Financial contagion and climate change: what can macroprudential regulation do to save the planet

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Road Map

- Introduction.
- Model.
- Results.
  - Equilibrium.
  - Efficiency.
  - Heterogeneous clients.
  - Heterogenous costs: asymmetric information.
- Policy implications and conclusion.

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Introduction: research question

- Research question
  - How will climate risk affect the economy?
  - How does the structure of a (financial) network (both efficient and equilibrium) react to contagion externalities to transmit that risk?
  - What is additional effect of heterogeneity and asymmetric information?
  - What does this mean for macroprudential regulation in its relation to climate?

Introduction: model and results

- Two types of firms: intermediaries (banks) and final customers.
- We concentrate on "customers" who will be affected by climate risks: through "stranded assets" or because climate directly affects them. Need not be emitters.
  - Linkages among intermediaries useful to share risks.
  - Linkages with final customers costly but can be compensated.
  - Costs of final customers to indirectly exposed not compensated (crucial externality).
- Main results:
  - Excessive equilibrium intermediation and low risk sharing.
  - Core-periphery structures.
  - Heterogeneity: too high exposure to "bad risks."
  - Asymmetric information: reduced connectivity out of "contagion fear."

Introduction: literature

A. Contagion in networks
   1. Allen and Gale (2000), Freixas et al. (2000), Allen et al. (2011), ...
   2. Nier et al. (2007), Leitner (2005), Blume et al. (2011), ...
   3. Elliott et al. (2014), Acemoglu et al. (2014), Glasserman and Young (2014), Cabrales, Gottardi and Vega-Redondo (2017)...

B. Heterogeneity and incomplete information
   1. Networks asymm. information. Francetich and Troyan (2012), McBride (2006), Leung (2015), Song and Schaar (2013)...
   2. Heterogeneous networks. Billant, Bravard and Sarangi (2011), (2012a), (2012b)...

The main model

- N intermediaries (B) and FN final customers (C) located in a network.
- n_i^{BD} and n_i^{CD} – direct i connections.
- n_i^{BI} and n_i^{CI} – indirectly i connections.
- n_i^{CBD} C (not including i) directly connected to same B as i.

$$u_B = g\left(n_i^{BD} + n_i^{BI}\right) - c\left(n_i^{CI} + n_i^{CD}\right) + t_i - \alpha l_i$$

$$u_C = f\left(n_i^{BD}\right) - cn_i^{CBD} - t_i$$

$$f\left(n_i^{BD}\right) = \begin{cases} K_B \text{ if } n_i^{BD} \geq 1 \\ 0 \text{ if } n_i^{BD} = 0 \end{cases}$$

and $g'(.) \geq 0$, $g''(.) < 0$

The main model

- $f(.)$ and $g(.)$ benefits for B and the C types of linkages to B, while c cost of linkages C .
- t_i net transfers by C to direct B contacts to compensate for losses.
- l_i direct links of B to other B, α (small) cost for those links.
- Linkages among B types risk sharing/trading possibilities.

The main model

- For C a linkage to B represents resources/borrowing.
  - A B and C linkage a benefit for C a cost for B.
  - Via linkages among B, obligations extend to all B directly or indirectly linked.
  - Benefit for C of linkage with B decreasing in number of other C linked toe same B.

Assumption 1

We assume F is sufficiently large, so that $F > K_B/2c$.

Results: efficiency

Main Result 1

At the optimum each component has a core periphery structure where every C firm is linked to only one B firm, B firms are minimally connected among them and each one should be linked to the same number of C types

$$C_B^* = \max\left\{\frac{K_B - (n_B - 1)c}{2c}, 0\right\}$$

$$\phi(n_B) \equiv n_B g\left(n_B - 1\right) + \frac{n_B}{4c}\left(\max\left\{K_B - (n_B - 1)c, 0\right\}\right)^2$$

Proposition 1

If $\phi(n_B)$ is either everywhere convex or everywhere concave all components are identical and n_B^* is closest feasible point to maximizer of $\phi\left(n_B\right)/n_B$.

Results: equilibrium

- Equilibrium networks from optimal bilateral contracting choices.
- Notion of equilibrium: features of bilateral (Goyal, Vega Redondo 2007) and pairwise equilibrium (Bloch, Jackson 2007):
- Network and transfers from C to B without pairwise profitable deviation:
  - deletion of any subset of their existing linkages *and*
  - formation of a new linkage between the two firms (possibly with transfer).

Results: equilibrium

Proposition 2

In equilibrium, a number $\overline{C} = \min\left\{F, \frac{K_B - c}{c}\right\}$ *of* C *types is linked to each* B *type. And all components are minimally connected trees and all of them, except at most one, have a number of* B *types,* $\bar{n}_B$*, that satisfies*

$$\bar{n}_B \in \arg\max_{n_B} \left\{g\left(n_B - 1\right) - cn_B\overline{C}\right\}, \tag{1}$$

with the remaining component, if it exists, having a number of B *types strictly smaller than* $\bar{n}_B$.

Results: equilibrium and efficiency

Main Result 2

The number $\bar{n}_B$ of B types in all (but at most one) components in equilibrium is smaller than the social optimum $\bar{n}_B \leq n_B^*$. Also the number of C for every B in equilibrium is larger than the social optimum $\bar{C} \geq C^*$ for $C^* \geq 1$.

- $\overline{C} = \min\left\{F, \frac{K_B - c}{c}\right\} \geq C_B^* = \max\left\{\frac{K_B - (n_B - 1)c}{2c}, 0\right\}$, when $C_B^* \geq 1$.
- Compare marginal value of new connection: equilibrium vs. efficient.

$$g'(n_B - 1) - c\bar{C}$$

$$g'(n_B - 1) - cC^*(n_B) \text{ if } n_B^* \geq K_B/c + 1 \text{, otherwise } g'(n_B - 1)\,.$$

Results: equilibrium and efficiency

- Contracting externality in the formation of financial linkages leads to:
  - excessive level of intermediation $\bar{C} \geq C^*$ (B do not internalize risk on contacts).
  - inefficiently low level of risk sharing by B firms, who anticipate large number of harmful C contacts.
- Each component except one reaches optimal n_B, conditional on C. Remaining B (conditionally inefficient) smaller component (rearranging would require non-pairwise compensations).

We have some robustness checks on assumptions.

Heterogeneous clients: model

- Now there are two types of C players", C_1 and C_2.
- C_1 has lower direct cost and a bigger cost on the indirect connections than C_2

$$u_B = g\left(n^{BD} + n^{BI}\right) - c_A\left(n_i^{C_1 D} + n_i^{C_2 I}\right) - c_F\left(n_i^{C_2 D} + n_i^{C_1 I}\right) + t_i - \alpha l_i$$

with $c_A < c_F$

$$\begin{aligned} u_{C_1} &= f\left(n_i^{BD}\right) - c_D n_i^{BC_1 D} - c_I n_I^{BC_2 D} - t_i \\ u_{C_2} &= f\left(n_i^{BD}\right) - c_I n_i^{BBC_1 D} - c_D n_i^{BC_2 D} - t_i \end{aligned}$$

$$f_j\left(n_i^{BD}\right) = \begin{cases} K_B \text{ if } n_i^{BD} \geq 1 \\ 0 \text{ if } n_i^{BD} = 0 \end{cases}$$

Heterogeneous clients: efficiency and equilibrium

- Equilibrium and efficiency qualitatively the same as before.
- Novelty: composition/proportion of C_1 to C_2 in equilibrium and efficient.

Main Result 3

$\widehat{C}_1 > \widehat{C}_2$ *iff* $c_F > c_A$. *In contrast,* $C_1^*(n_B) < C_2^*(n_B)$ *iff* $n_B^* > 1$

- C_1 more privately profitable and more socially harmful than C_2 ($c_F > c_A$).
  - In equilibrium there are more C_1 than C_2.
  - Opposite to what efficiency requires, more C_2 than C_1 (independent of c_D and c_I).
- Heterogeneity: increased inefficiency, through matching of customers.

Heterogeneous costs and asymmetric information

- Different type of heterogeneity, in cost of providing services to customers.
- Two types of B: H and L, assume $c_H > c_L$. Payoff for C as before.

$$\begin{aligned} u_{B_{ij}} &= g\left(n_i^{BD}\right) - c_j\left(n_i^{BCD}\right) + t_i - \alpha l_i \\ u_C &= f\left(n_i^{BD}\right) - cn_i^{BCD} - t_i \\ f\left(n_i^{BD}\right) &= \begin{cases} K_B \text{ if } n_i^{BD} \geq 1 \\ 0 \text{ if } n_i^{BD} = 0 \end{cases} \end{aligned}$$

- Type of B known to C. Then, in equilibrium:
- $\overline{C}_L = \min\left\{F, \frac{K_B - c_L}{c}\right\} \geq \overline{C}_H = \min\left\{F, \frac{K_B - c_H}{c}\right\}$

Heterogeneous costs and asymmetric information

- Under complete information: assortative matching.
- H types only want to match to other H types who have less connections.
- L would want to match H but blocked, too many externalities (C connections).
- Under asymmetric information, marginal cost of linkage for type L is lower
- hence $n_{B_L}^{AI} > n_{B_L}^{CI}$, thus the low cost types connect more under AI.
- Similarly $n_{B_H}^{AI} < n_{B_H}^{CI}$, so high cost types connect less under AI. But overall

Main Result 4

$$TC_{AI} - TC_{CI} < 0$$

Conclusion

- Stylized model of link formation between financial firms when:
  - engage in intermediation activity with others, and do not internalize default contagion externalities.
- Main results are:
  - Optimal network exhibits a core periphery structure.
  - Optimal structure cannot be obtained as a result of individual decisions:
    - excessive intermediation limits extent of risk sharing in the system.
  - Heterogeneous credit quality or in ability to resist contagion risk (especially under asymmetric information) amplifies inefficiency.
  - Macroprudential regulators have the mandate and the tools to avoid this problem.
  - They can increase regulatory capital for weighted loans to “brown” firms.
  - One can use the mandate to save banks in order to save the planet.


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