

Fire Sales in a Model of Complexity

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Introduction

- **Fire sales:** Collapse in asset prices during crises increases financial distress at the worst time. Downward spiral.
- **Uncertainty** and **precautionary response:** Might be a key ingredient.
- Recent crisis:
 - A “small” subprime shock generated massive **counterparty risk** and the worst flight-to-quality episode since the GD.
Why so many unconstrained agents refuse to “arbitrage”?
 - Policy: Attempts to break the perverse feedback loop (bailouts, asset price supports).

Need to understand the sources of uncertainty.

Our contribution: A model

- A model of the sudden rise in uncertainty and its interaction with asset fire sales.
- Normal times: Financial institutions (banks) need to only know the financial health of their direct counterparties.
- Distress shock hits the financial system: Need to learn about the health of the counterparties of the counterparties...
- At some point, it becomes too complex (i.e., complicated):
 - ⇒ Increase in banks' perceived uncertainty.
 - ⇒ Fire sales and credit crunch.

Preview of setup and results

- Financial system is a network of **cross-exposures** (as in Allen and Gale, 2000).

Complexity: Banks are uncertain about cross-exposures (only local knowledge).

- A surprise liquidity shock hits the network.
- This leads to a **partial cascade**.
- When shock is small, cascade short and prices are “fair.”
- When shock is larger, cascade longer, perceived uncertainty rises, potential buyers withdraw, prices plummet....
- **Amplification:** Low prices further lengthen the cascade.
- **Policy:** New source of inefficiency: **complexity externality**.

Our contribution: Literature “review”

- Relative to network failures and contagion in financial markets:
 - They focus on workings of cascades. We take these as the reason for the rise in uncertainty. Overcome “limited-size” critique.
- Relative to uncertainty and flight to quality:
 - They focus on the effect of the rise in uncertainty on financial markets. We generate the rise in uncertainty endogenously from the structure of the financial network.
- Relative to fire sales:
 - Panic (due to uncertainty) as the main reason for absence of buyers (as opposed to binding constraints or predatory reasons). Works for large number of potential buyers.

Outline of the talk

- Basic environment and benchmark with no network uncertainty.
Mechanics of the model and (partial) cascades.
- Environment with network uncertainty.
Role of complexity. Its interaction with asset prices.
- Complexity externality.
Sources of inefficiency and policy implications.
- Extension with counterparty insurance.
Robustness to CDS.

The model: banks face a liquidity-return trade-off

- Dates: 0, 1, 2 with single good (dollar).

Players: n banks denoted by $(b^j)_{j=1}^n$.

- Start with a given balance sheet at date 0 (coming up), and care about net worth at date 2.

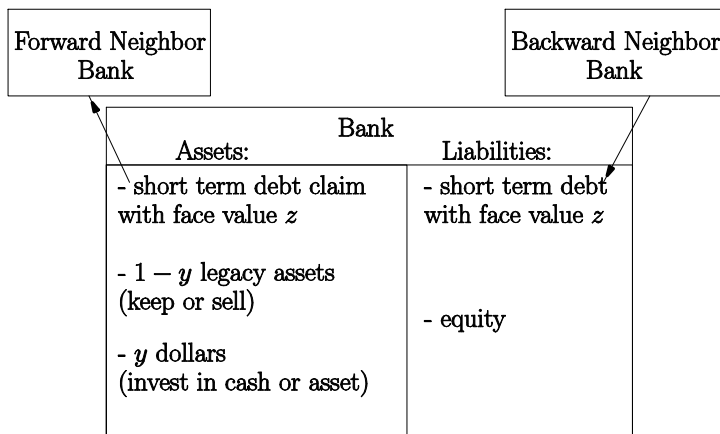
Investment technology:

- Cash: One dollar yields one dollar at the next date.
- **Asset:** Price 1 at primary market at date 0, yields $R > 1$ dollars at date 2. **Asset is illiquid at date 1.**

Secondary market for legacy assets at date 0:

- Natural buyers are other banks.
- Price $p \in [p_{scrap}, 1]$ determined in equilibrium.

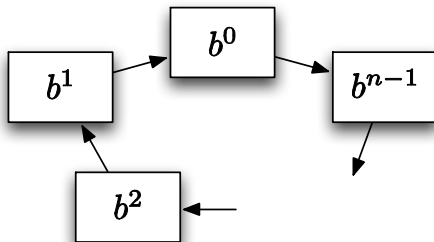
Banks start with initial balance sheets that feature cross-exposures



Cross debt claims capture cross-exposures.



A financial network is an ordering of banks around a circle



(1)

- **Main ingredient (later):** Uncertainty about the ordering. Captures uncertainty about cross-exposures.
- **Benchmark (next):** Banks know the ordering.

The shock: one bank needs additional liquidity

Date 0:

- Banks learn that one bank, b^0 , will need θ dollars **at date 1**.
- Each bank takes an action $A_0^i = \{S, B\}$.

Date 1:

- Bank pays $q_1^j \leq z$ on its short term debt.

Date 2:

- Bank pays out net worth, q_2^j .

Bank's objective: Maximize q_2^j subject to meeting debt payment.

Equilibrium definition is standard

Equilibrium: collection $\{A_0^j, q_1^j, q_2^j\}_{j, \mathbf{b}(\sigma)}$ and $p \in [p_{scrap}, 1]$, such that banks' actions are optimal and legacy asset market clears.

Useful notation:

- **Distance** from the distressed bank, k .
- **Liquidity need** of a bank with distance k :

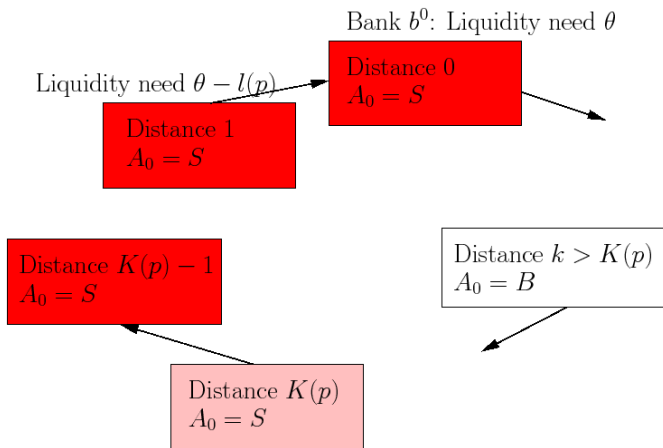
$$z - q_1^{k-1} + \theta [k = 0].$$

- **Available liquidity** of a bank that chooses $A_j = S$:

$$l(p) = y + (1 - y)p.$$

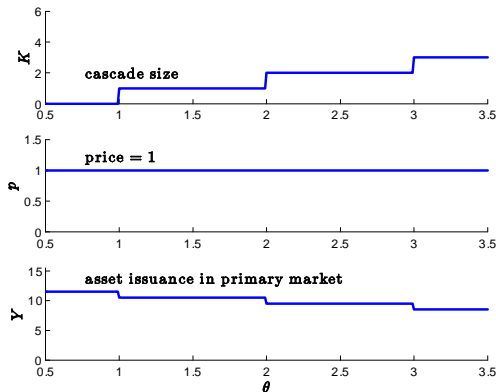
Characterization: (i) Partial eq for given p , (ii) General eq.

Partial equilibrium features a partial cascade



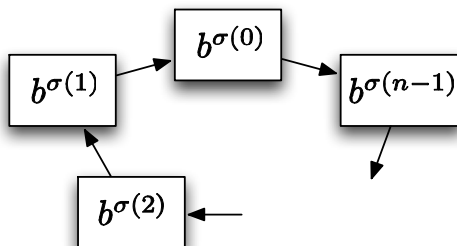
- There is a cascade of length $K(p) = \left\lceil \frac{\theta}{l(p)} \right\rceil - 1$.

General equilibrium: (i) No fire sales (for $\eta > \theta$), (ii) Equilibrium changes “smoothly”



With complexity, these results will dramatically change.

Complexity: Uncertainty about cross-exposures



- The set of ex-ante possible financial networks:

$$\mathcal{B} = \{ \mathbf{b}(\sigma) \mid \sigma : \{1, \dots, n\} \rightarrow \{1, \dots, n\} \text{ is a permutation} \}.$$

- Let $\mathcal{B}^j(\sigma) \subset \mathcal{B}$ denote the networks that b^j finds possible given the realization of $\mathbf{b}(\sigma)$.

Complexity: Uncertainty about cross-exposures

- **No-uncertainty benchmark:** $\mathcal{B}^j(\sigma) = \{\mathbf{b}(\sigma)\}$ for all j, σ .
- **Local information (next):**

$$\mathcal{B}^{\sigma(i)}(\sigma) = \left\{ \mathbf{b}(\tilde{\sigma}) \in \mathcal{B} \mid \begin{bmatrix} \tilde{\sigma}(i) = \sigma(i) \\ \tilde{\sigma}(i-1) = \sigma(i-1) \end{bmatrix} \right\}.$$

Banks know only their forward neighbor.

Definition of equilibrium with complexity

Knightian over network uncertainty: Bank's action solves:

$$\max_{A_0^j(\sigma) \in \{S, B\}} \min_{\mathbf{b}(\tilde{\sigma}) \in \mathcal{B}^j(\sigma)} q_2^j(\tilde{\sigma}).$$

Not necessary, but appropriate for context.

Equilibrium: collection $\left\{ A_0^j(\sigma), q_1^j(\sigma), q_2^j(\sigma) \right\}_{j, \mathbf{b}(\sigma)}$ and $p \in [p_{scrap}, 1]$, such that banks' actions are optimal and legacy asset market clears.

Banks act as if they are closer to the distressed bank than they actually are

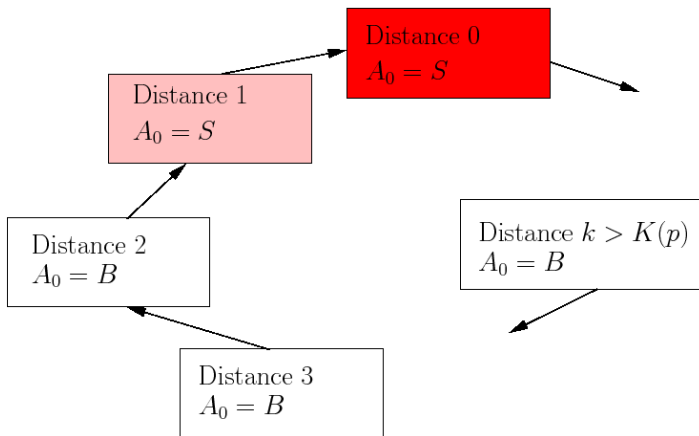
Key observation: A bank does not (necessarily) know its distance.

Maximin: Worst case scenario.

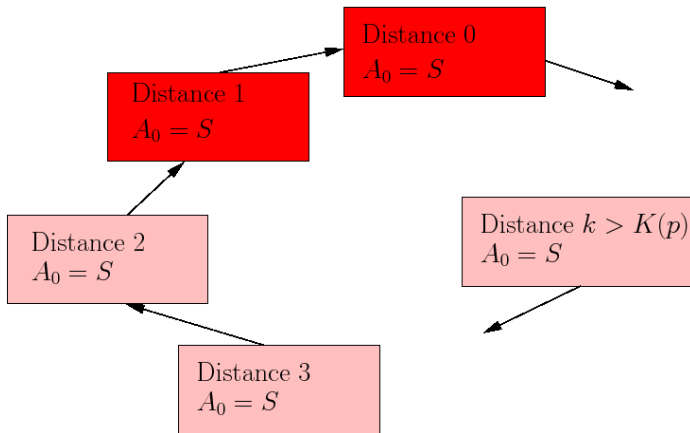
- Banks with $k \leq 1$ know k . Same action as before.
- Banks with $k \geq 2$ find possible all distances $\tilde{k} \in \{2, 3, \dots, n-1\}$. They act as if $\tilde{k} = 2$.

Partial equilibrium: Two cases depending on size of the shock, θ .

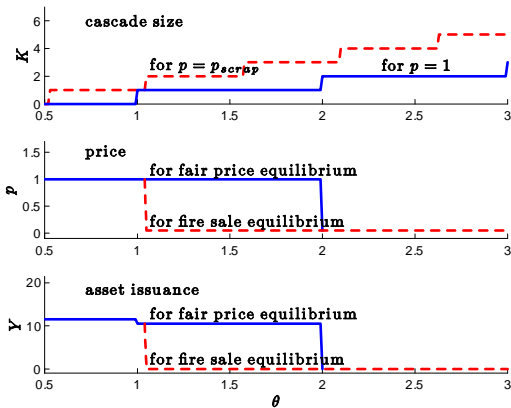
With small shocks, the partial equilibrium is identical to the no-uncertainty benchmark



With slightly larger shocks, there is a complete collapse of the financial system



General equilibrium with complexity: (i) Fire sales, (ii) Equilibrium changes “discontinuously”



Multiple equilibria because cascade size depends on p .

The model features a novel “complexity externality”

Complexity externality: Actions that increase K increase payoff uncertainty and lower welfare.

Two versions: Non-pecuniary and pecuniary.

Next: A related externality in a simple example, followed by the two versions of complexity externality.

Non-pecuniary externality in an alternative model

Consider a simple alternative model:

- Agents $i \in I$ (measure one) choose a costly action, $a^i \in \{0, 1\}$.
- Preferences given by $u(x^i - ca^i)$.
- Variance of each x^i given by $1 - \int_I a^i di$.

Equilibrium: all agents choose $a^i = 0$.

Pareto improvement: For sufficiently small c , all agents choose $a^i = 1$.

Inefficiency: A non-pecuniary (technological) externality.

Nonprice complexity externality and bank bailouts

- Consider the setup with fixed price, p , and cascade size $K(p) = 2$.
- **Bailout policy:** Suppose each bank can contribute $\{0, \frac{\theta}{n}\}$ to a bailout fund.

Equilibrium: All banks contribute 0.

Pareto improvement: All banks contribute $\frac{\theta}{n}$. Cascade is lowered to $K(p) = 0$.

Inefficiency: Nonprice complexity externality. Public good of stability.

Price complexity externality and asset purchases

- Consider the setup with endogenous p and multiple equilibria.
- Suppose the economy is at the fire-sale equilibrium.

Pareto improvement: Floor on asset prices. Coordinates on fair-price equilibrium.

Inefficiency: Price complexity externality.

- A bank that sells an asset increases $K(p)$ and raises payoff uncertainty.
- Different than the usual fire-sale externality.

Consider extension with counterparty insurance

Banks face **idiosyncratic** payoff uncertainty from cross-exposures.

- Can be reduced to some extent using CDS.
- Consider the setup with cascade size $K \geq 2$.

Extension: Contract, I^j , pays 1 dollar at date 1 if b^j is insolvent.

- **Key assumption:** Contract must be fully collateralized.
- Competitive market with price f^j and quantity x^j (endogenous).
- Banks in network choose not to sell insurance.
- Insurance sold by **outside agent** with collateral, y^{out} .
- Consider equilibrium in which $f^j = f$ and $x^j = x$ for each j .

Insurance increases banks' available liquidity

- **Insurance supply:** When

$$\underbrace{fnx}_{\text{premiums collected}} > \underbrace{Kx}_{\text{expected payoff}},$$

sell as much insurance as possible subject to collateral constraint:

$$(1 - f) nx \leq y^{out}.$$

- **Insurance demand:** All banks buy insurance on their forward neighbors. Available liquidity becomes:

$$l(p, f) = \frac{l(p)}{f} > l(p).$$

- Cascade length with insurance, $K(p, f)$, calculated as before.

When n is large, insurance does not overturn our results

- Equilibrium price:

$$f = \frac{l(p) n}{y^{out} + l(p) n}.$$

- When y^{out} is small relative to n , results are qualitatively unchanged.
- **Limited supply:** Consistent with CDS markets during Bear Sterns and Lehman episodes.

Conclusion

- During severe crises the **complexity of the environment** rises, and this causes financial retrenchment.
- We capture complexity with:
Uncertainty about cross-exposures.
- We also show that complexity and fire sales reinforce each other.

Complexity externality provides plenty of scope for policy.

- **Crisis policies:** reducing counterparty risk (TBTF), supporting asset prices (loan guarantees), stress testing...
- **Preventive policies:** simplifying the network (OTC transactions to exchanges), increasing transparency...

Examples of cross-exposures

Interbank loans.

Upper (2007): “at the end of June 2005 interbank credits accounted for 29% of total assets of Swiss banks and 25% of total assets of German banks.”

OTC derivatives: Interest rate swaps, credit default swaps...
BIS: Gross credit exposures by the end of 2008 in G10 and Switzerland are \$5 trillion.

