



Temporal Evolution of Community Structure in a Japanese Credit Network*

Hiroshi Iyetomi

Department of Mathematics, Niigata University

Collaborators:

Yuki Matsuura¹ and Takashi Iino²

¹Graduate School of Science and Technology, Niigata University

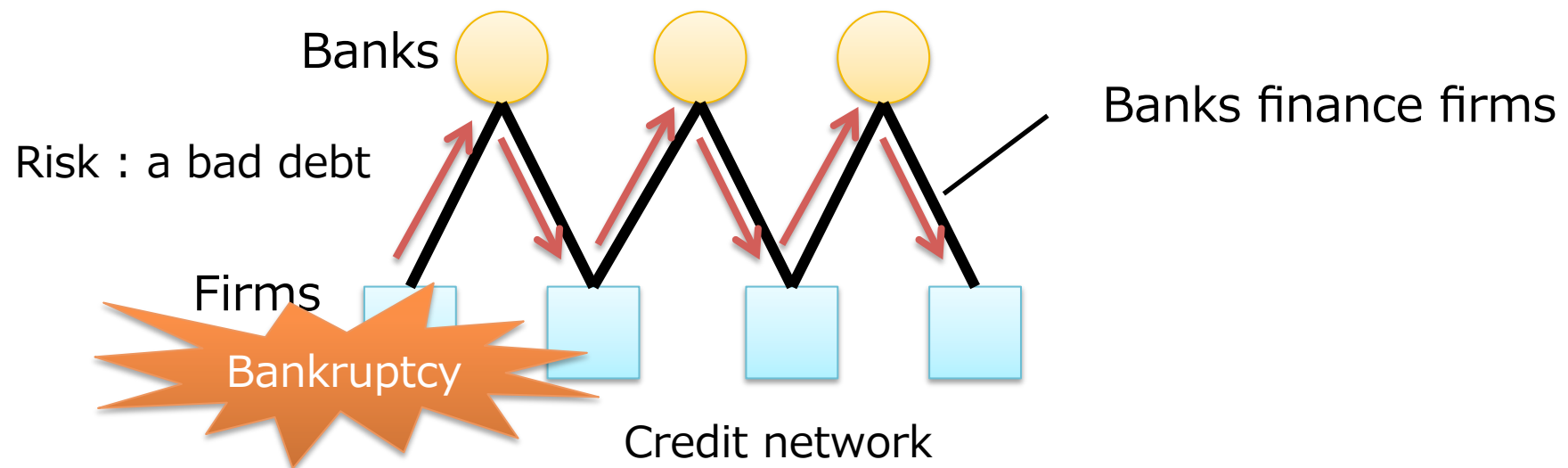
²Faculty of Science, Niigata University

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Introduction



- Credit relationship between banks and firms → Credit network
- Risk spreads through the credit network
- There is a fear that a global crisis may occur in the near future

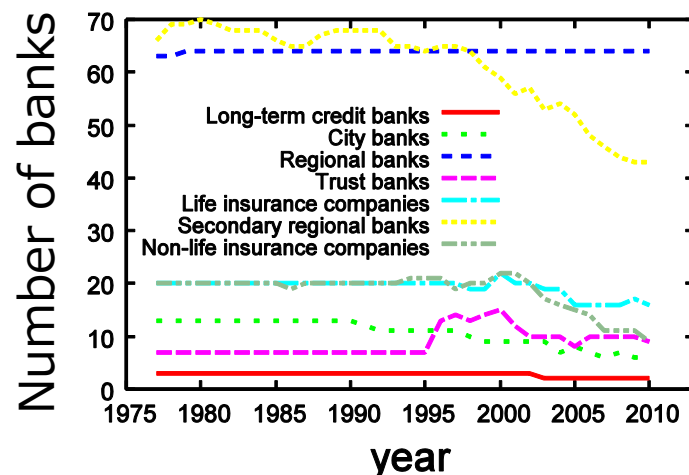


To accurately estimate such a chain propagation of risk, we have to analyze the credit relationship between banks and firms from a network theoretic point of view.

Major Economic Events in Japan

Year	Events
1990	Burst of economic bubble
1996~2002	Financial big bang
2001	Burst of internet bubble
2008	Lehman shock
2011	Great East Japan Earthquake

- Temporal change of number of banks of several categories

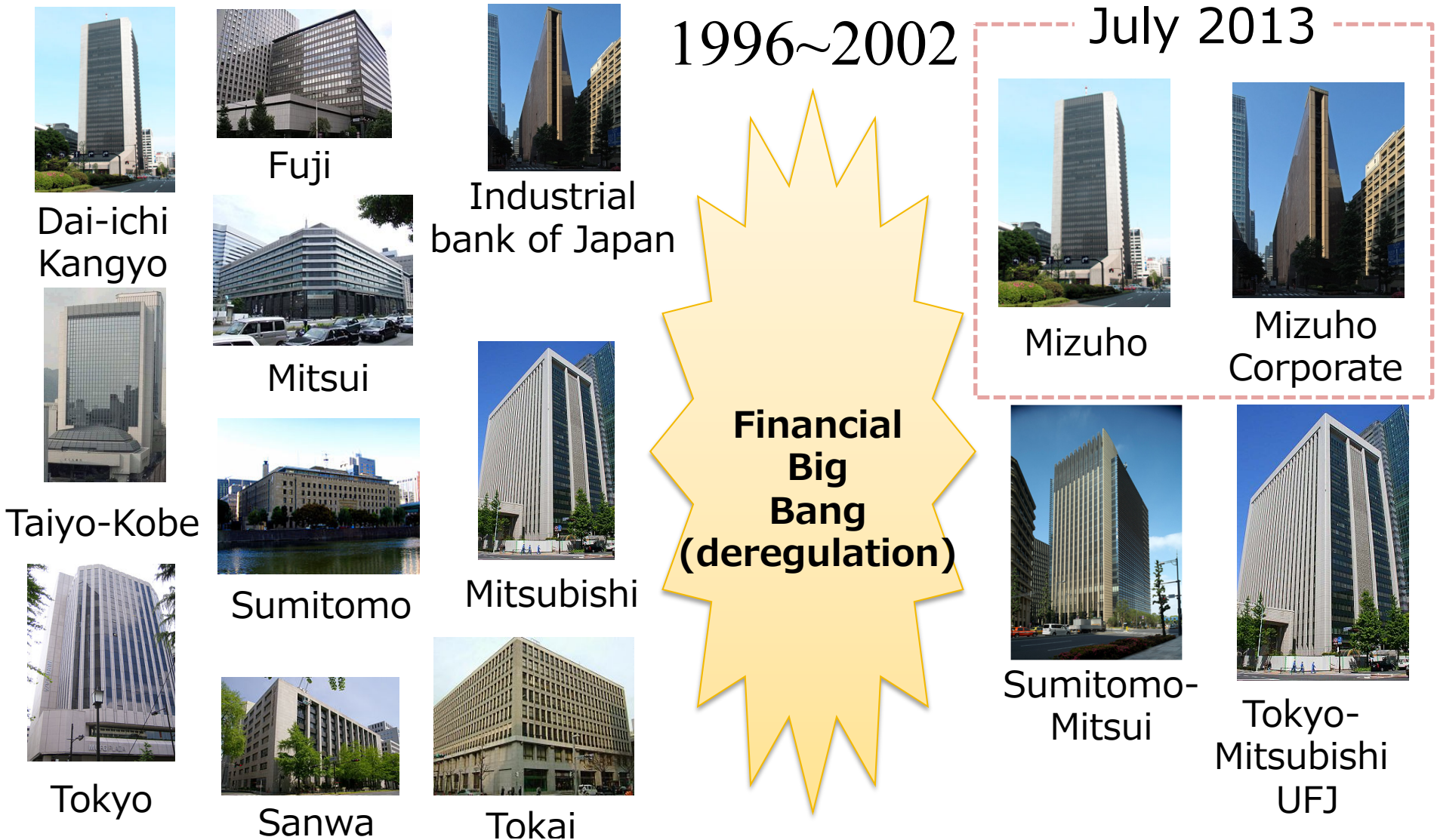


After Burst of economic bubble, banks got financially damaged and even some of city banks went bankrupt.

History of City Banks in Japan

Past

Present



Merging of the City Banks

July 2013



Dai-ichi
Kangyo



Fuji



Industrial
Bank of Japan

2002



Mizuho



Mizuho Corporate



Taiyo-Kobe



Mitsui



Sumitomo

1990, 2001



Sumitomo-Mitsui



Mitsubishi



Tokyo



Tokai



Sanwa

1996, 2002, 2006



Tokyo-Mitsubishi UFJ

Appendix A: Bond Rating of Major Banks:

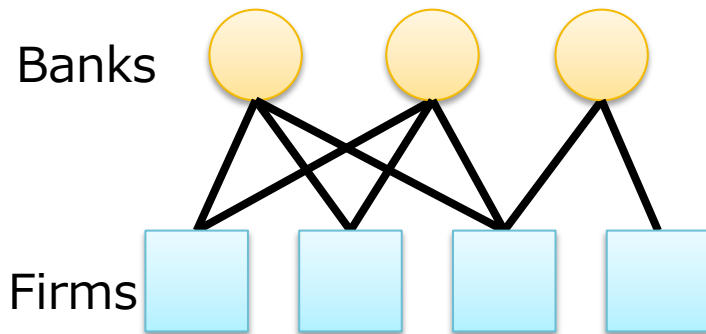
The most conservative rating of S&P, Moody's, JCRI and IBCA

							Phase I		Phase II		Phase III			(Year)
Old Name	New Name	3/91	3/92	3/93	3/94	3/95	3/96	3/97	3/98	3/99	3/00	3/01	3/02	
IBJ	IBJ	AAA	AA	AA-	A+	A+	A	A	A-	BBB	BBB+	BBB+	A	
LTCB	Shinsei	AA	AA-	A	A-	A-	BBB+	BBB+	BBB-	BB-	BBB-	BBB-	BBB-	
NCB	Aozora	AA+	AA	A	A	A	BBB-	BB+	BB+	BB-	BB-	BB	BBB-	
DKB	Mizuho	AA	AA-	AA-	A+	A+	A	A	BBB+	A	A	A	BBB	
Sakura	Sakura	AA+	AA+	AA-	AA-	AA-	A-	A-	A-	BBB	BBB	A-	A-	
Fuji	Mizuho	AA	AA-	A+	A+	A+	A-	A-	BBB+	A	A+	A+	BBB	
Mitsubishi	Tokyo-Mitsubishi	AA+	AA	AA-	AA-	AA-	A+	A+	A	A-	A-	A-	BBB+	
Asahi	Asahi	AA+	AA	A+	A	A	A	A	A	BBB	BBB	BB+	BB+	
Sanwa	UFJ	AA	AA	AA-	AA-	AA-	A	A	A	BBB+	BBB+	BBB+	BBB	
Sumitomo	SMBC	AA+	AA	AA-	A+	A+	A	A	A-	BBB	BBB	BBB+	BBB	
Daiwa	Daiwa	AA+	A+	A+	A-	A-	BBB+	BBB+	BBB-	BB+	BB+	BB+	BB+	
Tokai	Tokai	AAA	AA+	AA-	A	A	A	A	A	BBB-	BBB-	BBB	A	
Hokkaido-Takushoku	-	AA	AA	A	A	.	BBB-	BBB-	BBB-	
Tokyo	-	AA+	AA+	AA+	AA+	.	AA+	AA+	

Ref.: H. Miyajima and Y. Yafeh. RIETI Discussion Paper Series 03-E-010 (2003).

Data for Credit Network

- Source: Nikkei NEEDS (<http://www.nikkeieu.com/needs/Index.aspx>)
- Period : 1980~2012 (33 years)



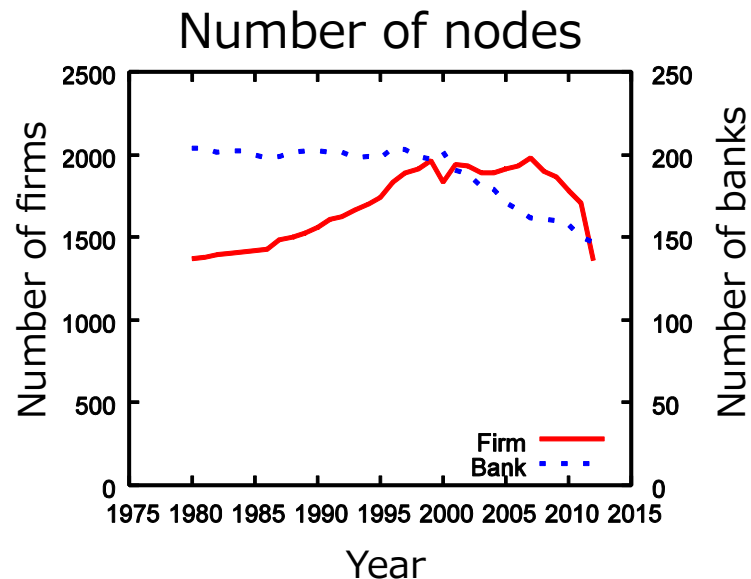
Bipartite graph

Node 1

- Long-term credit banks
- City banks
- Regional banks
- Secondary regional banks
- Trust banks
- Life insurance companies
- Non-life insurance companies, etc.

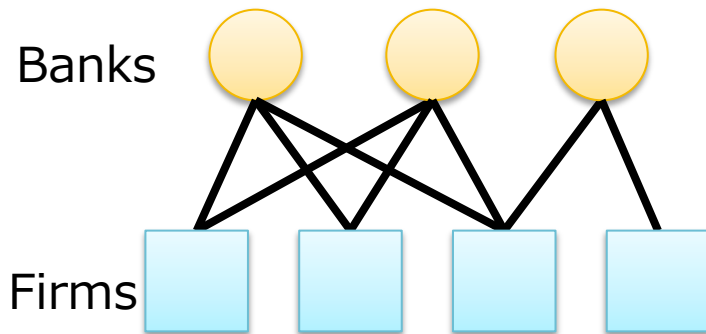
Node 2

- Listed firms (Tokyo, Osaka, Nagoya, Kyoto, Hiroshima, Fukuoka, Hercules and Sapporo Stock Exchange Markets)



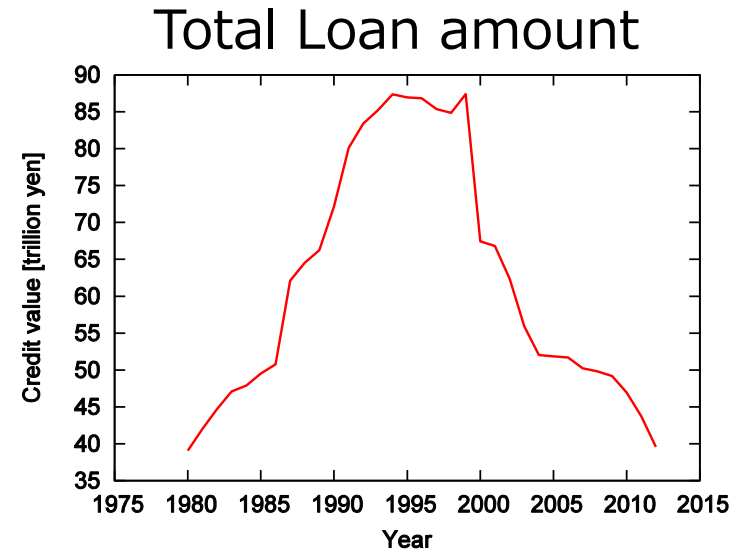
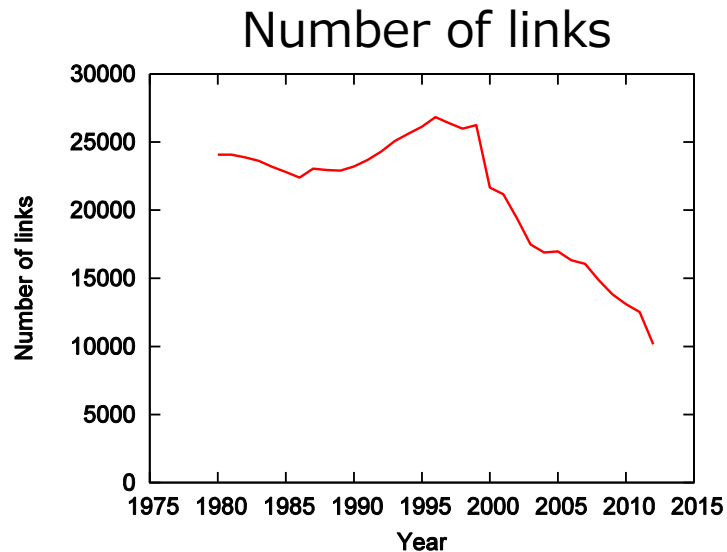
Data for Credit Network

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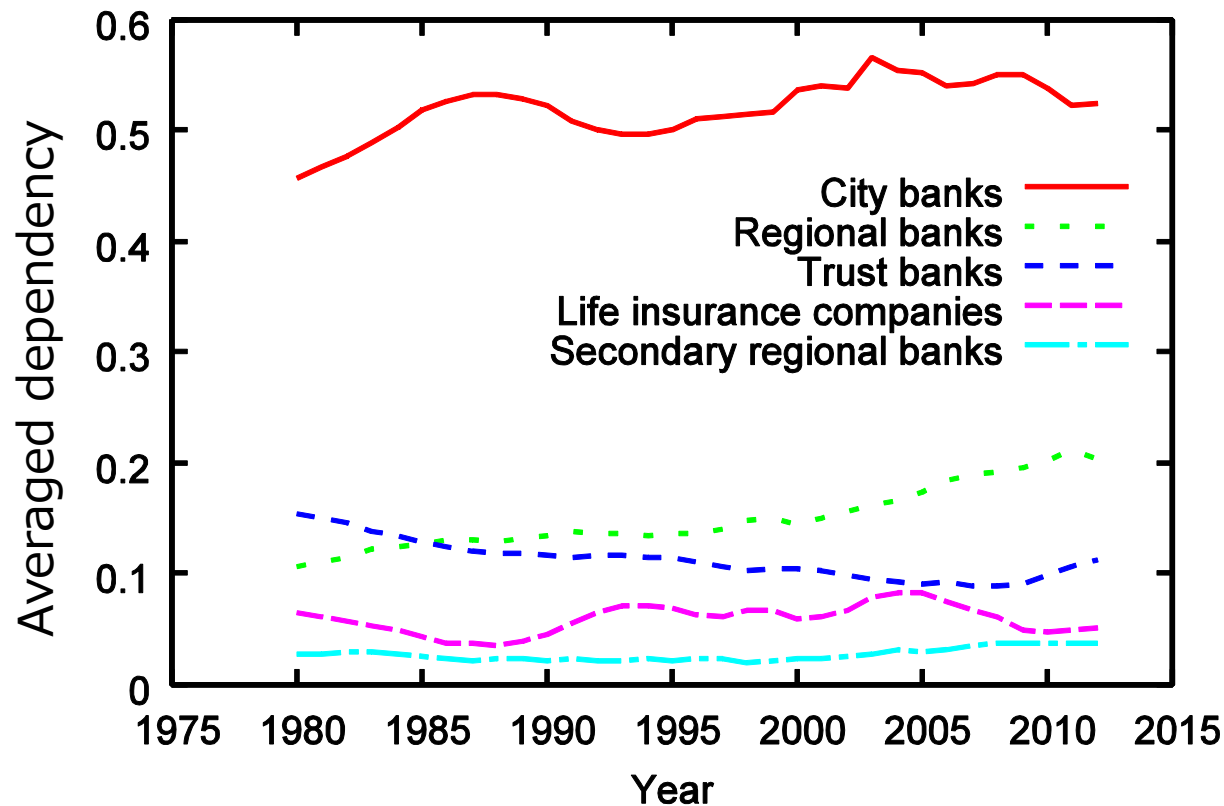
Link with weight

- debtor-creditor relations between banks and firms with loan amounts.



We study the credit network thus formed by banks and listed firms in Japan.

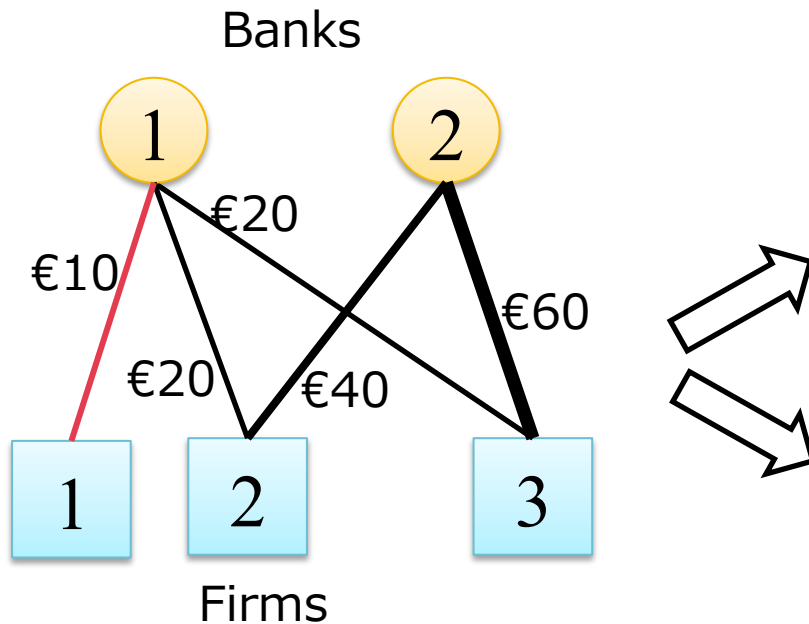
Averaged Dependency of Firms on the Top Five Categories of Banks



- The predominance of **city banks** has been steadily increasing and even exceeded **50%** around 2000.
- Data with “unknown” financial sources are excluded.

Bidirectional links

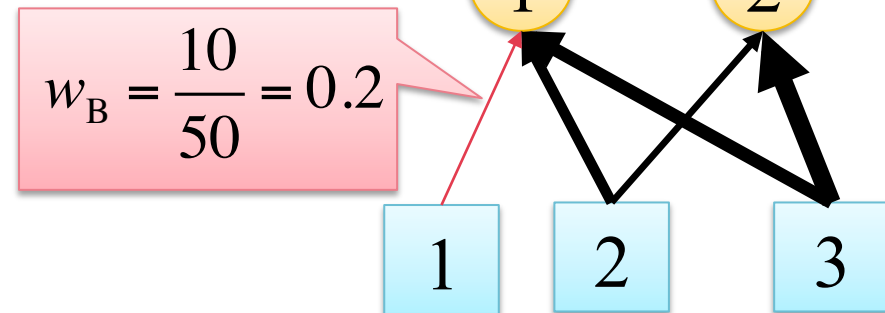
Absolute loan amount



Relative loan amount[1,2]

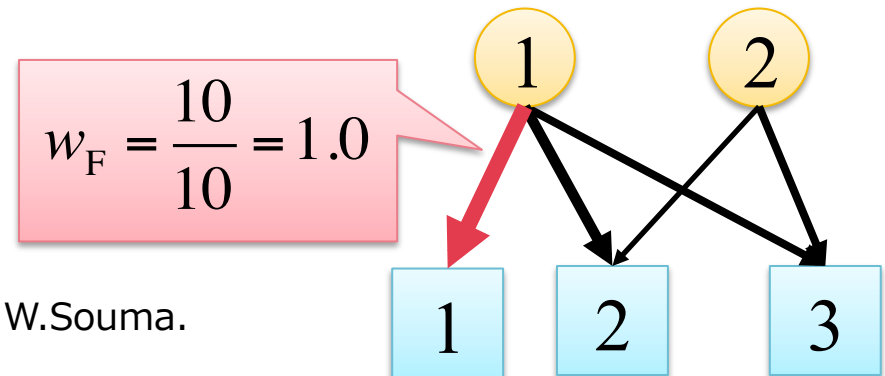
Dependency of banks on firms

→ **WB** network



Dependency of firms on banks

→ **WF** network



[1] Y. Fujiwara, H.Aoyama, Y. Ikeda, H.Iyetomi and W.Souma.
Economics E-Journal, Vol. 3, No.2009-7 (2009).

[2] G. De Masi, Y. Fujiwara, M. Gallegati, B. C. Greenwald and J. E. Stiglitz,
Evolutionary and Institutional Economics Review, Vol. 7, 209 (2010).

Purpose of This Study

- We analyze temporal change of the credit network between banks and firms over the last 30 years in Japan.

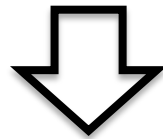
→ Community detection

1. W_B network (Banks → Firms)

- To find groups of banks which largely share risks due to failure of firms.

2. W_F network (Firms → Banks)

- To find group of firms which largely share risks due to failure of banks.



3. Overlapping parts of the two community sets

- To find cores of the risk concentration in the credit network

Community Detection

Community is a group of nodes which are tightly connected with each other through links.

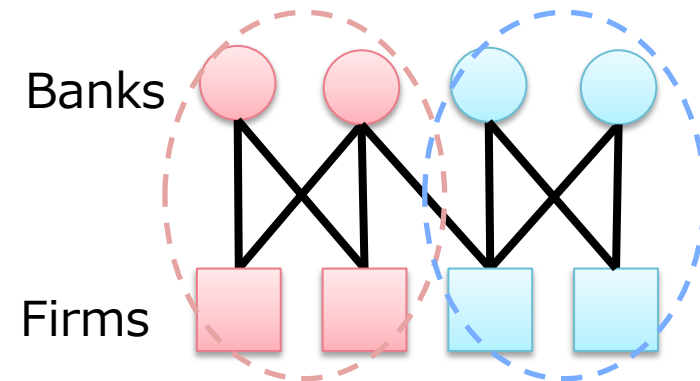
Modularity Q is one of the criteria to evaluate how good is a given network division.

Modularity Q for a bipartite graph:

$$Q = \sum_{s=1}^r Q_s = \sum_{s=1}^r \left[\frac{l_s}{L} - \frac{d_s^B d_s^F}{L^2} \right]$$

Density of links in a community

Expected density of links in a community

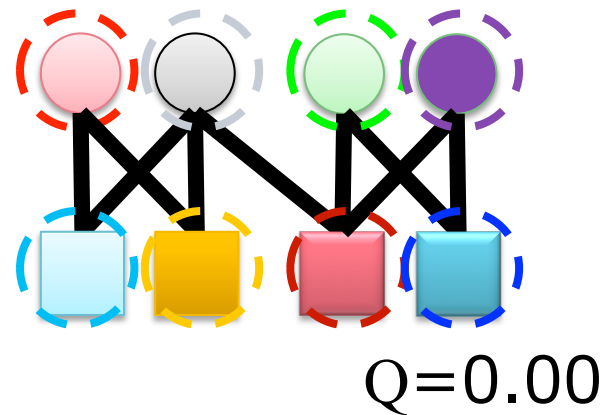
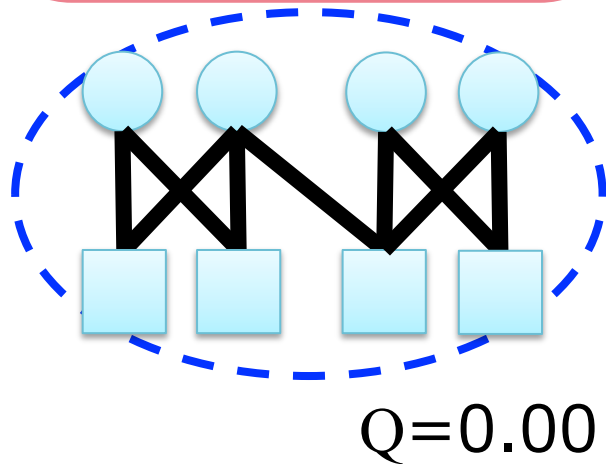
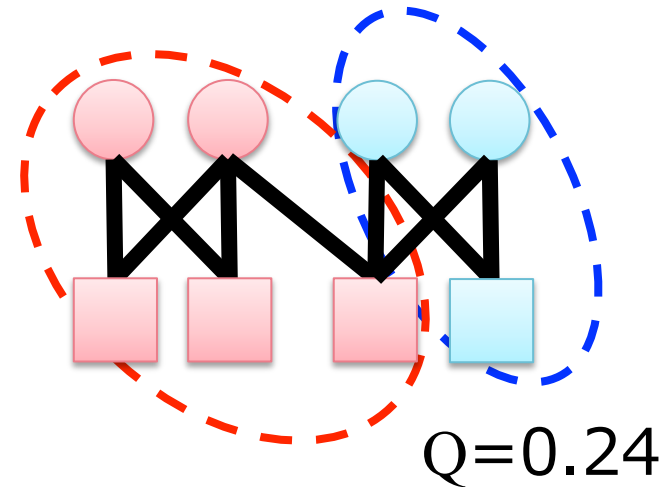
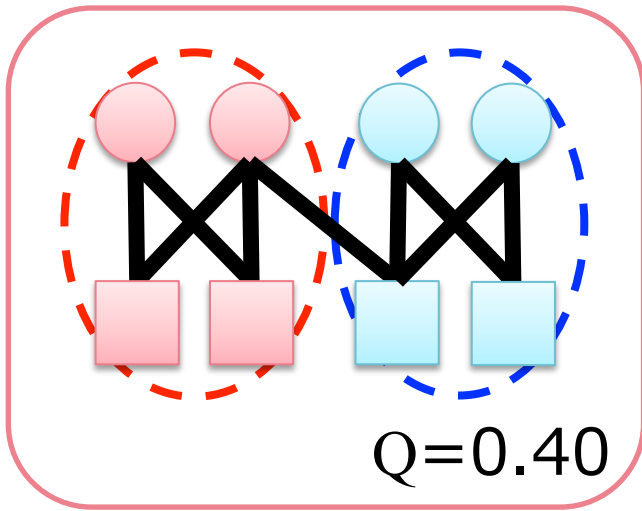


$Q=0.40$

- l_s : number of links in community s
- d_s^B : sum of weights for banks in community s
- d_s^F : sum of weights for firms in community s
- L : sum of weights in the whole network
- r : total number of communities

Example of Network Division

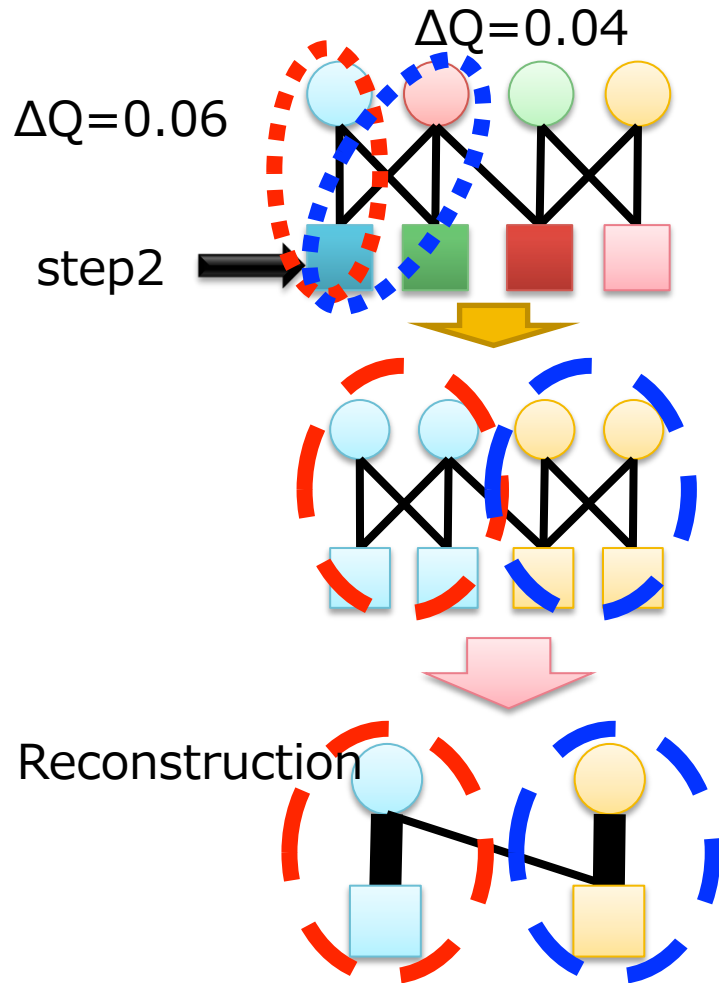
Which is the network division with the largest modularity?



Finding the optimum division \rightarrow community structure in the network

Optimization of Modularity

Fast unfolding method

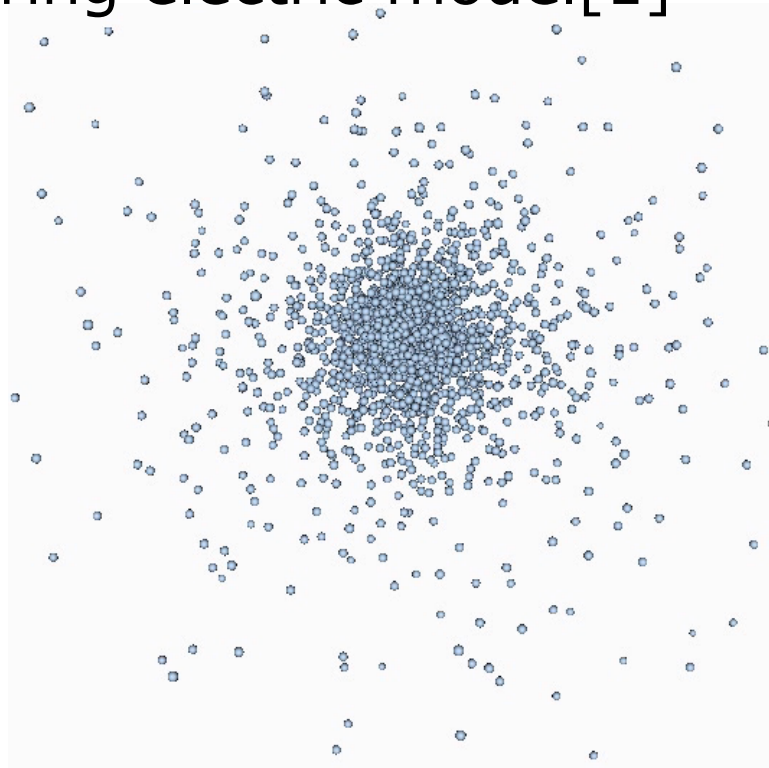


1. We assign different community to each node.
 2. We randomly select a node.
 3. We evaluate the gain of modularity $\Delta Q = Q' - Q$ when the selected node was replaced to adjacent community of it. The community of selected node is replaced to the community of maximum of ΔQ .
 4. We repeat step 2~4 until no further improvement of Q .
- ↓
5. Reconstruction of the network
Community \rightarrow Node, the Nodes in a community \rightarrow Inner link of a community, links between communities \rightarrow a link of between nodes
 6. Repeat step 1~6

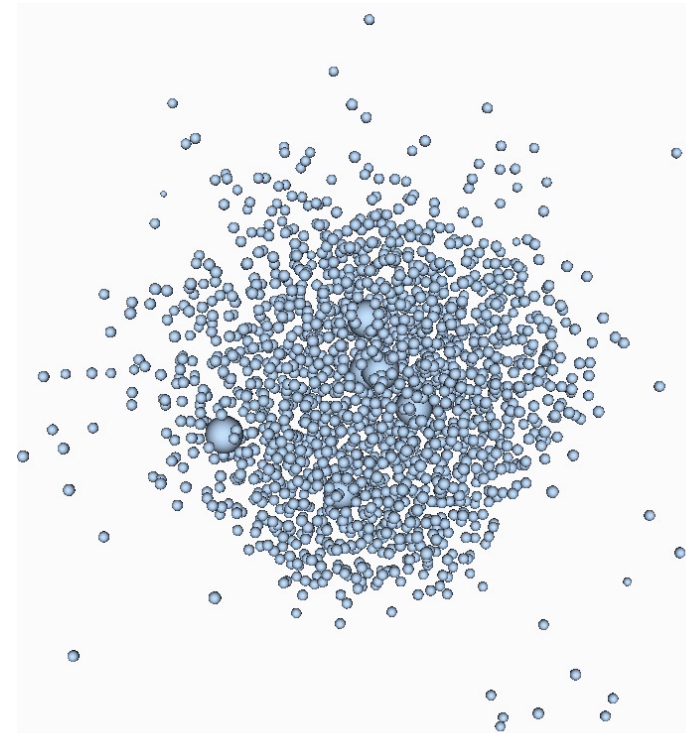
- [1] V. D. Blondel, J.-L. Guillaume, R. Lambiotte and E. Lefebvre, *J. Stat. Mech. : Theory and Experiment*, (2008), p. P10008.
[2] M. J. Barber. *Phys. Rev. E* **76**, 066102(2007).
[3] T. Ikeya and T. Murata. *Computer Software*, Vol. 28, No. 1, pp. 91 {102, 2011.

Network visualization

- The optimized configurations of the networks were obtained by molecular dynamics simulation in a spring electric model[1]



WB network in 2011

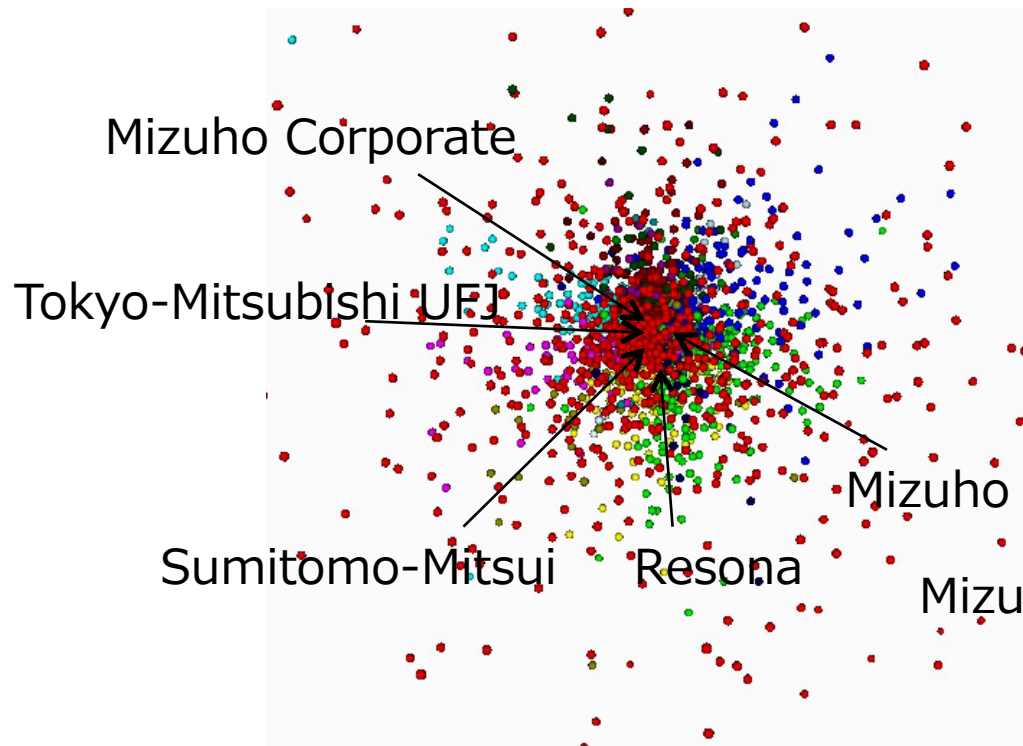


WF network in 2011

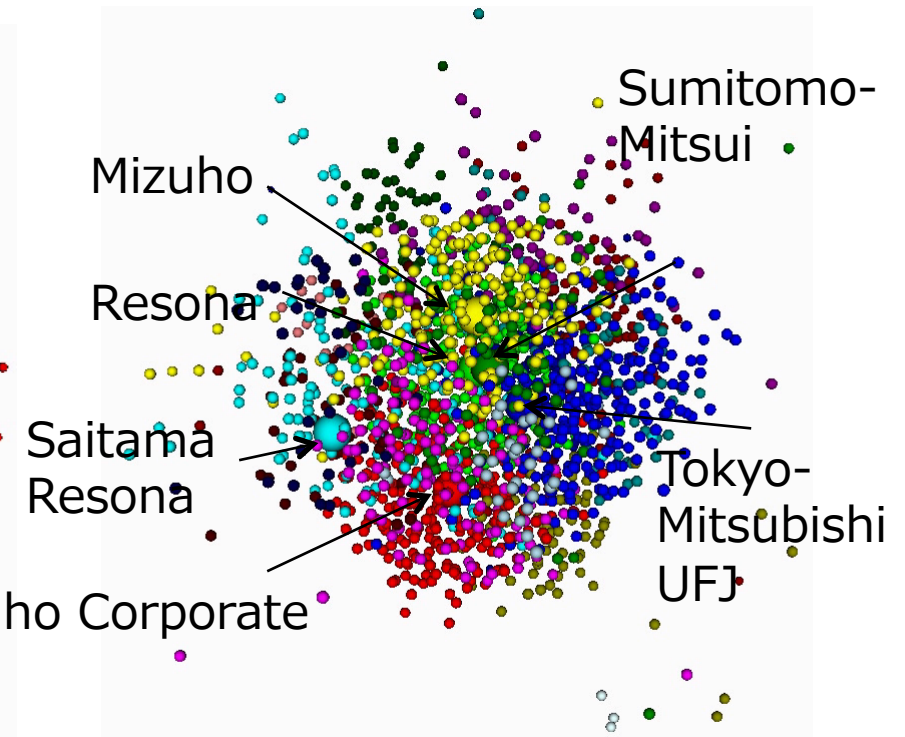
[1] K. Kamehama, T. Iino, H. Iyetomi, Y. Ikeda, T. Ohnishi, H. Takayasu and M. Takayasu, *J. Phys.: Conf. Ser.*, **221** (2010), 012013.

Community structures

- Nodes in the same community are colored identically



WB network in 2011



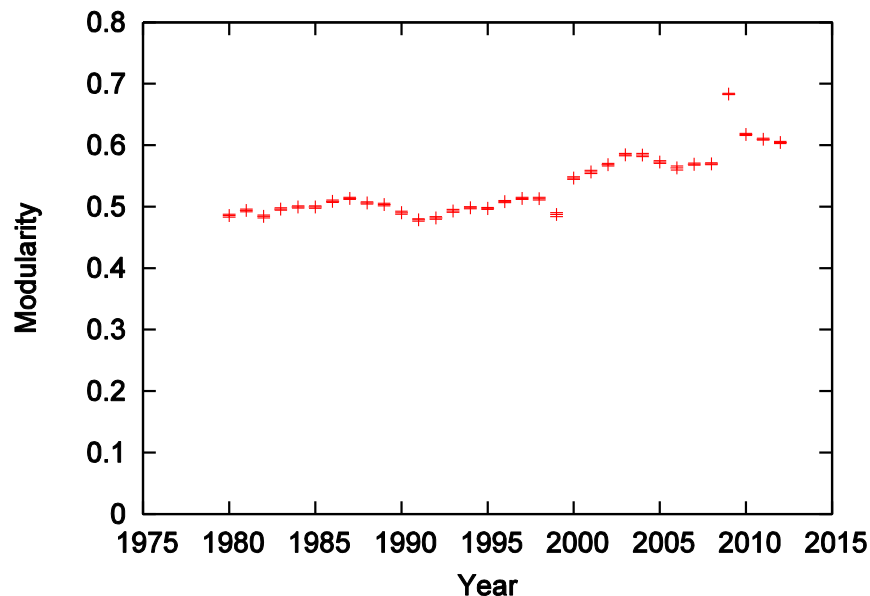
WF network in 2011

The community detection works well!

From Firms to Banks

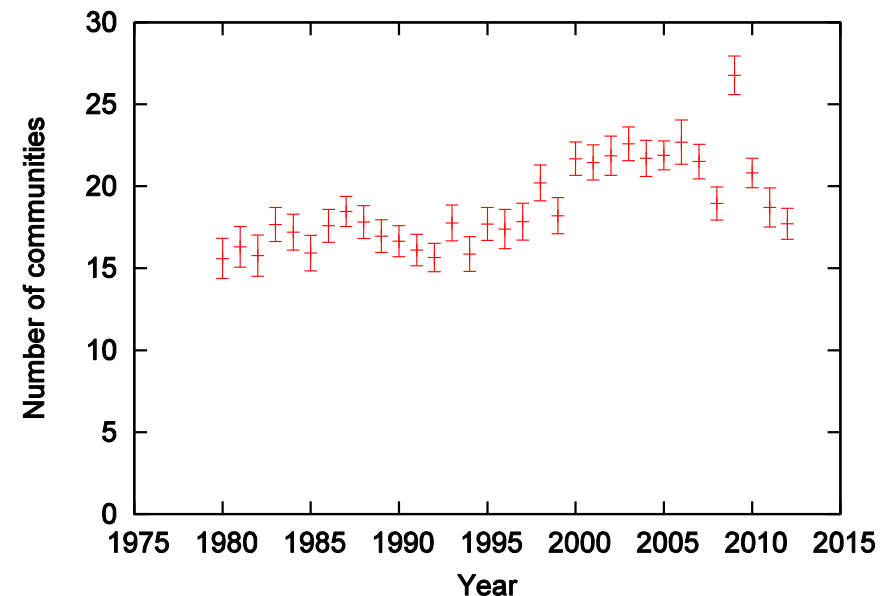
The results of community detection on WB network
We have generated 1000 samples for the community decomposition

Modularity Q



Almost constant (before 2000)
Gradually increasing (after 2000)

Number of communities

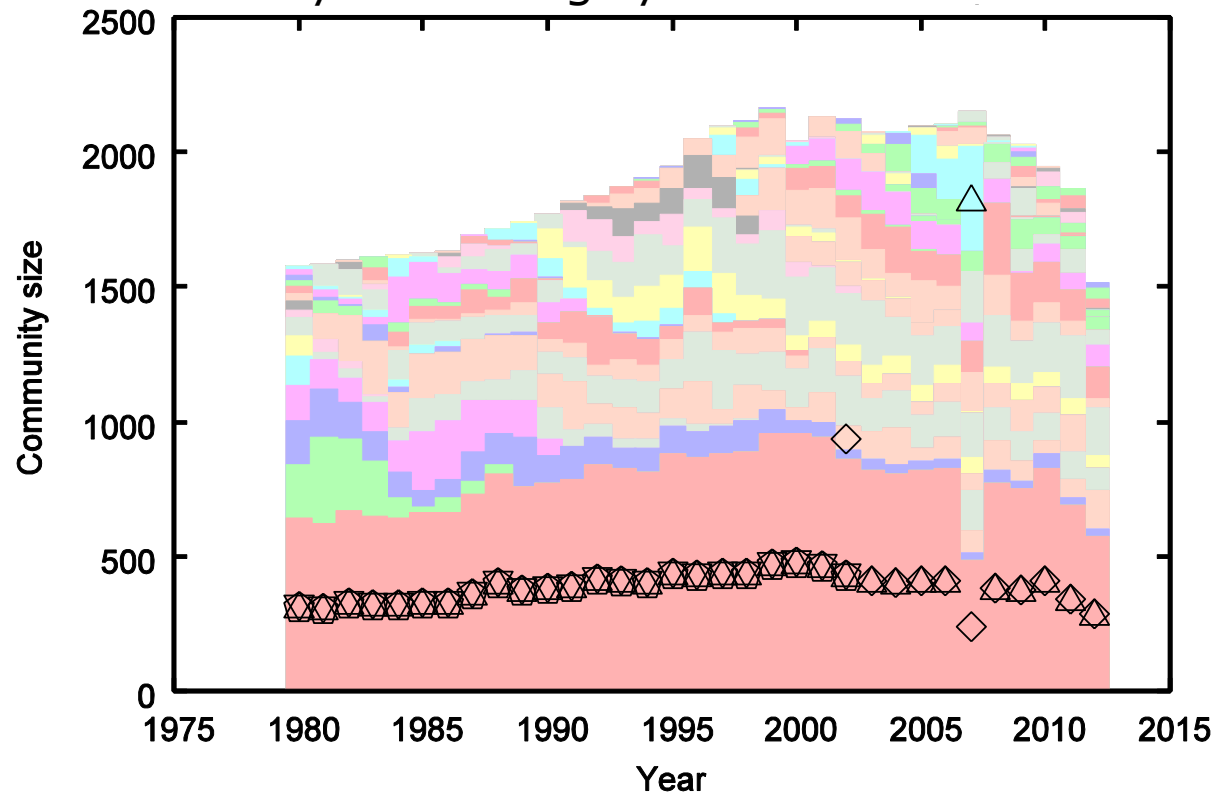


around 15 (before 2000)
Gradually increasing to about 25
(after 2000)

The variations in the samples are so small → The results are quite robust

Temporal Change of the Community Structure of the WB Network

- Belt-like structures
 - Continuous evolution of the communities (birth, growth, death and decay)
- Most of the city banks belong to the largest community over 30 years
 - The city banks largely share risks due to failure of firms.



Mizuho

- Dai-ichi Kangyo, Mizuho \triangle
- Fuji ∇
- Mizuho Corporate \diamond
- Industrial Bank of Japan \square

Hokkaido-Takushoku Bank



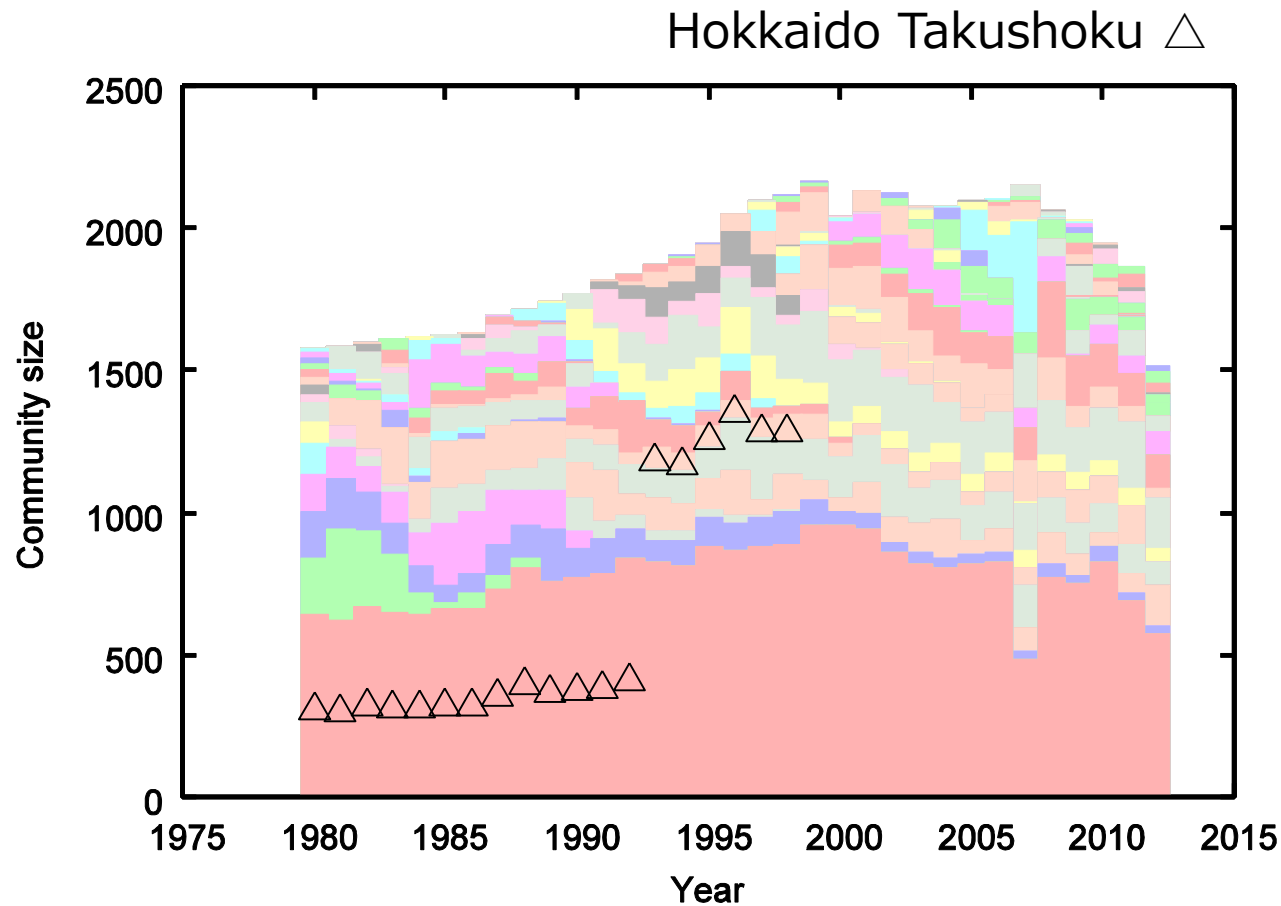
- Hokkaido-Takushoku bank was one of the city banks in Japan.
- It was the main bank in Hokkaido prefecture and went bankrupt in November, 1997.

Loan amount : 354 billion yen (1985) ; 13th in 13 city banks

How did Hokkaido-Takushoku bank behave in the credit network?

Behavior of Hokkaido-Takushoku Bank

- Hokkaido-Takushoku bank went away from the city bank community 6 years prior to its bankruptcy!



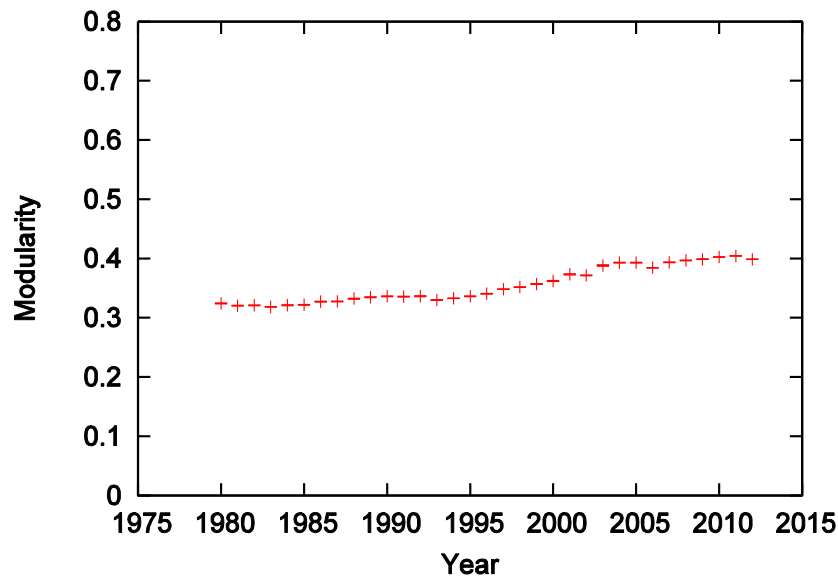
Promising applicability of the present analysis to risk control in financial systems!

From Banks to Firms

The results of community detection on WF network

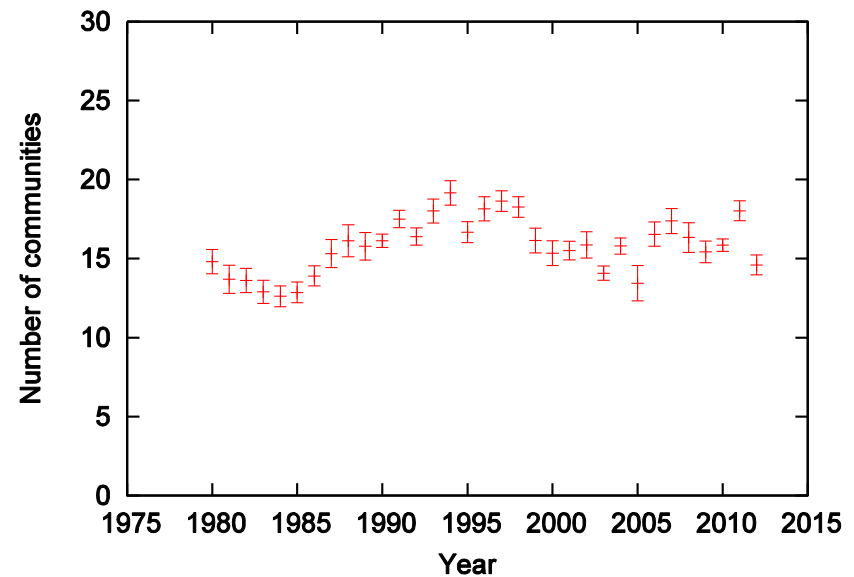
We have generated 1000 samples for the community decomposition

Modularity Q



Slightly increasing

Number of communities

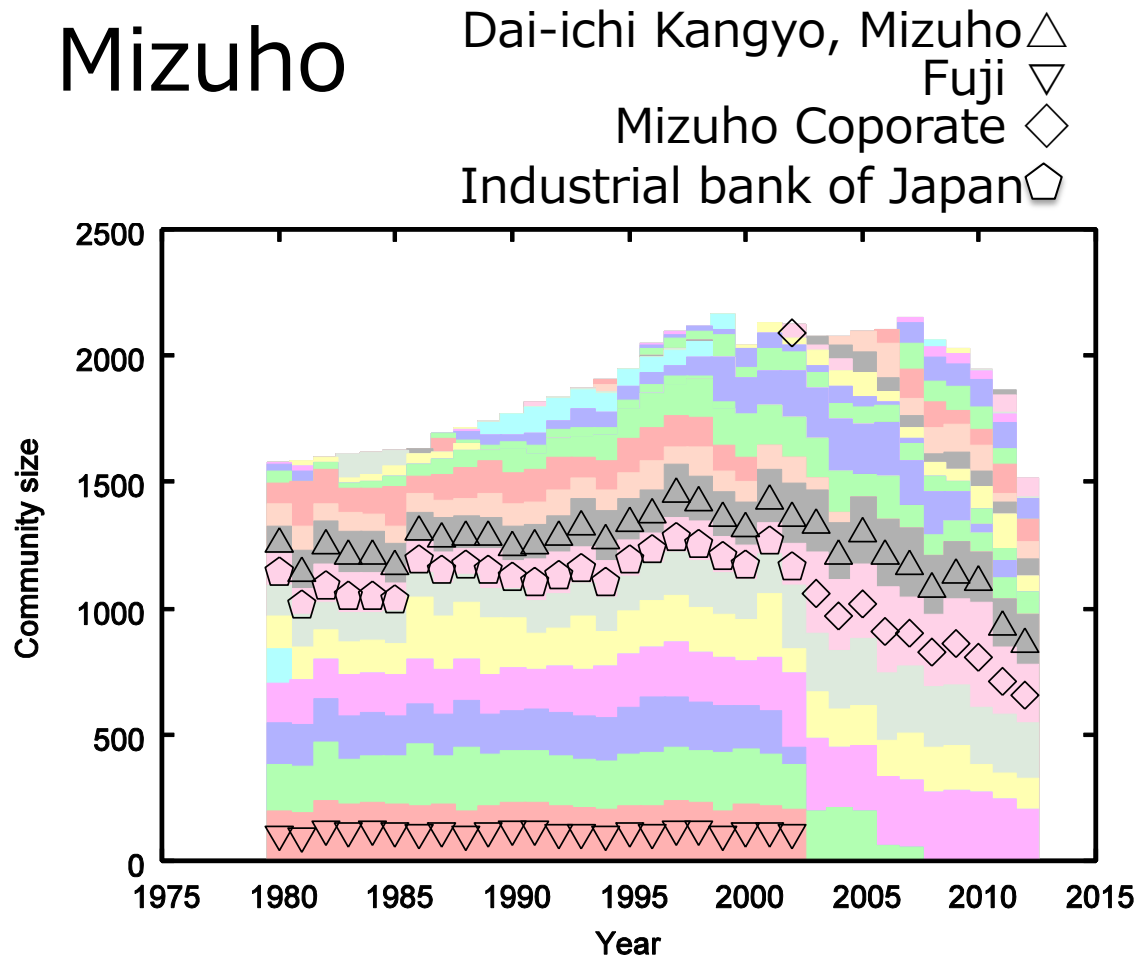


Stable in the whole period

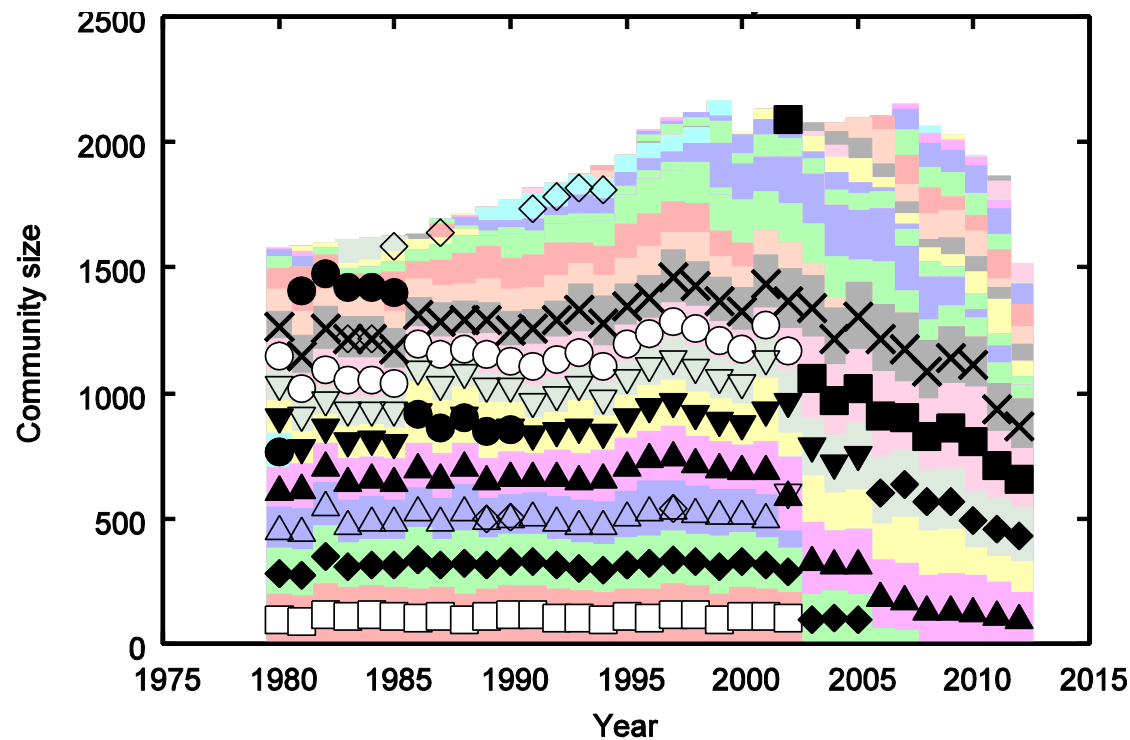
The variations in the samples are so small → The results are quite robust

Temporal Change of the Community Structure of the WF Network

- Each of the city banks forms its own community



Tracks of the City Banks: WF Network



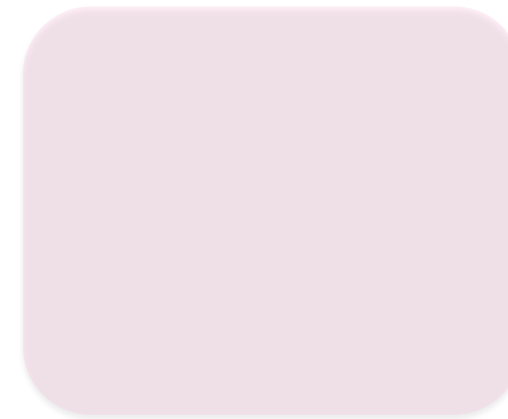
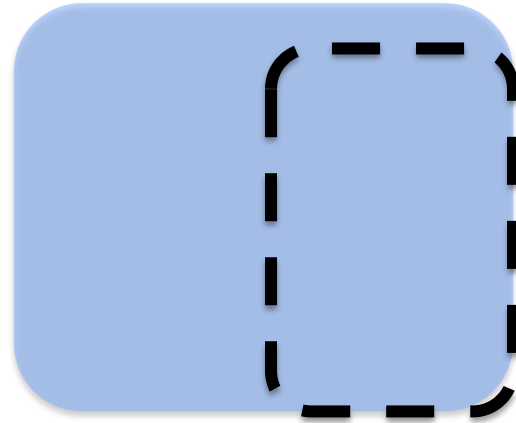
- Dai-ichi Kangyo, Mizuho x
- Fuji □
- Mizuho Corporate ■
- Industrial bank of Japan ○
- Taiyokobe ●
- Mitsui, Mitsui-Taiyokobe △
- Sumitomo, Sumitomo-Mitsui ▲
- Tokai ▽
- Sanwa, UFJ ▼
- Tokyo ◇
- Mitsubishi, Tokyo-Mitsubishi, Tokyo-MitsubishiUFJ ◆

Each of the city banks forms its own community.

Intersection of the Two Community Sets

- Cores of the risk concentration in the credit network

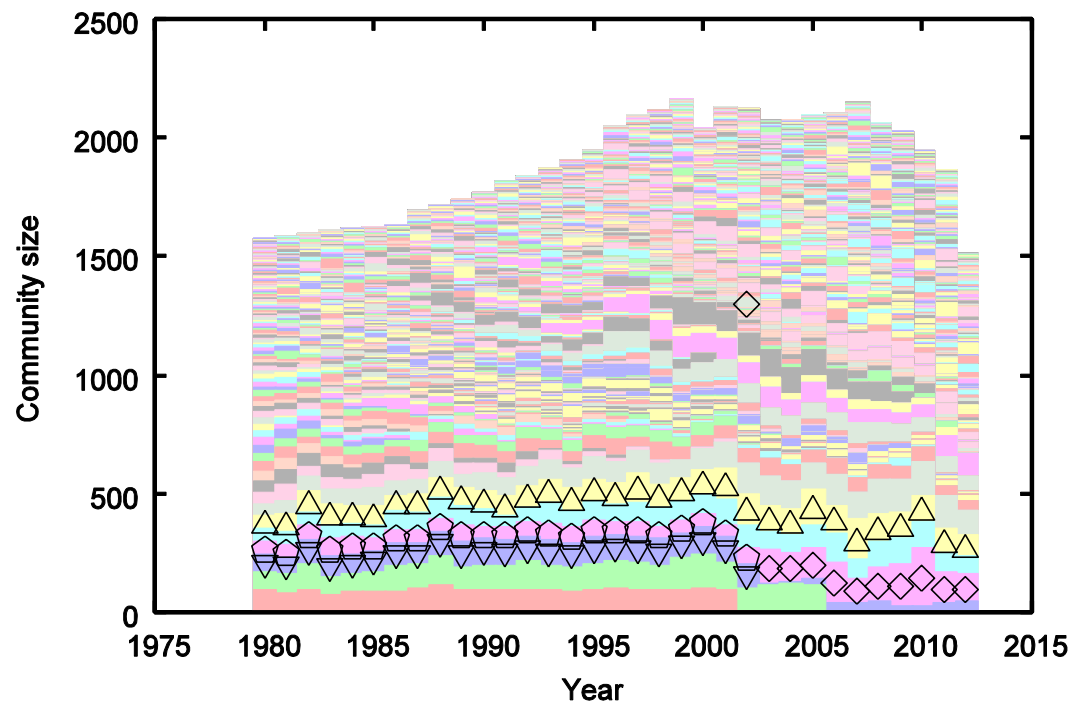
Community set of WB network



Community set of WF network

Overlapping Parts between the WB and WF Communities

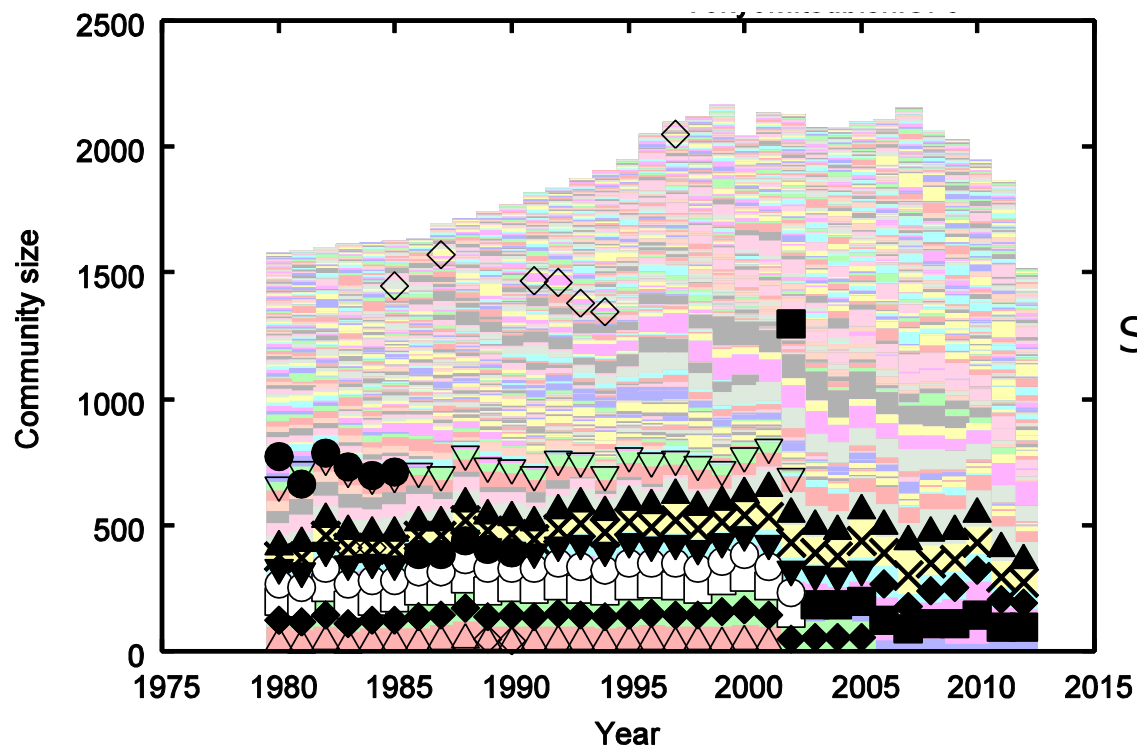
- The credit network is fragmented into much smaller pieces.
- The relatively thick bands continuously exist
→ Those steady bands correspond to the communities individually led by the city banks



Mizuho

Dai-ichi Kangyo, Mizuho \triangle
Fuji ∇
Mizuho Coporate \diamond
Industrial bank of Japan \pentagon

All of major three groups of city banks are depicted by different symbols



- Dai-ichi Kangyo, Mizuho x
- Fuji □
- Mizuho Coporate ■
- Industrial bank of Japan ○
- Taiyokobe ●
- Mitsui, Mitsui-Taiyokobe △
- Sumitomo, Sumitomo-Mitsui ▲
- Tokai ▽
- Sanwa, UFJ ▼
- Tokyo ◇
- Mitsubishi, Tokyo-Mitsubishi, Tokyo-MitsubishiUFJ ◆

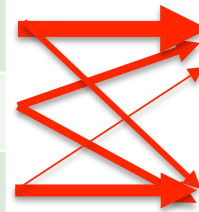
Change of the Community Structure on Reconstruction of the City Banks

2002

City bank that let the community	Community size
Dai-ichi Kangyo	130
Fuji	101
Industrial Bank of Japan (IBJ)	67

2003

City bank that let the community	Community size
Mizuho	113
Mizuho Corporate	142



From Dai-ichi Kangyo

number of nodes	City bank that let the community
51	Mizuho
27	
22	Mizuho Corporate
2	Sumitomo-Mitsui
1	

From Fuji com.

number of nodes	City bank that let the community
32	Mizuho Corporate
28	Mizuho
5	
4	Saitama Resona
3	Mitsubishi-Tokyo

From IBJ com.

number of nodes	City bank that let the community
36	Mizuho Corporate
6	
3	Mizuho
2	
2	

Summary

We have initiated a network-theoretic study on temporal change of the credit relationship formed by banks and listed firms in Japan.

- WB network
 - Nodes in a community share risk when firms go wrong.
 - Existence of the large city bank community
 - Detection of abnormal behavior of the city bank 6 years before its bankruptcy

- WF network
 - Nodes in a community share risks due to failure of banks
 - Each of the city banks has its own community

- Overlapping parts of the two community sets
 - Cores of the risk concentration
 - The respective communities of the city banks still survive.

We hope that the present results would open a new door for approaching to the systemic risk problem in financial systems.