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

$p \quad \quad p$
Motivating Example
Shocks propagate through exposures
Motivating Example

Shocks propagate through exposures
Motivating Example
Shocks propagate through exposures
Motivating Example
Shocks propagate through exposures
Case 1: $p$ is known

Optimal policy: $x_p(c)$

$x_p = 3$
$x_p = 2$
$x_p = 1$
$x_p = 0$

$c = 0$
$c = \frac{1}{3}$
$c = \frac{1}{3} + \frac{4}{9}p$
$c = \frac{1}{3} + \frac{8}{9}p + \frac{2}{3}p^2$
Case 1: $p$ is known

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

$\begin{align*}
x_p &= 3 \\
x_p &= 2 \\
x_p &= 1 \\
x_p &= 0
\end{align*}$

$\begin{align*}
0 &\quad (1/3) \\
(1/3) &\quad (1/3) + (4/9)p \\
(1/3) + (8/9)p &\quad (1/3) + (4/3)p + (2/3)p^2
\end{align*}$
Case 2: $p$ is unknown

- $p \in \{\frac{1}{5}, \frac{4}{5}\}$.
- $\mathbb{P}(p = \frac{1}{5}) = \phi$.
- Smooth ambiguity certainty equivalent
  
  $$\text{SCE}(x_A) \equiv \mathbb{E}_{\bar{p}} [\text{TO}|x_A] - \left(\frac{\theta}{2}\right) \vee [\mathbb{E}_p (\text{TO}|x_A)]$$

- $\bar{p} = \phi \frac{1}{5} + (1 - \phi) \frac{4}{5}$.
- $\theta$: attitude toward model uncertainty.
Case 2: $p$ is unknown

Optimal policy: $x_A(\phi, \theta)$
Case 2: $p$ is unknown

Improving network transparency

\begin{align*}
\phi & = 0.2 \\
\phi & = 0.4 \\
\phi & = 0.6 \\
\phi & = 0.8 \\
\phi & = 1.0 \\
\kappa & = 0.2 \\
\kappa & = 0.4 \\
\kappa & = 0.6 \\
\kappa & = 0.8 \\
\kappa & = 1.0 \\
\theta & = 1 \\
\theta & = 5 \\
\theta & = 10 \\
\theta & = 20
\end{align*}
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

<table>
<thead>
<tr>
<th>Period 0</th>
<th>Period 1</th>
<th>Period 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planner decides whether to improve net. transparency</td>
<td>Planner restricts banks</td>
<td>Banks react to regulation (change portfolio allocation)</td>
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<td>Shocks spread through the network</td>
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<td>Payoffs are realized</td>
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Banks’ problem

• Bank $i$ chooses the fraction of liquid assets in its portfolio, $\omega_i$, to maximize profits.

$$\max_{\omega_i \in \{\omega_L, \omega_H\}} \mathbb{E}[\pi_i] = \mathbb{E}[\omega_i \times R_L + (1 - \omega_i) \times R_I - \beta \omega_i \times \varepsilon_i]$$

s.t. $\omega_H \times e_i \leq \omega_i$ (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.

\[
E \left[ \frac{1}{n} \text{TO} \bigg| x \right] = \nu - \nu (1-x) \frac{\langle \phi^x \rangle}{n} - x \Delta \omega E[\Delta R],
\]

costs of contagion regulation losses

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

Increasing \( x \)

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

Increasing transparency

alters \( \langle \phi^x \rangle \)
Optimal $x^*$

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

marginal benefit

marginal cost

Value of network transparency

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

Optimal Intervention with Poisson Distribution
$\nu = 1. \kappa = 1/10.$
Case 1: $\{p_k\}_k$ is known

Value of network transparency

Contour plots of SVI. Poisson Distribution
Case 1: \( \{p_k\}_k \) is known

Optimal fraction of restricted banks

Optimal Intervention with Power-law Distribution

\( \nu = 1. \kappa = 1/10. \)

\[
\Delta \omega(E[\Delta R] + \mu) = 1/2
\]
\[
\Delta \omega(E[\Delta R] + \mu) = 1
\]
\[
\Delta \omega(E[\Delta R] + \mu) = 2
\]
Case 1: \( \{p_k\}_k \) is known

Value of network transparency

Contour plots of SVI. Power-law Distribution
Case 2: \( \{p_k\}_k \) is unknown

Optimal fraction of restricted banks

Optimal Intervention with Poisson Distribution

\( \nu = 1. \Delta \omega E[\Delta R] = 2. \kappa = 1/10. \)
Case 2: $\{p_k\}_k$ is unknown

Value of network transparency

Contour plots of SVI. Poisson Distribution
Case 2: $\{p_k\}_k$ is unknown

Optimal fraction of restricted banks

Optimal Intervention with Power-law Distribution

$\nu = 1. \, \Delta \omega E[\Delta R] = 2. \, \kappa = 1/10.$
Case 2: $\{p_k\}_k$ is unknown

Value of network transparency

Contour plots of SVI. Power-law Distribution

$\Delta \omega E[\Delta R]$

$\sigma^2$

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

0 2 4 6 8 10 12 14 16 18 20
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: $x_c(p)$

$c = \frac{5}{9}$
Motivating Example

Optimal Policy: $x_c(p)$

$c = \frac{5}{9}$
Preventing large cascades of distress with Poisson Distribution
Preventing large cascades of distress with Power-law Distribution

$\alpha$-axis

$\beta$-axis
Value of Information with Poisson Distribution

\( \nu = 1 \)

\[
\Delta \omega(E[\Delta R] + \mu) = \frac{1}{2}
\]

\[
\Delta \omega(E[\Delta R] + \mu) = 1
\]

\[
\Delta \omega(E[\Delta R] + \mu) = 2
\]
Value of Information with Power-law Distribution

\[ \nu = 1 \]

\[ \Delta \omega(E[\Delta R] + \mu) = \frac{1}{2} \]

\[ \Delta \omega(E[\Delta R] + \mu) = 1 \]

\[ \Delta \omega(E[\Delta R] + \mu) = 2 \]
Incorporating Ambiguity

- Given $I$, planner chooses $R_I$ to solve

$$\max_{R_I} \mathbb{E}_{\bar{\alpha}} (TO_\alpha | R_I) - \left( \frac{\theta}{2} \right) \times \nabla f (\mathbb{E}_\alpha (TO_\alpha | R_I)) - \kappa \times 1\kappa$$

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

- The planner chooses $I \in \{I_0, I_1\}$ and $R_I$ to solve

$$\max_{I \in \{I_0, I_1\}} \left\{ \max_{R_{I_0}} \left( \mathbb{E}_{\bar{\alpha}} (TO_\alpha | R_{I_0}) - \frac{\theta}{2} \nabla f (\mathbb{E}_\alpha (TO_\alpha | R_{I_0})) \right), \max_{R_{I_1}} \left( \mathbb{E}_{\bar{\alpha}} (TO_\alpha | R_{I_1}) - \frac{\theta}{2} \nabla f (\mathbb{E}_\alpha (TO_\alpha | R_{I_1})) - \kappa \right) \right\}$$

- Social value of network transparency is now captured by

$$\left[ \mathbb{E}_{\bar{\alpha}} (TO_\alpha | x_{I_1}^*) - \mathbb{E}_{\bar{\alpha}} (TO_\alpha | x_{I_0}^*) \right] - \left( \frac{\theta}{2} \right) \times \Delta \nabla \mu,$$
The Rise of Large Cascading Failures

- Large cascading failures arise if
  \[
  \lim_{n \to \infty} \frac{\langle k^2 \rangle}{\langle k \rangle} \leq 2.
  \]

- Preventing large cascading failures
  - When the planner cannot differentiate among banks before implementing policies,
    \[
    x^* = 1 - \frac{\langle k \rangle}{\langle k^2 \rangle - \langle k \rangle}.
    \]
  - When the planner can rank banks based on their future number of susceptible links,
    \[
    K(x^*) \sum_{k=0} k(k-1)p_k = \langle k \rangle \quad \text{and} \quad x^* = 1 - \sum_{k=0} K(x^*)p_k.
    \]