this uncertainty, it does not necessarily lead to welfare improving interventions.

- Preventing large cascades of distress may be suboptimal.

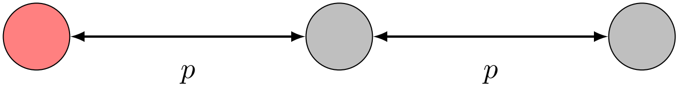
- Optimal policy is jointly determined by
    - (expected) susceptibility of the network to contagion
    - cost of improving network transparency
    - cost of regulating institutions
    - investors' preferences.

Motivating Example



Motivating Example

Shocks propagate through exposures



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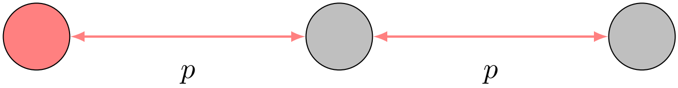

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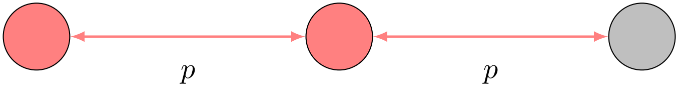

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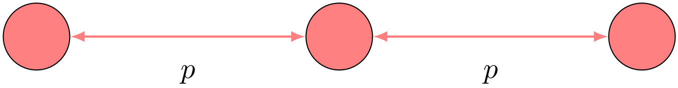
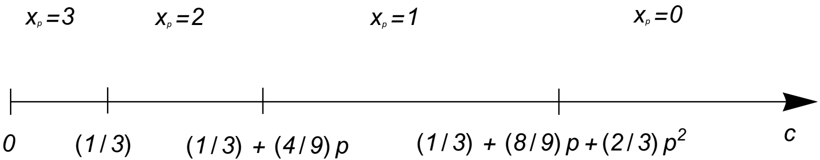


Case 1: p is known

Optimal policy: $x_p(c)$



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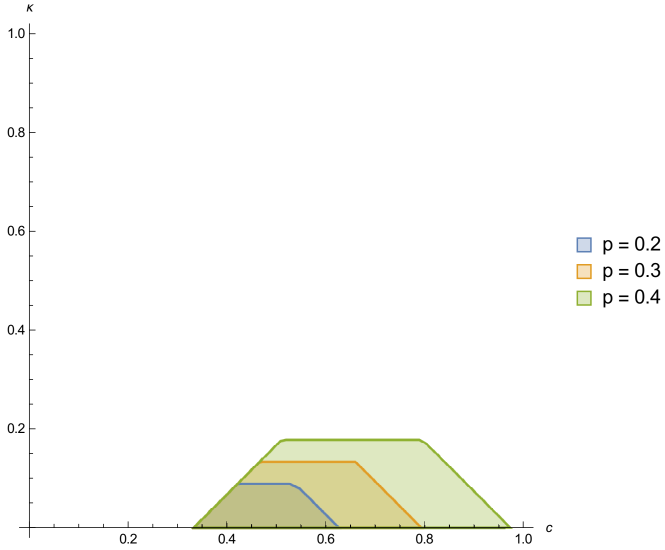
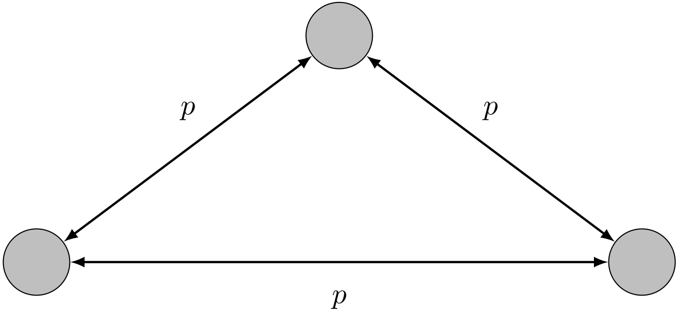
Improving network transparency



Case 1: p is known

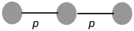
What happens if the network architecture changes?

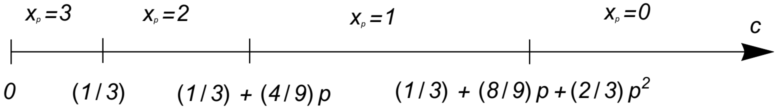


Case 1: p is known

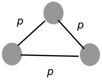
Optimal Policy: $x_p(c)$

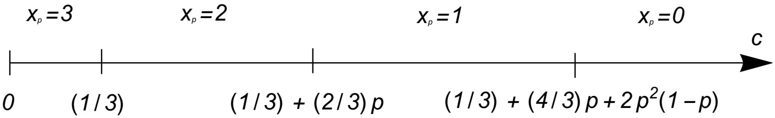
Network





Network





Case 2: p is unknown

- $p \in \left\{\frac{1}{5}, \frac{4}{5}\right\}$.

- $\mathbb{P}\left(p = \frac{1}{5}\right) = \phi$.

- Smooth ambiguity certainty equivalent

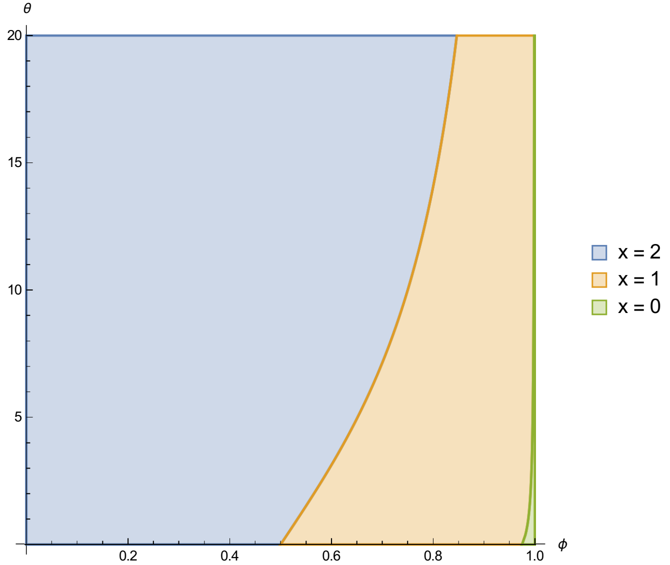
$$\text{SCE}(x_A) \equiv \mathbb{E}_{\bar{p}}\left[\text{TO}|x_A\right] - \left(\frac{\theta}{2}\right)\mathbb{V}\left[\mathbb{E}_p\left(\text{TO}|x_A\right)\right]$$

- $\bar{p} = \phi\frac{1}{5} + (1-\phi)\frac{4}{5}$.

- θ : attitude toward model uncertainty.

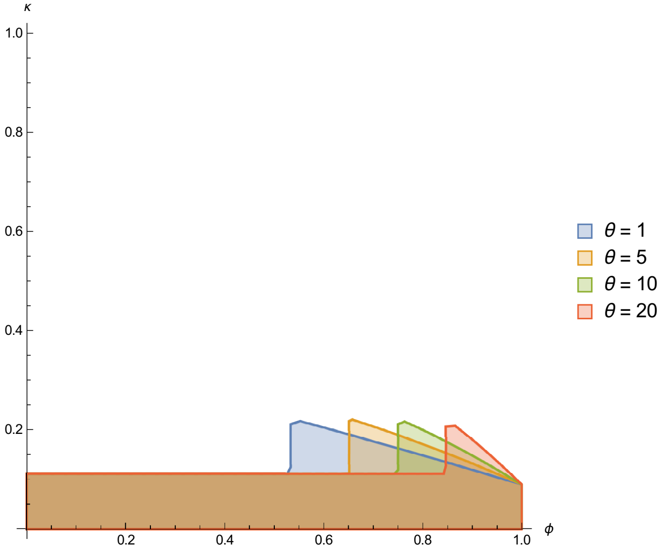
Case 2: p is unknown

Optimal policy: $x_A(\phi, \theta)$



Case 2: p is unknown

Improving network transparency



Challenges

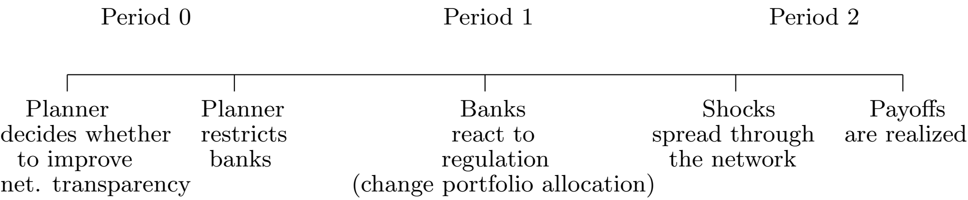
- What happens if the size of the economy increases?
- How can we deal with arbitrary network architectures?

Potential Solution

- Random networks

General Framework

- n banks, each endowed with one dollar
- network has an arbitrary architecture
- distribution of contagious exposures across banks is characterized by $\{p_k\}_{k=0}^{n-1}$, where p_k denotes the probability that a randomly chosen bank has k contagious exposures
- Timeline



Banks' problem

- Bank i chooses the fraction of liquid assets in its portfolio, ω_i, to maximize profits.

$$\max_{\omega_i \in \{\omega_L, \omega_H\}} \quad \mathbb{E}[\pi_i] = \mathbb{E}[\omega_i \times R_L + (1-\omega_i) \times R_I - \beta_{\omega_i} \times \varepsilon_i]$$
$$\text{s.t.} \quad \omega_H \times e_i \leq \omega_i \text{ (regulatory constraint)}$$

with $\omega_L < \omega_H$ and $\mathbb{E}[R_L] < \mathbb{E}[R_I]$.

- If i faces a liquidity shock, then $\varepsilon_i = 1$ (otherwise, $\varepsilon_i = 0$)
- Portfolio liquidity **matters**:

$$\beta_{\omega_i} = \begin{cases} 0, \text{ if } \omega_i = \omega_H \\ \omega_L \times R_L + (1-\omega_L) \times R_I, \text{ otherwise.} \end{cases}$$

- If i is regulated, then $e_i = 1$ (otherwise, $e_i = 0$)
- Banks **underestimate** the likelihood of being affected by cascades of liquidity shocks at $t = 2 \rightarrow \omega_i = \omega_L$ if $e_i = 0$.

Welfare effects of regulation

Suppose $\{p_k\}_k$ is known and the planner restricts a fraction x of banks.

$$\mathbb{E}\left[\frac{1}{n}\text{TO}\middle|x\right] = \nu - \underbrace{\nu(1-x)\frac{\langle\phi^x\rangle}{n}}_{\text{costs of contagion}} - \underbrace{x\Delta\omega\mathbb{E}[\Delta R]}_{\text{regulation losses}},$$

where $\nu \equiv \mathbb{E}[R_I] - \omega_L\mathbb{E}[\Delta R]$ and $\langle\phi^x\rangle \equiv \left(\sum_{m=1}^{n(1-x)} m\phi_m^x\right)$.

Increasing x

$\uparrow x\Delta\omega\mathbb{E}[\Delta R]$,
$\downarrow (1-x)$, but
$\uparrow\downarrow \langle\phi^x\rangle$

Increasing transparency

alters $\langle\phi^x\rangle$

Optimal x^*

$$\underbrace{\nu\left(\frac{\langle\phi^{x^*}\rangle}{n} - (1-x^*)\frac{\partial}{\partial x}\left(\frac{\langle\phi^{x}\rangle}{n}\right)\Bigg|_{x=x^*}\right)}_{\text{marginal benefit}} = \underbrace{\Delta\omega\mathbb{E}[\Delta R].}_{\text{marginal cost}}$$

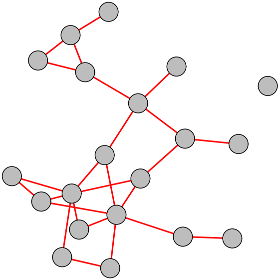
Value of network transparency

$$\text{SVI} = (x_r - x_t)\Delta\omega\mathbb{E}[\Delta R] + \nu\left((1-x_r)\frac{\langle\phi^{x_r}\rangle}{n} - (1-x_t)\frac{\langle\phi^{x_t}\rangle}{n}\right)$$

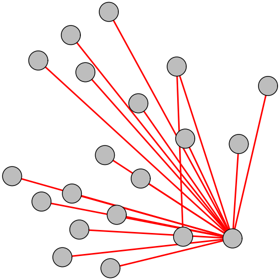
The network architecture matters

- Different families of distributions $\{p_k\}_k$ imply differences in connectivity structures.

Poisson

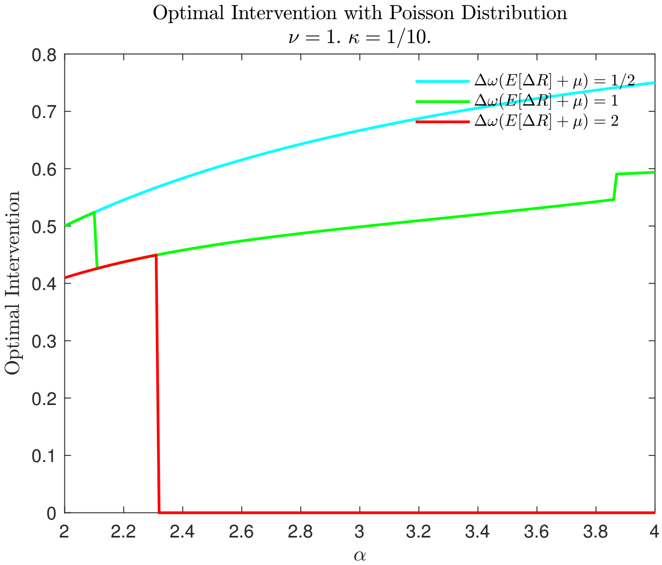


Power-law



Case 1: $\{p_k\}_k$ is known

Optimal fraction of restricted banks



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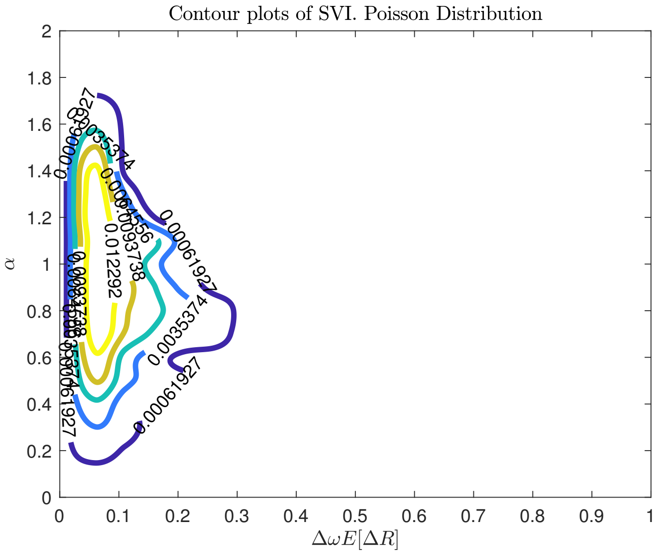

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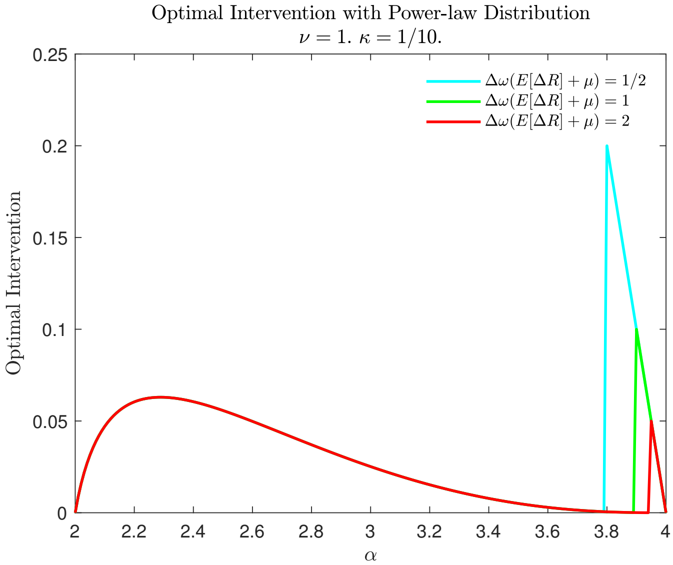

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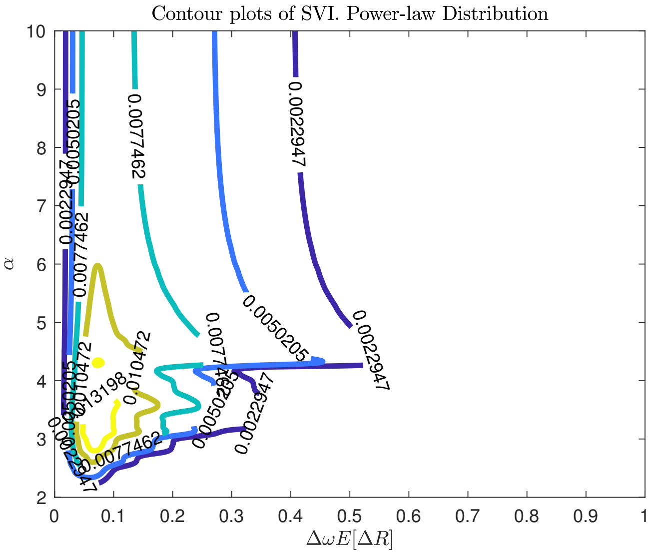
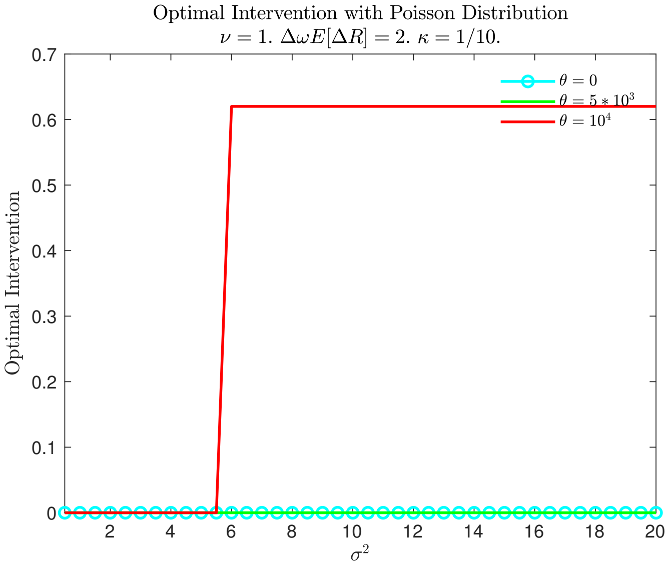


Case 2: $\{p_k\}_k$ is unknown

Optimal fraction of restricted banks



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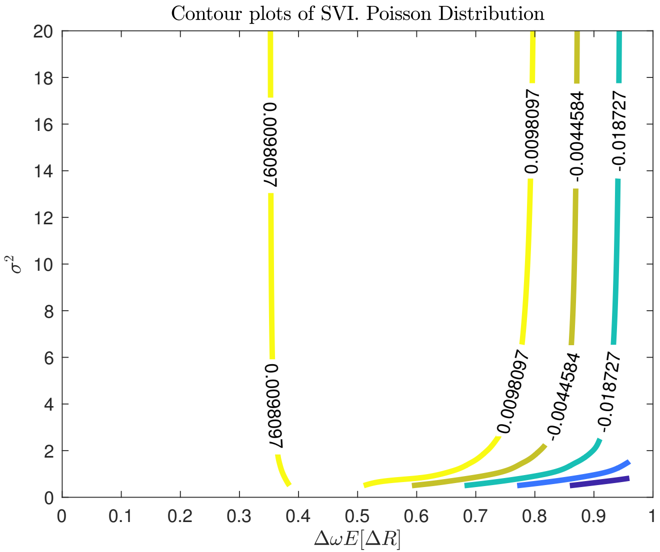

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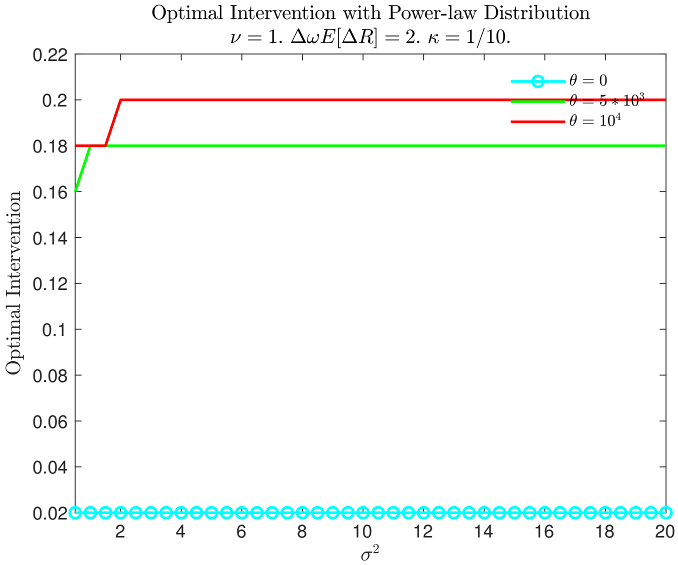

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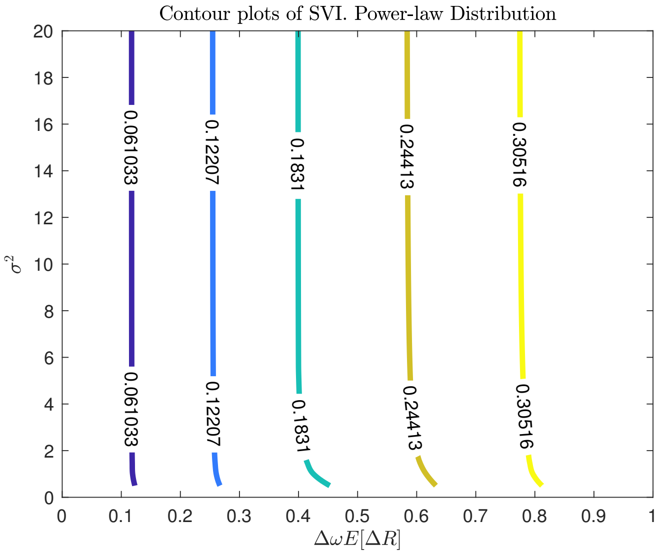


Concluding Remarks

- Uncertainty about the precise structure of the network reduces the scope for welfare improving regulations.
- While improving network transparency potentially reduces this uncertainty, it does not necessarily lead to welfare improving interventions.
  - The (social) value of improving network transparency is linked to aggregate characteristics of the network structure.
- Preventing large cascades of distress may be suboptimal.

Caveats

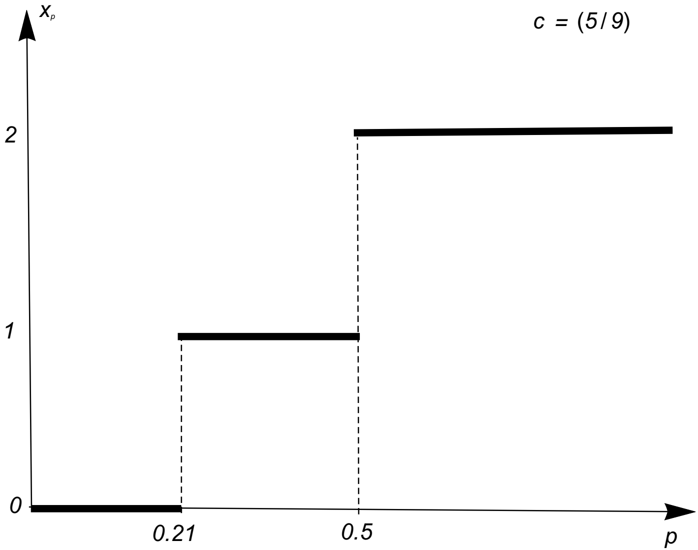
- Model does not capture
  - economic incentives underlying the formation of exposures,
  - reasons some institutions may be more prone to propagating distress
- Emphasis on the relevance of network uncertainty should not be understood as downplaying the important role that
  - leverage
  - size
  - short-term funding

  play in the design of optimal policies
- As the network structure interacts with the above variables, policy interventions should be mindful of such interactions

APPENDIX

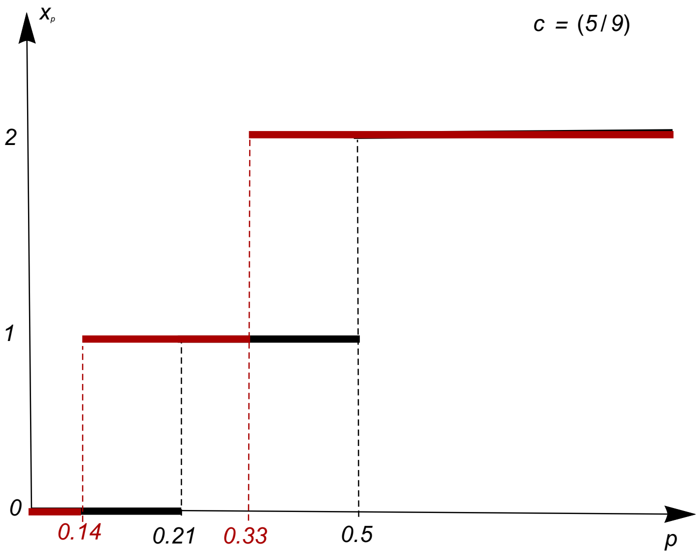
Case 1: p is known

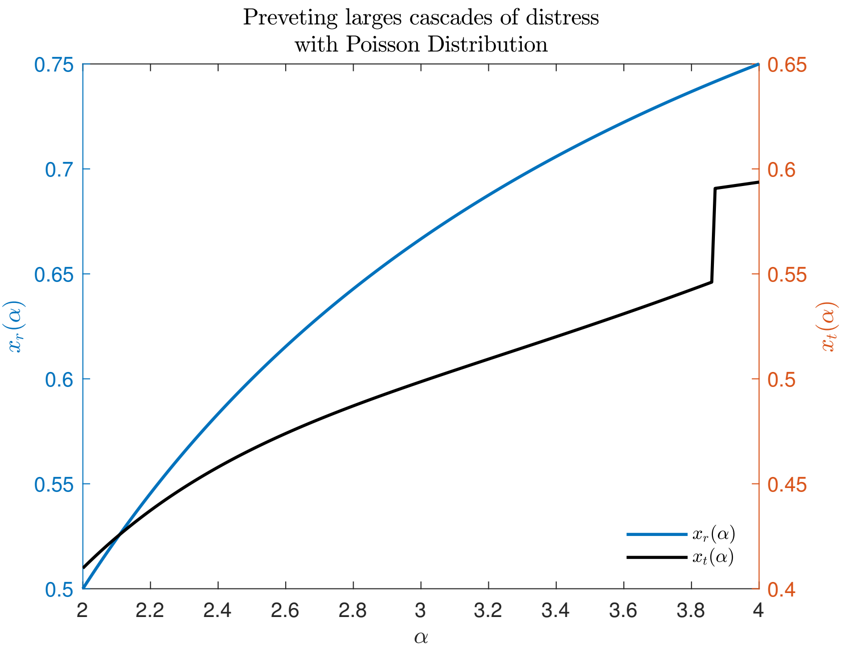
Optimal policy: $x_c(p)$



Motivating Example

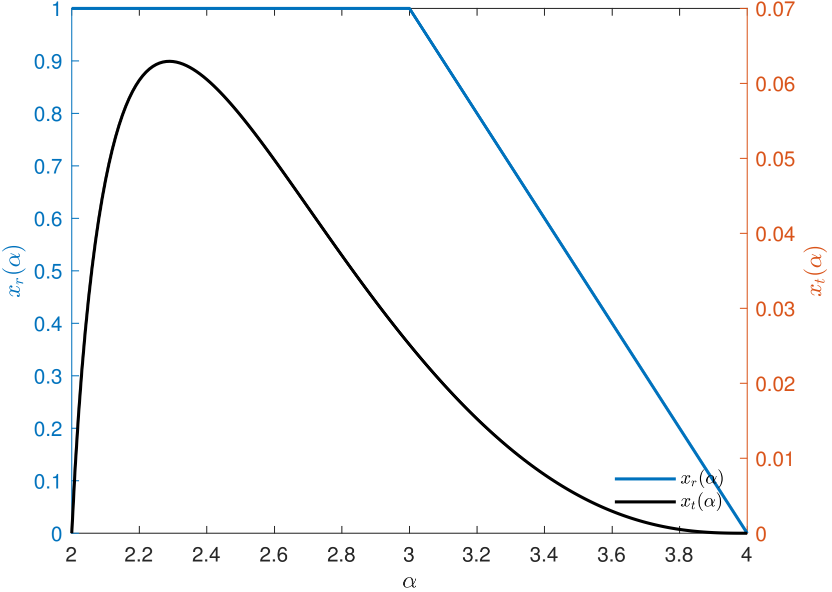
Optimal Policy: $x_c(p)$

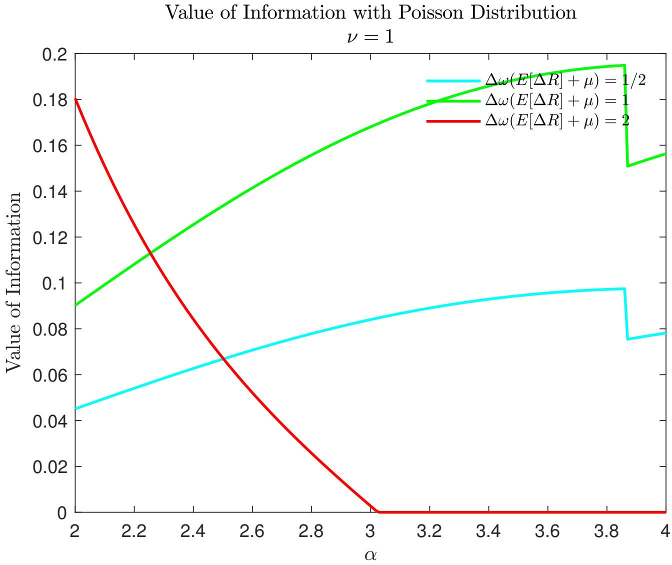




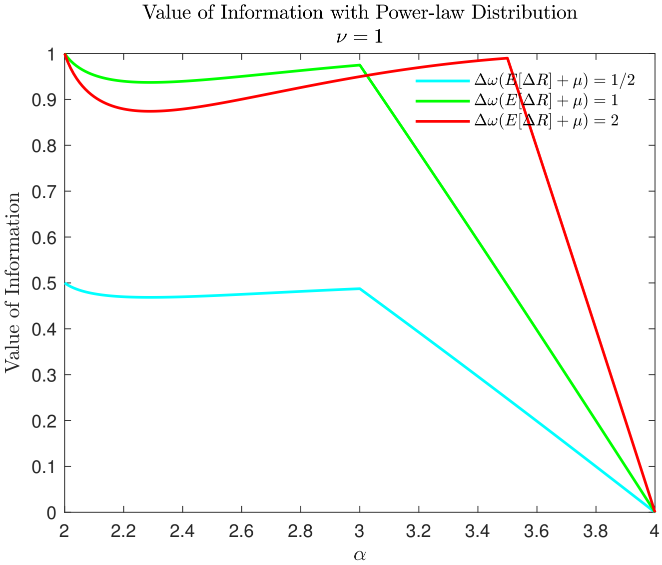
Preveting larges cascades of distress
with Poisson Distribution
0.75
0.7
0.65
0.6
0.55
0.5
$x_r(\alpha)$
0.65
0.6
0.55
0.5
0.45
0.4
$x_t(\alpha)$
2
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
3.8
4
α
$x_r(\alpha)$
$x_t(\alpha)$

Preveting larges cascades of distress
with Power-law Distribution





Value of Information with Poisson Distribution
$\nu = 1$
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Value of Information
2
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
3.8
4
α
$\Delta\omega(E[\Delta R] + \mu) = 1/2$
$\Delta\omega(E[\Delta R] + \mu) = 1$
$\Delta\omega(E[\Delta R] + \mu) = 2$


Value of Information with Power-law Distribution
$\nu = 1$
Value of Information
α
$\Delta\omega(E[\Delta R] + \mu) = 1/2$
$\Delta\omega(E[\Delta R] + \mu) = 1$
$\Delta\omega(E[\Delta R] + \mu) = 2$
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
3.8
4

Incorporating Ambiguity

- Given $\mathcal{I}$, planner chooses $\mathcal{R}_{\mathcal{I}}$ to solve

$$\max_{\mathcal{R}_{\mathcal{I}}} \quad \mathbb{E}_{\bar{\alpha}}\left(\text{TO}_{\alpha} \middle| \mathcal{R}_{\mathcal{I}}\right) - \left(\frac{\theta}{2}\right) \times \mathbb{V}_f\left(\mathbb{E}_{\alpha}\left(\text{TO}_{\alpha} \middle| \mathcal{R}_{\mathcal{I}}\right)\right) - \kappa \times 1_{\kappa}$$

where $\mathcal{A}$ is the set of plausible values for α and f denotes investors' subjective beliefs over $\mathcal{A}$, with $\bar{\alpha} \equiv \int_{\alpha \in \mathcal{A}} \alpha df$

- The planner chooses $\mathcal{I} \in \{\mathcal{I}_0, \mathcal{I}_1\}$ and $\mathcal{R}_{\mathcal{I}}$ to solve

$$\max_{\mathcal{I} \in \{\mathcal{I}_0, \mathcal{I}_1\}} \begin{Bmatrix} \max_{\mathcal{R}_{\mathcal{I}_0}} \left(\mathbb{E}_{\bar{\alpha}}\left(\text{TO}_{\alpha} \middle| \mathcal{R}_{\mathcal{I}_0}\right) - \frac{\theta}{2}\mathbb{V}_f\left(\mathbb{E}_{\alpha}\left(\text{TO}_{\alpha} \middle| \mathcal{R}_{\mathcal{I}_0}\right)\right)\right), \\ \max_{\mathcal{R}_{\mathcal{I}_1}} \left(\mathbb{E}_{\bar{\alpha}}\left(\text{TO}_{\alpha} \middle| \mathcal{R}_{\mathcal{I}_1}\right) - \frac{\theta}{2}\mathbb{V}_f\left(\mathbb{E}_{\alpha}\left(\text{TO}_{\alpha} \middle| \mathcal{R}_{\mathcal{I}_1}\right)\right) - \kappa\right) \end{Bmatrix}$$

- Social value of network transparency is now captured by

$$\left[\mathbb{E}_{\bar{\alpha}}\left(\text{TO}_{\alpha} \middle| x^*_{\mathcal{I}_1}\right) - \mathbb{E}_{\bar{\alpha}}\left(\text{TO}_{\alpha} \middle| x^*_{\mathcal{I}_0}\right)\right] - \left(\frac{\theta}{2}\right) \times \Delta\mathbb{V}_{\mu},$$

The Rise of Large Cascading Failures

- Large cascading failures arise if

$$\lim_{n\to\infty} \frac{\langle k^2 \rangle}{\langle k \rangle} \quad \leq \quad 2.$$

- Preventing large cascading failures
  - When the planner cannot differentiate among banks before implementing policies,

$$x^* \quad = \quad 1 - \frac{\langle k \rangle}{\langle k^2 \rangle - \langle k \rangle}.$$

  - When the planner can rank banks based on their future number of susceptible links,

$$\sum_{k=0}^{K(x^*)} k(k-1)p_k = \langle k \rangle \quad \text{and} \quad x^* = 1 - \sum_{k=0}^{K(x^*)} p_k.$$