Mandatory Disclosure and Financial Contagion

Fernando Alvarez Gadi Barlevy

University of Chicago Chicago Fed

July 2013
Introduction

- Why did collapse of US house prices result in a financial crisis?
Introduction

Why did collapse of US house prices result in a financial crisis?

- Gorton (2008) argued key part was uncertainty about who bore losses:
Why did collapse of US house prices result in a financial crisis?

Gorton (2008) argued key part was uncertainty about who bore losses:

“The ongoing Panic of 2007 is due to a loss of information about the location and size of risks of loss due to default on a number of interlinked securities, special purpose vehicles, and derivatives, all related to subprime mortgages.”...

“...But, it was not possible to know where the risk resided and without this information market participants rationally worried about the solvency of their trading counter parties.

This led to a general freeze of intra-bank markets ..."
Introduction

- Similar view echoed by market participants
Similar view echoed by market participants

Lewis Ranieri, the “godfather” of mortgage finance in 2007 WSJ article:

“The problem, [Ranieri] says, is that in the past few years the business has changed so much that if the U.S. housing market takes another lurch downward, no one will know where all the bodies are buried.

‘I don’t know how to understand the ripple effects through the system today’ ”
Policy makers seem to adopt this view in highlighting role of stress tests
Policy makers seem to adopt this view in highlighting role of stress tests

Bernanke (2013) on stress tests:

“In retrospect, the SCAP [stress test] stands out for me as one of the critical turning points in the financial crisis.

It provided anxious investors with something they craved: credible information about prospective losses at banks.

Supervisors’ public disclosure of the stress test results helped restore confidence in the banking system and enabled its successful recapitalization.”
Key Questions

- Can uncertainty about location of losses lead to market freezes?
- Is mandatory disclosure good? Why don’t banks run own stress tests?

Our analysis focuses on the role of financial contagion

- Contagion ≡ shock to some banks lead to losses at others not hit by shock

Key finding:

- Mandatory disclosure is welfare improving for large contagion
- Mandatory disclosure cannot raise welfare for small contagion

Intuition: Contagion $\Rightarrow$ informational spillovers $\Rightarrow$ too little disclosure

Literature Review
Overview of Full Model

- $n$ banks, indexed $j \in \{0, ..., n-1\}$ arranged in a network

- Bank $j$ has obligation $\Lambda_{ij} \geq 0$ from bank $i$

- $b < n$ banks are “bad”, i.e. they each suffer a loss $\phi > 0$

- Banks that don’t directly suffer losses $\phi$ may still be defaulted on

- Banks know if they are bad, but not which other banks are bad
Overview of Full Model

- $n$ banks, indexed $j \in \{0, \ldots, n - 1\}$ arranged in a network
- Bank $j$ has obligation $\Lambda_{ij} \geq 0$ from bank $i$
- $b < n$ banks are “bad”, i.e. they each suffer a loss $\phi > 0$
- Banks that don’t directly suffer losses $\phi$ may still be defaulted on
- Banks know if they are bad, but not which other banks are bad
- All banks, including bad banks, can profitably invest new funds ...

... BUT agency problem implies only banks w/enough equity will invest
Overview of Full Model

- $n$ banks, indexed $j \in \{0, \ldots, n - 1\}$ arranged in a network
- Bank $j$ has obligation $\Lambda_{ij} \geq 0$ from bank $i$
- $b < n$ banks are “bad”, i.e. they each suffer a loss $\phi > 0$
- Banks that don’t directly suffer losses $\phi$ may still be defaulted on
- Banks know if they are bad, but not which other banks are bad
- All banks, including bad banks, can profitably invest new funds ...
  ... BUT agency problem implies only banks w/enough equity will invest
- Banks can disclose at cost $c \geq 0$ if they have suffered loss $\phi$ or not
Nature decides which banks are bad

2. Banks learn if they are good or bad, decide whether to disclose

3. Outside investors contract with banks given all disclosures

4. Location of bad banks is revealed ⇒ each bank learns its equity

   (we can assume instead that state is revealed by payments)

5. Once banks learn their equity, can divert funds for private benefits
Timeline of Full Model

1. Nature decides which banks are bad
2. Banks learn if they are good or bad, decide whether to disclose
3. Outside investors contract with banks given all disclosures
4. Location of bad banks is revealed \( \Rightarrow \) each bank learns its equity
   (we can assume instead that state is revealed by payments)
5. Once banks learn their equity, can divert funds for private benefits

We start with contagion ignoring disclosure/investment, then add it back
Bank Network

- Balance sheet contagion *a la* Eisenberg and Noe, Acemoglu et al
Bank Network

- Balance sheet contagion *a la* Eisenberg and Noe, Acemoglu et al
- All banks endowed with $\pi$ worth of assets (before raising new funds)
- Bad banks hit with loss $\phi$ where $\pi < \phi < \frac{n}{b} \pi$ (more senior obligation)
- State of network $S = (S_0, ..., S_{n-1})$ where $S_j = 1$ if bank is bad, 0 else
- Every realization of $S$ has exactly $b$ bad banks
- Each of the $\binom{n}{b}$ realizations of $S$ have the same probability
Bank Network

- Balance sheet contagion *a la* Eisenberg and Noe, Acemoglu et al
- All banks endowed with $\pi$ worth of assets (before raising new funds)
- Bad banks hit with loss $\phi$ where $\pi < \phi < \frac{n^b}{b} \pi$ (more senior obligation)
- State of network $S = (S_0, ..., S_{n-1})$ where $S_j = 1$ if bank is bad, $0$ else
- Every realization of $S$ has exactly $b$ bad banks
- Each of the $\binom{n}{b}$ realizations of $S$ have the same probability
- Network is defined by matrix $\Lambda_{ij}$ of obligations of $i$ to $j$
Balance sheet contagion *a la* Eisenberg and Noe, Acemoglu et al

All banks endowed with $\pi$ worth of assets (before raising new funds)

Bad banks hit with loss $\phi$ where $\pi < \phi < \frac{n}{b} \pi$ (more senior obligation)

State of network $S = (S_0, ..., S_{n-1})$ where $S_j = 1$ if bank is bad, 0 else

Every realization of $S$ has exactly $b$ bad banks

Each of the $\binom{n}{b}$ realizations of $S$ have the same probability

Network is defined by matrix $\Lambda_{ij}$ of obligations of $i$ to $j$

Here focus on circular network where $\Lambda_{ij} = \begin{cases} 
\lambda & \text{if } j = i + 1 \pmod{n} \\
0 & \text{else} 
\end{cases}$

Results extend to other networks with analogous symmetry properties, e.g. circulant networks where $\Lambda_{ij} = \lambda(j-i) \pmod{n}$
Graphical Illustration of Circular Network

Same as Caballero and Simsek (2012), except we allow $b > 1$:
Consider special case where $b = 1$; wlog, let bank 0 be bad

- Since $\phi < \frac{n}{b}\pi$, bank $n - 1$ pays bank 0 in full

- Bank 0 has total resources of $(\lambda + \pi - \phi)_+$, owes $\lambda$ to bank 1

Bank 0’s shortfall $\Delta_0 = \min(\phi - \pi, \lambda)$

- Bank 1 can add $\pi$, so leaves shortfall of $\Delta_1 = \Delta_0 - \pi$

- Assume $\phi$ and $\lambda$ both integers

$$\Rightarrow k = \frac{\Delta_0}{\pi} = \frac{\min(\phi - \pi, \lambda)}{\pi}$$

is an integer, exactly $k$ banks have zero equity
Contagion with Multiple Bad Banks

Suppose $b > 1$. Key issue is possibility of overlap:

![Diagram showing financial network with overlap]

**Figure**: $n = 12$, $b = 3$, $k = 3$

- Number of good banks with zero equity at most $bk$, but may be random
  - Large $\lambda$: For all $S$, exactly $bk$ good banks have zero equity
  - Small $\lambda$: number of good banks w/zero equity between $k$ and $bk$
Measuring Contagion

- For \( b > 1 \), contagion no longer equal to \( k \)

- Instead, we measure it by \( p_g = \Pr \{ e_j = \pi \mid \text{bank } j \text{ good} \} \)
  
  - \( p_g \rightarrow 1 \) means little contagion (good banks keep their equity)
  
  - \( p_g \rightarrow 0 \) means strong contagion (good banks lose their equity)

- **Proposition:** For circular network

\[
p_g \left( b, n, \frac{\phi}{\pi}, \frac{\lambda}{\pi} \right) = \begin{cases} 
\prod_{i=1}^{\lambda/\pi} \left( \frac{n-b-i}{n-i} \right) & \text{if } 0 < \lambda < \phi - \pi \\
\psi \left( b, n, \frac{\phi}{\pi}, \frac{\lambda}{\pi} \right) & \text{if } \phi - \pi \leq \lambda \leq b(\phi - \pi) \\
1 - \frac{b}{n-b} \left( \frac{\phi}{\pi} - 1 \right) & \text{if } \lambda > b(\phi - \pi)
\end{cases}
\]

and, moreover, \( p_g \) decreasing in \( \lambda \) and \( \phi \).

- Our analysis hereon only depends on \( p_g \) and not any other aspects of \( \Lambda \)
Trade and Agency Problems

We now allow banks to raise additional funds they can invest
Trade and Agency Problems

We now allow banks to raise additional funds they can invest

- Banks have investment opportunity of size $1$ that yields $R$
- Large pool of outside investors with opportunity cost $r < R$
- Only debt contracts allowed between banks and outside investors
- Banks can divert funds to private gains obtaining $v$

Assume $R - r < v < R - \max \{r - \pi, 0\}$

- Temptation large enough that a bank with zero equity diverts
- Temptation small enough that a bank with equity $\pi > 0$ invests

Max rate outsiders can charge is $\bar{r} = \pi + R - v$
Agency Problems and Contagion

With full information, adding trade has no effect on contagion implications:

- Bank with zero equity couldn’t raise funds, so still at zero
- Bank with equity $\pi$ raises funds, has equity $\pi + R - r$

Inequality magnified, but banks with equity $\pi$ always get funding

With incomplete information, possible that no banks get funding

- Need to charge above $\tilde{r}$ to cover risk of diversion
- Contagion exacerbates problem; outsiders worried even if $\frac{b}{n}$ small
Adding Disclosure

After each bank learns own $S_j$, choose whether to disclose it.

Cost of disclosure $c \geq 0$: trade secrets, stress test costly.

After all disclosures, outside investors can offer debt contracts $\{r_j^*\}$.

Banks accept/reject contracts, payments take place, investment/diversion undertaken, payoffs realized.

Main questions:

1. Does a non-disclosure equilibrium exist?
2. Does a non-disclosure equilibrium involve investment?
3. Can mandatory disclosure be welfare improving if it exists?
Existence of Non-Disclosure Equilibrium

Suppose we expect no bank to disclose $S_j$. Should a good bank disclose?

- If no investment in eqbm, only reason to disclose is to attract investment
- Disclosure raises outsiders beliefs to $p_g$
- If $\bar{r}p_g < r$, no trade possible; no disclosure an eqbm for any $c \geq 0$
- If $\bar{r}p_g > r$, there is scope for trade
  - Non-disclosure with no investment eqbm if $c \geq p_gR + (1 - p_g)v - r$
  - Non-disclosure can only be an eqbm if disclosure is sufficiently costly
Existence of Non-Disclosure Equilibrium

Suppose we expect no bank to disclose $S_j$. Should a good bank disclose?

- If no investment in eqbm, only reason to disclose is to attract investment
- Disclosure raises outsiders beliefs to $p_g$
- If $\bar{r}p_g < r$, no trade possible; no disclosure an eqbm for any $c \geq 0$
- If $\bar{r}p_g > r$, there is scope for trade
  - Non-disclosure with no investment eqbm if $c \geq p_gR + (1 - p_g)v - r$
  - Non-disclosure can only be an eqbm if disclosure is sufficiently costly
- If $p_g$ very large, i.e. $p_g > \frac{n}{n-b} \left(\frac{r}{\bar{r}}\right)$, outsiders invest even w/o disclosure
- In this case, non-disclosure can be an equilibrium if $c \geq \frac{b}{n-b} r$, so improved terms not enough to disclose.
Non-disclosure equilibrium exists for small $p_g$ and large enough $c$
Pareto Improvement w/Mandatory Disclosure

- If force all banks to pay $c$ and disclose, full revelation
- Investors only fund banks with high equity, so no diversion of funds
- By contrast, non-disclosure equilibrium $\Rightarrow$ no investment or some diversion
If force all banks to pay $c$ and disclose, full revelation

Investors only fund banks with high equity, so no diversion of funds

By contrast, non-disclosure eqbm $\Rightarrow$ no investment or some diversion

Consider no investment eqbm; Pareto gain if $nc \leq (R - r)(n - b)p_g$

Disclosure desirable when $c$ is low, but non-disclosure eqbm for high $c$

Can a non-disclosure eqbm exist but mandatory disclosure desirable?
If force all banks to pay $c$ and disclose, full revelation

Investors only fund banks with high equity, so no diversion of funds

By contrast, non-disclosure eqbm $\Rightarrow$ no investment or some diversion

Consider no investment eqbm; Pareto gain if $nc \leq (R - r)(n - b)p_g$

Disclosure desirable when $c$ is low, but non-disclosure eqbm for high $c$

Can a non-disclosure eqbm exist but mandatory disclosure desirable?

**Key Result:**

- Always possible for $p_g$ close to zero if $c$ small
- Never possible for $p_g$ close to one.
Blue shaded area: Pareto improvement possible.
Blue region nonempty as $p_g \to 0$, turns empty as $p_g \to 1$
Intuition for Results

- When $p_g$ close to 1, no informational spillovers
  - Agents fully internalize benefits of disclosure
  - If disclosure optimal, agents will undertake it
  - True regardless of whether there is investment at $p_g \to 1$

- When $p_g$ close to 0, no disclosure $\Rightarrow$ no investment
  - Disclosure raises beliefs from $Pr(e_j = \pi)$ to $Pr(e_j = \pi | S_j = 1) = p_g$
  - Unilateral disclosure not enough to induce investment
  - Coordination failure - no reason to reveal when other banks don’t

Intermediate cases
Consider increase in $\phi$

Effect on $p_g$ depends on $\lambda$

- If $\lambda$ small (low leverage), no effect on $p_g$
- If $\lambda$ large (high leverage), $p_g$ falls

Economy can move from eqbm w/investment to one w/no investment

Mandatory disclosure may be welfare improving in this case

Model highlights role of leverage within network to create contagion
Some of the things left out

- Multiple equilibria
- Heterogeneity across banks (e.g. core-periphery network)
- Sequential vs simultaneous moves
- What if we need more info than just location of bad apples?
  - e.g. magnitude of losses, what is the network structure?
- Stress test:
  - Exposure to risk vs realization of risk
  - Bankruptcy vs recapitalization
$p_g$ as a Function of Network Features

\[ \lambda = b (\phi - \pi) \]

\[ \frac{\partial p_g}{\partial \lambda} = 0 \]

\[ \frac{\partial p_g}{\partial \phi} < 0 \]

\[ \frac{\partial p_g}{\partial \lambda} < 0 \]

\[ \frac{\partial p_g}{\partial \phi} = 0 \]

Figure: Comparative Static of $p_g$ in the Ring Network
Network is *Symmetrically Vulnerable to Contagion (SVC)* if

$$\Pr(e_j = x | S_j = 0) \text{ for all } x \in [0, \pi]$$

is independent of $j$.

Relationship among networks:

Circular $\implies$ Circulant $\implies$ Symmetric $\implies$ SVC

Need to modify equilibrium arguments, because equity can be $(0, \pi)$.  

But conclusion for small and large $p_g$ same

Comparative static more involved for circulant network, but similar
$x_{ij}(S)$ payment from $i$ to $j$ and equity $e_{j}(S)$:

$$x_{ij}(S) = \frac{\Lambda_{ij}}{\sum_q \Lambda_{iq}} \max \left\{ \min \left\{ \sum_q \Lambda_{iq} , \pi - S_i \phi + \sum_r x_{ri}(S) \right\} , 0 \right\}$$

$$e_{j}(S) = \pi + \sum_r x_{rj}(S) - S_j \phi - \sum_q x_{jq}(S).$$

Total debt bank $i$: $\sum_q \Lambda_{iq}$. Term: $\frac{\Lambda_{ij}}{\sum_q \Lambda_{iq}}$ pro-rata payment on default.
Bank network for a given state $S$

- $x_{ij}(S)$ payment from $i$ to $j$ and equity $e_j(S)$:

$$x_{ij}(S) = \frac{\Lambda_{ij}}{\sum_q \Lambda_{iq}} \max \left\{ \min \left\{ \sum_q \Lambda_{iq}, \pi - S_i \phi + \sum_r x_{ri}(S) \right\}, 0 \right\}$$

$$e_j(S) = \pi + \sum_r x_{rj}(S) - S_j \phi - \sum_q x_{jq}(S).$$

- Total debt bank $i: \sum_q \Lambda_{iq}$. Term: $\frac{\Lambda_{ij}}{\sum_q \Lambda_{iq}}$ pro-rata payment on default.

- Circulant matrix $\Lambda_{i,j} = \Lambda_{k,l}$ whenever $j - i = l - k \pmod{n}$ for $\lambda \in \mathbb{R}_n^+$:

$$\Lambda = \begin{bmatrix}
0 & \lambda_1 & \lambda_2 & \cdots & \lambda_{n-1} \\
\lambda_{n-1} & 0 & \lambda_1 & \cdots & \lambda_{n-2} \\
\lambda_{n-2} & \lambda_{n-1} & 0 & \cdots & \lambda_{n-3} \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
\lambda_1 & \lambda_2 & \lambda_3 & \cdots & 0
\end{bmatrix}$$

and $\bar{\lambda} \equiv \sum_{i=0}^{n} \lambda_i$.
If $p_g > \frac{\ell}{\bar{r}}$, good bank can raise funds if it discloses

Outsiders believe $Pr(e_j = \pi | S_j = 0) = p_g$, enough to allow trade

Mandatory disclosure can beat non-disclosure w/o coordination problems

Value of mandatory disclosure emerges when $v > r$

If $Pr(e_j = \pi) = \frac{n}{n-b} p_g < \frac{\ell}{\bar{r}}$, non-disclosure implies no investment

- When $v > r$, disclosure helps avoid outsiders funds being diverted
- Downstream banks safer than upstream banks
- Banks don’t internalize, so undersupply information

If $Pr(e_j = \pi) = \frac{n}{n-b} p_g > \frac{\ell}{\bar{r}}$, non-disclosure implies investment

- Again, disclosure helps avoid outsiders funds being diverted
- Banks don’t internalize, so undersupply information
Three strands of related theoretical literature

- Literature on Networks of Financial Institutions:
  - Survey in Allen and Babus (2009)
  - Allen-Gale, Einseberg-Noe, Caballero-Simsek, Acemoglu- Oezdaglar-Tahbaz.
  - Generalization of Caballero-Simsek ring + General Symmetric network.

- Literature on Disclosure of Information
  - Large literature on disclosure, starting from Milgrom (1981) and Grossman (1981)
  - Admati and Pfleiderer (2000) also model informational spillovers
  - We still obtain new results regarding disclosure