Chained Financial Failures at Nation-wide Scale in Japan

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Banks-Firms credit

Interbank

Banks

Firms

Firms’ credit on supplier-customer NW
Distress propagation on Banks-Firms credit

Distress propagation on Supplier-Customer NW

0.2K #Banks

2M #Firms
Credit network between banks and firms
= bipartite graph with weights

\[ C_{\beta f} \]
\[ = \text{amount of credit} \]
Distress propagation between banks and firms

\[ x_\beta : \text{level of bank } \beta \text{'s financial distress} \]

corresponding to
✓ shrinking amount of supplied credit
✓ increasing interest-rate
✓ shortening the due time of repayment

\[ y_f : \text{level of firm } f \text{'s financial distress} \]

causing
✓ delaying repayment to banks
✓ default / bankruptcy
Data

- **firms**: listed in Japanese stock-exchange markets covering large firms
- based on financial statements & surveys by *Nikkei, Inc.*
- short-term + long-term borrowings from financial institutions

- **banks**: commercial banks are selected
  - long-term and city banks
  - regional (primary/secondary) trust banks
  - insurance companies
  - others (credit associations, agricultural, Shoko Chukin)
Firms’ debt from banks

Source: Small & Medium Enterprise Agency (2008)

Large: capitalized at 100M yen or more
Small-Medium: otherwise

~160T yen
#L-firms= 1.25%
#S-firms= 98.75%
• annual snapshots: from 1980 to 2005
• bankrupted or merged banks included; #banks ~ 230
• surviving firms included; #firms ~ 2,000
A small fraction of firms account for nearly all loans due to long-tailed distribution of debt.
And similarly for long-tailed distribution of banks’ lending amount.
MST: closer banks have similar lending
City and metropolitan banks

Tokyo Mitsubishi UFJ
Mizuho
Mitsui Sumitomo
Risona
Regional banks

Banks in Tohoku region

Banks in Hokkaido and Northern regions
Regional banks

Banks in Chubu region

Banks in Kinki region
- bank supplies credit in anticipation of interest margin
- firm uses credit as a source of financing in anticipation of growth in its business

\[ \text{edge of credit} = \text{dependency} \]

A same amount of credit has different importance to bank \( \beta \) and firm \( f \).
Dependency or Relative Exposure

bank $\beta$ on firm $f$  
$w_{f \rightarrow \beta} := \frac{C_{\beta f}}{C_{\beta}}$

$C_{\beta} := \sum_{f} C_{\beta f}$

diagram:

banks

firms

Distress propagation

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Dependency or Relative Exposure

\[ w_{\beta \rightarrow f} := \frac{C_{\beta f}}{C_f} \]

\[ C_f := \sum_{\beta} C_{\beta f} \]

Dependence or relative exposure of firm \( f \) on bank \( \beta \):

- Total borrowing:
  \[ C_f := \sum_{\beta} C_{\beta f} \]

- Graph representation:
  - Banks 1, 2, 3
  - Firms
  - Distress propagation

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(1) Eigenvector Approach

\[ \vec{y} \propto w_{\beta \rightarrow f} \cdot \vec{x} \]

\[ \vec{x} \propto w_{f \rightarrow \beta} \cdot \vec{y} \]

\[ P \vec{x} = \lambda \vec{x} \]

\[ P := w_{f \rightarrow \beta} \cdot w_{\beta \rightarrow f} \]

banks’ distress = solution of eigenvalue problem
The propagation of fragility-profile is given by:

\[ P^r \tilde{x} = \lambda_2^r a_2 \tilde{x}^{(2)} + \lambda_3^r a_3 \tilde{x}^{(3)} + \cdots + \lambda_n^r a_n \tilde{x}^{(n)} \]

\[ = \lambda_2^r \left[ a_2 \tilde{x}^{(2)} + \left( \frac{\lambda_3}{\lambda_2} \right)^r a_3 \tilde{x}^{(3)} + \cdots + \left( \frac{\lambda_n}{\lambda_2} \right)^r a_n \tilde{x}^{(n)} \right] \]

This can be expanded by eigen-modes as:

\[ \tilde{x} := \bar{x} \quad \text{without trivial-mode} \]

where

\[ 1 = \lambda_1 \geq \lambda_2 \geq \lambda_3 \cdots \lambda_n > 0 \]

larger eigenvalues ~ more robust modes
- strong peak in the late 80s
- drop in 1990
- peaks in 1992 and 1997
Bubble in the late 80s
→ Large firms became less dependent on bank loans after financial deregulation
→ Many banks increased loans to real-estate

Bubble collapse in 1990
→ Financial institutions had accumulated loan losses nearly 80 T Yen (15% of GDP)

Long recovery in 90s and even longer
→ Reduced bank capitalization
→ Failures of 3 major banks and other small banks in 1997
  2 of the 3 banks nationalized
→ other political decisions for stability of financial system 1991/92
→ most banks decreased the supply of credit immediately even by reducing existing loans
→ firms suffered loss of funding for a decade or longer

components of eigenvectors \( |x^{(2)}_\beta| + |x^{(3)}_\beta| \)

- stable patterns 80-85, 00-05
- change in late 80s
- bubble collapse and 90s
- back to previous profile with more peaks in late 90s
(2) DebtRank approach (S. Battiston et al., 2012)

\[
\begin{align*}
\dot{h}_\beta(t + 1) &= h_\beta(t) + \sum_{f} w_{f \rightarrow \beta} h_f(t) \\
\dot{h}_f(t + 1) &= h_f(t) + \sum_{\beta} w_{\beta \rightarrow f} h_\beta(t)
\end{align*}
\]
$s_{\beta,f}(t) \in [\text{UNDISTRESSED, ACTIVE, INACTIVE}]$

INACTIVE =
It cannot propagate distress to others, while it can receive distress from others.

$h_\beta(t = 0) = \begin{cases} 1 & \text{for } \beta = \beta_0 \\ 0 & \text{for others} \end{cases}$
DebtRank

\[ h_{\beta_0} = \sum_{\beta \neq \beta_0} h_\beta \frac{A_\beta}{\sum \alpha A_\alpha} + \sum_f h_f / N_f \]

Total impact to financial system

Total impact to firms

\[ A_\beta \] Total-assets of bank
DebtRank of Japanese Banks: 1986

- city banks
- regional banks
- long-term
- trust banks

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DebtRank of Japanese Banks: 1990

- city banks
- regional banks
- long-term
- trust banks
DebtRank of Japanese Banks: 1992

- city banks
- regional banks
- long-term
- trust banks

Graph showing the relationship between DebtRank and Total Asset for different types of banks in 1992.
DebtRank of Japanese Banks: 1993

- City banks
- Regional banks
- Long-term
- Trust banks
DebtRank of Japanese Banks: 1994

- city banks
- regional banks
- long-term
- trust banks

![Graph showing DebtRank of Japanese Banks in 1994](image-url)
DebtRank of Japanese Banks: 1995

- City banks
- Regional banks
- Long-term
- Trust banks

Graph showing the relationship between DebtRank and Total Asset for different types of banks in 1995.
DebtRank of Japanese Banks: 1997

- city banks
- regional banks
- long-term
- trust banks

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DebtRank of Japanese Banks: 1999

- city banks
- regional banks
- long-term
- trust banks

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DebtRank of Japanese Banks: 2001

- City banks
- Regional banks
- Long-term
- Trust banks

Total Asset vs. DebtRank graph showing the distribution of Japanese banks based on their total asset and DebtRank.
DebtRank of Japanese Banks: 2002

- city banks
- regional banks
- long-term
- trust banks

Graph showing the DebtRank of Japanese banks in 2002, categorized by type of bank and their total asset.
DebtRank of Japanese Banks: 2003

- city banks
- regional banks
- long-term
- trust banks

Total Asset

DebtRank
DebtRank of Japanese Banks: 2004

- City banks
- Regional banks
- Long-term
- Trust banks

Total Asset vs. DebtRank
DebtRank of Japanese Banks:

- city banks
- regional banks
- long-term
- trust banks

Year: 2005
summary

- Structure and temporal change of credit network between banks and large firms from 1985 for 25 yrs with each snapshot as a bipartite weighted graph
- Influence from debtor to creditor, and vice versa quantified by relative exposure
- Distress propagation can be described by
  1. Eigenvalue problem
  2. DebtRank calculation for bipartite NW
- These methods can quantitatively describe stability / fragility of the credit NW during the past 25 years
Papers (downloadable)

Y. Fujiwara, H. Aoyama, Y. Ikeda, H. Iyetomi, and W. Souma, Structure and temporal change of credit network between banks and large firms in Japan Economics E-Journal (2009); arxiv/0901.2377
