Runs, Panics, and Contagion

Macroeconomics IV

Ricardo J. Caballero

MIT

Spring 2011

References

1. Diamond, D.W. and P.H.Dybvig, "Bank Runs, Deposit Insurance, and Liquidity," *Journal of Political Economy,* 91(3), 401-419, June 1983.
2. Caballero, R.J. and A. Simsek,"Fire Sales in a Model of Complexity," MIT mimeo, March 2011

Main points

- The maturity transformation of banks builds on the LLN. As such, it is inherently fragile to an endogenous breakdown in heterogenity (coordination failure)
- Contagion can arise from network effects and fire sales of common assets
- Complexity is in itself a source of panics

The Diamong-Dybvig model of bank runs

- Depository institutions as "pools of liquidity." They transform illiquid assets (long term inv.) into liquid liabilities (deposits).
- Danger: Bank runs (too many decide to use the "liquidity option" at the same time).
- Policy: Deposit insurance, LLR, suspension.

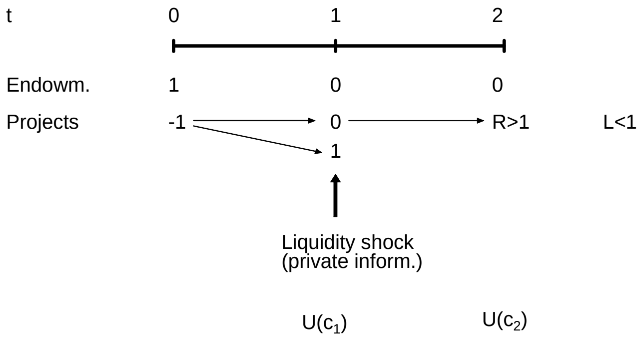
The Diamong-Dybvig model of bank runs

- Continuum 1 of individuals each endowed with one unit of currency. $t = 0, 1, 2$
- At $t = 0$, individuals can either invest in short-run project with return equal to 1, or invest in a long-run project that yields a return $R > 1$ at $t = 2$.
- If liquidate the long-run project at $t = 1$, return is $L < 1$ only.
- At $t = 1$, fraction π of individuals gets liquidity shock and only value consumption at $t = 1$. The remaining fraction $1 - \pi$ is patient and only values consumption at $t = 2$.
- Ex-ante expected utility is

$$U = \pi u(c_1^1) + (1 - \pi) u(c_2^2),$$

where c_1^1 is consumption in period 1 if impatient and c_2^2 consumption in period 2 if patient.

The Diamong-Dybvig model of bank runs



Autarky

- Denote $I \in [0,1]$ the investment in the long-run project
- Under autarky, the individual solves

$$\max_I U \qquad \text{s.t. } c_1^1 = \{1 - I + LI, 0\}, c_2^2 = \{RI + (1 - I), 0\}$$

- Ex-post inefficient. Would like $I = 1$ if patient, $I = 0$ if impatient.

Ex-post Financial Market

- Bond at $t = 1$; p units of t_1 goods for one t_2 good.
- Impatient individuals buy t_1 goods, so

$$c_1 = pRI + (1 - I).$$

- Patient individuals buy t_2-goods, so

$$c_2 = RI + \frac{1 - I}{p}.$$

- The equilibrium price must satisfy

$$L \leq p \leq 1.$$

- Equilibrium: $p = 1/R$; $c_1 = 1$, $c_2 = R$, $I^M = 1 - \pi$.

Intermediation

- Ex-post market in general involves too much liquidity risk: $c_2 >> c_1$
- Financial interm. offers c_1^* or c_2^* in exchange for deposit such that:

$$\max U \qquad \text{s.t. } \pi c_1 + (1-\pi)\frac{c_2}{R} = 1$$

- Bank saves πc_1 to fulfill obligations.

Run

- If many patient consumers withdraw early, nothing is left for those who wait. Second Nash equilibrium. Expectations can lead to bank run.
- **Sequential servicing constraint** (first-come-first-serve) creates incentives to run early.
- Solutions: deposit insurance, LLR, suspend convertibility.
- Before 1913 (Fed was founded), the US experienced many runs. During the great depression it took too long for the Fed to react.
- Current crisis. Runs on unprotected investment banks (repo market)
- Fixed exchange rates

Appendix: Side Trades

- Suppose we are in the banking arrangement with $c_1 > 1$ and $c_2 < R$
- Suppose that a "rogue" trader can stay outside the conglomerate (bank). Then by investing $I = 1$ it clearly can do better than by staying in the conglomerate
- If the trader is not hit by a liquidity shock, it gets $R > c_2$
- It the trader is hit by a liquidity shock, it can entice a patient consumer in the conglomerate to fetch c_1 and trade for $R > c_2$ (i.e., the patient consumer will be happy to make this trade)
- Many insurance arrangements or policy interventions (e.g. liquidity requirements) are fragile to side trades (markets)

Contagion and Panics in a Financial Network

- Recent crisis: A “small” subprime shock generated massive counterparty risk and the worst ‡ight-to-quality episode since the GD
- Why so many unconstrained agents refused to “arbitrage”?
- Policy: many attempts to put a floor on asset prices (loan guarantees) and break the perverse feedback loop.
- Caballero-Simsek (2011)

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

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

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

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

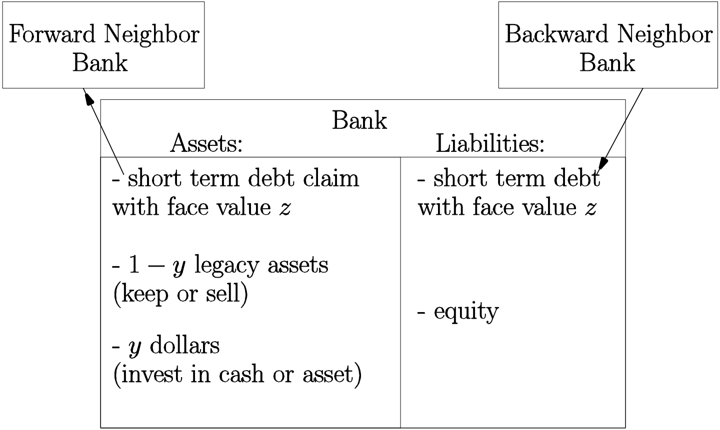
Investment technology:

- 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:

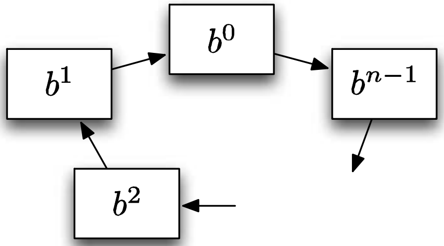
- Natural buyers are other banks.
- Price $p \in [p_{scrap}, 1]$ determined in equilibrium.

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

- At date 0, banks learn that a rare event happened and one bank, b^0, will experience liquidity needs of θ at date 1.
- These losses might spill over to other banks at date 1.
- To prepare for date 1, each bank takes an action $A_0^j = \{S, B\}$ at date 0.
- Denote the bank's payment on its short term debt with $q_1^j \leq z$, and its date 2 net worth with q_2^j.
- Bank maximizes q_2^j subject to meeting debt payment. Otherwise **insolvent**: $q_1^j < z$ and $q_2^j = 0$.
- **Equilibrium:** collection $\left\{A_0^j, q_1^j, q_2^j\right\}_{j,\mathbf{b}(\sigma)}$ and $p \in [p_{scrap}, 1]$, such that banks' actions are optimal and legacy asset market clears.

Roadmap for characterization

Useful notation:

- **Distance** (from the distressed bank): For the network in (1), bank b^j has distance $k = j$.
- **Cascade of length** K**:** Bank is insolvent iff $k \leq K - 1$.
- **Flight-to-quality of size** F**:** Bank chooses $A_0 = S$ iff $k \leq F - 1$.

Characterization in three steps:

- A bank's solvency and optimal action,
- Partial equilibrium for a given p,
- General equilibrium.

Bank's solvency and optimal action

- The bank with distance k has **liquidity need**:

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

- By choosing $A_0 = S$, it obtains **available liquidity** of:

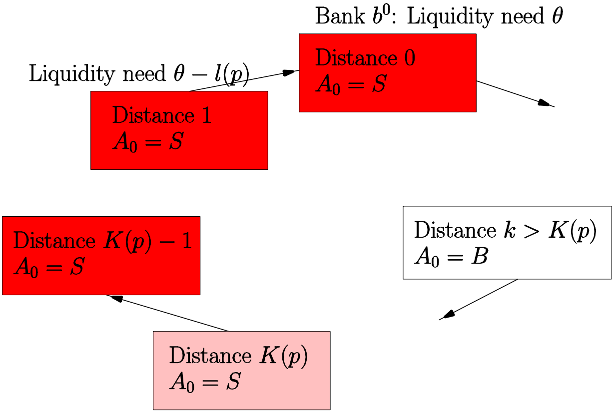
$$l\,(p) = y + (1 - y)\,p.$$

Bank is insolvent iff its liquidity need $> l\,(p)$.

Bank chooses $A_0 = S$ iff its liquidity need > 0.

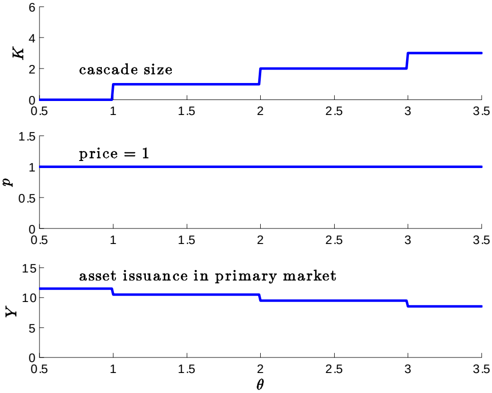
1. If liquidity need $= 0$, then $A_0 = B$ to maximize q_2.
2. If liquidity need $\in (0, l\,(p)]$, then $A_0 = S$ to avoid insolvency.
3. If liquidity need $> l\,(p)$, then $A_0 = S$ to maximize liquidation outcome.

Partial equilibrium features a partial cascade



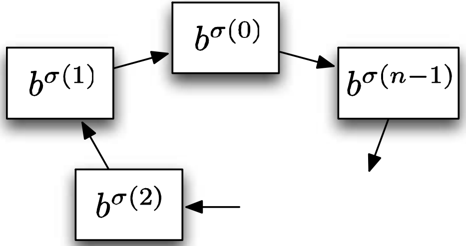
- There is a cascade of length $K(p) = \left\lceil \frac{\theta}{l(p)} \right\rceil - 1$ and a flight-to-quality of size $F = K(p) + 1$.
- **Cascade length is decreasing in p.**

General equilibrium: (i) No fire sales (for ny>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:

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

- 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.

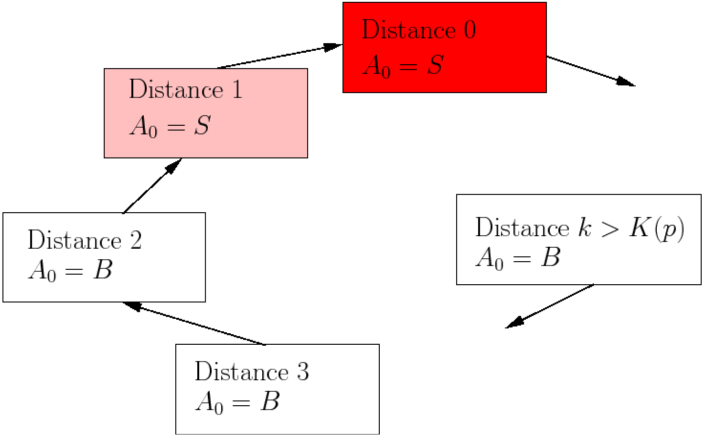
- **Notation:** Definitions of distance, cascade, flight-to-quality generalize to this setting.
- **Characterization:** Three steps as before.

Bank's optimal action with complexity

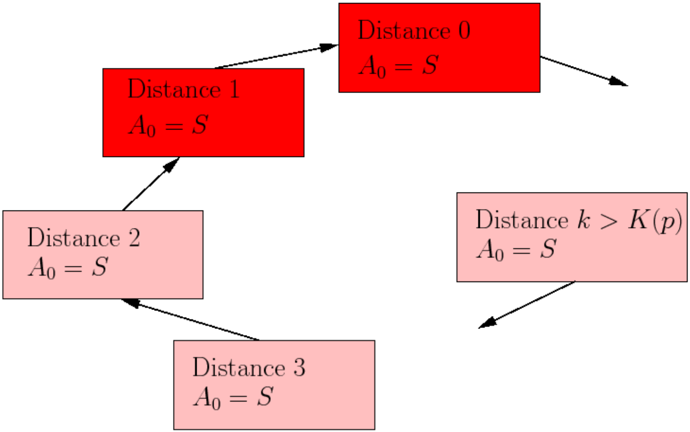
- **Key observation:** A bank does not (necessarily) know its distance, k.
  $\Longrightarrow$ Does not know **its liquidity need**.
- **Maximin:** Act according to the worst case scenario.
  - Banks with $k \leq 1$ know k. Same action as before.
  - Banks with $k \geq 2$ find possible all distances $\tilde{k} \in \{2, 3, .., n-1\}$. They act as if $\tilde{k} = 2$**.**
- **Banks act as if they are closer to the distressed bank than they actually are.**

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

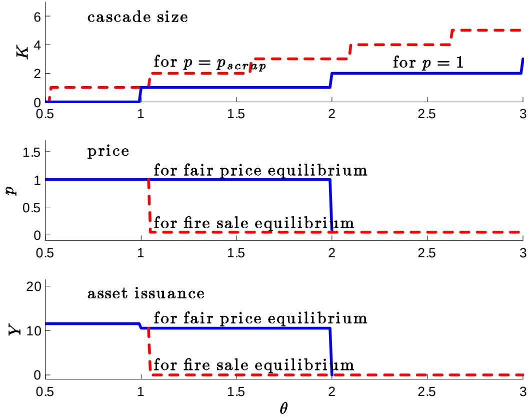
With small shocks, the partial equilibrium is identical to the no-uncertainty benchmark



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 $u\left(x^i - ca^i\right)$.
- 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 $\left\{0, \frac{\theta}{n}\right\}$ 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.

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.

14.454 Economic Crises
Spring 2011