Financial Distress Propagation in Japanese Credit Network

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DebtRank Analysis of the Japanese Credit Network

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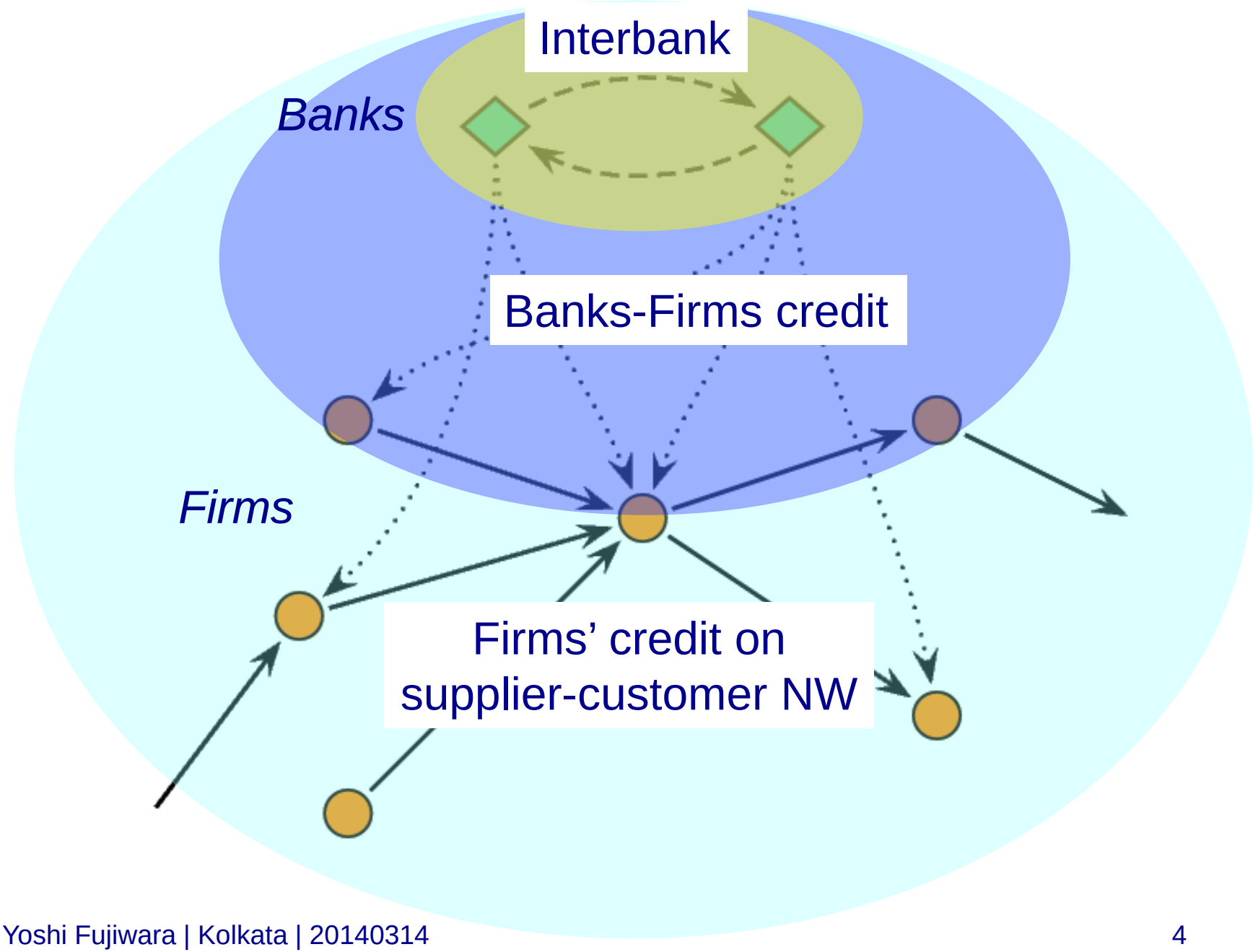
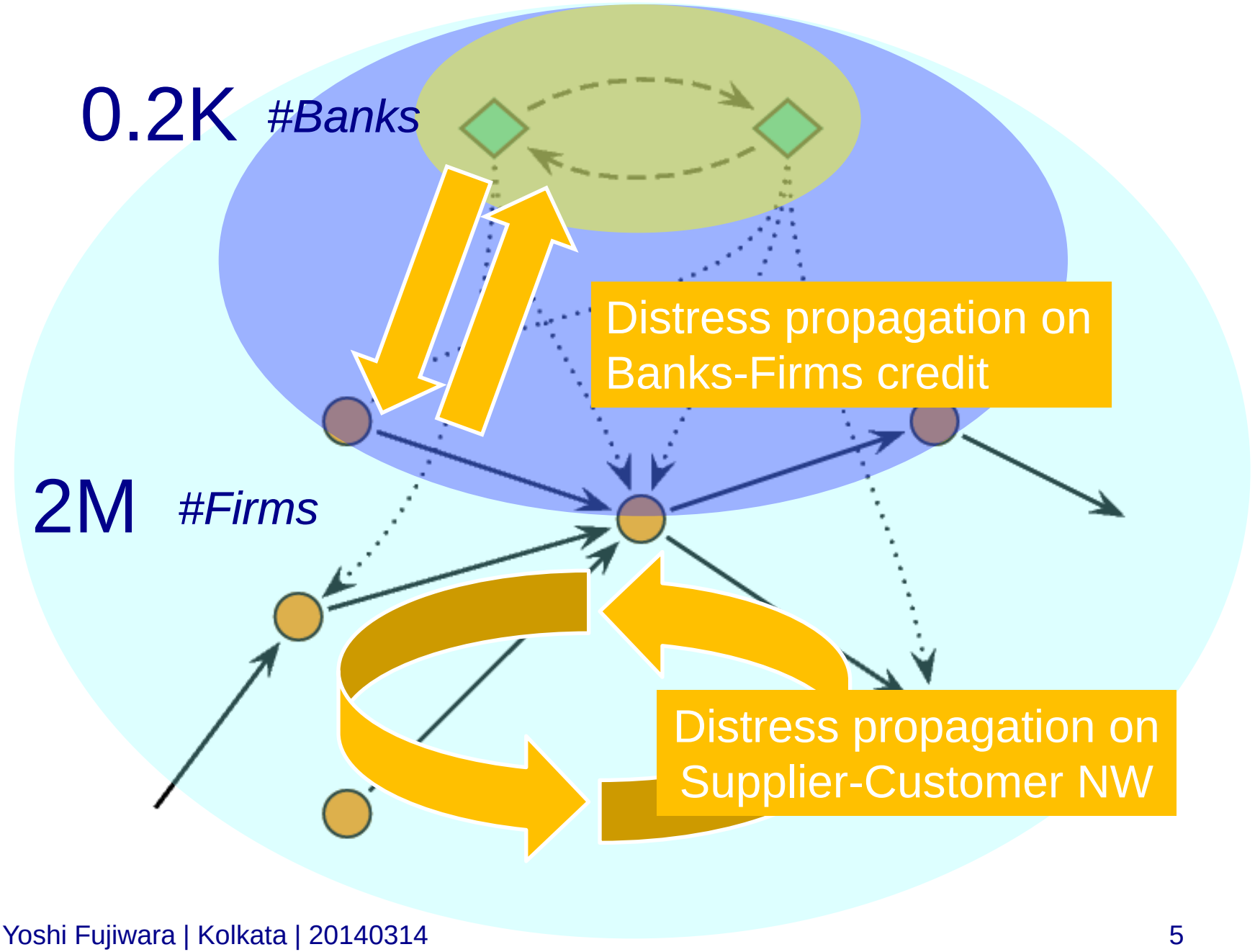
RIETI
Research Institute of Economy, Trade & Industry, IAA
The Research Institute of Economy, Trade and Industry
http://www.rieti.go.jp/en/

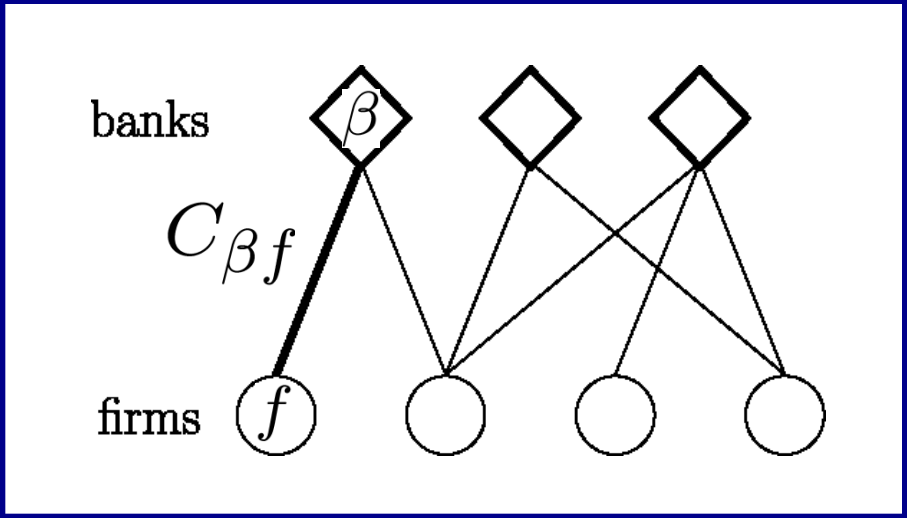
Ministry of Economy, Trade and Industry, Japan


Interbank
Banks
Banks-Firms credit
Firms
Firms' credit on
supplier-customer NW


0.2K #Banks
2M #Firms
Distress propagation on Banks-Firms credit
Distress propagation on Supplier-Customer NW

Banks-firms Credit NW

Credit network between banks and firms
= *bipartite graph* with weights



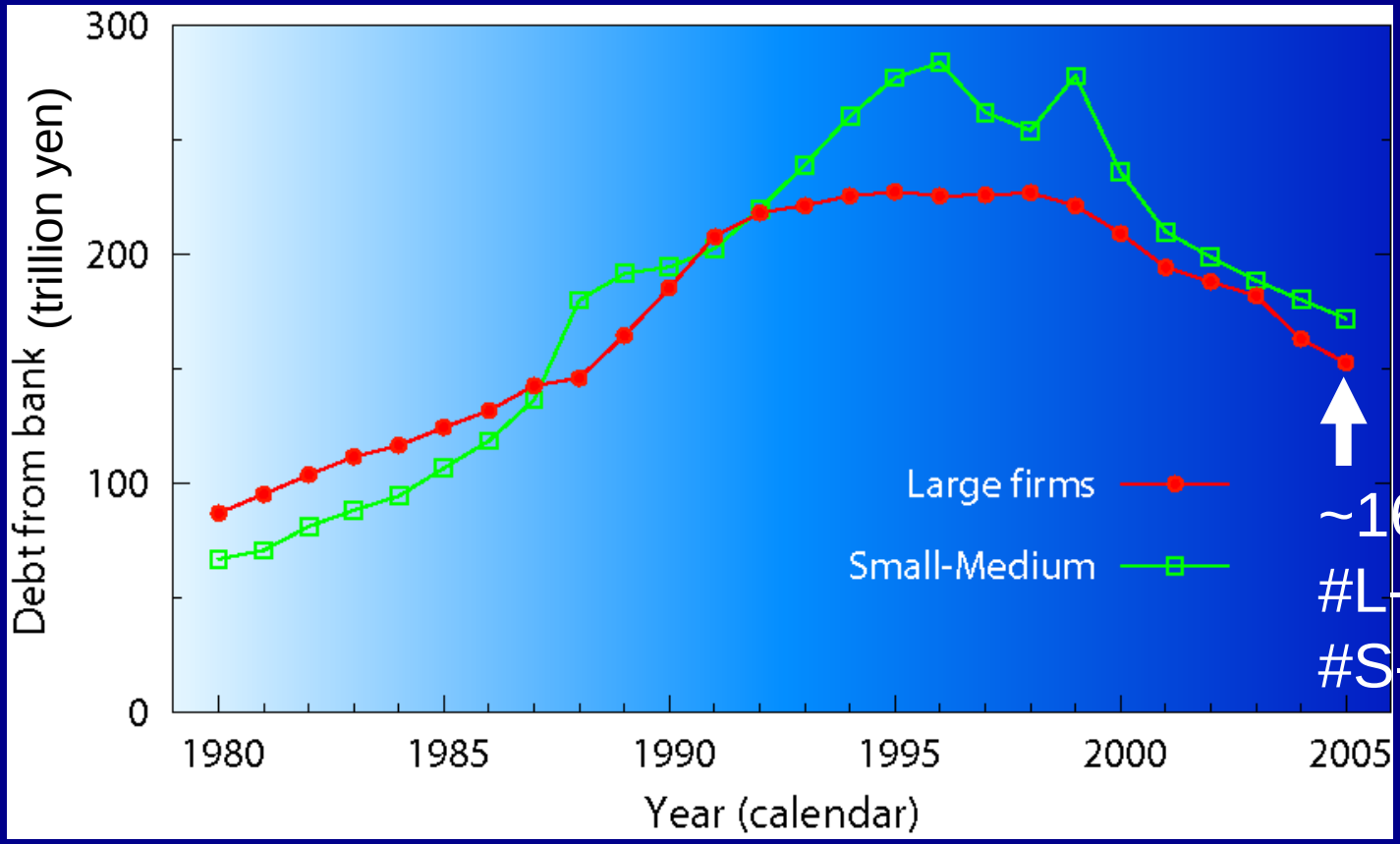
$C_{\beta f}$
= amount of credit

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

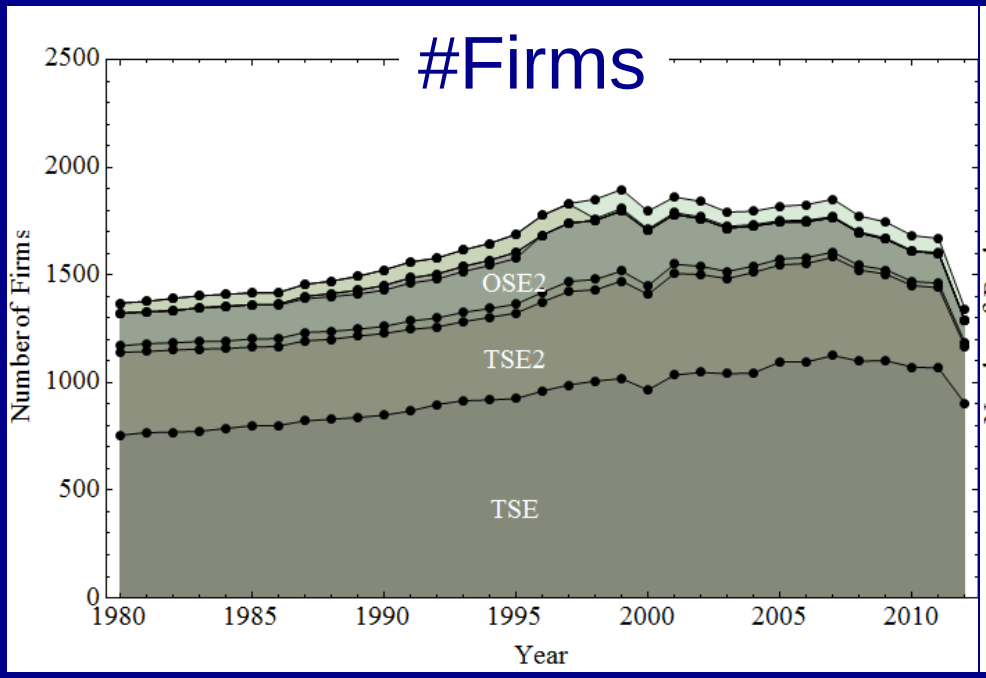


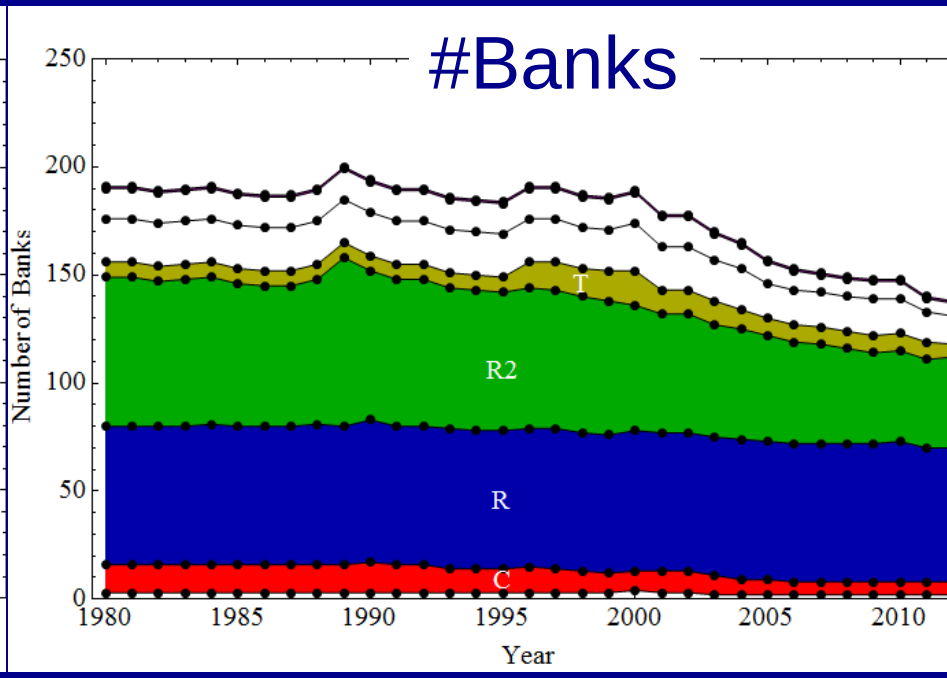
~160T yen
#L-firms= 1.25%
#S-firms= 98.75%

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

Source: *Small & Medium Enterprise Agency (2008)*

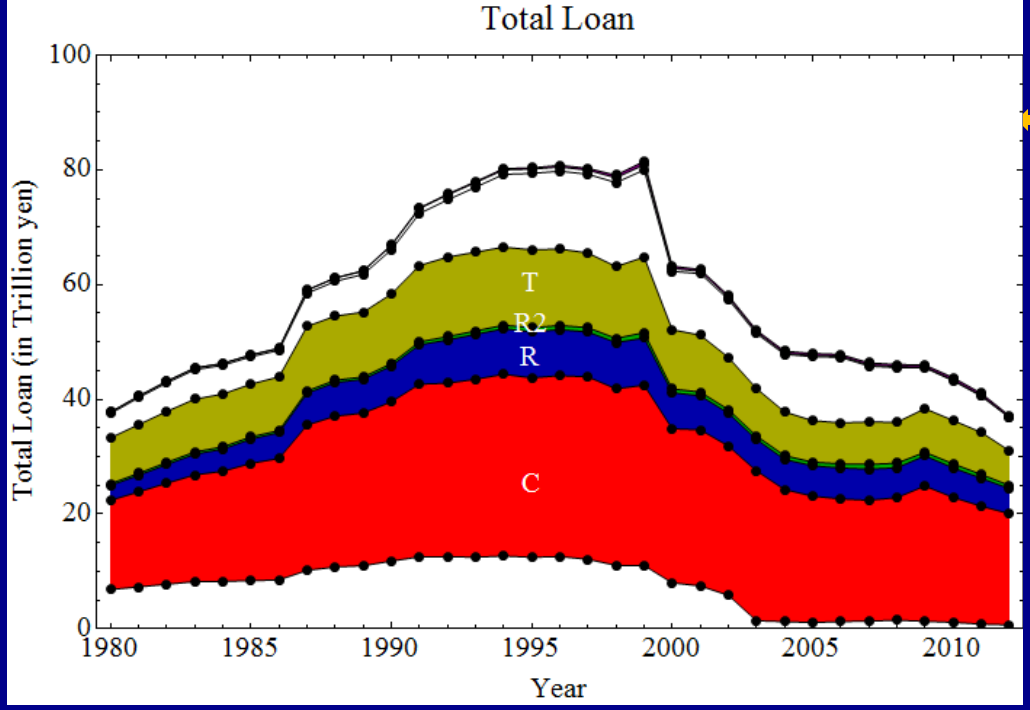
- annual *snapshots*: from 1980 to 2011
- bankrupted / merged banks in each yr; #banks ~ 200
- surviving firms in each yr; #firms ~ 2,000



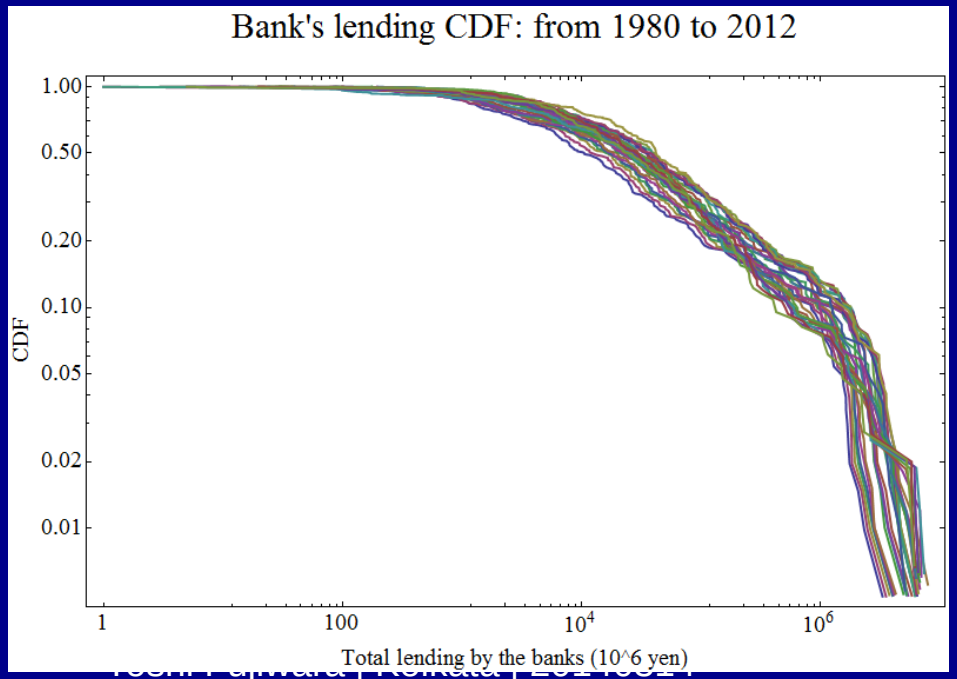


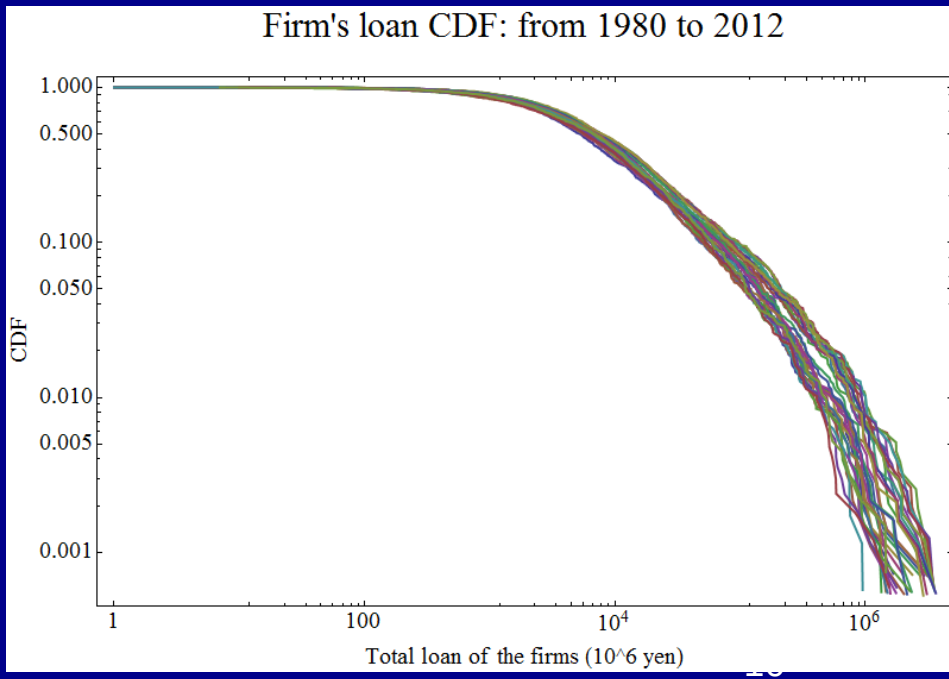
TSE: Tokyo Stock Exchange
OSE: Osaka Stock Exchange

- City bank
- Regional bank
- 2nd Regional bank
- Trust bank
- Credit Associaton

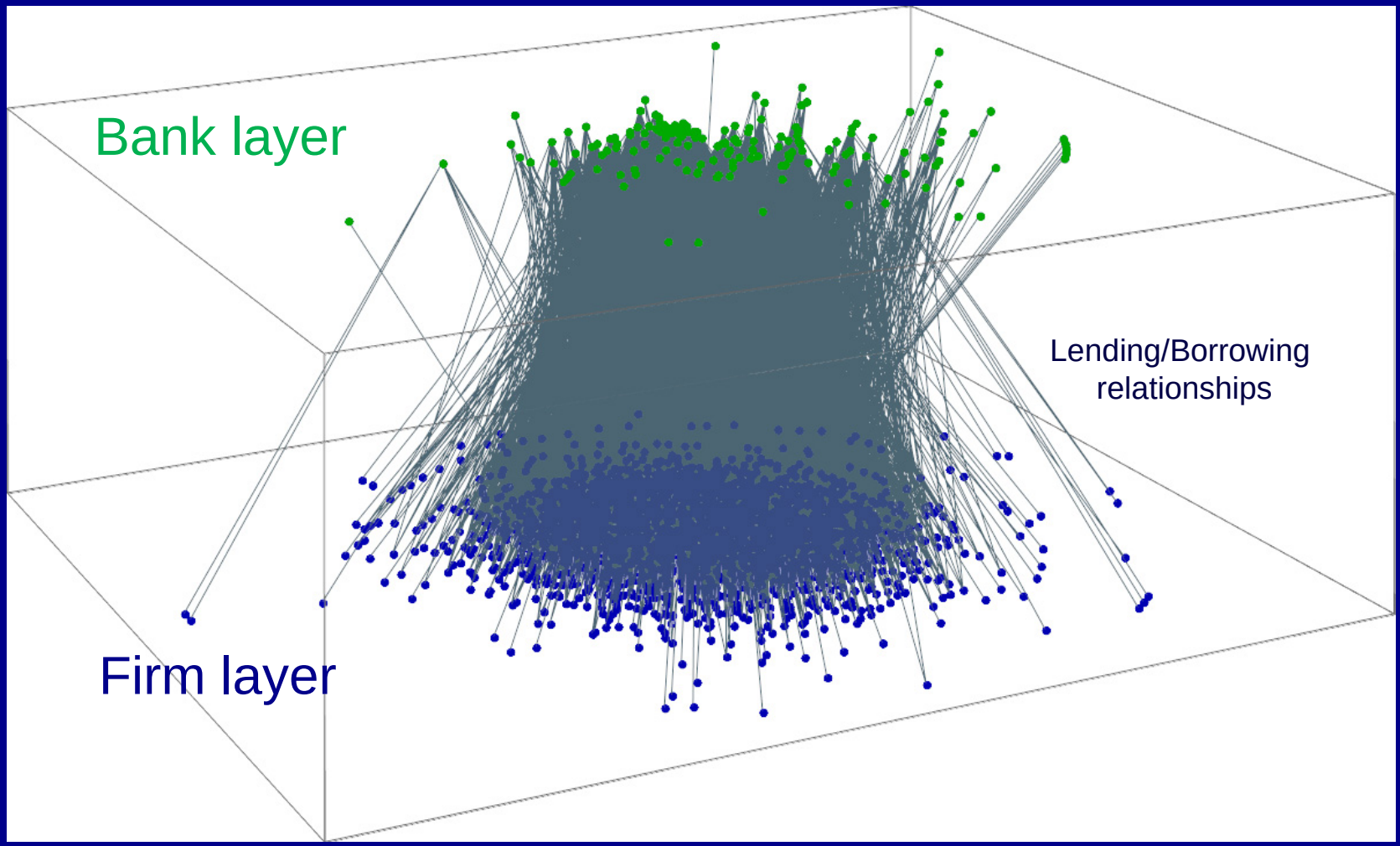


Trillion U.S. Dollars

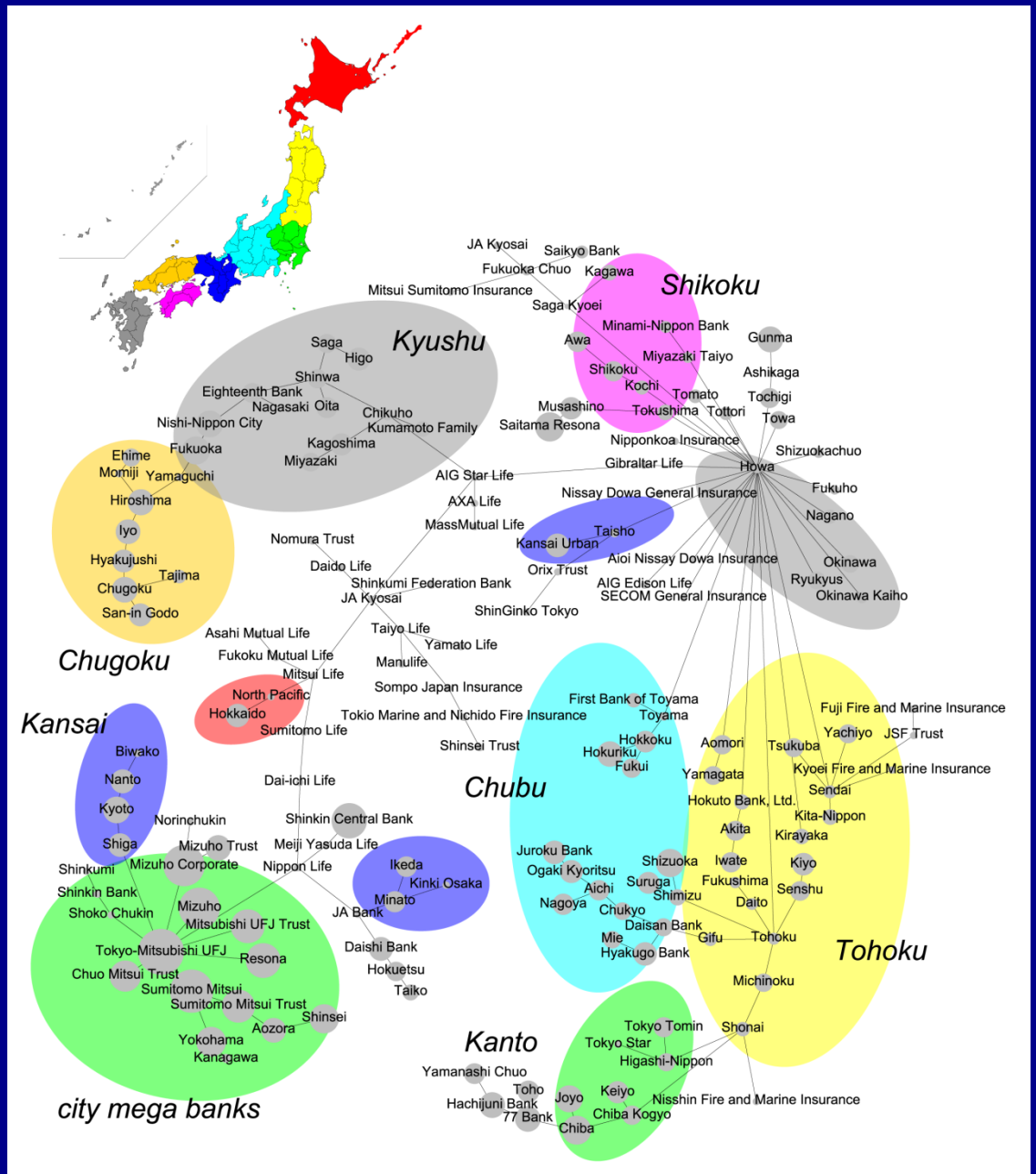




Visualized bipartite NW



Minimum Spanning Tree



Spatially closer banks have similar lending patterns to firms

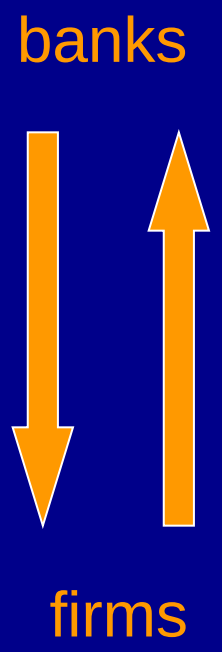
Distress propagation between banks and firms

x_β : level of bank β 's financial distress

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

y_f : level of firm f 's financial distress

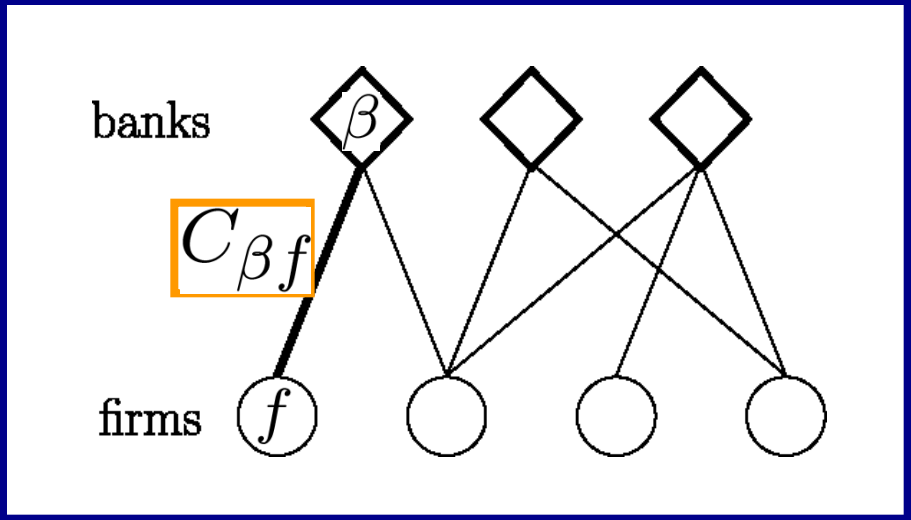
causing
- ✓ delaying repayment to banks
- ✓ default / bankruptcy



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

→ *edge of credit* = dependency of one agent on the other

a same amount of credit
has different importance to
bank β and firm f



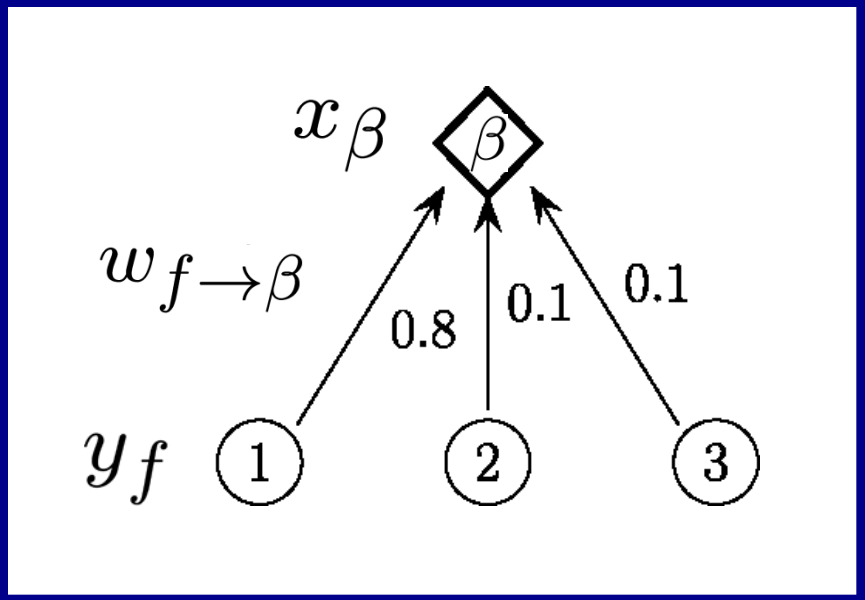
Dependency or Relative Exposure

dependency of bank β on firm f

$$w_{f\to\beta} := \frac{C_{\beta f}}{C_\beta}$$

total lending

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



banks

Distress propagation

firms

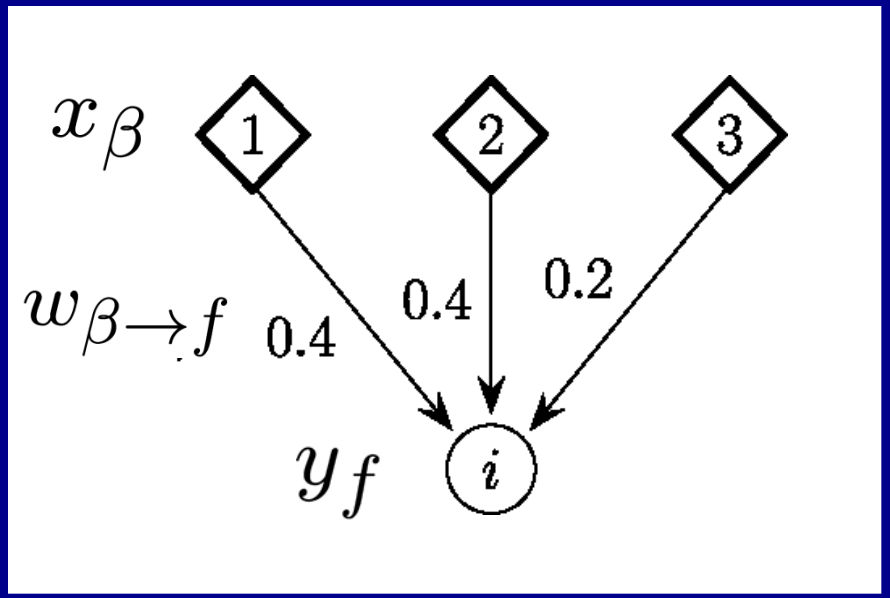
Dependency or Relative Exposure

dependency of firm f on bank β

$$w_{\beta \to f} := \frac{C_{\beta f}}{C_f}$$

total borrowing

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

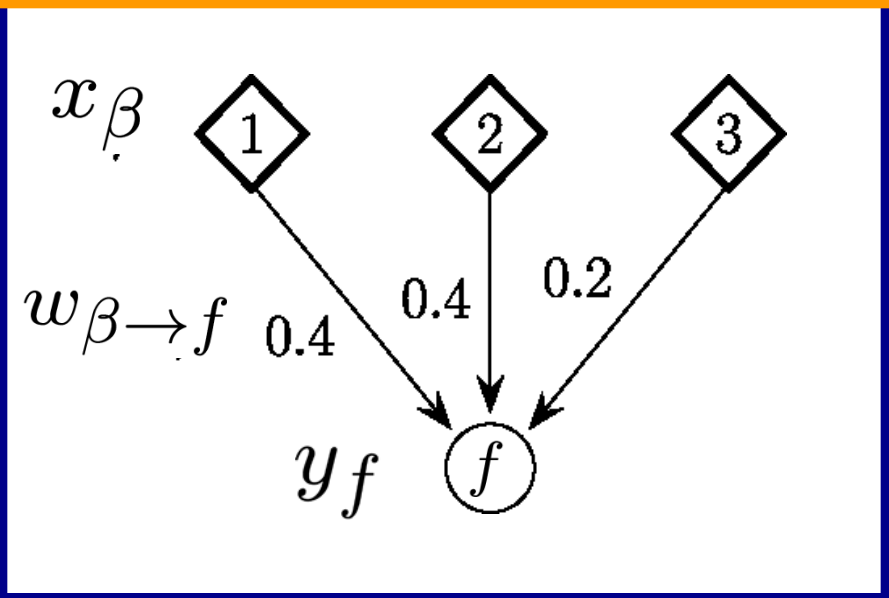


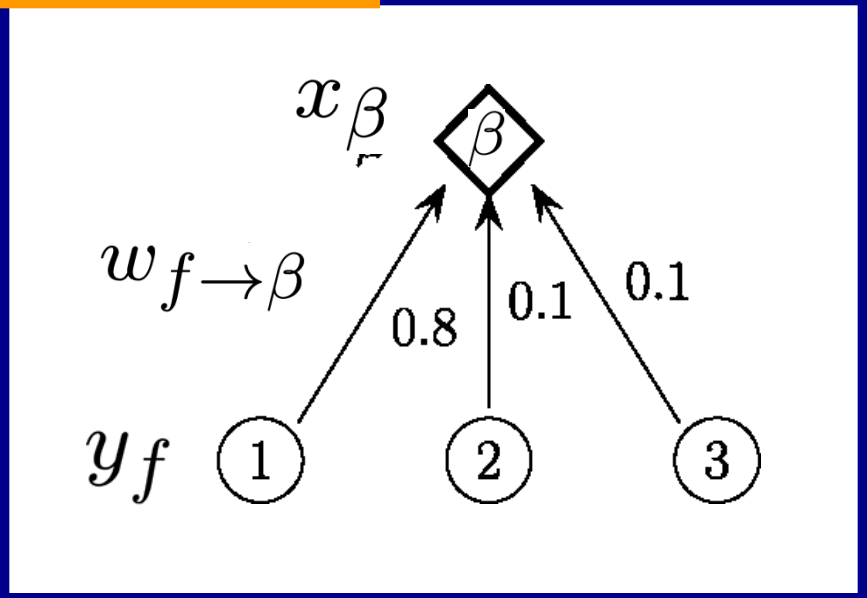
banks

Distress propagation

firms

(1) Eigenvector Approach





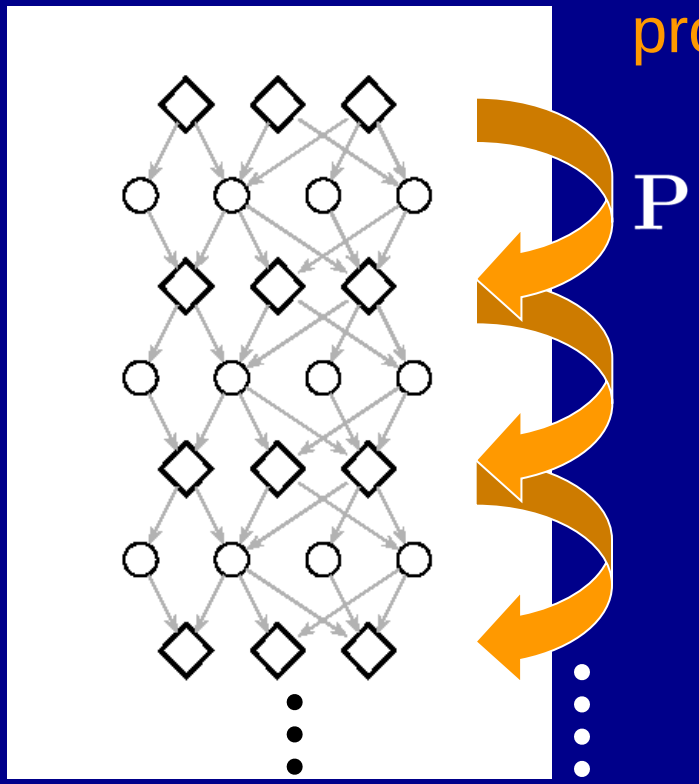
$$\vec{y} \propto \mathbf{w}_{\beta\to f} \cdot \vec{x}$$

$$\vec{x} \propto \mathbf{w}_{f\to\beta} \cdot \vec{y}$$

$$\mathbf{P}\,\vec{x} = \lambda\,\vec{x} \qquad \text{where}$$

$$\mathbf{P} := \mathbf{w}_{f\to\beta} \cdot \mathbf{w}_{\beta\to f}$$

banks' distress = solution of eigenvalue problem



propagation of fragility-profile

$\tilde{\vec{x}} := \vec{x}$ without trivial-mode

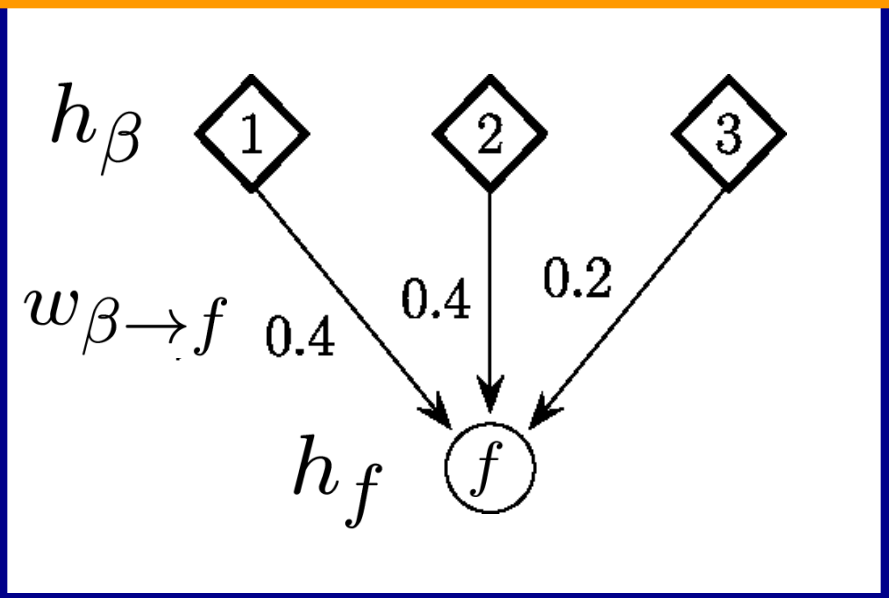
expand by eigen-modes

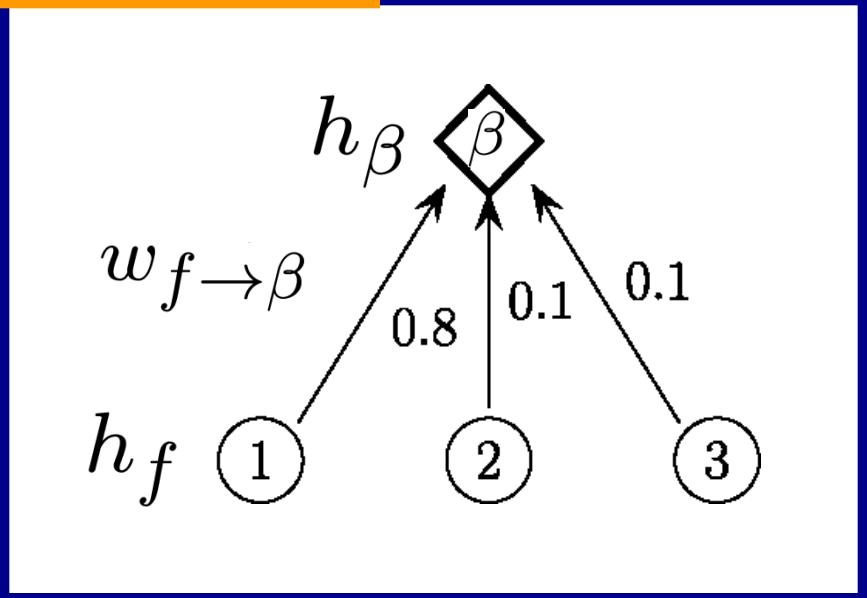
$$1 = \lambda_1 \geq \lambda_2 \geq \lambda_3 \cdots \lambda_n > 0$$

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

larger eigenvalues ~ more robust modes

(2) DebtRank approach (*S. Battiston et al.*, 2012)





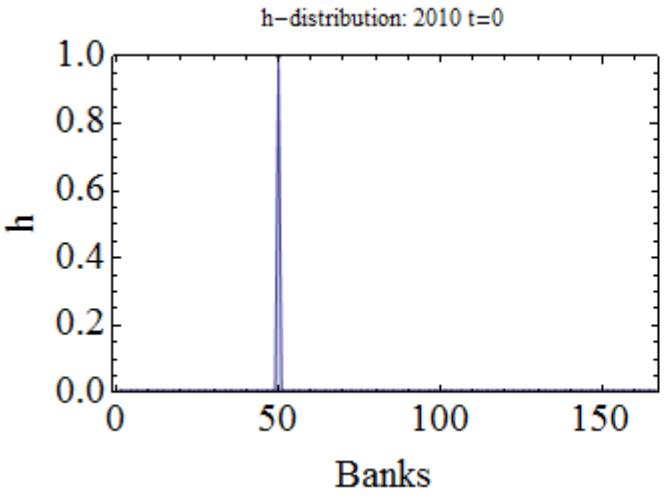
$$\begin{cases} h_\beta(t+1) = h_\beta(t) + \sum_f w_{f\to\beta}\, h_f(t) \\ h_f(t+1) = h_f(t) + \sum_\beta w_{\beta\to f}\, h_\beta(t) \end{cases}$$

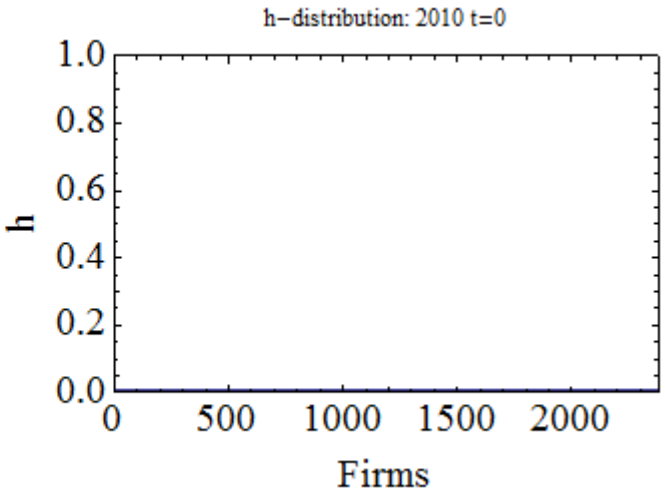
$$h_{\beta,f}(t) \in [0,1]$$

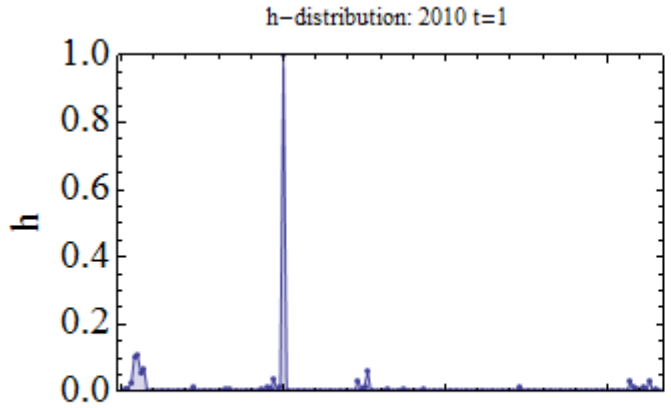
$s_{\beta,f}(t) \in$ [UNDISTRESSED, ACTIVE, INACTIVE]

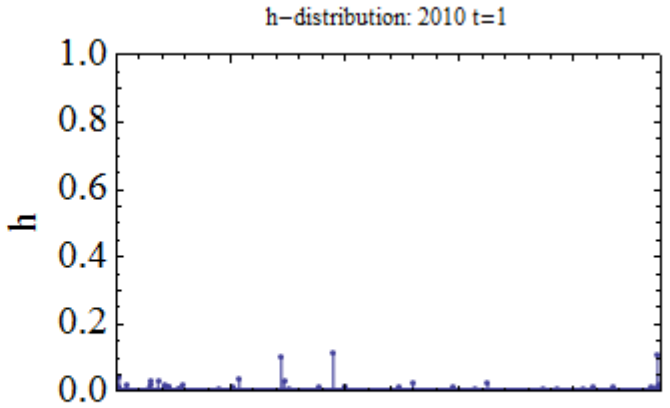
INACTIVE =
It cannot propagate distress to others,
while it can receive distress from others.

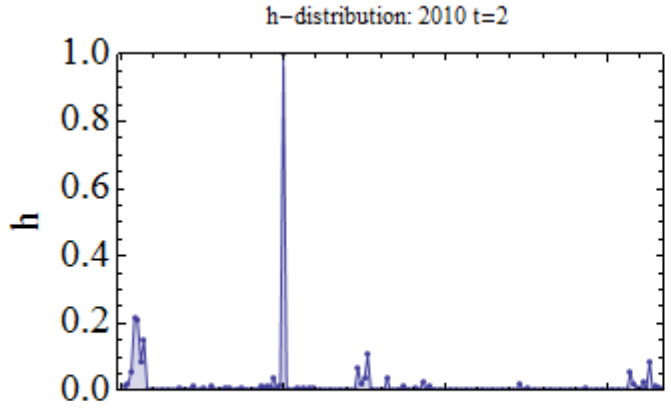
$$h_\beta(t=0) = \begin{cases} 1 & \text{for } \beta = \beta_0 \\ 0 & \text{for others} \end{cases}$$

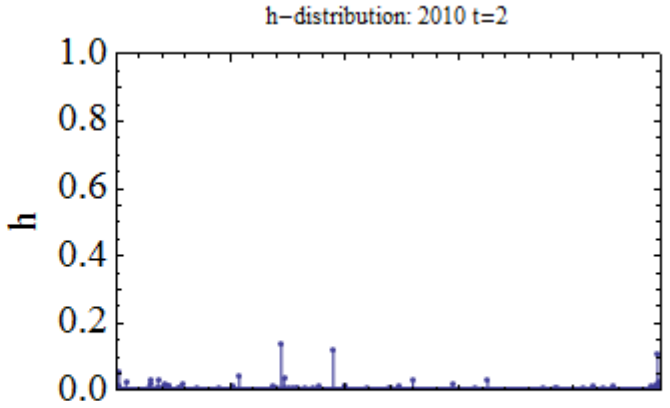


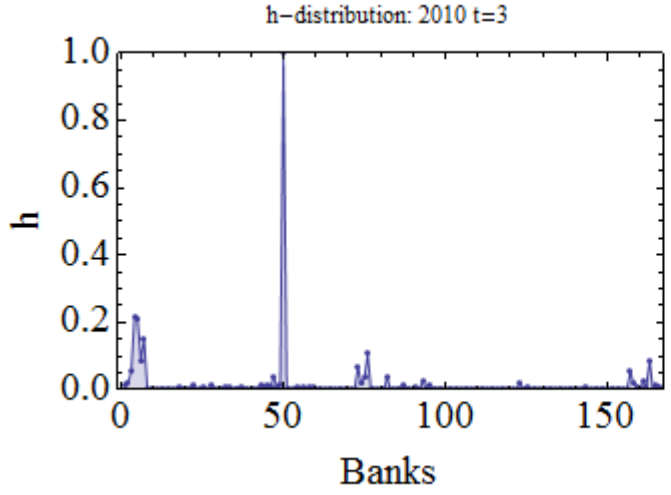


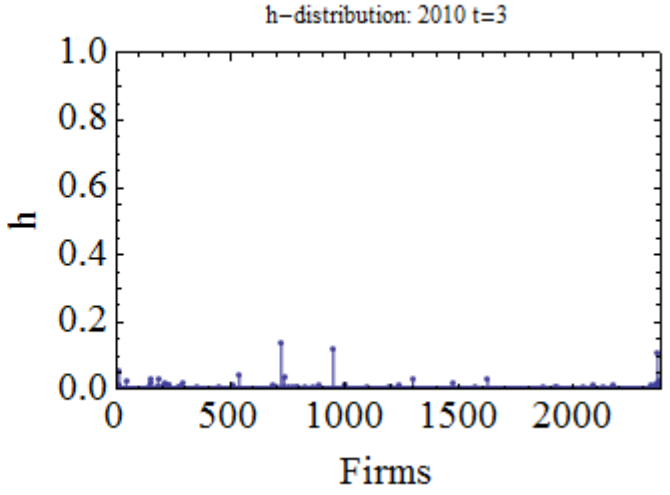

h−distribution: 2010 t=1
h
1.0
0.8
0.6
0.4
0.2
0.0


h−distribution: 2010 t=1
h
1.0
0.8
0.6
0.4
0.2
0.0


h−distribution: 2010 t=2
h
1.0
0.8
0.6
0.4
0.2
0.0


h−distribution: 2010 t=2
h
1.0
0.8
0.6
0.4
0.2
0.0


h−distribution: 2010 t=3
h
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
Banks


h−distribution: 2010 t=3
h
1.0
0.8
0.6
0.4
0.2
0.0
0
500
1000
1500
2000
Firms

DebtRank for bank β_0

$$h_{\beta_0} = \sum_{\beta \neq \beta_0} h_\beta A_\beta / \sum_\alpha A_\alpha$$

Total impact to financial system

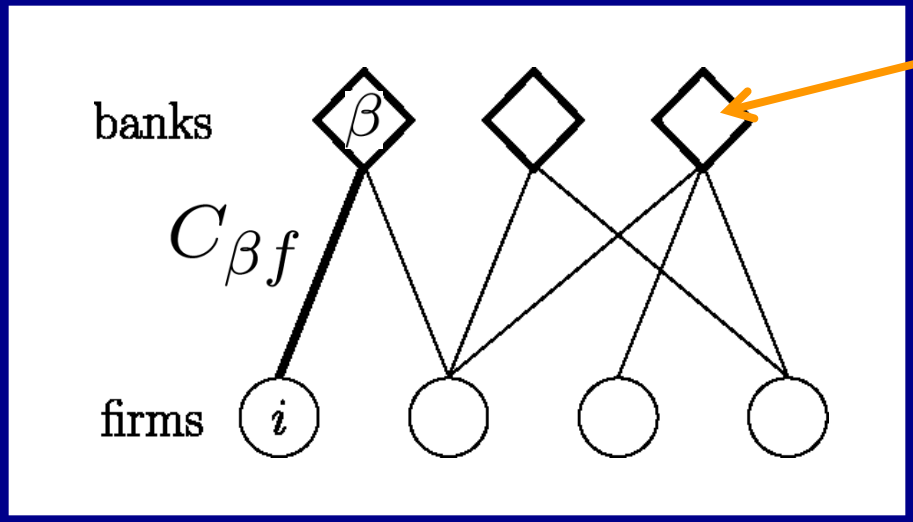
$$+ \sum_f h_f A_f / \sum_g A_g$$

Total impact to firms

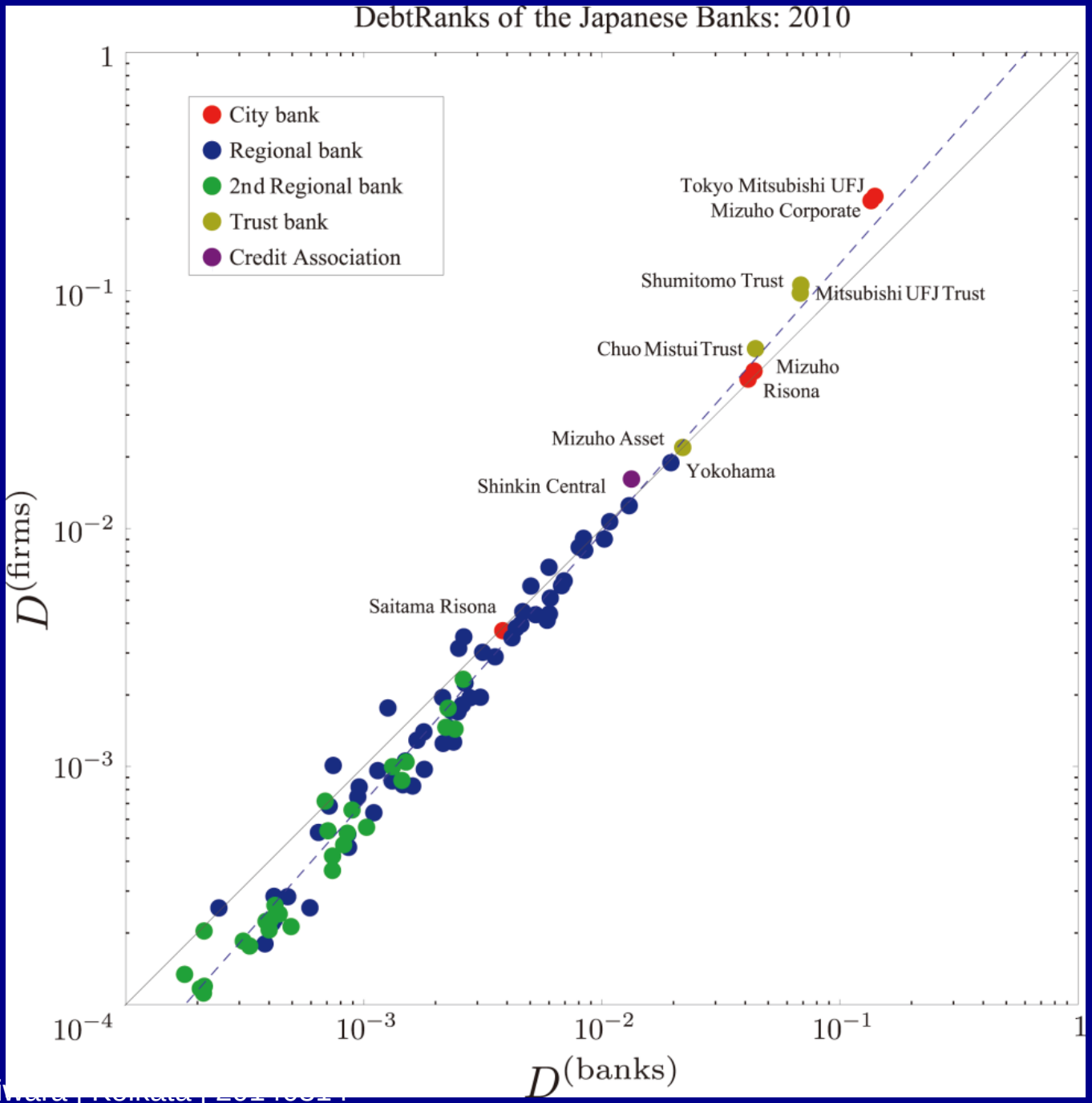
A_β Total-asset of bank (bank-size)

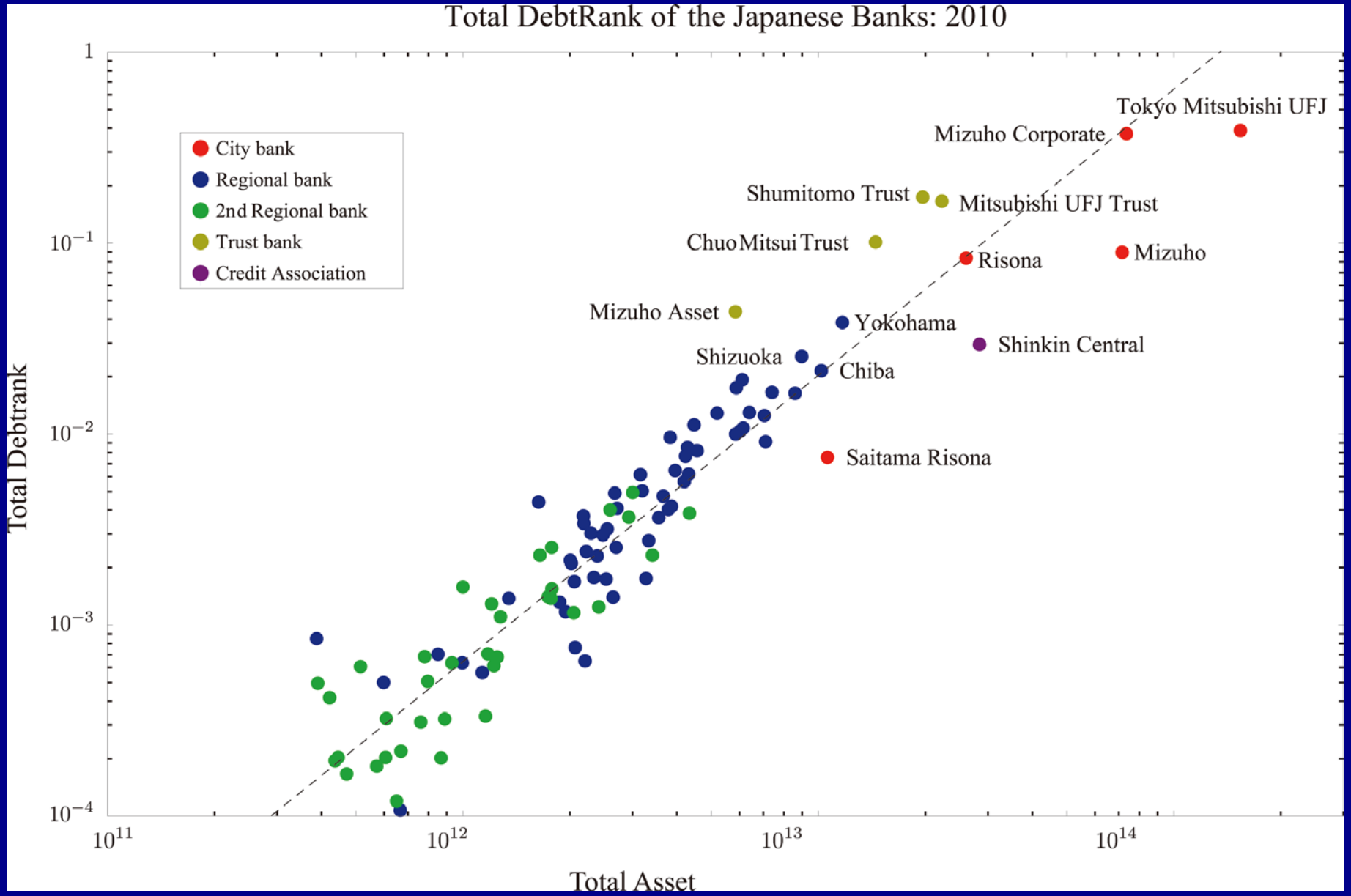
A_f Total-asset of firm (firm-size)

Simulation 1 : Distress on each bank

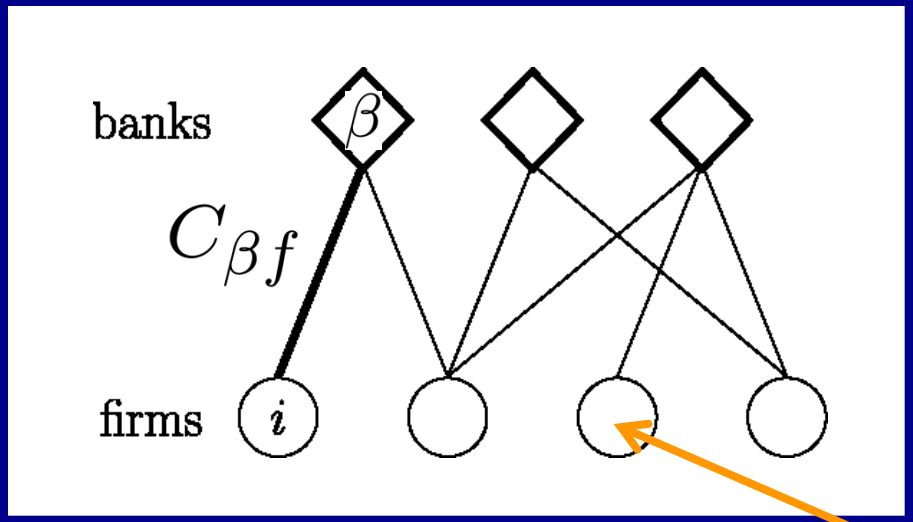


Initial distress at a bank β_0


DebtRanks of the Japanese Banks: 2010
City bank
Regional bank
2nd Regional bank
Trust bank
Credit Association
Tokyo Mitsubishi UFJ
Mizuho Corporate
Shumitomo Trust
Mitsubishi UFJ Trust
Chuo Mistui Trust
Mizuho
Risona
Mizuho Asset
Yokohama
Shinkin Central
Saitama Risona
$D^{(\mathrm{firms})}$
$D^{(\mathrm{banks})}$
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}

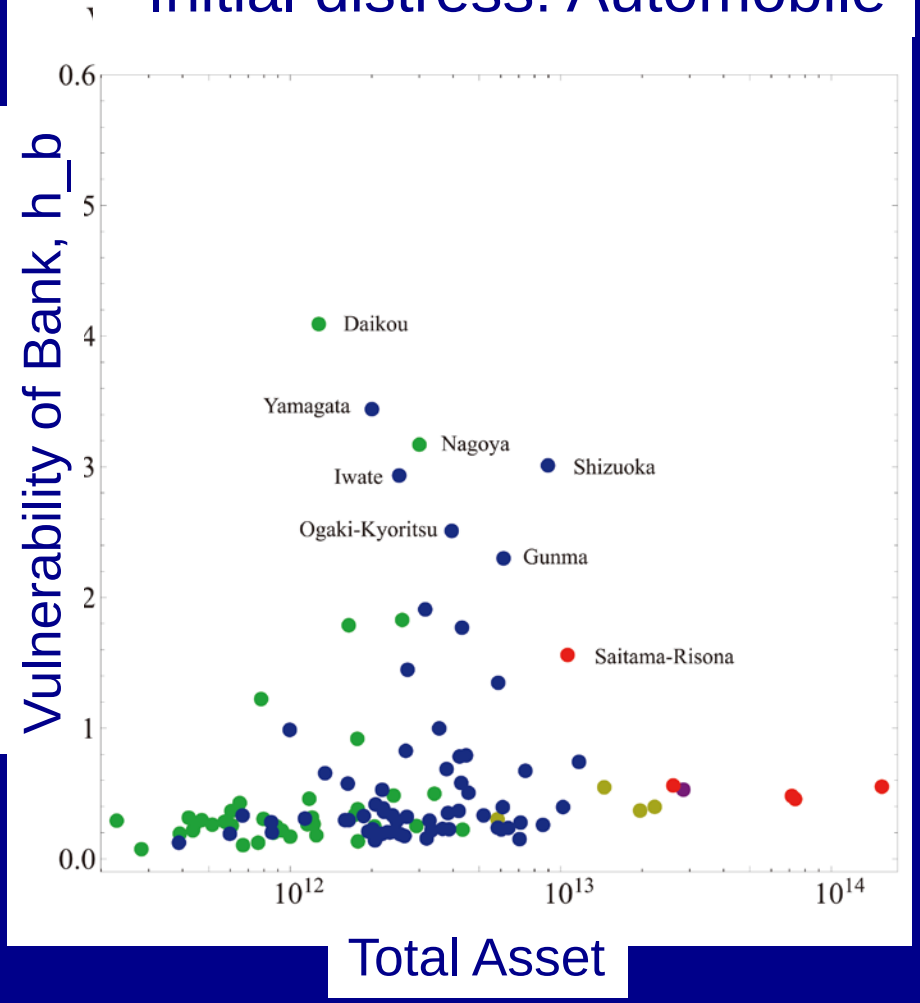

Total DebtRank of the Japanese Banks: 2010
City bank
Regional bank
2nd Regional bank
Trust bank
Credit Association
Tokyo Mitsubishi UFJ
Mizuho Corporate
Shumitomo Trust
Mitsubishi UFJ Trust
Chuo Mitsui Trust
Risona
Mizuho
Mizuho Asset
Yokohama
Shinkin Central
Shizuoka
Chiba
Saitama Risona
Total Debtrank
Total Asset
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{11}
10^{12}
10^{13}
10^{14}

Simulation 2 : Distress on firm / sector

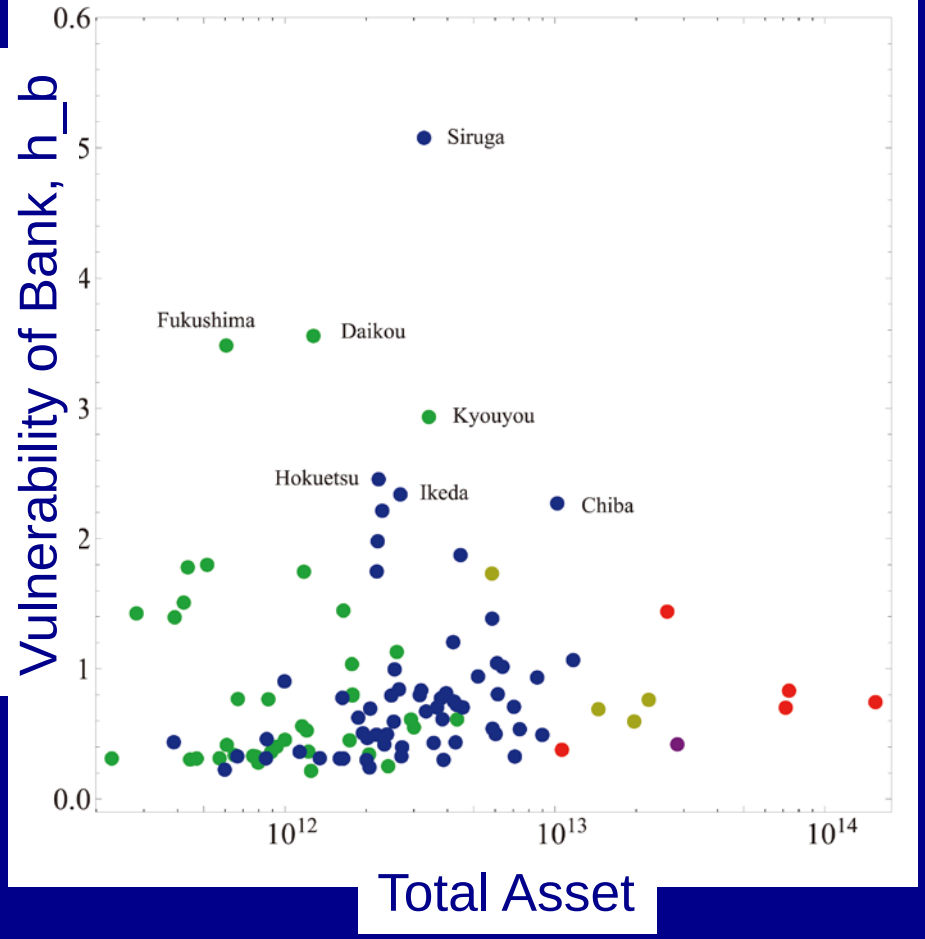


Initial distress at
a firm, or
a set of firms
(an industrial sector)

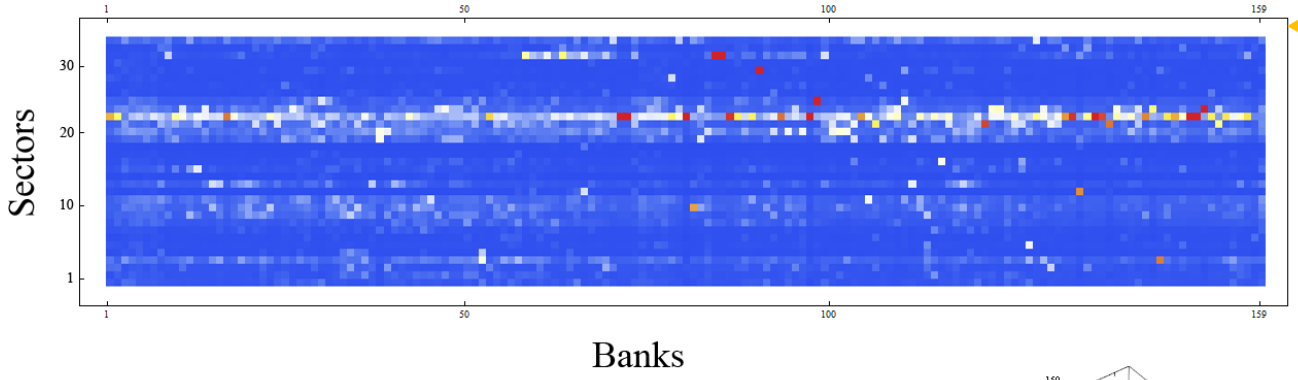
Initial distress: Automobile



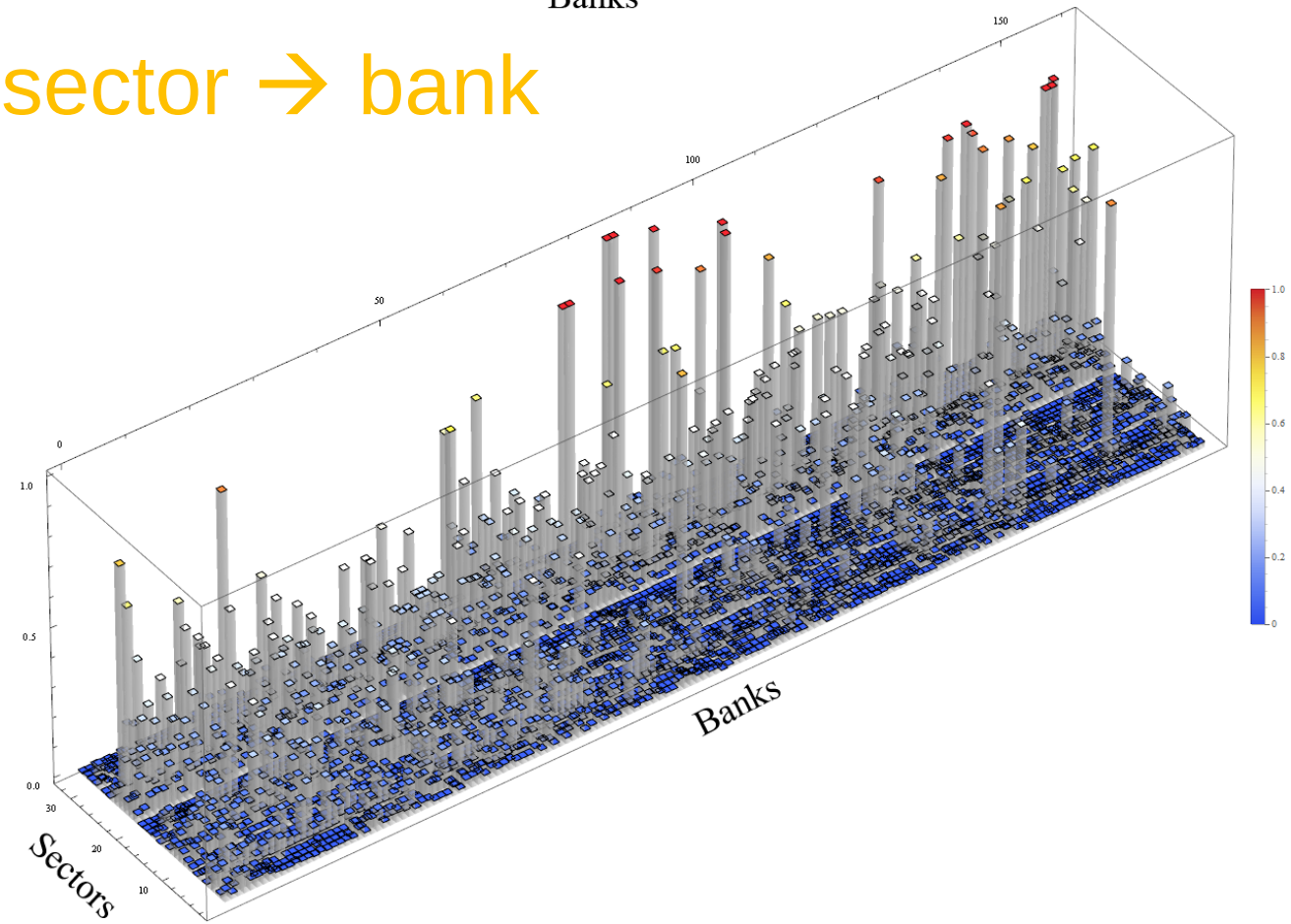
Initial distress: Construction



Initially-distressed sector



sector → bank

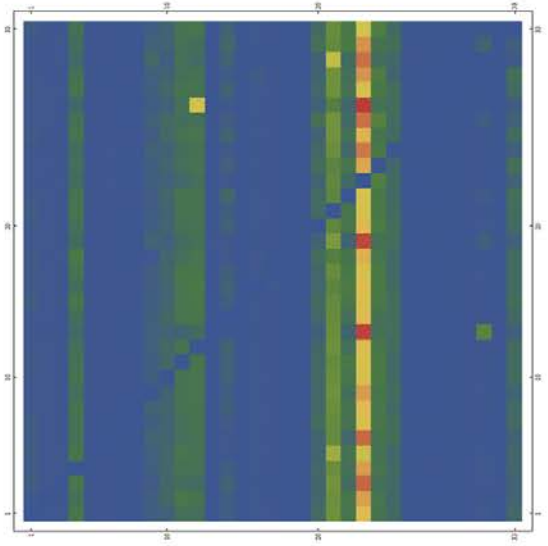


Influential order

1. Credit & Leasing
2. Retail trades
3. Wholesale trades
4. Real estates
5. Chemicals
6. Machinery
7. Electronics
8. Construction

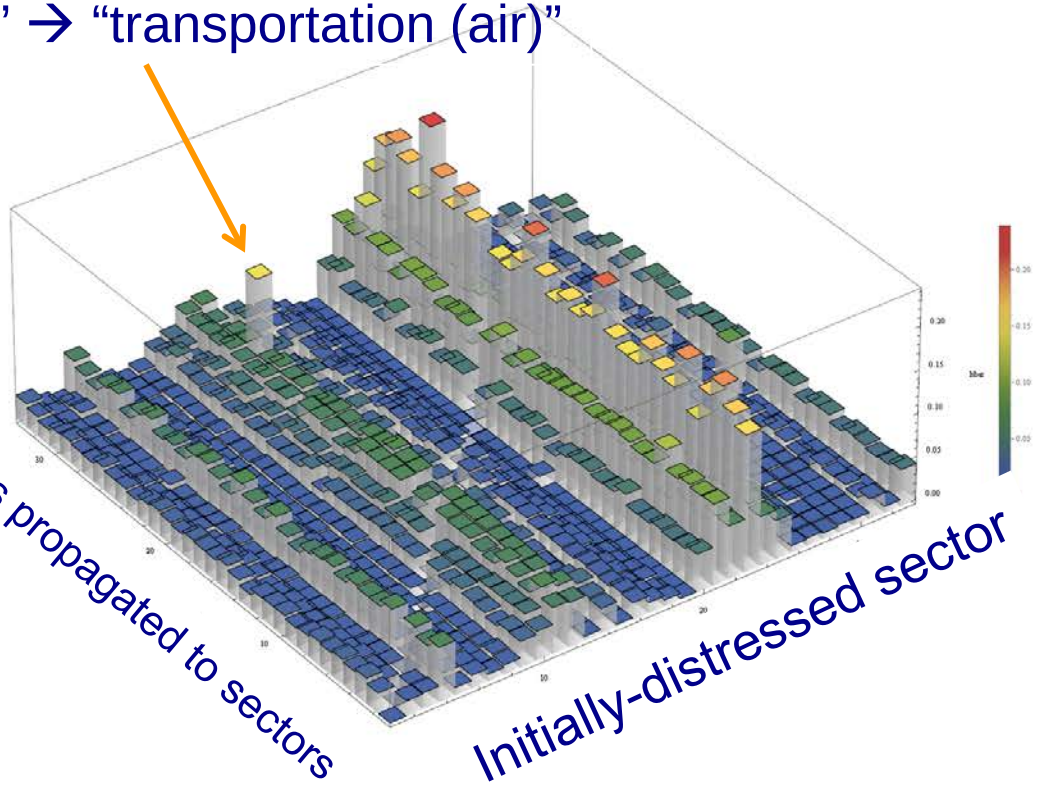
sector → sector

Distress propagated to sectors



Initially-distressed sector

“electronics” → “transportation (air)”



summary

- Extend DebtRank method to a biparite graph of banks-firms
- Use the method to quantify individual players' robustness/vulnerability
- DebtRank

  (1) Distress on a bank →

  Influence on the whole, weighted by players' sizes

  "bigger is more important" to an extent, quantifiable

  (2) Distress on industrial sector(s) →

  Influence on the banks, firms, other individual sectors

Thank you!

H. Aoyama, S. Battiston, Y. Fujiwara
DebtRank Analysis of the Japanese Credit Network
European Physical Journal B (2010); arxiv/0806.4280

G. De Masi, Y. Fujiwara, M. Gallegati, B. Greenwald, J. E. Stiglitz,
An Analysis of the Japanese Credit Network
Evolutionary and Institutional Economics Review (2011); arxiv/0901.2384

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