Credit Networks and Systemic Risk

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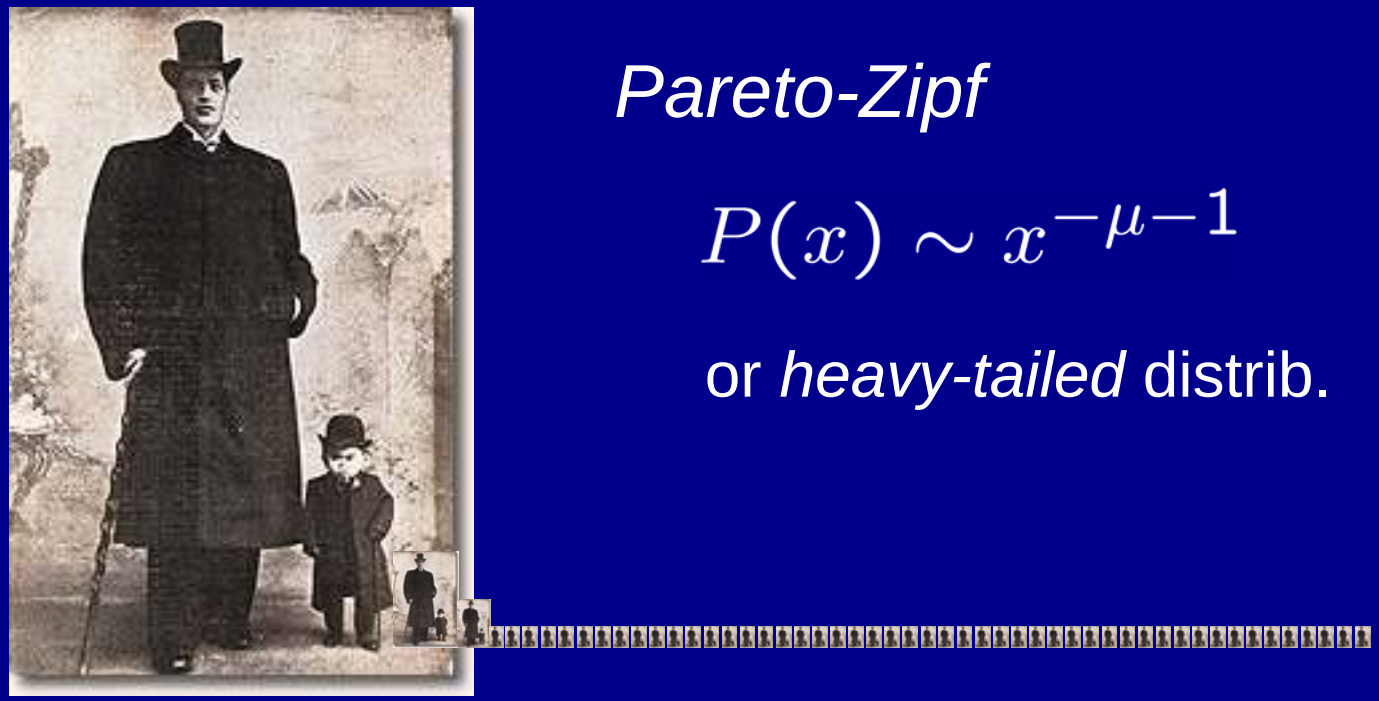
Why "economic networks" are important?

a lá "Pareto-Zipf" and fluctuations

a few giants and many dwarfs
and
they are mutually dependent for growth/failure

a few giants and many dwarfs



Pareto-Zipf

$$P(x) \sim x^{-\mu-1}$$

or *heavy-tailed* distrib.

ex.

$$X(t) = \sum_i x_i(t)$$

fluctuation

$$\frac{\delta X(t)}{X(t)} = \frac{\delta x_i(t)}{\sum_k x_k(t)} = \underbrace{\frac{x_i(t)}{\sum_k x_k(t)}}_{\text{share } s_i} \cdot \frac{\delta x_i(t)}{x_i(t)}$$

$$\mathrm{Var}\frac{\delta X(t)}{X(t)} \sim \sum_i s_i^2 \, \mathrm{Var}\frac{\delta x_i}{x_i}$$

if uncorrelated
and trivial conditions

e.g.

$s_i \sim 0.1$

$s_{j \neq i} \sim 0.9/N$

→ The giant dominate.

Gabaix, “The granular origins of aggregate fluctuations.” NBER working paper (2008)

$$X(t) = \sum_i x_i(t)$$

fluctuation

$$\mathrm{Var}\frac{\delta X(t)}{X(t)} \sim \sum_i s_i^2 \,\mathrm{Var}\frac{\delta x_i}{x_i} + \sum_{i<j} s_i\, s_j \,\mathrm{Cor}\left(\frac{\delta x_i}{x_i}, \frac{\delta x_j}{x_j}\right)$$

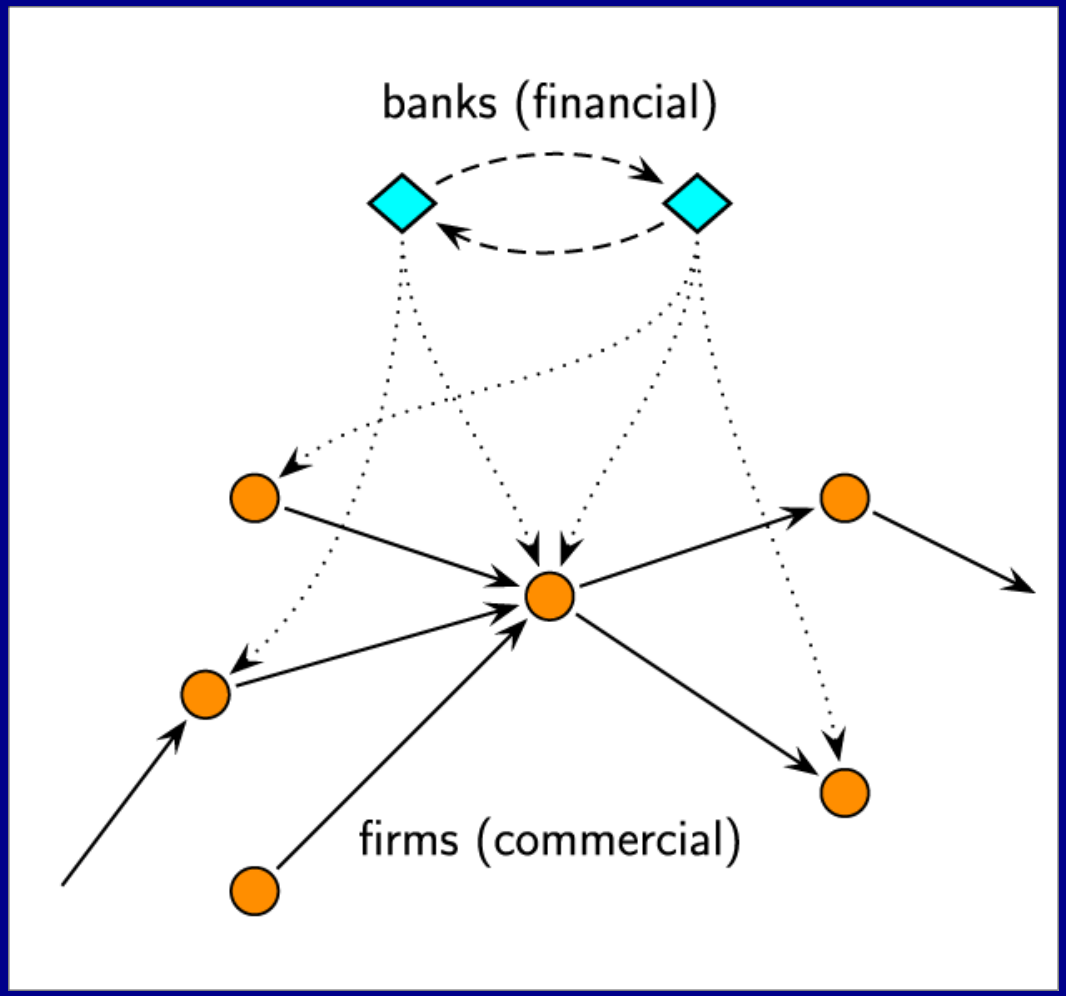
e.g.

$s_i \sim 0.1$

$s_{j\neq i} \sim 0.9/N$

→ clustered dwarfs can be comparable.

生産と金融とそれらの関係網



- - →

稲岡・二宮・谷口・清水・高安(2003)
Iori, Roberto, De Masi, Caldarelli (2007)
副島・今久保(2007)　etc.

·····→

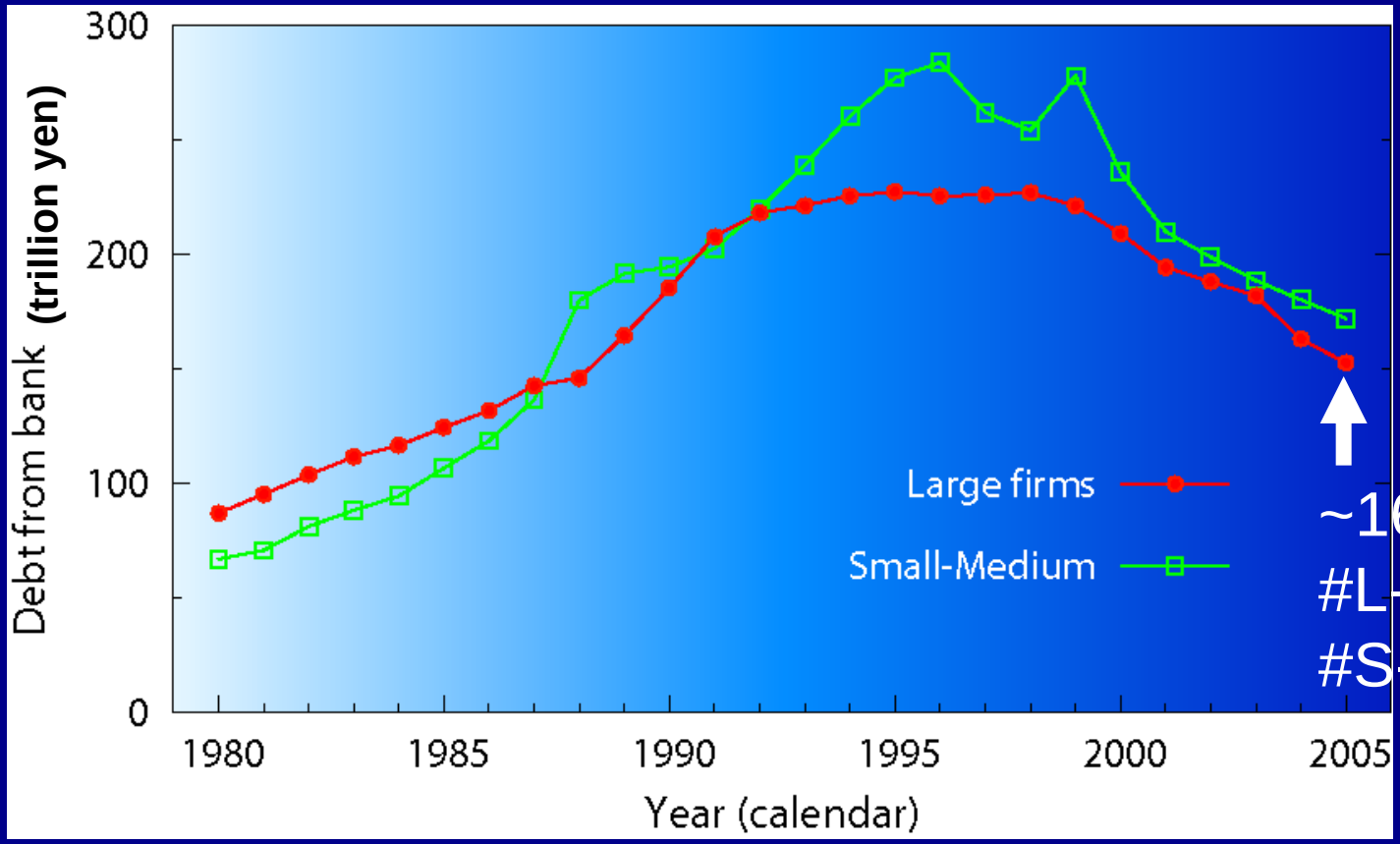
De Masi, Fujiwara, Gallegati, Greenwald, Stiglitz (2008)
Fujiwara et al.(2010)

——→ this talk

生産

Example 1/2
credit network
(firms-banks NW)

Firms' debt from banks

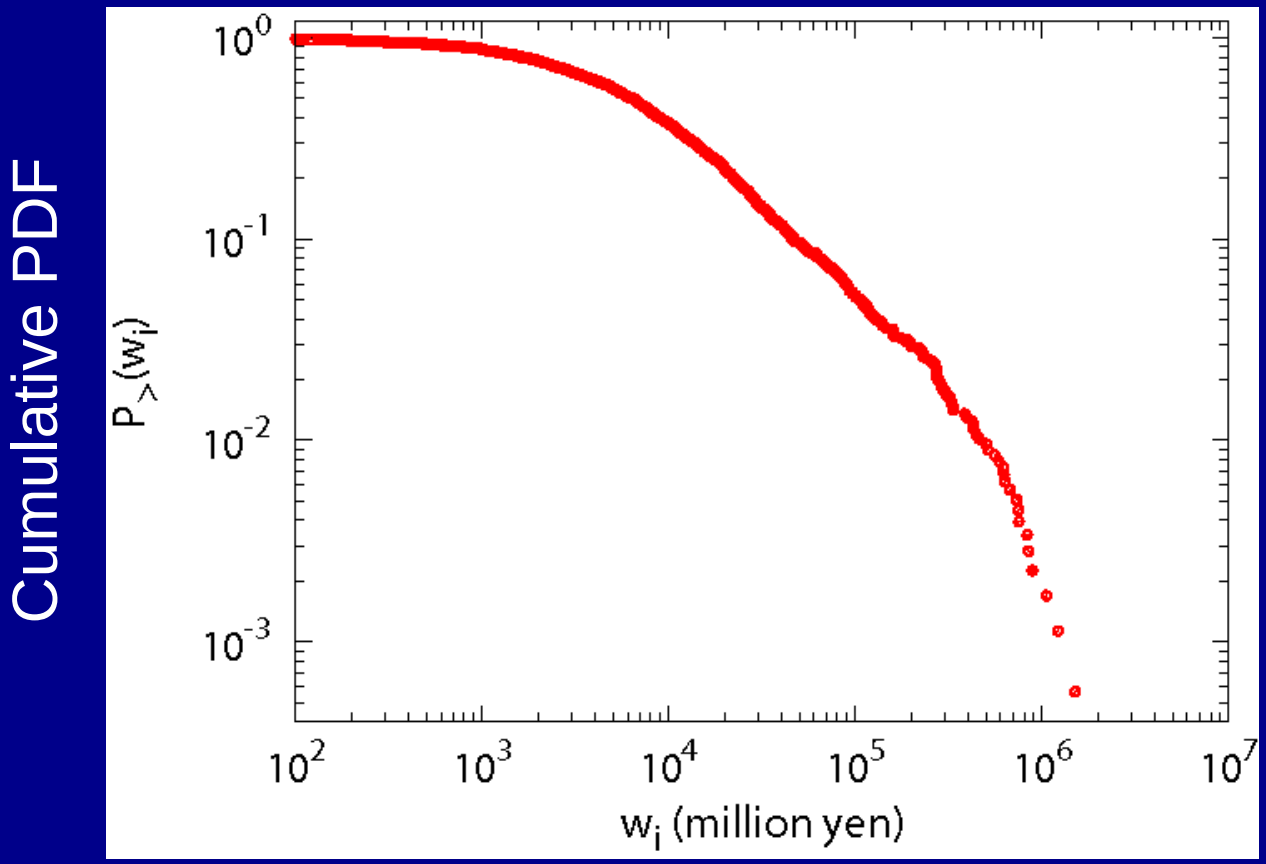


~160B yen
#L-firms= 1.25%
#S-firms= 98.75%

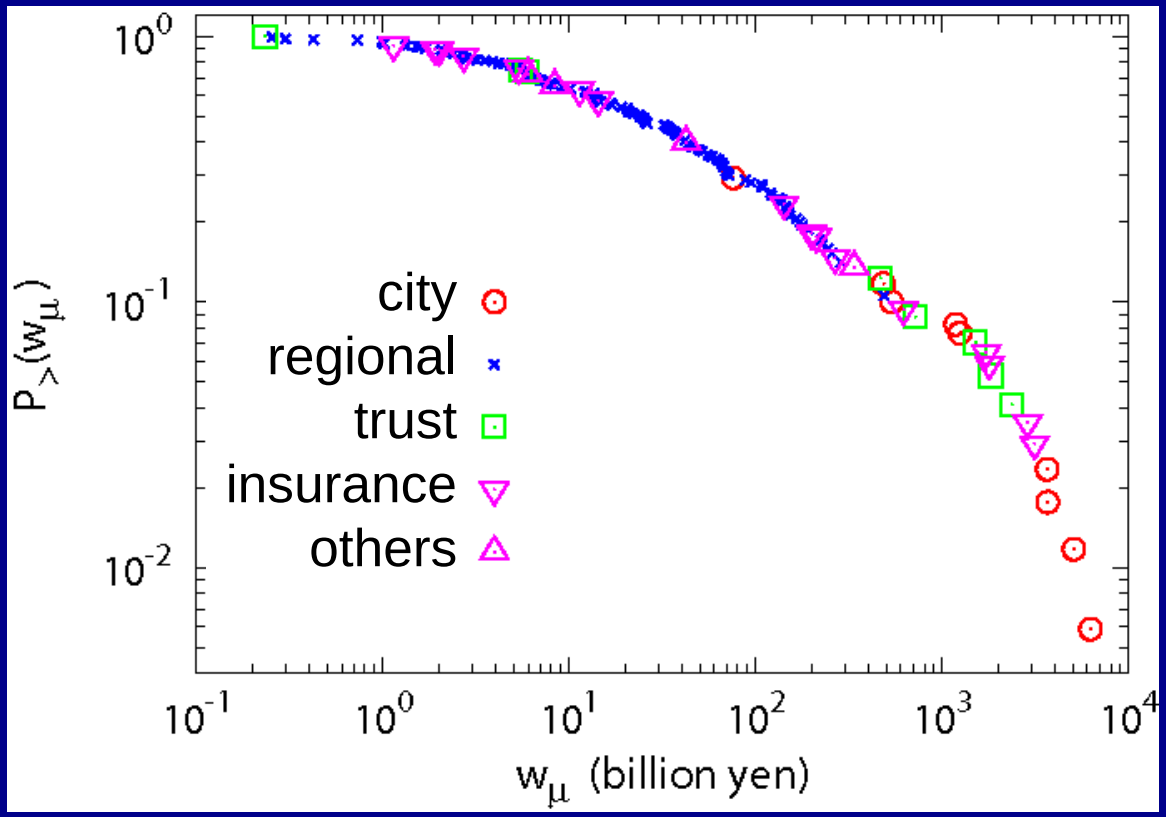
Large: capitalized at 100M yen or more
Small-Medium: otherwise

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

A small fraction of firms account for nearly all loans due to long-tailed distribution of debt.



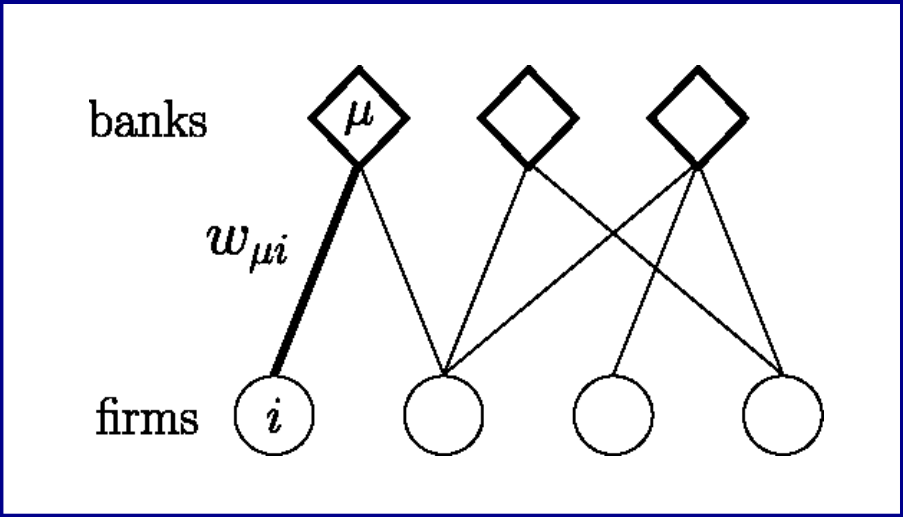
And similarly for
long-tailed distribution of banks' lending amount.



Bank's lending

Goal

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



weight $w_{\mu i}$
= *amount of credit*

Quantify dependency / influence between banks & firms
1. based on Structure of Credit NW in Japan
2. Temporal Change for the past 25 years

References (selected)

- Kano, Uchida, Udell, Watanabe, W.
"Information verifiability, bank organization, bank competition and bank-borrower relationships",
RIETI-DP (2006) 06-E-003
特に中小企業の借入に関して
- Uchida, Udell, Watanabe, W.
"Bank size and lending relationships in Japan"
J. Japanese and International Economics 22 (2008) 242
企業サイズと信用関係数の関係など
- Ogawa, Sterken, Tokutsu
"Why do Japanese firms perfer multiple bank relationship? Some evidence from firm-level data"
Economic Systems 31 (2007) 49
複数信用取引(multiple lending)について

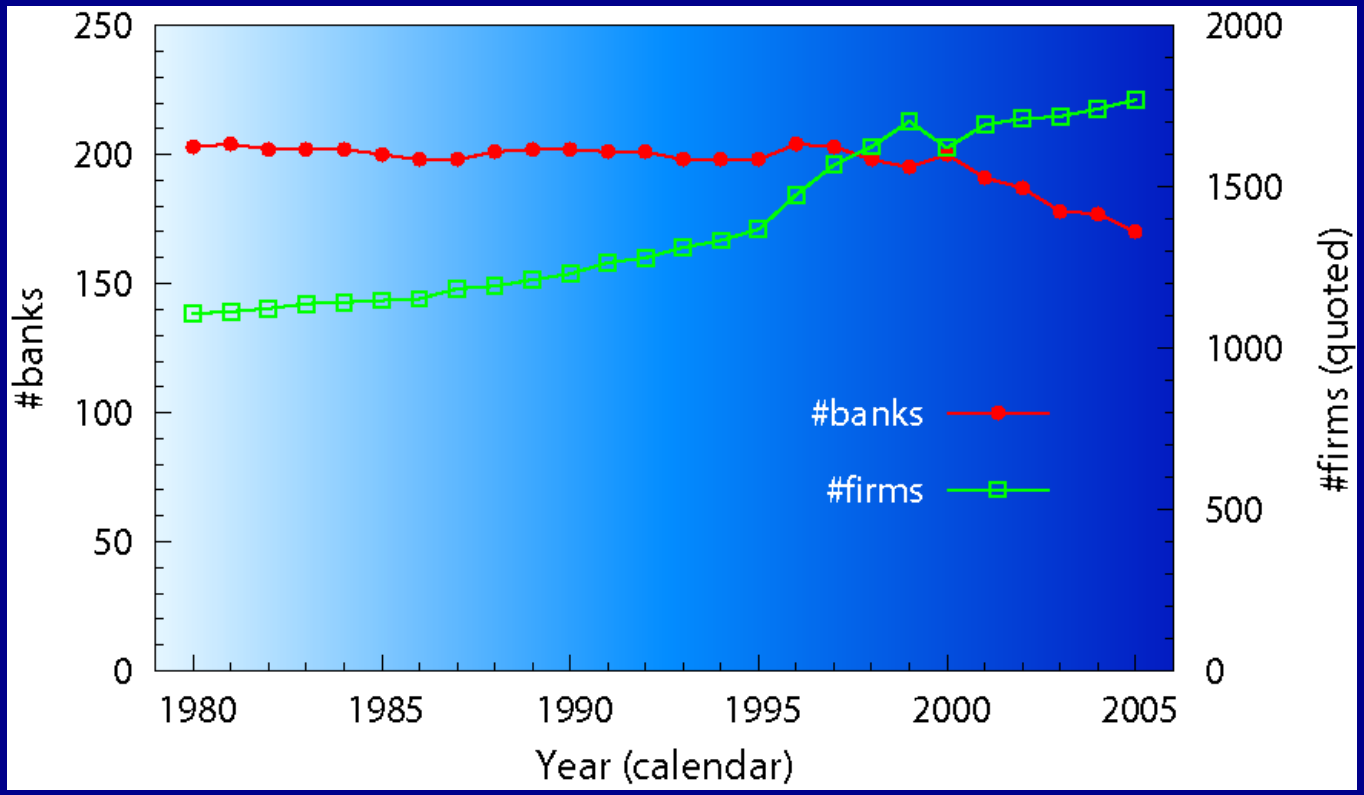
and many …

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)

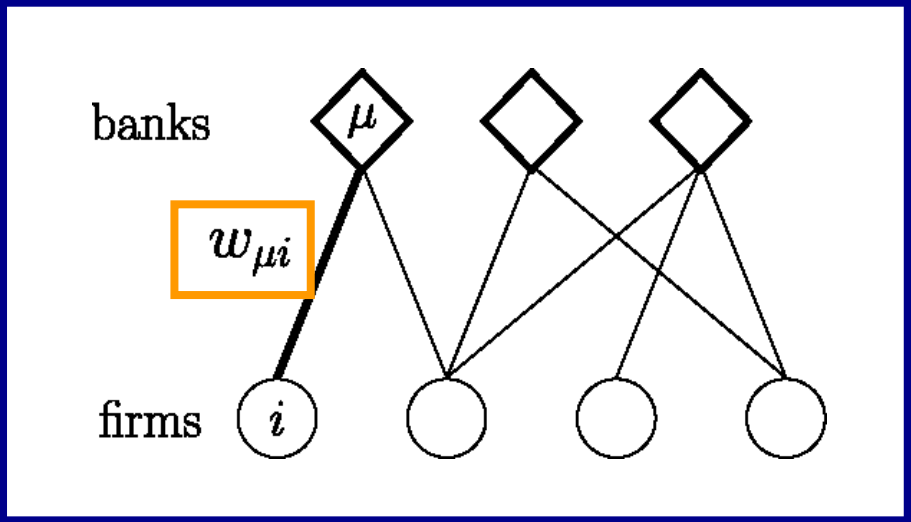
- annual snapshots: from 1980 to 2005
- bankrupted or merged banks included; #banks ~ 230
- surviving firms included; #firms ~ 2,000



- 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 μ and firm i



Dependency

bank μ on firm i $\quad A_{\mu i} := \dfrac{w_{\mu i}}{w_\mu}$

total lending

$$w_\mu := \sum_i w_{\mu i}$$

$$\sum_i A_{\mu i} = 1 \quad \text{for all } \mu$$

firm i on bank μ $\quad B_{i\mu} := \dfrac{w_{\mu i}}{w_i}$

total borrowing

$$w_i := \sum_\mu w_{\mu i}$$

$$\sum_\mu B_{i\mu} = 1 \quad \text{for all } i$$

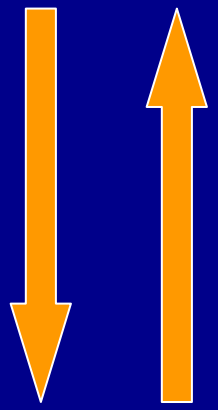
dependency = potential influence between banks and firms

Suppose one can quantify

x_μ : level of bank μ 's financial deterioration

bank's fragility

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



y_i : level of firm i 's financial deterioration

firm's fragility

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

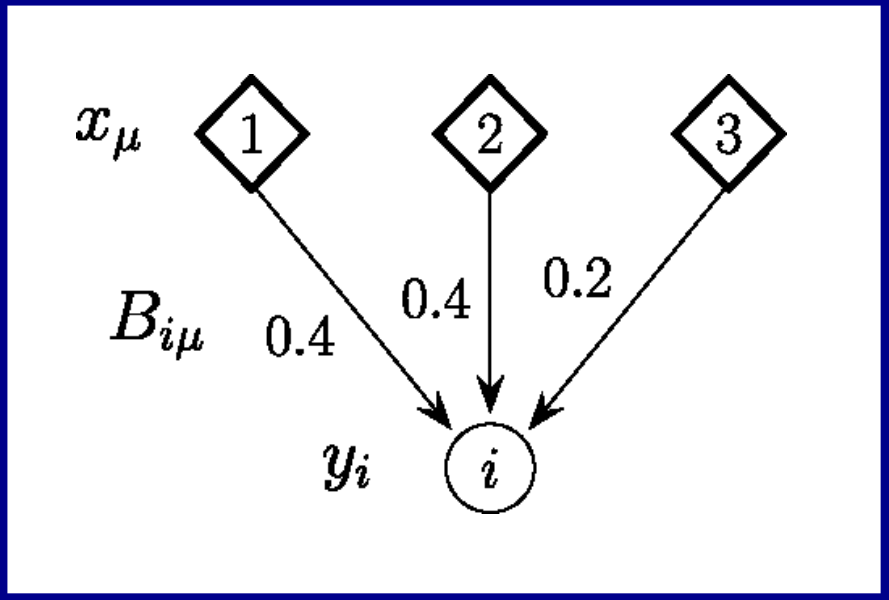
propagation on credit NW

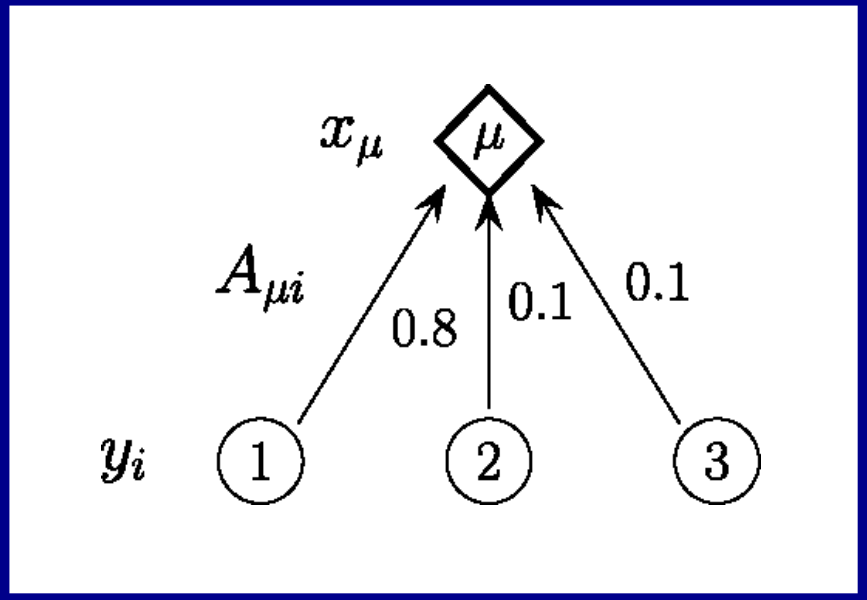
N.B. based on topology alone

Stiglitz and Greenwald,

"*the high rate of bankruptcy is a cause of the hight interest rate as much as a consequence of it*"

Towards a new paradigm of monetary economics (Cambridge, 2003)





$$\vec{y} \propto \mathbf{B}\vec{x}$$

$$\vec{x} \propto \mathbf{A}\vec{y}$$

$$\mathbf{P}\,\vec{x} = \lambda\,\vec{x}$$

$$\mathbf{P} := \mathbf{A}\,\mathbf{B}$$

banks' fragility = solution of eigenvalue problem

Mathematical properties

- spectrum

$$0 < \lambda \leq 1$$

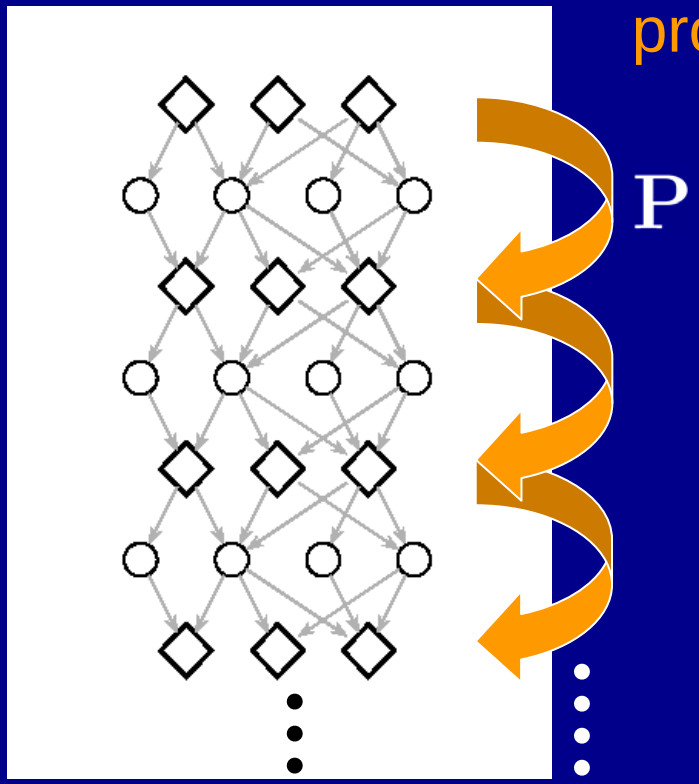
- largest eigenvalue corresponds to trivial mode

$$\lambda = 1 \text{ if and only if } x_\mu = \text{constant}$$

- sum of eigenvalues

$$\sum_k \lambda_k = \sum_{\mu,i} A_{\mu i} B_{i\mu} = \mathrm{tr}\,\mathbf{P}$$

propagation of fragility-profile



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

expand by eigen-modes

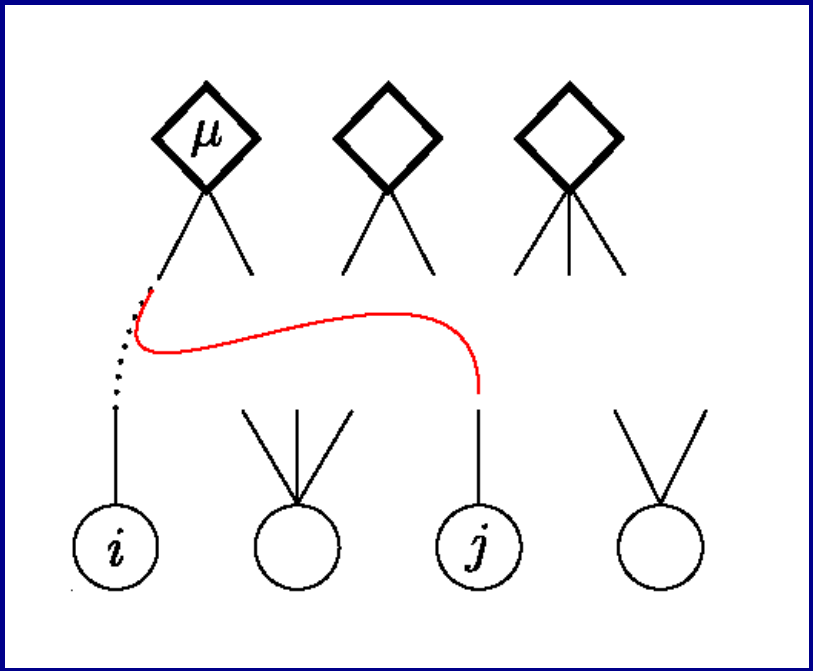
$$1 = \lambda_1 \geq \lambda_2 \geq \lambda_3 \cdots \lambda_n > 0$$

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

larger eigenvalues ~ more robust modes

random graph

= cut every edges and rewire them randomly

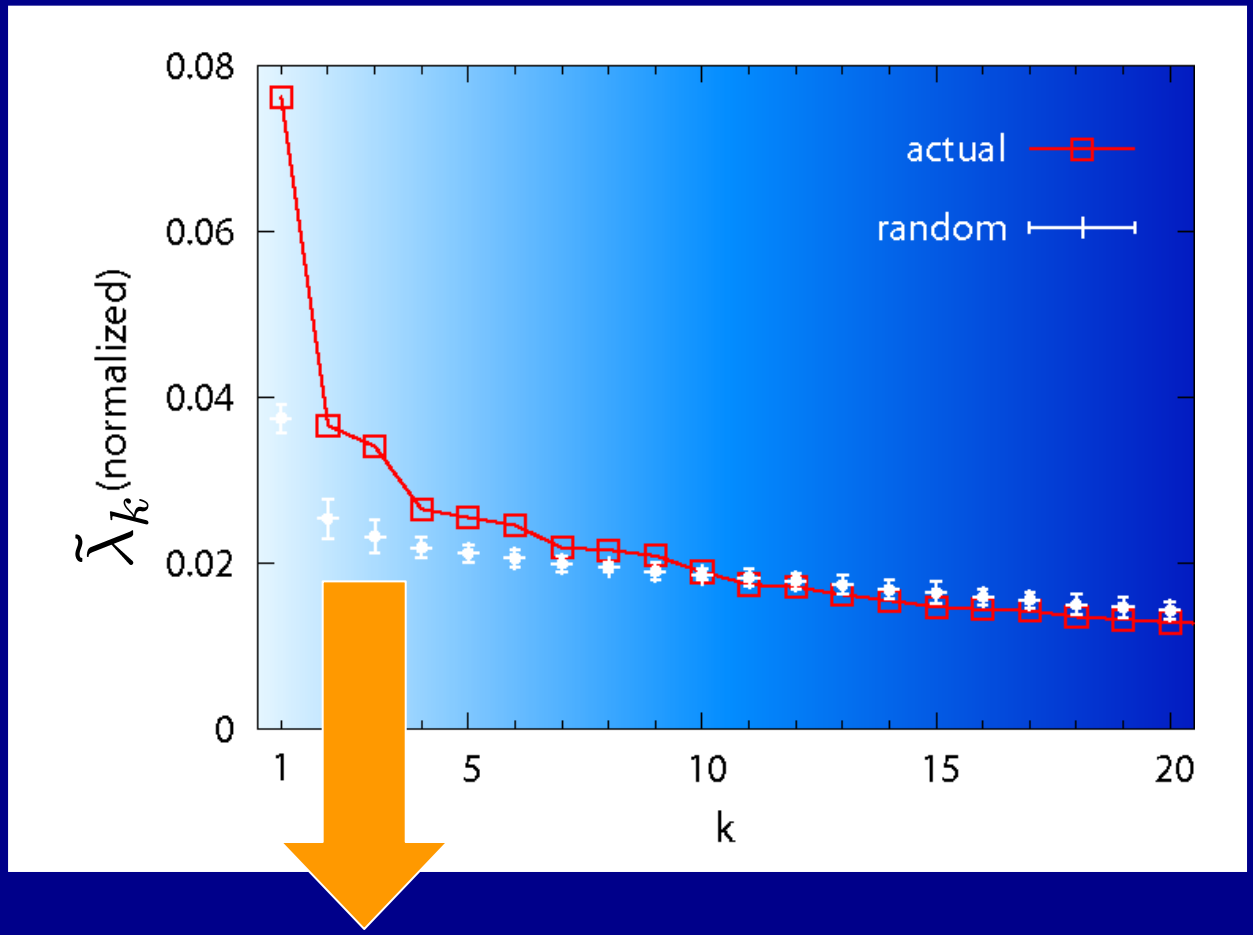


$$w_{\mu i} \rightarrow w_{\mu j}$$

The same credit is supplied to different firm
with total amount of lending being invariant.

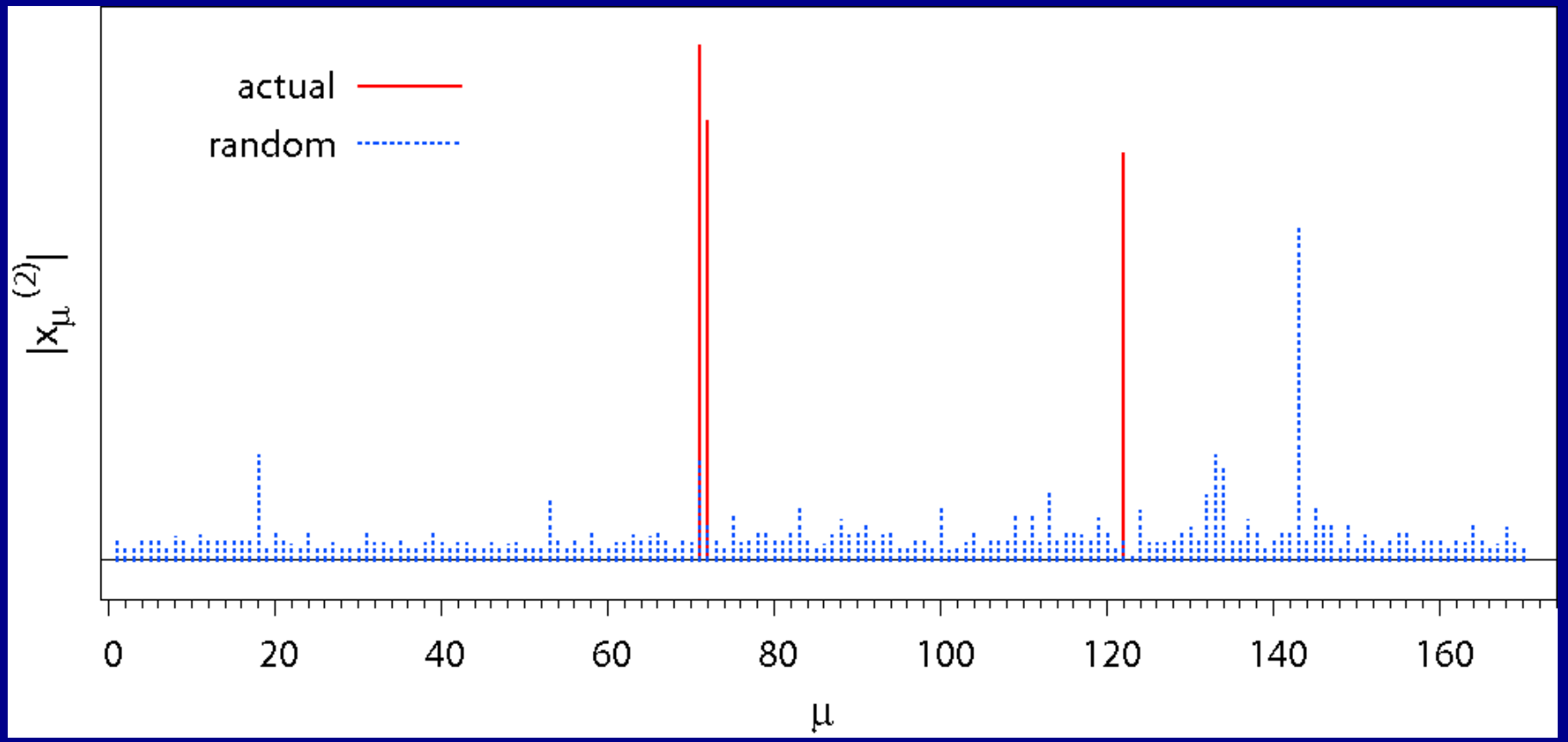
- A invariant
- B randomized

$$\tilde{\lambda}_k = \frac{\lambda_k}{\sum_{\ell=1}^{n} \lambda_\ell}$$

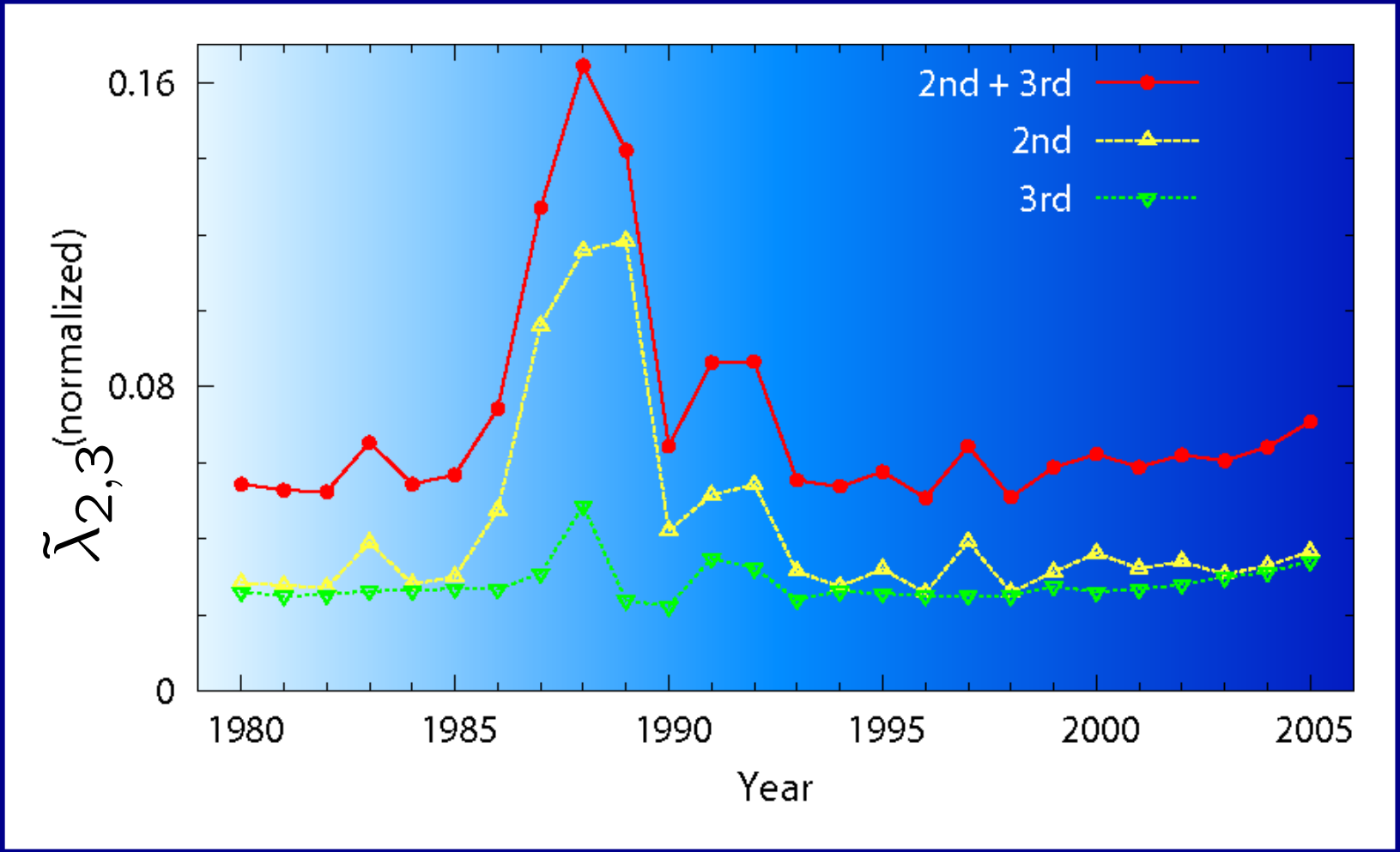


Only the first two non-trivial eigenvalues are significant

components of eigenvector $|x_\mu^{(2)}|$
corresponding to 2nd largest eigenvalue



banks



- ✓ strong peak in the late 80s
- ✓ drop in 1990
- ✓ peaks in 1992 and 1997

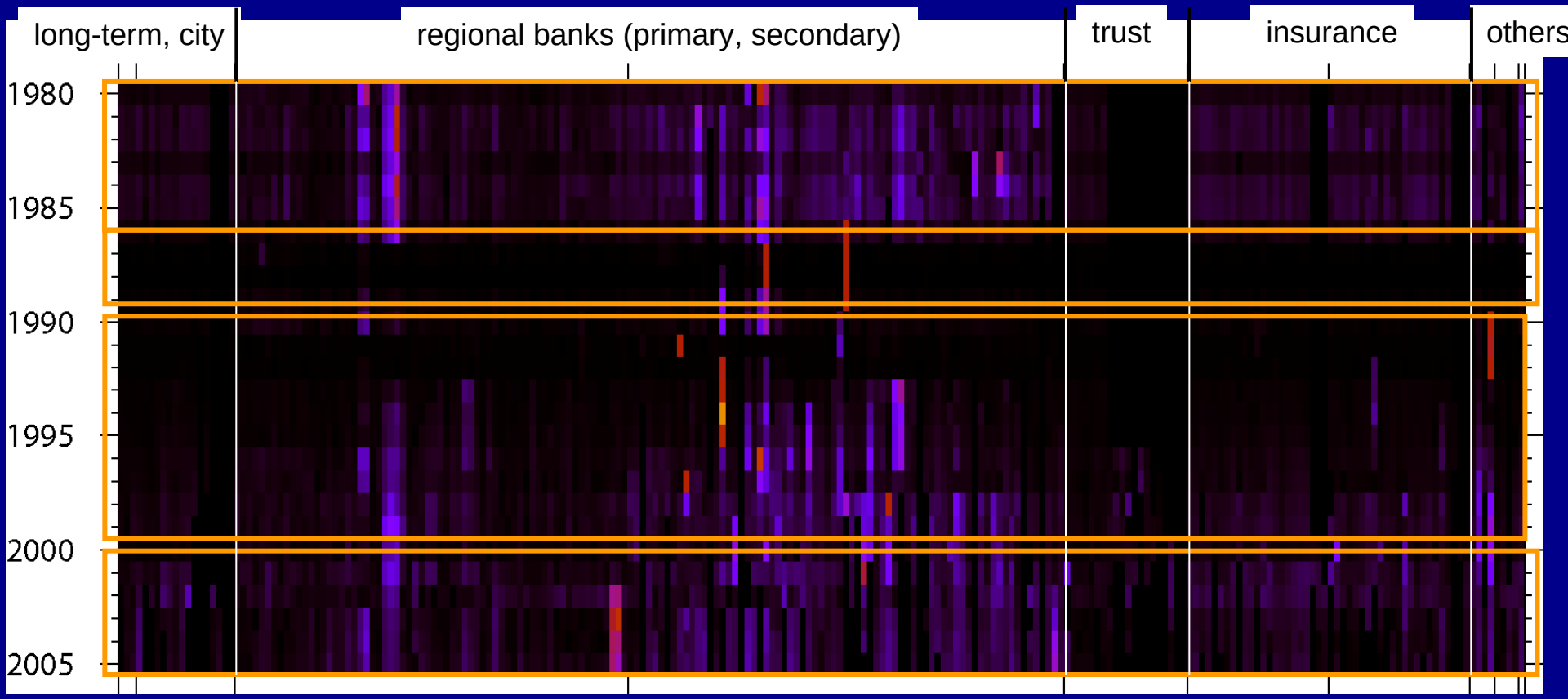
Credit relationship changed in Japanese bubble
in the late 80s up to 1990 and after it.

1. Firms became to be less dependent on bank loans,
   by issuing public debt, e.g., after financial deregulation.
2. After bubble collapse, banks had non-performing loans
   degrading the intermediary role of banks.
   --- During the bubble (late 80s),
   large firms tended to rely on single relation to banks.
   --- In the long stagnation after the bubble collapse (1990),
   percentage of multiple lending increased.
3. Banks spent a decade in 90s to recover from bad loans

experiencing a financial crisis for a couple of years from 1997,
which results in credit shrink during the period.

cf. *Ogawa, Sterken, Tokutsu* (2007)
Brewer, Genay, Kaufman (2003)

components of eigenvectors $|x_\mu^{(2)}| + |x_\mu^{(3)}|$



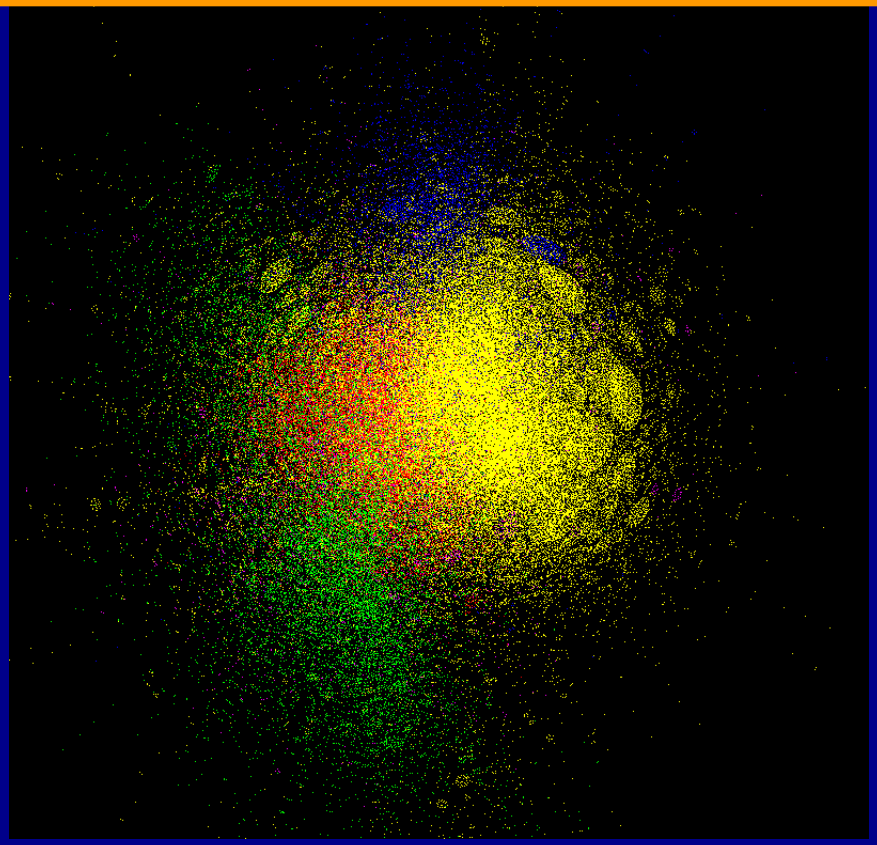
- ✓ stable patterns 80-85, 00-05
- ✓ change in late 80s
- ✓ bubble collapse and 90s
- ✓ back to previous profile with more peaks in late 90s

Part I まとめ

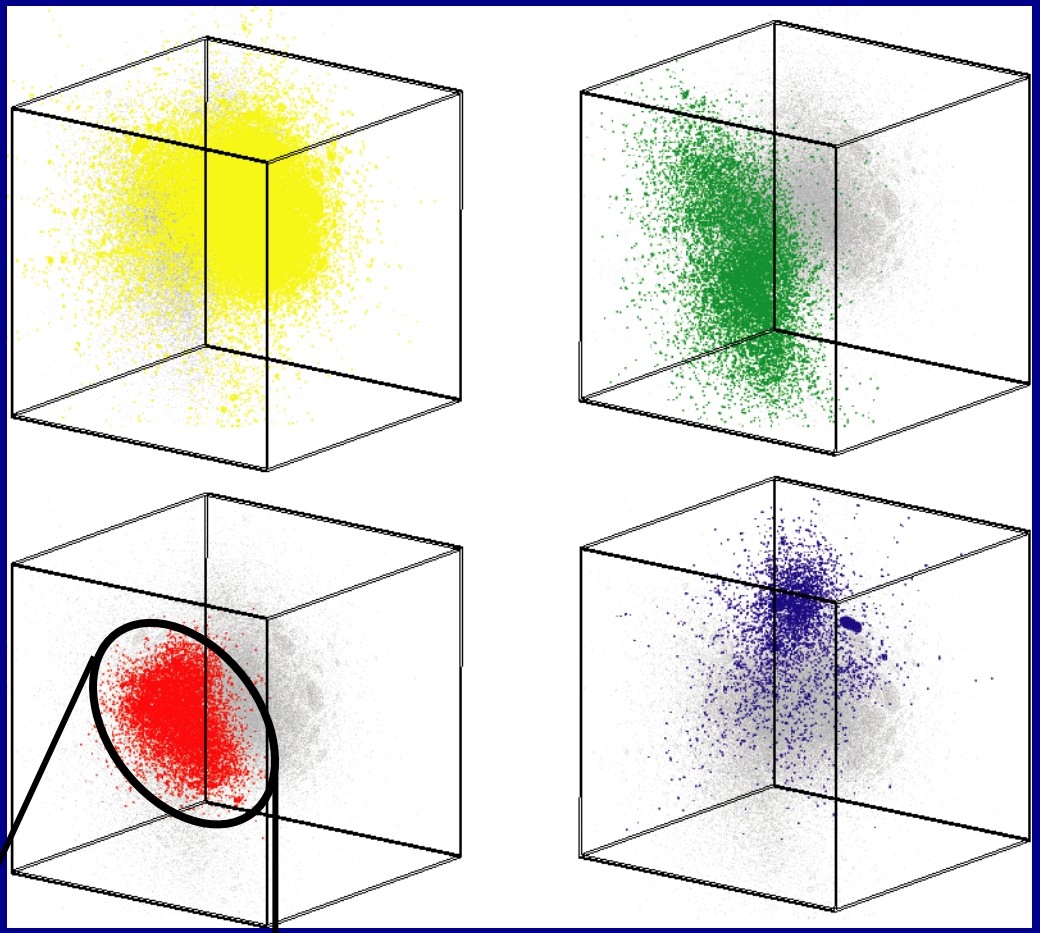
- 銀行・企業間信用ネットワークを重み(借入貸出金)付きの
  2部グラフとして解析する手法を提案
  1980年～2005年について，その構造と変化を解析した
- 借手から貸手，貸手から借手への依存度合いと影響度合いを
  2部グラフからself-consistentに計算する手法
  → これにより脆弱性指標を固有値問題として計算できる
- 帰無仮説としてランダム2部グラフを用いると，
  上位数個の固有値とそれに対応する固有ベクトルが有意
- 過去25年間について脆弱性指標を解析して
  その変化と金融構造の変化について議論
  → *comparison with financial states of banks necessary*
  → *firms' fragility relation to bankruptcy to be studied*

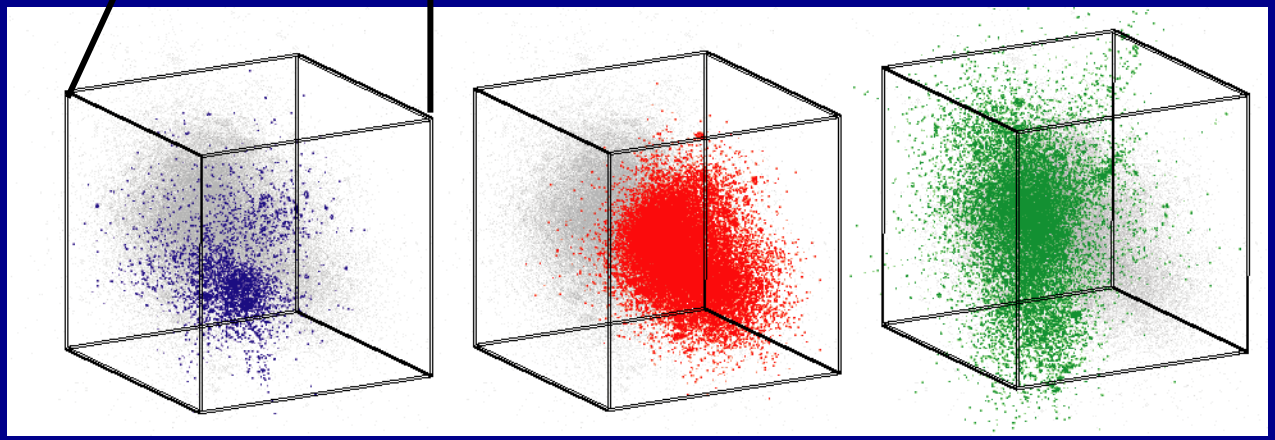
Example 2/2 production network (supplier-customer NW)

cluster (community) structure



0.14M manufacturing sector
Modularity optimization (Yutaka Leon Suematsu)
Force-directed spring+Coulomb+resistence
N-body simulation by GRAPE (gravity pipeline)
(with Yuji Fujita, Atsushi Kawai)





化学

重工業

自動車

電気機器

電気機器 (a)

電気機器 (b)

電気機器(c)

コミュニティサイズ

凸版印刷，大日本印刷，大日本インキ化学工業，東洋インキ製造，レンゴー
三菱化学，三井化学，サカタインクス，住友化学　．．．

化学

松下電器産業，東芝，三菱電機，日立製作所，富士通，シャープ
松下電工，ソニー，三洋電機，京セラ　．．．

電気機器

三菱重工業，川崎重工業，本田技研工業，トヨタ自動車，神戸製鋼所
石川島播磨重工業，王子製紙，住友重機械工業，クボタ　．．．

重工業

東レ，日本製紙，東洋紡績，ヤマハ，ユニチカ，丸紅
グンゼ，クラレ，三菱レイヨン　．．．

化学

三菱マテリアル，太平洋セメント，宇部興産，フルサト工業，住友大阪セメント
長府製作所，タキロン，JFE建材，フェニックスコーポレ　．．．

窯業化学

イトーキ，松下エコシステムズ，関包スチール，明道メタル，北海道サッシ工業
ヤマトインダストリー　台和，日本調理機，日本金属工業　．．．

金属

．．．．．．．．．．．．

仙台味噌醤油，だい久製麺，山形朝日そば，星栄商店，大塚樽店
宮城クミアイ醤油，松尾，石渡商店，オリヒロマテリアル

東北そば

cf. Fortunato, Barthelemy (2007)
“resolution limit in community detection”

再帰的なコミュニティ解析

ソニー，京セラ，キヤノン，シャープ，セイコーエプソン，オムロン，
TDK，富士写真フイルム，リコー，．．．

三菱電機，松下電工，日本電気，古河電気工業，住友電気工業，沖電気工業，
村田製作所，日立電線，日本圧着端子製造，．．．

トステム，新日軽，大和ハウス工業，旭硝子，三和シヤッター工業，三協立山アルミ，
日本軽金属，立山アルミニウム工業，不二サッシ，．．．

松下電器産業，三洋電機，パナソニック四国エレ，東芝ライテック，スタンレー電気，
松下電池工業，日本金型材，鳥取三洋電機，松下冷機，．．．

日立製作所，アルプス電気，日立ハイテクノロジー，日立国際電気，アルバック，
東京エレクトロン，東北パイオニア，東京エレクトロンAT，長野日本無線，．．．

東芝，富士通，横河電機，東芝セラミックス，東京エレクトロン九州，日本インター，
信越半導体，富士通アクセス，鷺宮製作所，．．．

パナソニックエレクト，パナソニックモバイル，パナソニックコミュニ，山武，パナソニックCC宮崎，
アダマンド工業，オムロン岡山，東立通信工業，山武コントロールプロ，．．．

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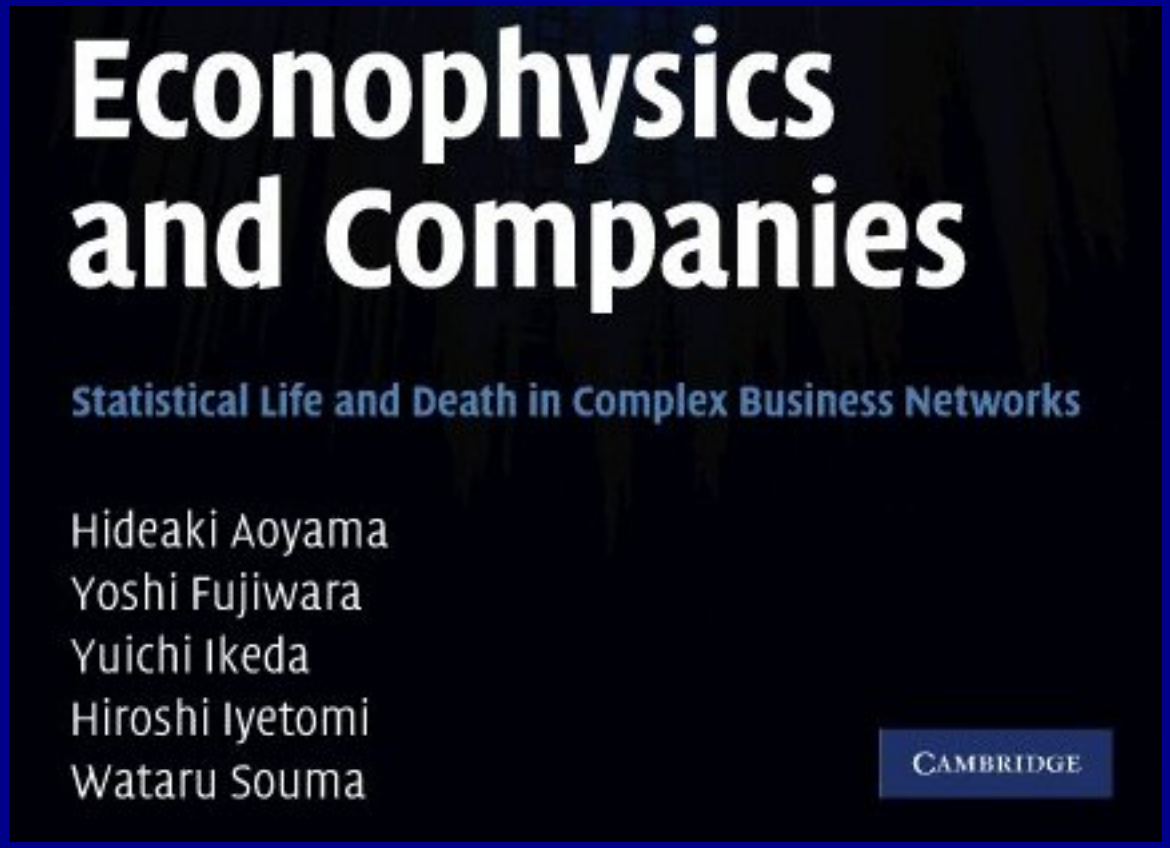
Visualizing a large-scale structure of production network by N-body simulation, 2009.
Progress of Theoretical Physics Supplement (2009); arxiv/0901.2381

Y. Fujiwara,
Chain of firms bankruptcy: a macroscopic study of link effect in a production network.
Advances in Complex Systems (2008)

and, this book (2010) of course!



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