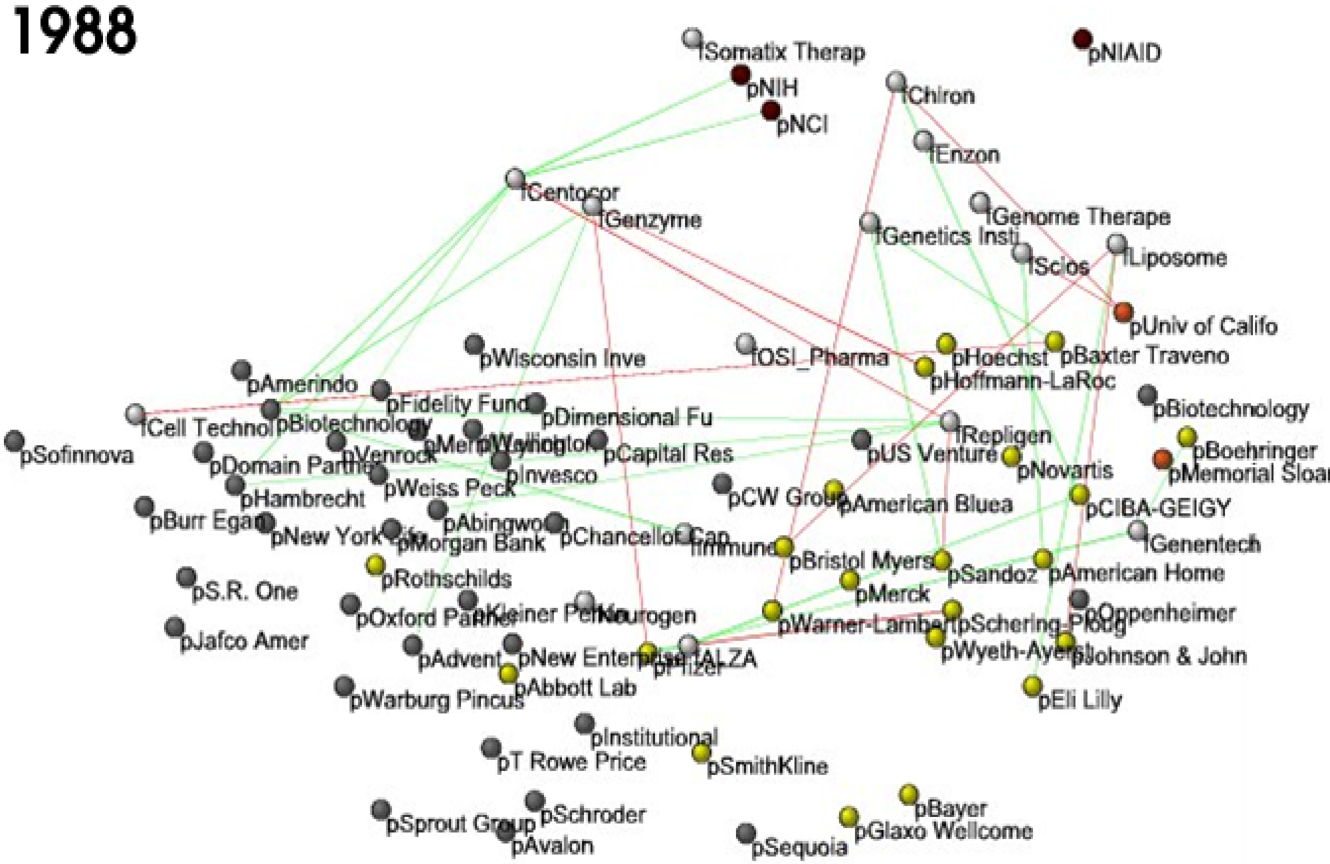
Networks and hypernetworks 3

Networks in economy

Rui Vilela Mendes

http://label2.ist.utl.pt/vilela/

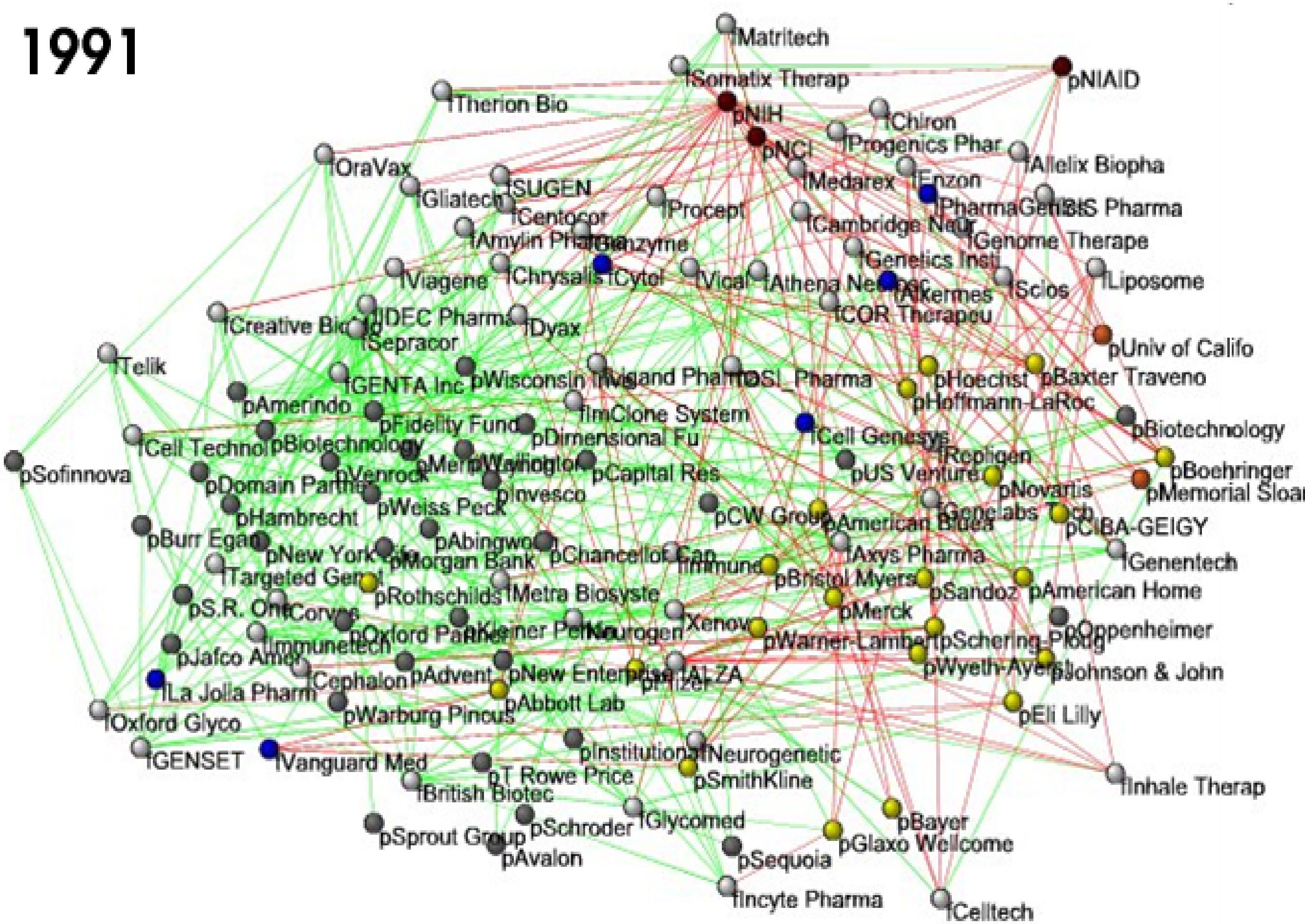
Business ties in US biotech-industry



Nodes: companies: **investment**
pharma
research labs
public
biotechnology

Links: **financial**
R&D collaborations

Business ties in US biotech-industry



Nodes: companies: investment

pharma

research labs

public

biotechnology

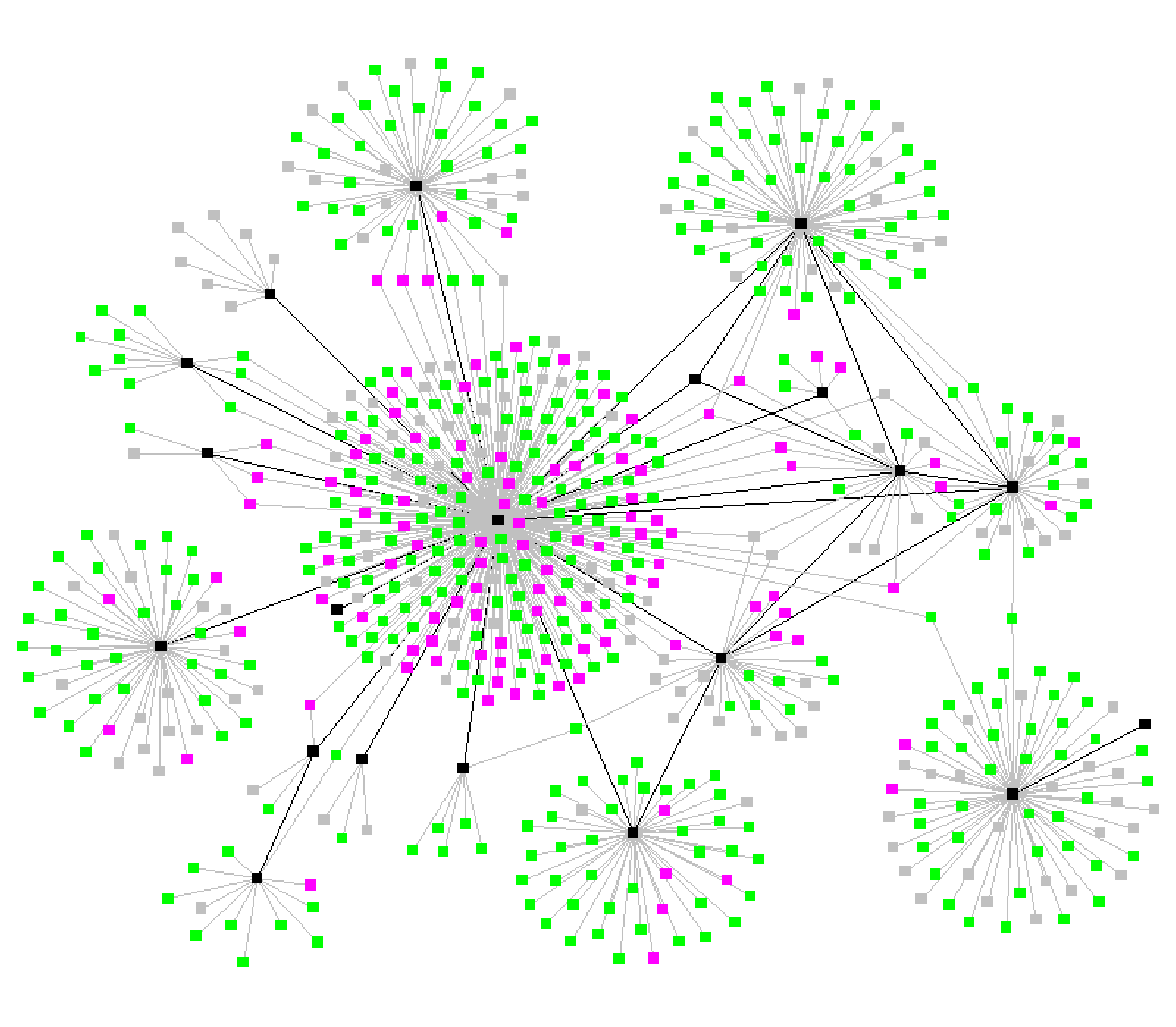
Links: financial

R&D collaborations

Viral marketing

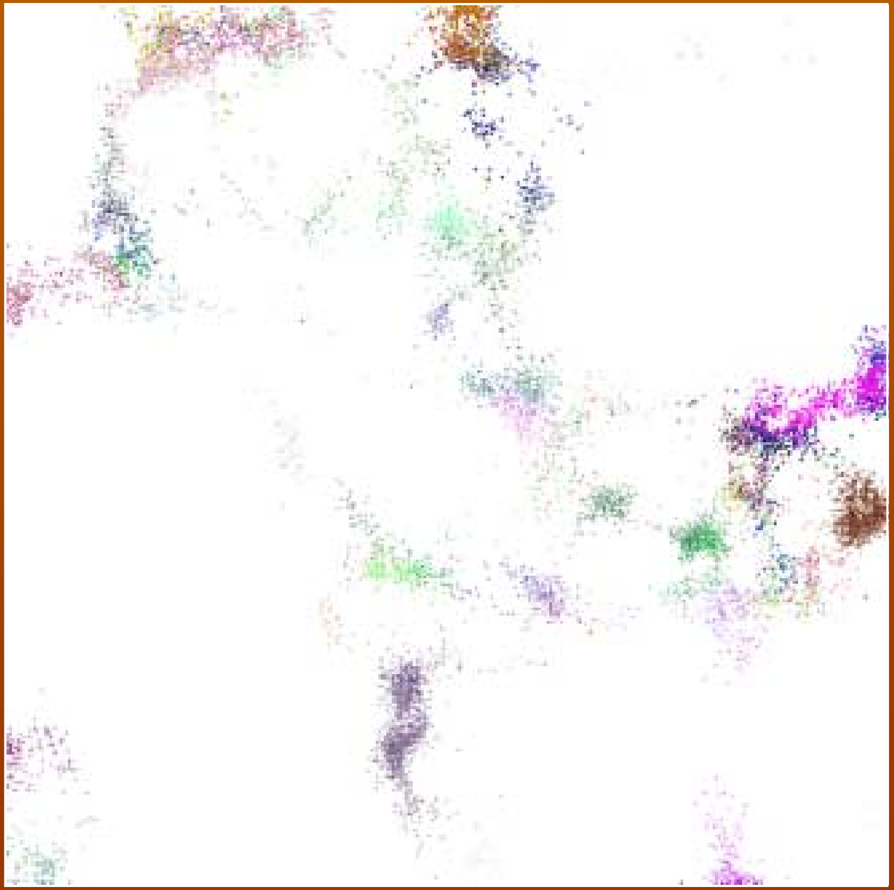
Hubs:

'broadcast' weakly infectious viruses, ideas



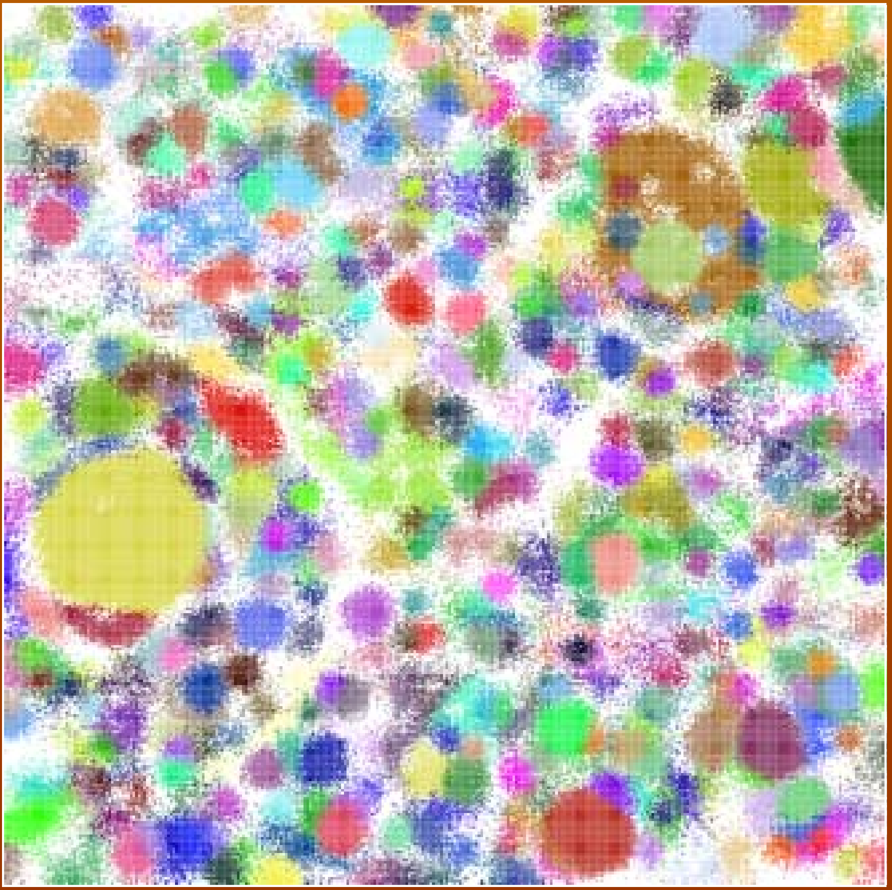
black: opinion leaders
red: influenced
green: uninfluenced
grey: undecided

500 randomly chosen users



Day [illegible]

500 *most active* users



Day [illegible]

Empirical wealth distributions

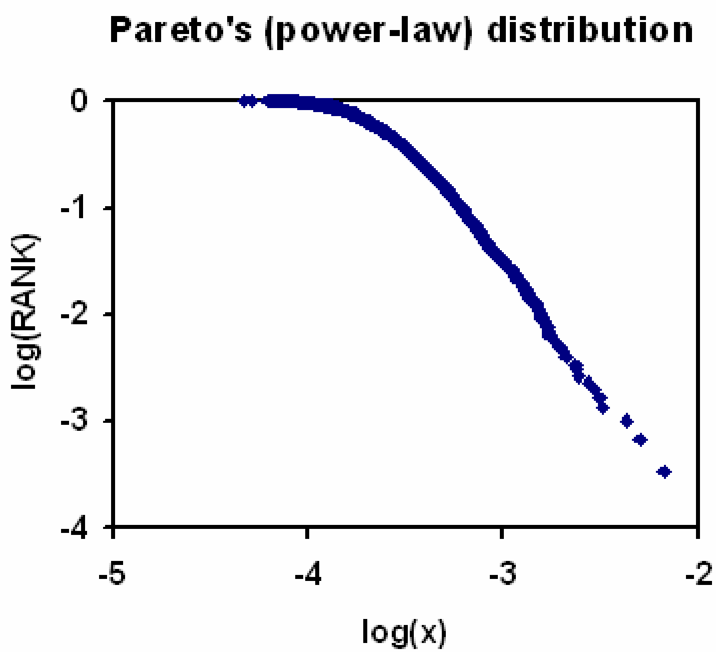
Two typical forms:

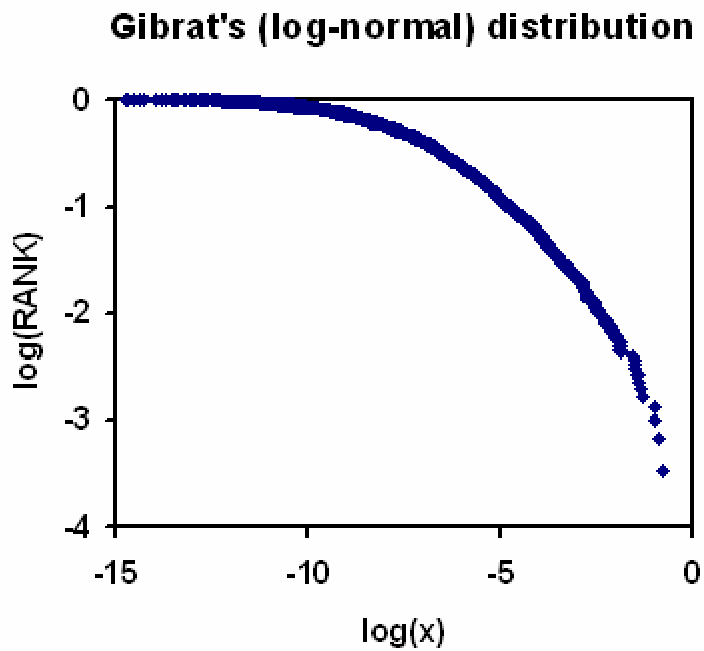
Large wealth: Pareto's law *(power-law distribution):*

$$P(w) \propto w^{-1-\alpha}$$

Small wealth: Gibrat's law *(log-normal distribution):*

$$P(w) = \frac{1}{w\sqrt{2\pi\sigma^2}} \exp\left[-\frac{1}{2\sigma^2}\log^2\frac{w}{w_0}\right]$$

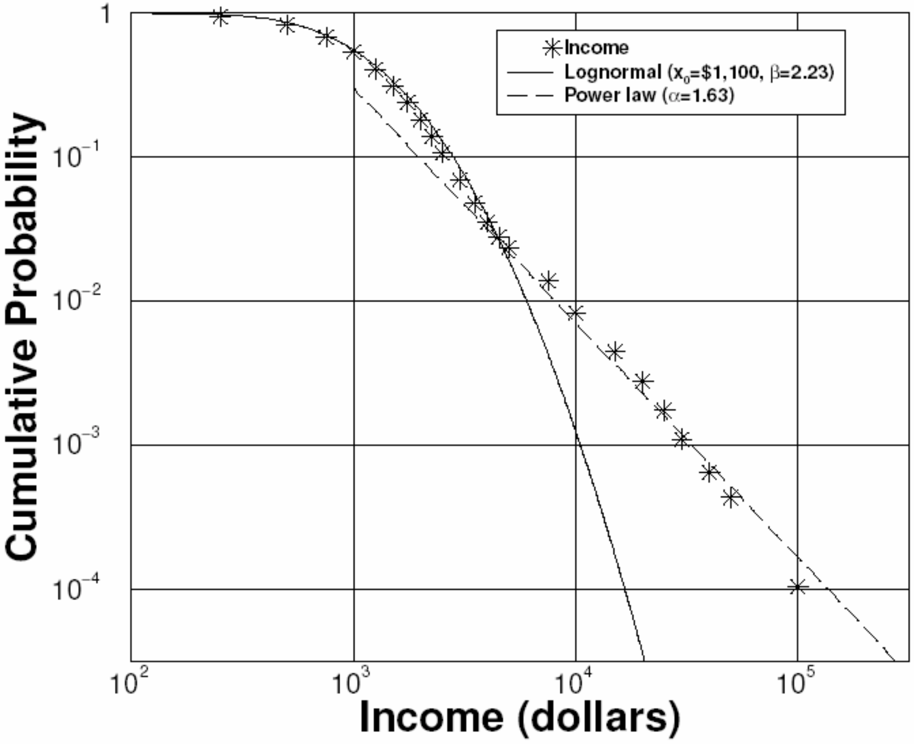




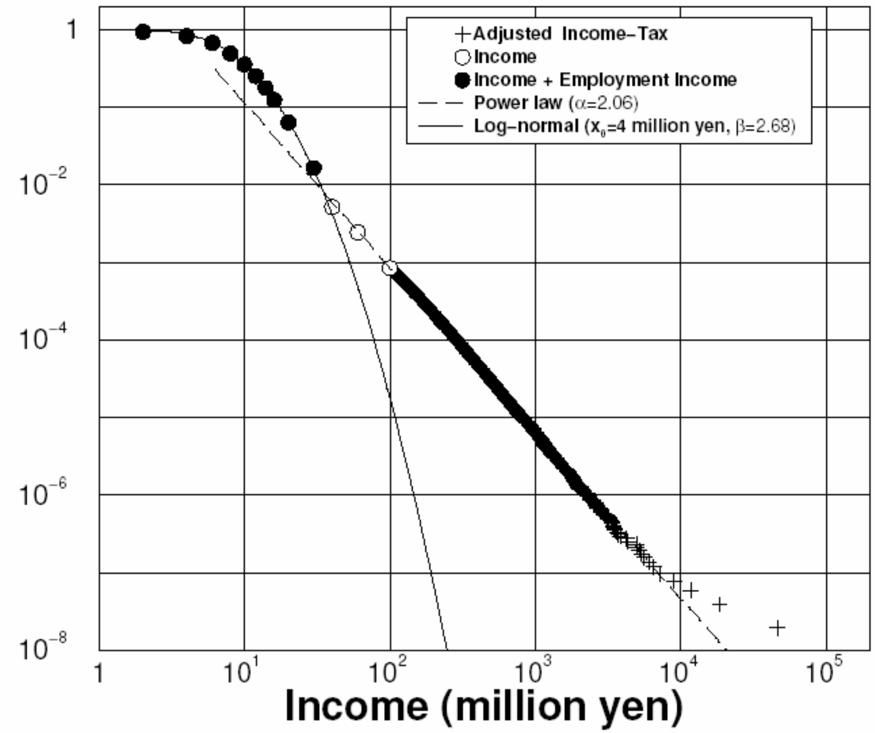
Cumulative distribution: $P_>(x) = \int_x^\infty P(x')dx' \qquad x \equiv w/w_{tot}$

Personal Income Distribution

U.S.A. 1935-36 ($)

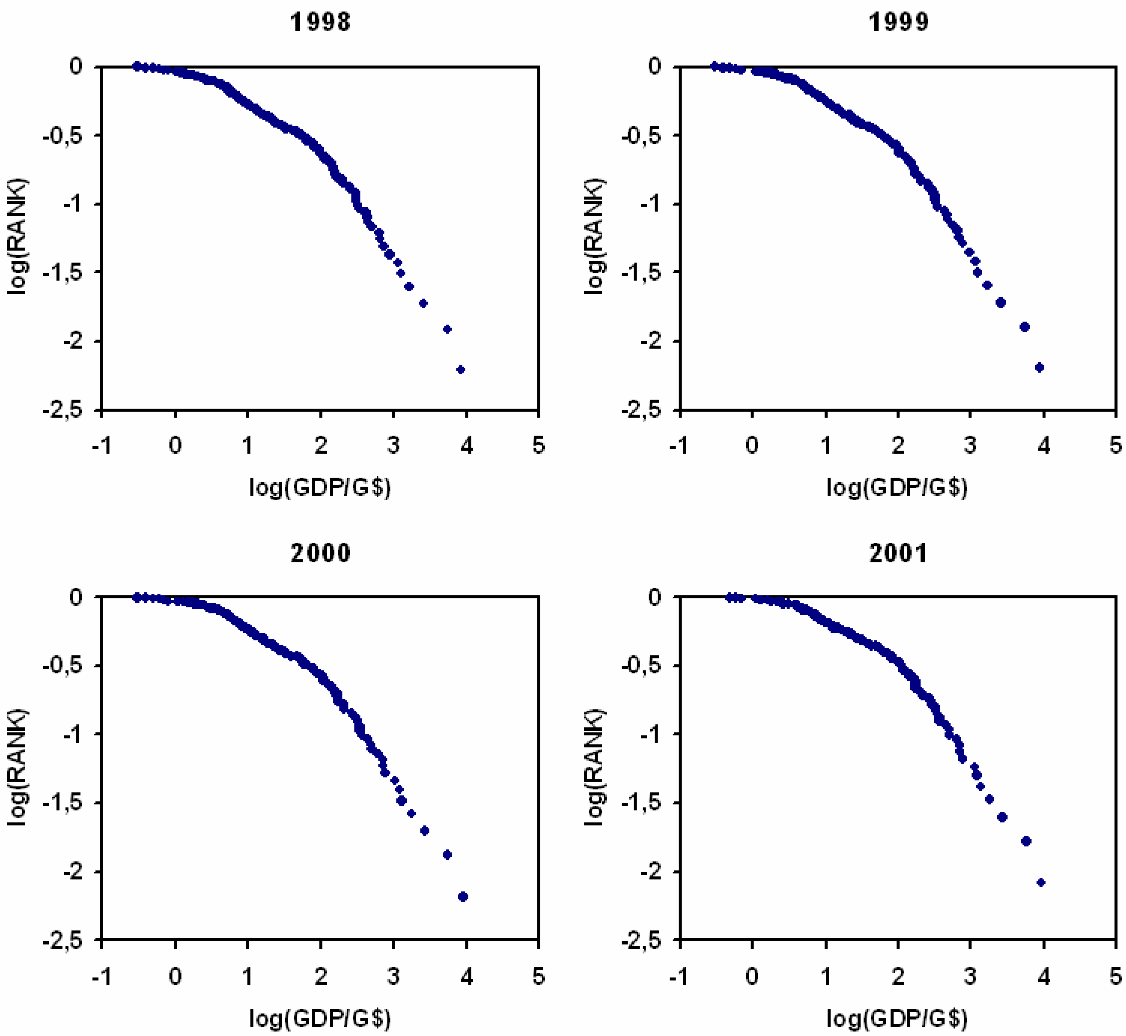


Japan 1998 (M¥)



Log-normal distribution with power-law tails (mixed form)

Gross Domestic Product Distribution *(GDP)*



All countries; 1998, 1999, 2000, 2001 (**G$**): log-normal and power-law (mixed)

Empirical forms of "wealth" distributions:

The most general form of ***P(w)*** is "mixed":

Combination of a power-law and a log-normal distribution

↓

Theoretical models that can reproduce the mixed form

Independent agents models

Purely multiplicative stochastic process:

$$\dot{w}_i(t) = \eta_i(t) w_i(t)$$

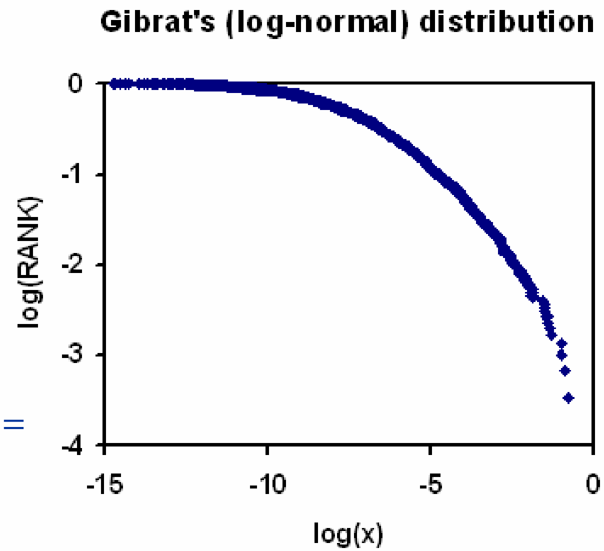
$w_i(t)$ = wealth of agent i at time t

$\eta_i(t)$ = Gaussian process (mean m and variance $2\sigma^2$)

Log-normal distribution

$$w_i(t+1) = w_i(t) + \eta_i(t) w_i(t) = [1+\eta_i(t)] w_i(t)$$

$$\begin{aligned} & \log[w_i(t+1)] = \\ & = \log[w_i(t)] + \log[1+\eta_i(t)] = \\ & = \log[w_i(t-1)] + \log[1+\eta_i(t-1)] + \log[1+\eta_i(t)] = \\ & = \ldots \end{aligned}$$



Independent agents models

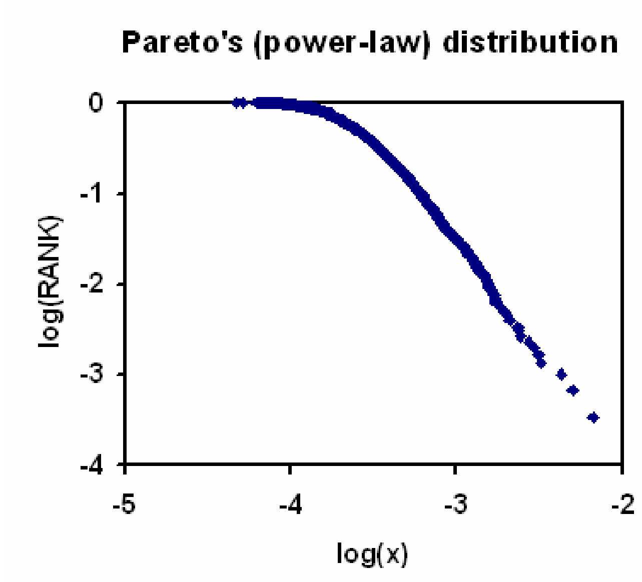
Multiplicative stochastic process with a lower boundary:

$$\dot{w}_i(t) = \eta_i(t) w_i(t) \qquad w_i(t) > w_{min}$$

Multiplicative-additive stochastic process:

$$\dot{w}_i(t) = \eta_i(t) w_i(t) + \xi_i(t) \qquad \langle \log \eta_i(t) \rangle < 0$$

Power-law distribution



Model of Bouchaud and Mézard *(BM)*

Interactive multiplicative stochastic process:
wealth evolution is determined by the interactions among economic agents

Wealth evolution with ***N*** agents:

$$\dot{w}_i(t) = \eta_i(t) w_i(t) + \sum_{j \neq i} J_{ij} w_j(t) - \sum_{j \neq i} J_{ji} w_i(t)$$

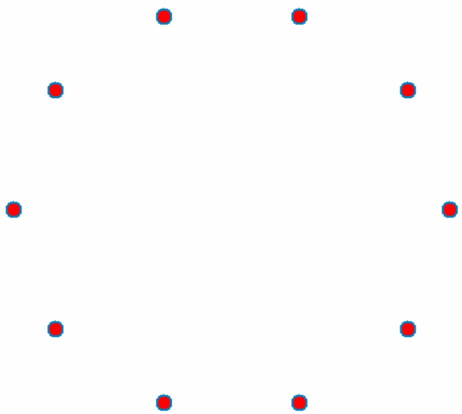
$w_i(t)$ = wealth of agent i at time t

$\eta_i(t)$ = Gaussian process (mean m and variance $2\sigma^2$)

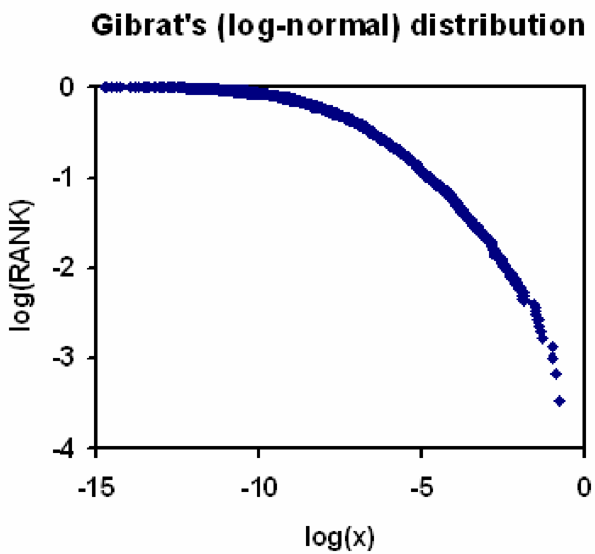
J_{ij} = fraction of wealth flowing from j to i

Independent agents

$J_{ij} = 0 \quad \forall i,j$

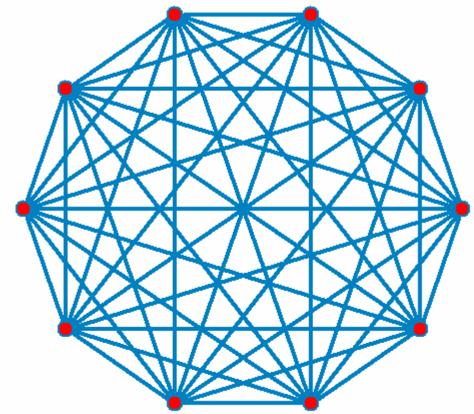


$$\dot{w}_i(t) = \eta_i(t) w_i(t)$$

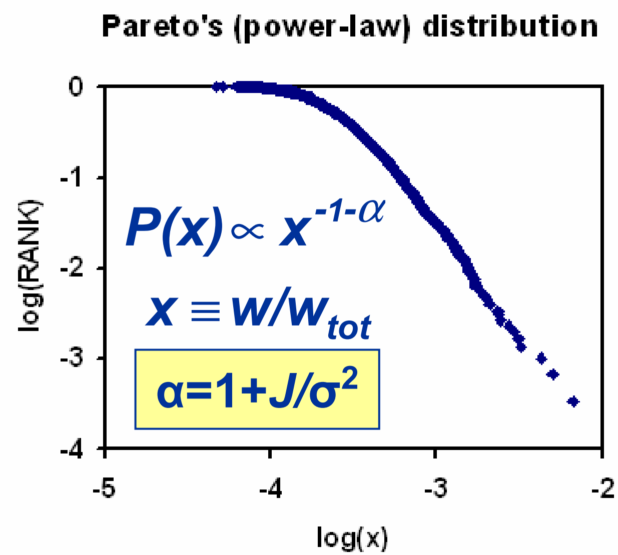


Mean field

$J_{ij} = J/N \quad \forall i,j$

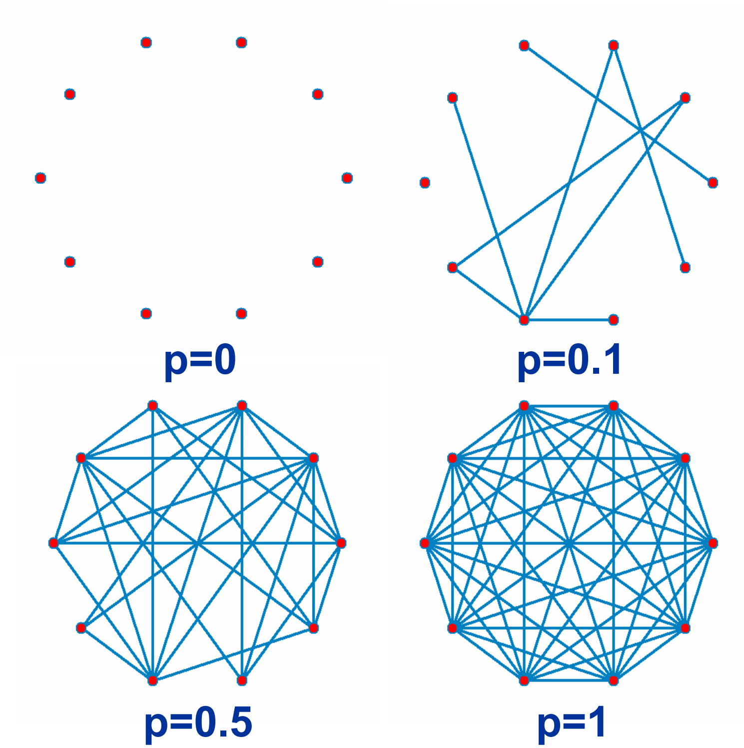


$$\dot{w}_i(t) = \eta_i(t) w_i(t) + J\overline{w}(t) - J w_i(t)$$



BM model on random graphs

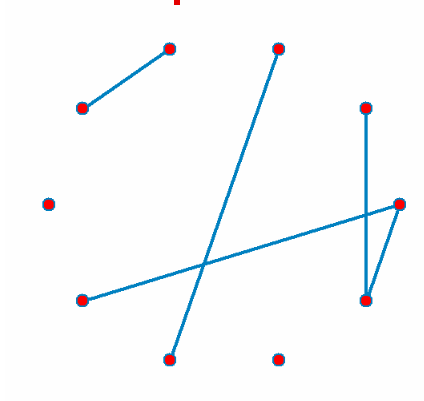
- Start with a set of ***N*** isolated vertices;
- For each pair of vertices draw a link with uniform probability ***p***.

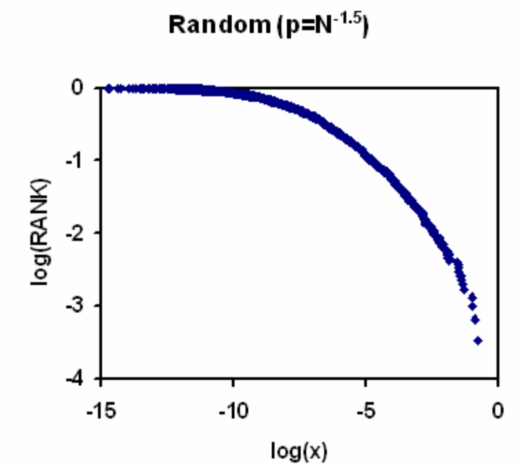


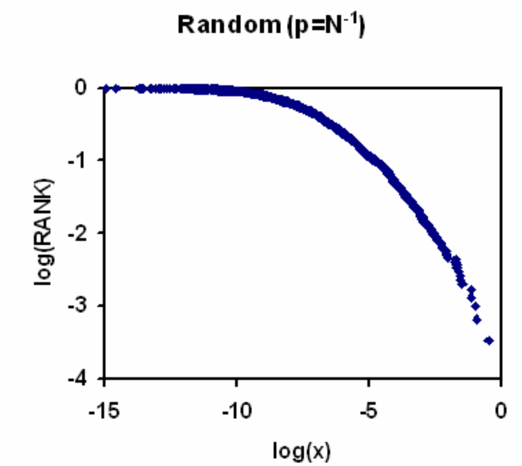
BM model on random graphs

The wealth distribution ***P(w)*** changes suddenly
from log-normal ($p<p_c$) to power-law ($p>p_c$)

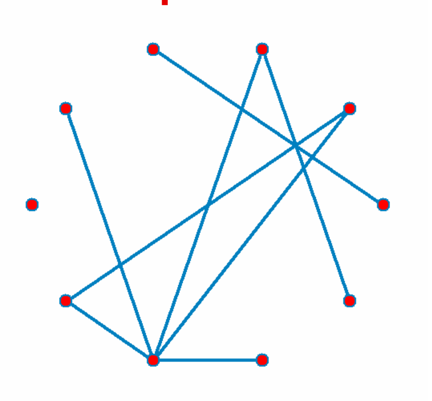
$p=N^{-1.5}$



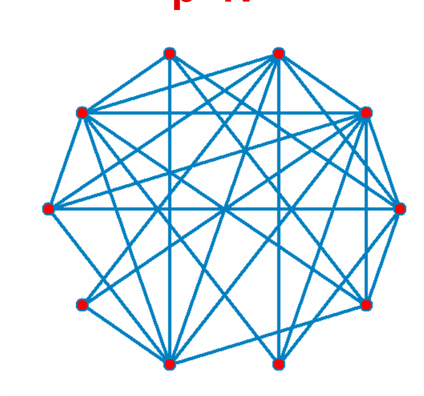


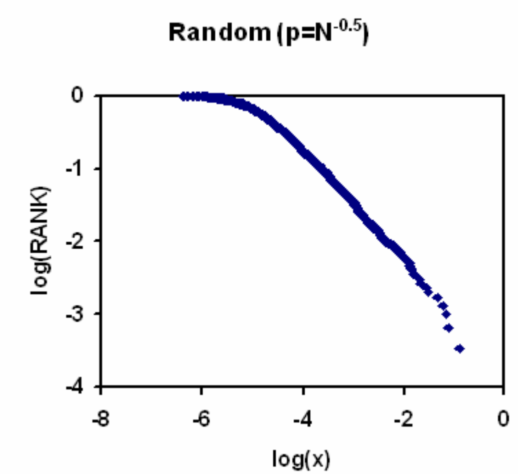


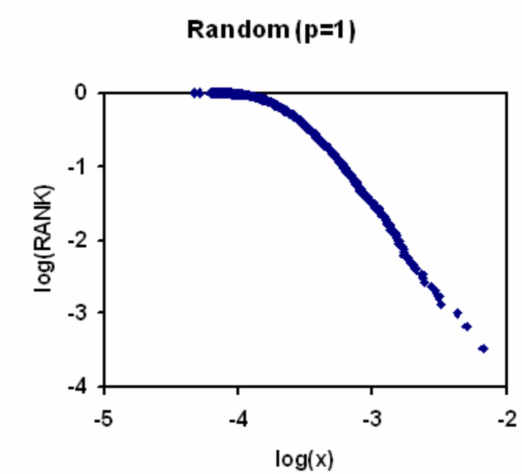
$p=N^{-1}$



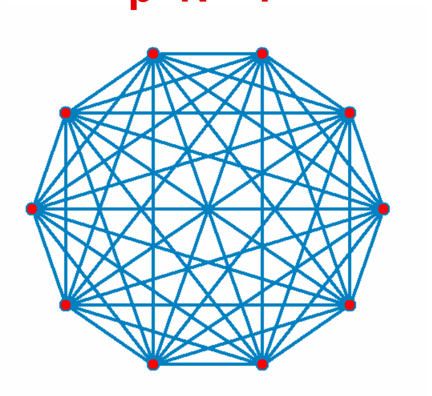
$p=N^{-0.5}$







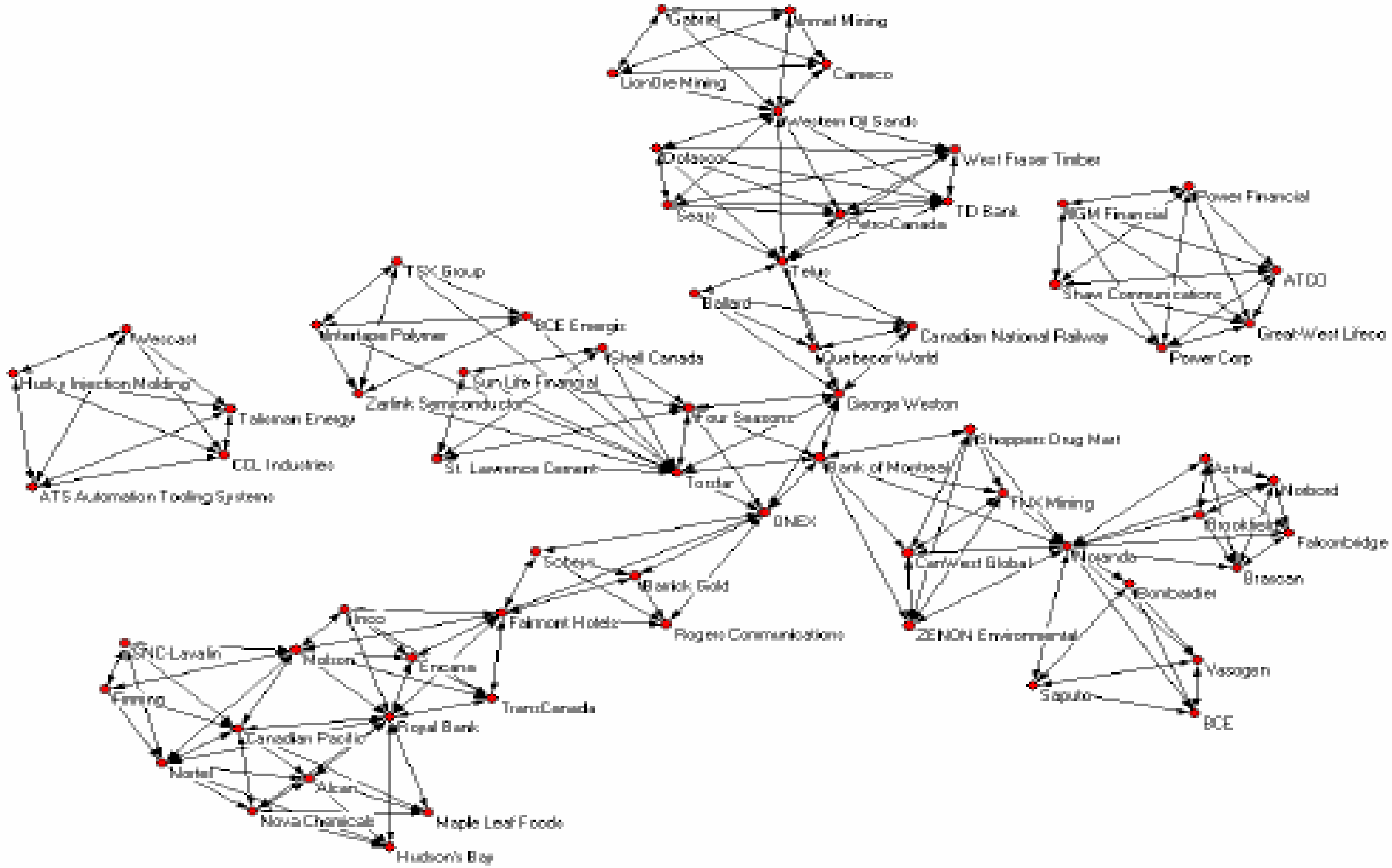
$p=N^0=1$



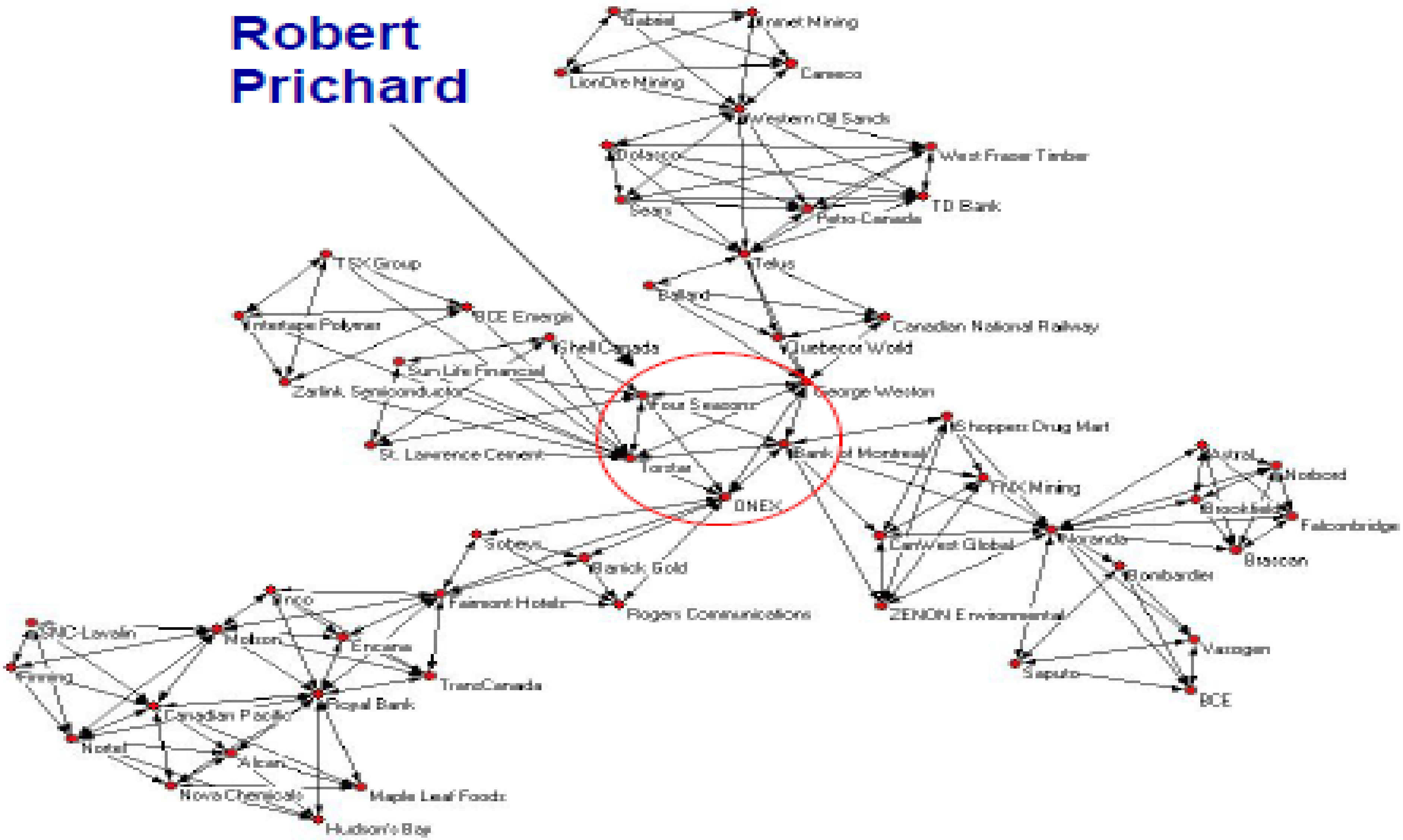
Simulation parameters: ***N*=3000 *T*=10000**

$J=0.05$ $\langle\eta\rangle=1$ $\langle\eta^2\rangle-\langle\eta\rangle^2 = 0.1$

The networks of the corporate elite
The Elite 16 in Canada (2004)



The networks of the corporate elite



The networks of the corporate elite

- Individuals, at the core of the network, control the diffusion of information in the network
- Corporate governance practices spread through shared directors
- Firms are more likely to adopt an acquisition strategy if they share a director with a company that has an acquisition strategy
- Anti-takeover strategies diffuse along director networks

The global corporate elite

- Network of overlapping membership among directors of the world's (500) leading corporations and transnational policy boards
- 500 leading corporations
- 7 global policy groups
- 4 transnational business councils

(*W. K. Carroll and J. P. Sapinsky, International Sociology 25 (2010) 501-538*)

The global corporate elite

- Global policy groups

	No. of directors					
	1996	2006	Agenda priorities	Organizational form	Core membership	Geopolitical reach
1: ***Global policy groups***						
International Chamber of Commerce Est. 1919 Paris headquarters	27	25	Corporate self-regulated, global laissez faire	International business organization; government lobbyist; linking to locals (national committees)	7000 corporations from 130 countries	Global; corporations and regional committees worldwide, including the Americas, Europe, the Middle East, Africa and the Asia-Pacific
Bilderberg Conferences Est. 1952 Geneva origin; office in Leiden (Netherlands)	112	135	Economic order among 'heartland' states	Secretive policy-planning and elite consensus-seeking forum	130 national and international corporate, govt, military and academic elite; no set membership	North Atlantic 'heartland'; draws elite representation from Western Europe and North America
Trilateral Commission Est. 1972 Washington, Paris & Tokyo headquarters	304	413	Economic order among 'Triad' states	Policy-planning and elite consensus-seeking forum; research task forces; discourse producer	350 national and international corporate, media, academia, public service and NGO elite	'The Triad'; draws elite representation from North Atlantic, Japan, ASEAN

The global corporate elite

	No. of directors		Agenda priorities	Organizational form	Core membership	Geopolitical reach
	1996	2006				
World Economic Forum Est. 1971 (1987) Geneva headquarters	55	47	'Global' economic order	Combined elite transnational business organization, and policy-planning and consensus-seeking forum; research task forces; discourse producer	1000 top transnational corporations	Global; draws elite representation from Western Europe, Central and Eastern Europe, Africa, North America, Latin America, Asia and Oceania
International Advisory Board of the Council on Foreign Relations Est. 1995 New York headquarters (CFR)	35	33	Strategic orientation of US foreign policy	*CFR*: policy-planning and consensus-seeking forum, discourse producer, task forces; *Advisory board*: Advisory function to CFR	*CFR*: US citizens; 250 corporate members (US and foreign firms); *Advisory board*: 33 corporate and political elites from around the world	Global; Advisory board draws elite representation from Western Europe, Central and Eastern Europe, Africa, North America, Latin America, Asia and Oceania
World Business Council for Sustainable Development	116	185	'Global' environmental and economic reform	Combined elite transnational business organization, and policy-planning and	206 corporations (by invitation)	Global; draws elite representation from Western Europe,

The global corporate elite

- Transnational business councils

	No. of directors		Agenda priorities	Organizational form	Core membership	Geopolitical reach
	1996	2006				
Est. 1995 Geneva headquarters				consensus-seeking forum; research task forces; discourse producer		Central and Eastern Europe, Africa, North America, Latin America, Asia and Oceania
UN Global Compact (Board) Est. 2000 New York headquarters (UN)	n/a	19	Promotion of corporate social and environmental responsibility	Combined elite transnational organization; national or regional communication networks	Board composed of representatives from business (12), labour (2), NGOs (4) and the UN (2)	Global; draws elite representation from Western Europe, Central and Eastern Europe, Africa, North America, Latin America, Asia and Oceania
2: *Transnational business councils*						
Europe						
European Round Table of Industrialists Est. 1983 Brussels headquarters	56	57	Economic integration in Europe; European corporations' global economic position	Combined elite regional business organization, and policy-planning and consensus-seeking forum; lobbying; working groups; discourse producer	Corporate chief executives and chairpersons of major European-owned TNCs from industrial and technology sectors	European Union

The global corporate elite

	No. of directors 1996	2006	Agenda priorities	Organizational form	Core membership	Geopolitical reach
Europe and Asia						
EU–Japan Business Round Table Est. 1995 Brussels & Tokyo headquarters	26	50	Strengthening economic ties between EU and Japan	Combined interregional business organization, and policy-planning and consensus-seeking forum; lobbying; task forces; discourse producer	50 EU and Japanese (about half from each) corporate executives and directors	European Union and Japan
North Atlantic						
TransAtlantic Business Dialogue Est. 1995 Washington headquarters	68 (see note 3)	33	Economic integration and trade liberalization between the US and EU	Combined elite interregional business organization, and policy-planning and consensus-seeking forum	31 US and EU CEOs/chairs	United States and European Union
North America						
North American Competitiveness Council Est. 2006 Ottawa, Mexico & Washington, DC headquarters	n/a	33	Economic integration and trade liberalization in North America; North American corporations' global economic position	Combined elite regional business organization, and policy-planning and consensus-seeking forum	33 corporate executives total; 10 members nominated by each of Canada and Mexico, 13 nominated by US	North America (Canada, US, Mexico)

The global corporate elite

Table 2 *Policy-Board Memberships and Corporate Directorships, 1996 and 2006*

	A	B	(B–A)/A
Patterns of affiliation	1996	2006	% change
a 1 corporate board	7921	5248	–33.7
b 1 policy board	419	650	+55.1
c 2+ corporate board	**757**	**611**	**–19.3**
d 2+ policy boards	**26**	**32**	**+23.1**
e 1 corporate board and 1 policy board	**109**	**138**	**+26.6**
f 1 corporate board and 2+ policy boards	**9**	**22**	**+144.4**
g 2+ corporate boards and 1 policy board	**72**	**57**	**–20.8**
h 2+ corporate boards and 2+ policy boards	**27**	**27**	**0**
Total: members of the corporate-policy elite	**1000**	**887**	**–11.3**
Grand total	9330	6785	–27.3

The global corporate elite

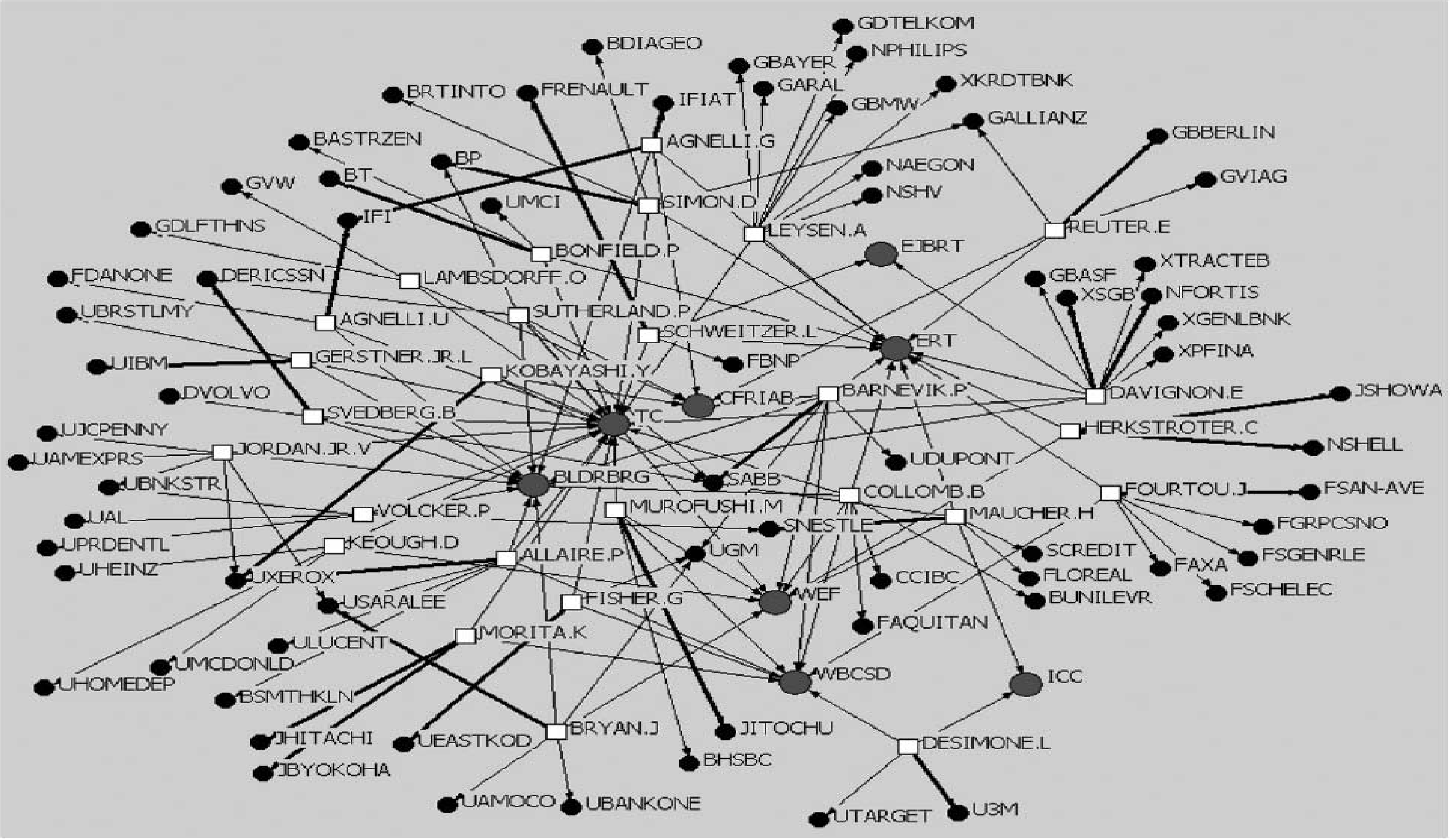


Figure 2 *Twenty-Seven Key Players and Their Organizational Affiliations, 1996*

The global corporate elite

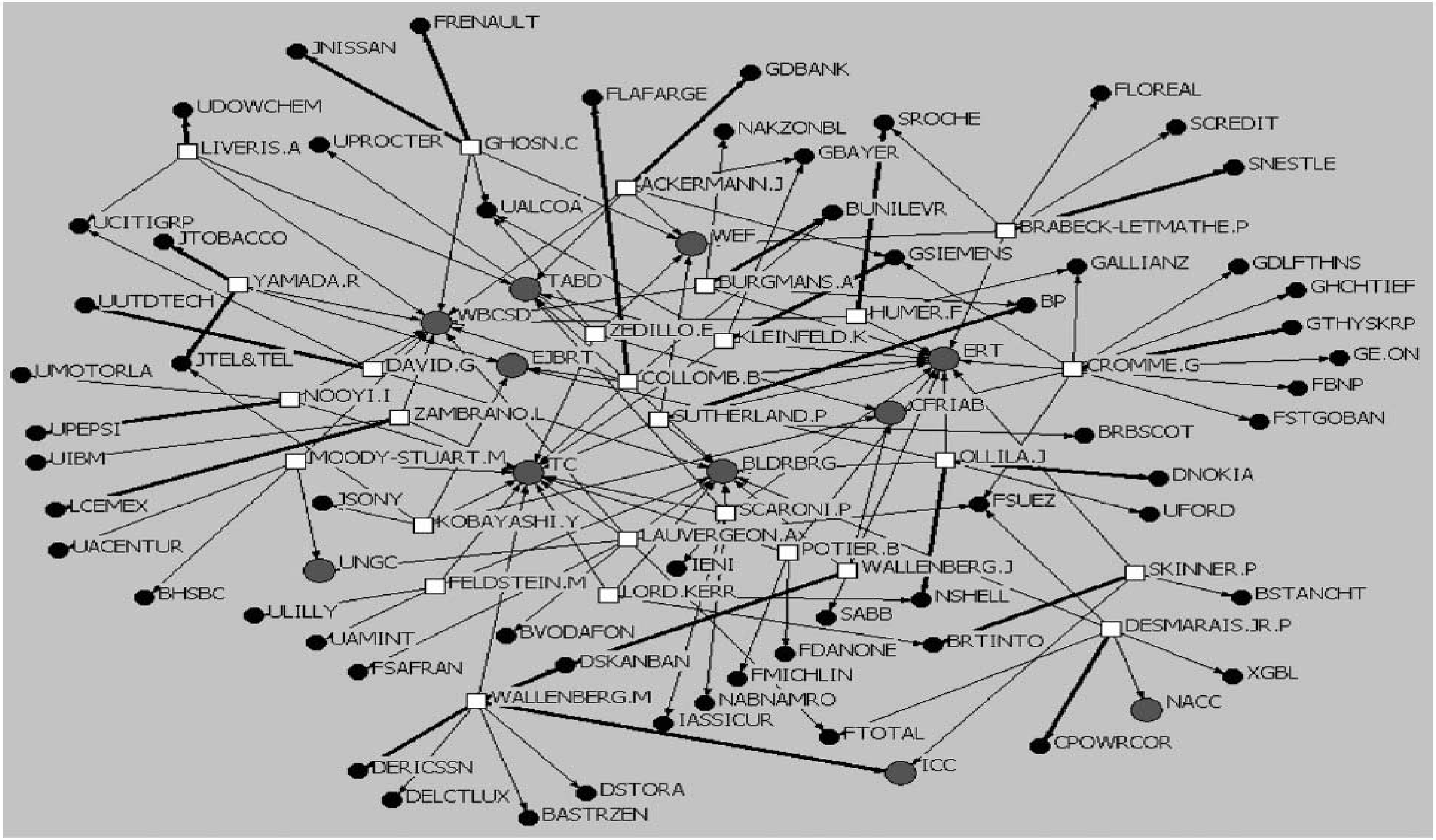


Figure 3 *Twenty-Seven Key Players and Their Organizational Affiliations, 2006*

The global corporate elite

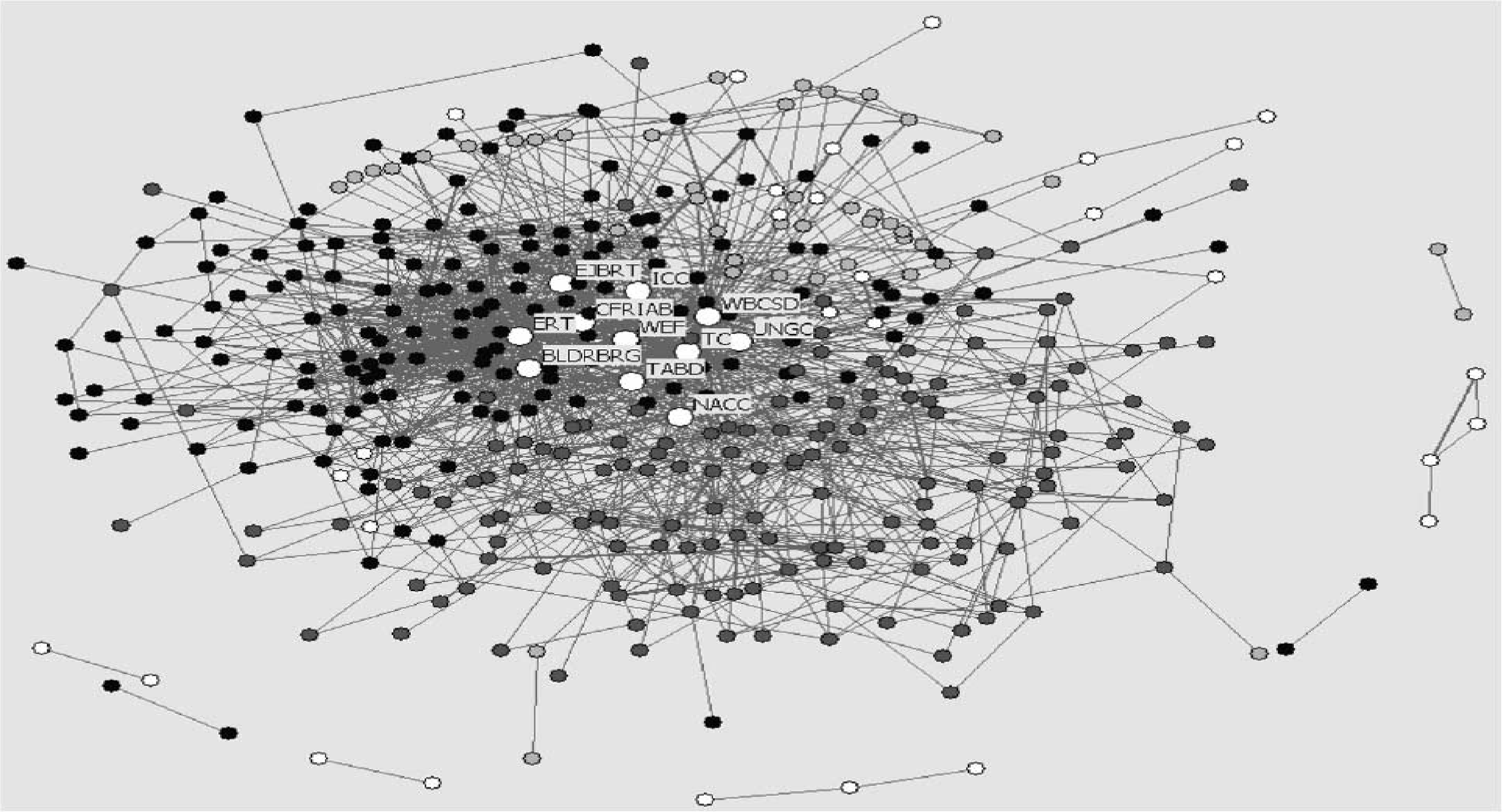
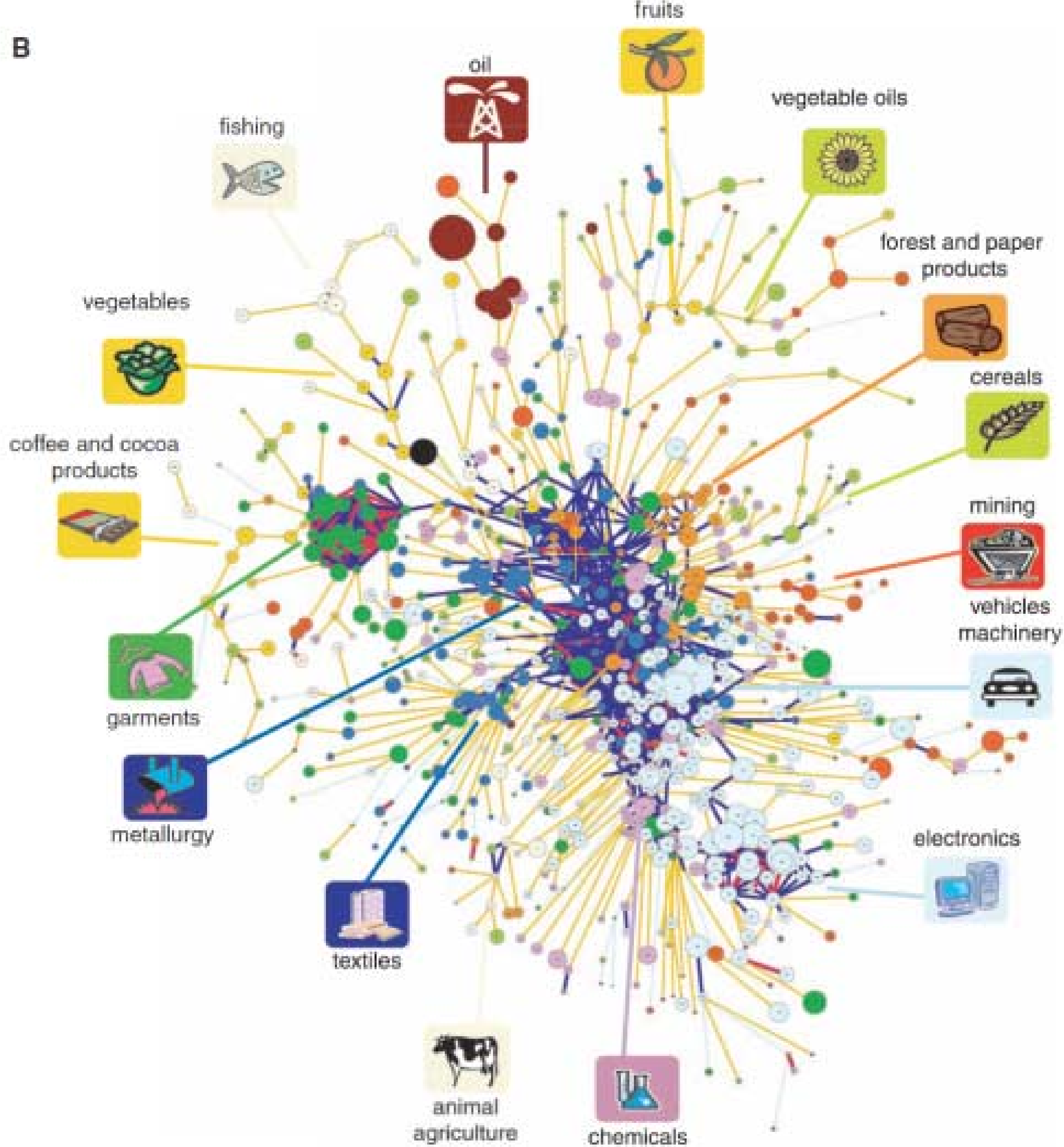


Figure 4 *Interorganizational Relations, 2006*

Key: White (large circles): policy boards; black: Europe; dark grey: US and Canada; light grey: Japan-Australia; white (small circles): rest of the world.

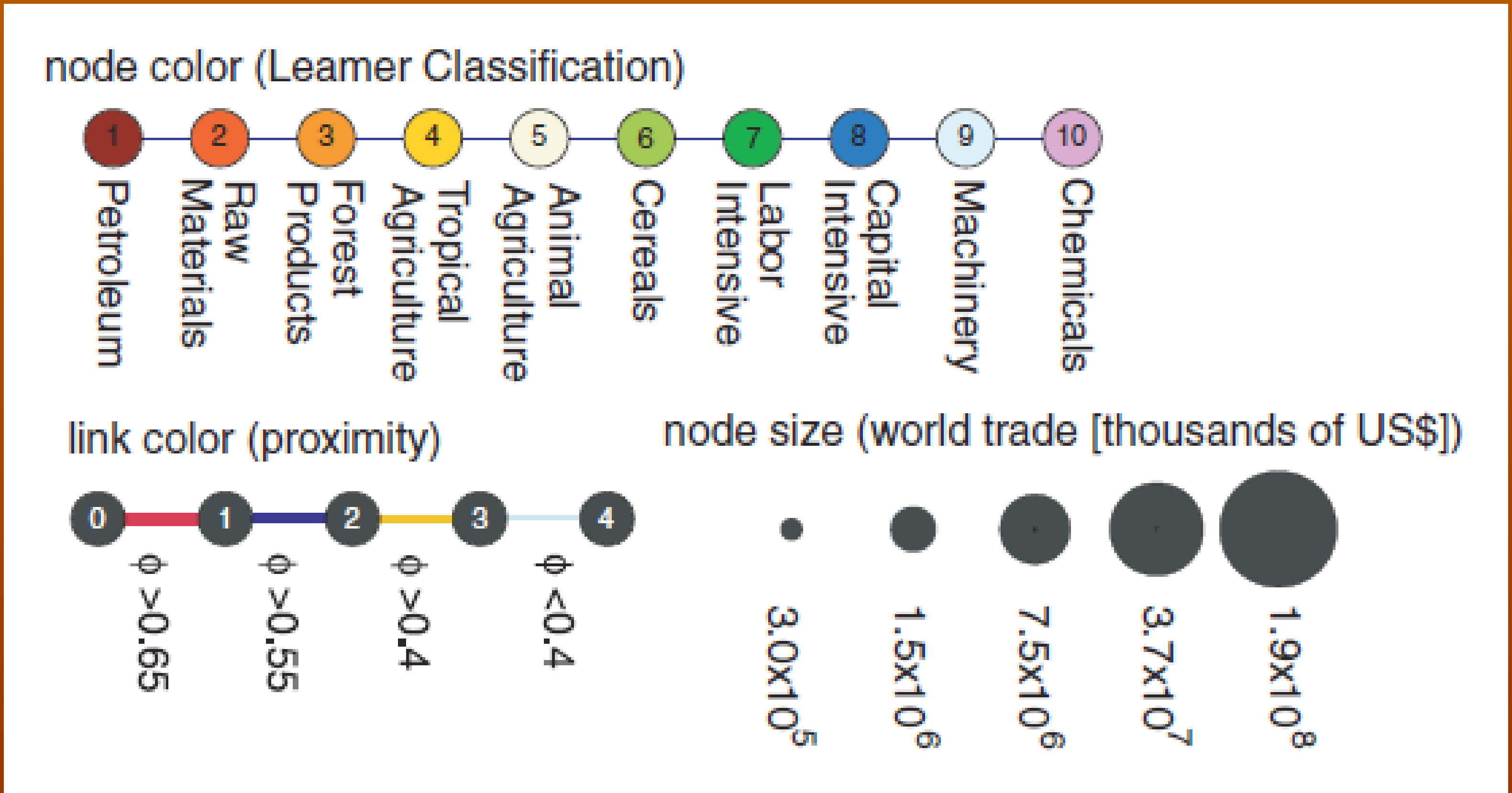
Networks and the product space

- Economies grow upgrading the products they produce and export
- Technology, capital and skills needed to make newer products are more easily adapted from some products than from others
- The network of relations between products, is called the "product space,"
- Sophisticated products are located in a densely connected core
- Less sophisticated ones occupy a less-connected periphery.
- Countries move through product space developing goods close to those they currently produce.
- To reach the core most countries need to move through large distances,
- Explains why poor countries have trouble developing competitive exports and converge to the income level of rich countries


B
fruits
oil
vegetable oils
fishing
forest and paper products
vegetables
cereals
coffee and cocoa products
mining
vehicles machinery
garments
metallurgy
electronics
textiles
animal agriculture
chemicals

Networks and the product space

- Product codes, size and proximity



(C. A. Hidalgo, B. Klinger, A. L. Barabási and R. Hausmann, Science 317 (2007) 482-487)

Models for the formation of strategic networks

- In an economic context a network link is formed if and only if both agents (nodes) find that establishing that link is beneficial to them
- Therefore models require an utility function
- The notion of "**pairwise stability**" of a network g with links between agents i and j denoted ij

- $u_i(g) \geq u_i(g-ij)$ for each i and ij in g
- $u_i(g+ij) \geq u_i(g)$ implies $u_j(g+ij) \geq u_j(g)$ for each ij not in g

- Different from Nash equilibrium
- Efficient network when the total utility is maximum

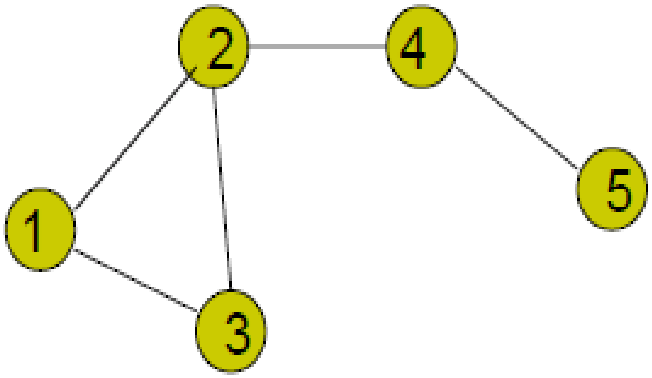
The connections model

Jackson and Wolinsky (1996):

- benefit from a friend is δ
- benefit from a friend of a friend is δ^2,...
- cost of a link is c

$u_2 = 3\delta + \delta^2 - 3c$

$u_1 = 2\delta + \delta^2 + \delta^3 - 2c$



$u_5 = \delta + \delta^2 + 2\,\delta^3 - c$

The connections model

Efficient Networks

- low cost: $c < \delta - \delta^2$
  - complete network is efficient
- medium cost: $\delta - \delta^2 < c < \delta + (n-2)\delta^2/2$
  - star network is efficient
    - minimal number of links to connect
    - connection at length 2 is more valuable than at 1 ($\delta - c < \delta^2$)
- high cost: $\delta + (n-2)\delta^2/2 < c$
  - empty network is efficient

The connections model

Pairwise Stable Networks:

- low cost: $c < \delta - \delta^2$
  - complete network is pairwise stable (and efficient)
- medium/low cost: $\delta - \delta^2 < c < \delta$
  - star network is pairwise stable (and efficient)
  - others are also pairwise stable
- medium/high cost: $\delta < c < \delta + (n-2)\delta^2/2$
  - star network is not pairwise stable (no loose ends)
  - nonempty pairwise stable networks are over-connected and may include too few agents
- high cost: $\delta + (n-2)\delta^2/2 < c$
  - empty network is pairwise stable (and efficient)

Innovation and self-organization

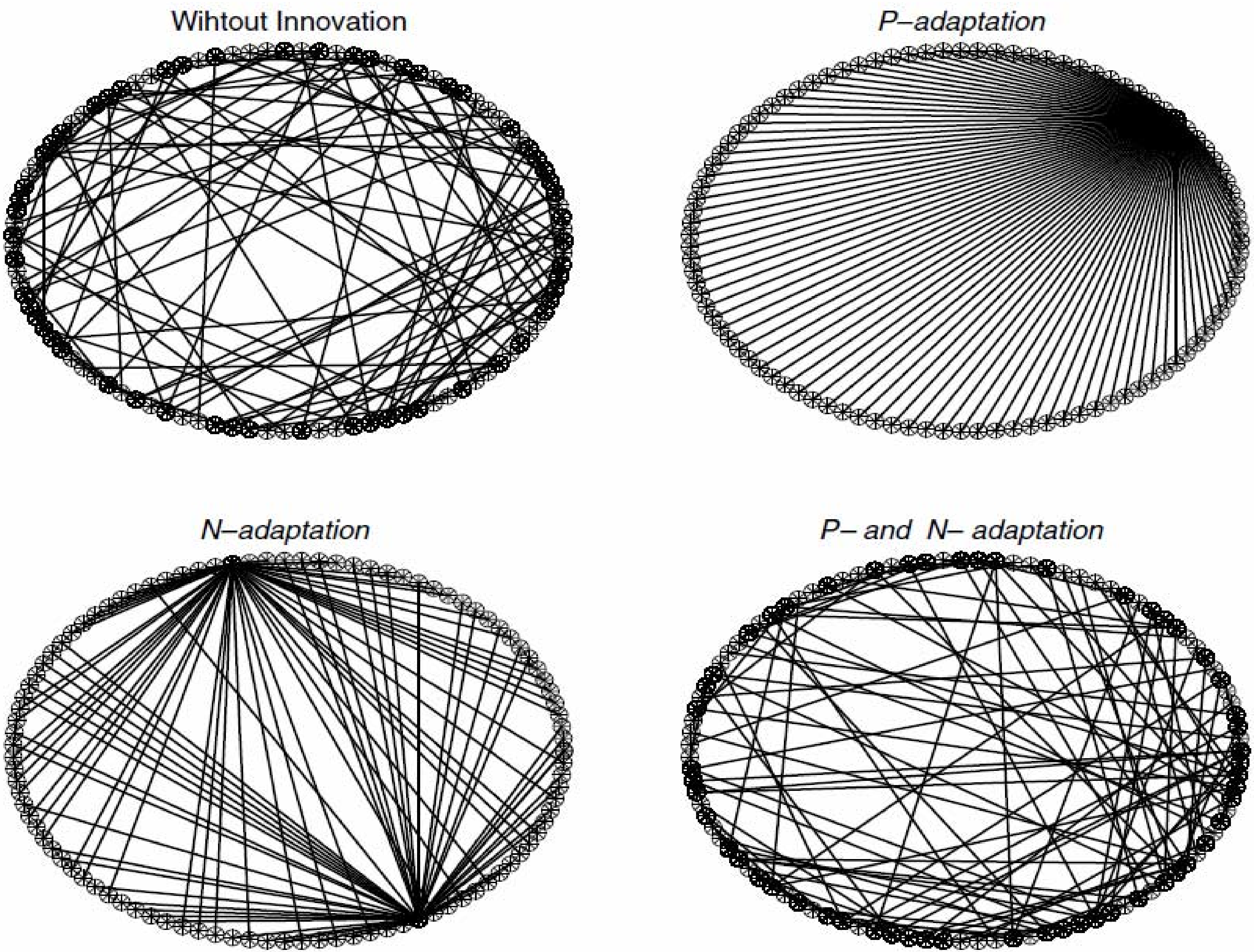
Innovation and self-organization

- A multi-agent model
- Each agent is characterized by two bit strings
- P-string: What the agent extracts from the environment (the other agents)
- N-string: What the other agents may extract from him.
- The model applies both to an economy or an ecological context
- Fitness of each agent

$$F_i(t+1) = F_i(t) + \sum_{j(i)} \frac{q^*_{ij}}{k} - \frac{q^*_{l(i)i}}{k}.$$

Innovation and self-organization

- At each step of the evolution each agent matches his P string to the N strings of the other agents.
- Then, among those P-strings with the higher matching with a particular N-string, one is chosen at random that supplies (economy) or preys (ecology) the agent with the corresponding N-string. The q's in the fitness are the overlaps.
- P-innovation means to change each time one bit to increase matching with the N-strings
- N-innovation means to change the bits to decrease the matching, therefore reducing what is given to the matching P-string.
- Supply (Economy) or Predation (Ecology) networks


Wihtout Innovation
P–adaptation
N–adaptation
P– and N– adaptation

Innovation and self-organization

- Conclusions:
- With P-innovation alone: a winner(s)-take-all situation
- With N-innovation alone: diversified suppliers, low cost
- With both P- and N-innovation: similar to the without innovation case

(*T. Araújo and RVM, Advances in Complex Systems 12 (2009) 233-253*)

The stock market: An undirected weighted network

Nodes: Companies

Links: established by a metric dependending on the fluctuation correlations

RVM, T. Araújo and F. Louçã, Physica A 323 (2003) 625-648

T. Araújo and F. Louçã, Quantitave Finance 7 (2007) 63-74

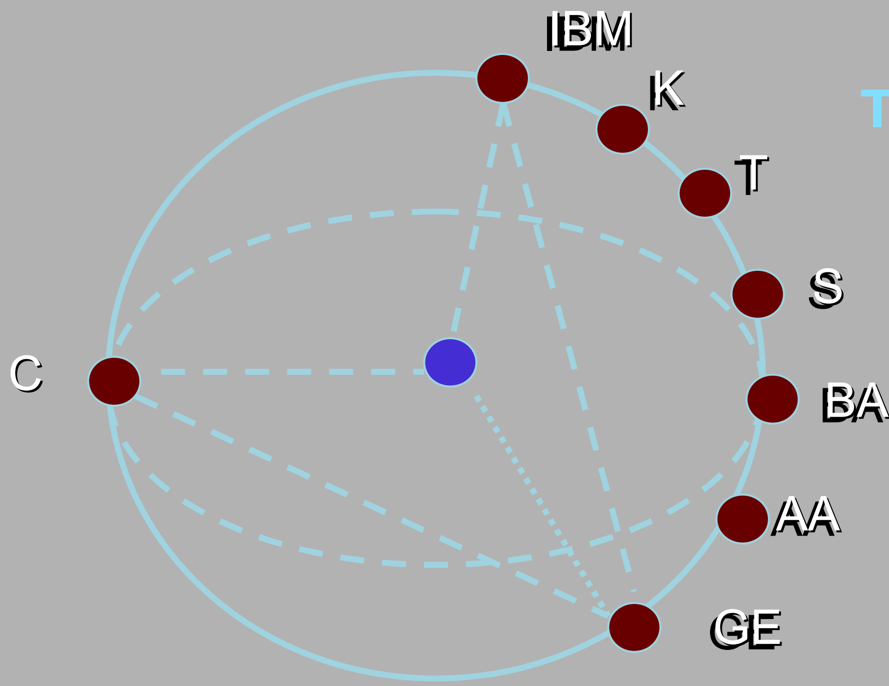
Financial market geometry

r: return $r(k) = \log(p_t(k)) - \log(p_{t-1}(k))$ **p: price**

Metric

Distances defined from the returns correlation

$$d_{ij} = \sqrt{2(1 - c_{ij})}$$



The market space

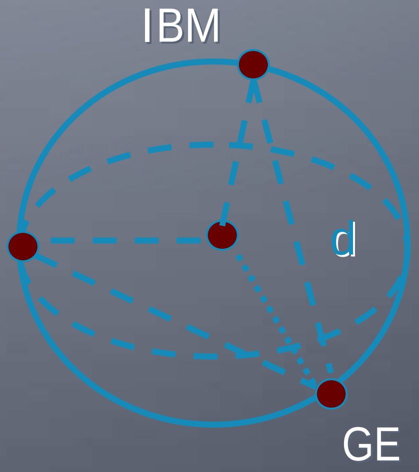
1. Compute each stock coordinates from the distances
2. Define the center of mass as the origin
3. Construct the inertia tensor
4. Identify the relevant ***f*** dimensions by comparison with a random permutation of the data

The number of embedding dimensions

S&P500 and Dow Jones, daily data

- 35 companies, 10 years
- 70 companies, 10 years
- 249 companies, 33 years
- 253 companies, 35 years
- 253 companies, 22 years
- 424 companies, 10 years

In all cases: No more than 6 dimensions !

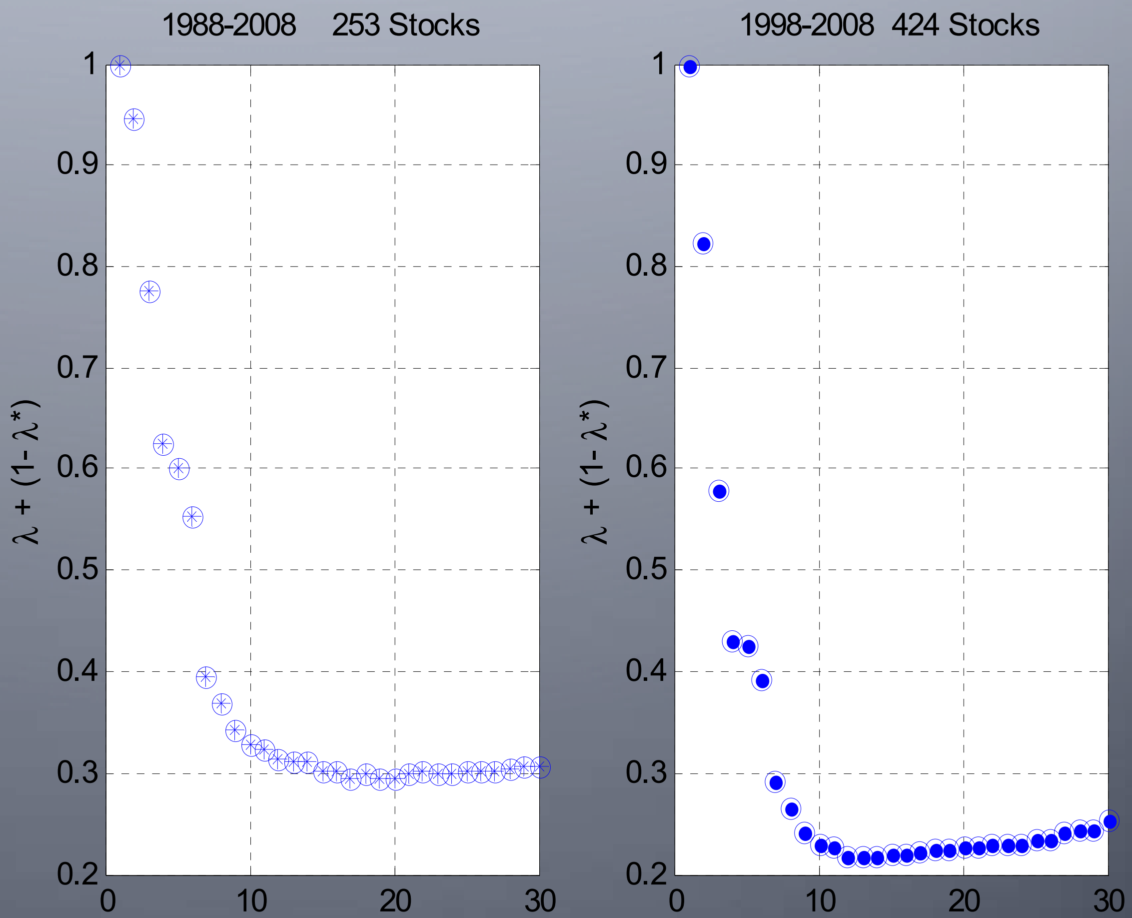


Eigenvalues compared with random permutation

λ + (1-λ')

λ : actual

λ' : random

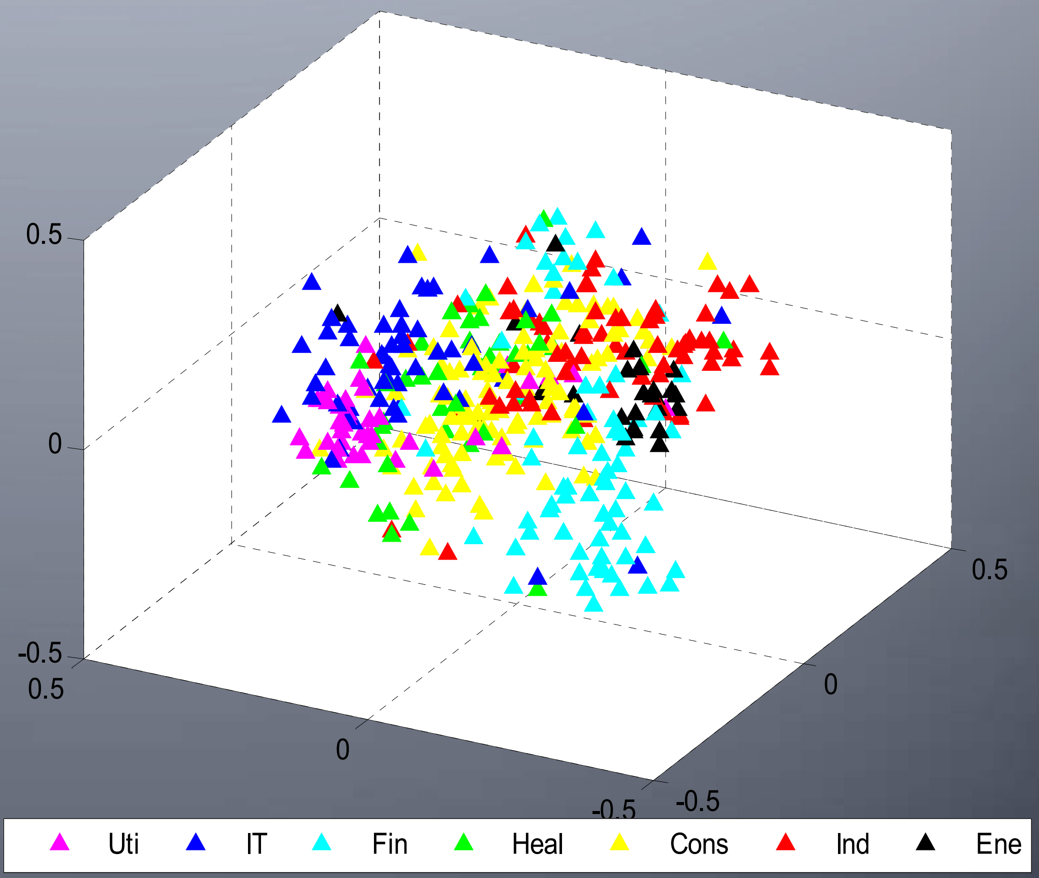


Shape modification at the crisis

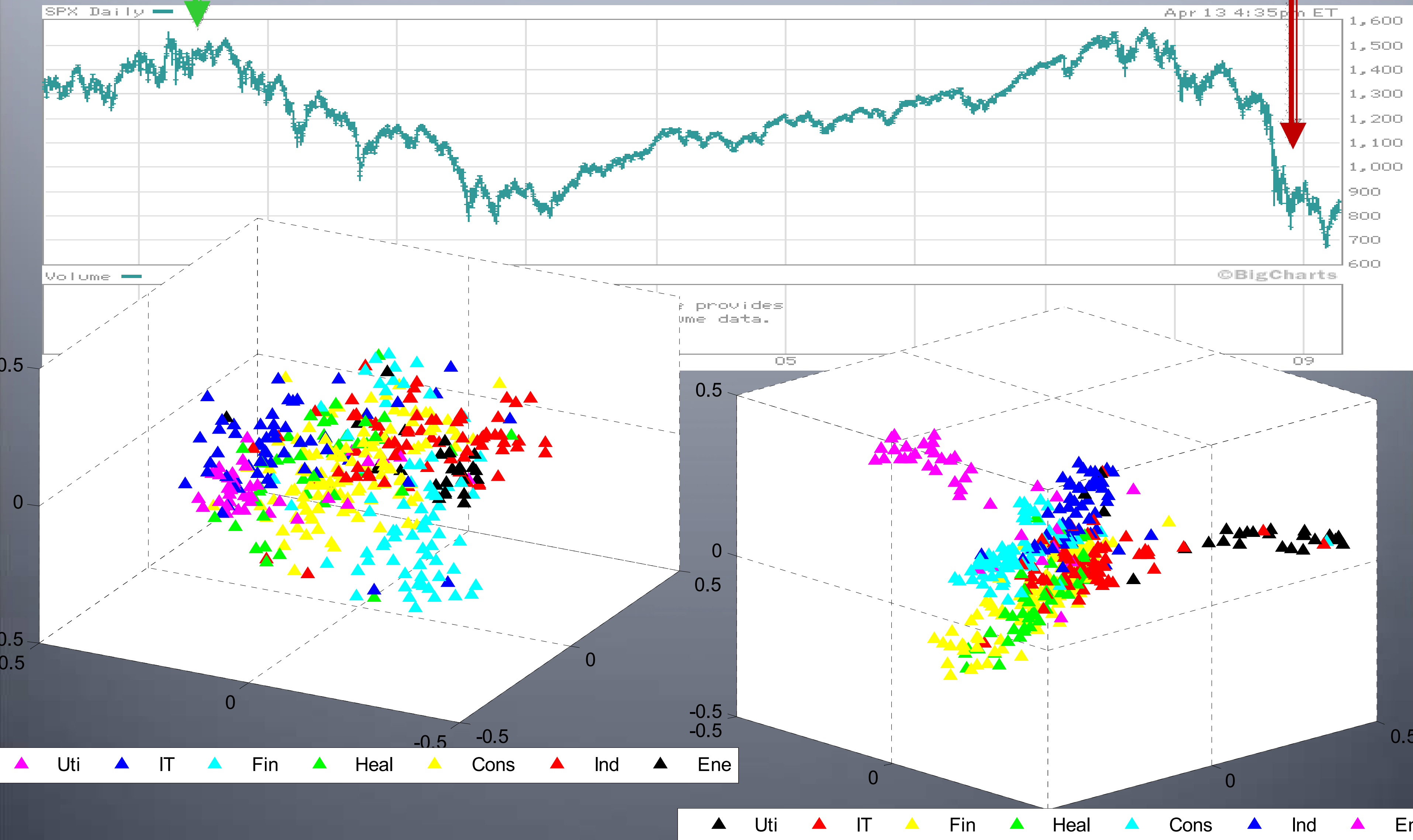
"Spherical" form

Typical of "surrogate data" and "business-as-usual" periods

Distorsions and reduction of the distances during crisis



Market shape: S&P500



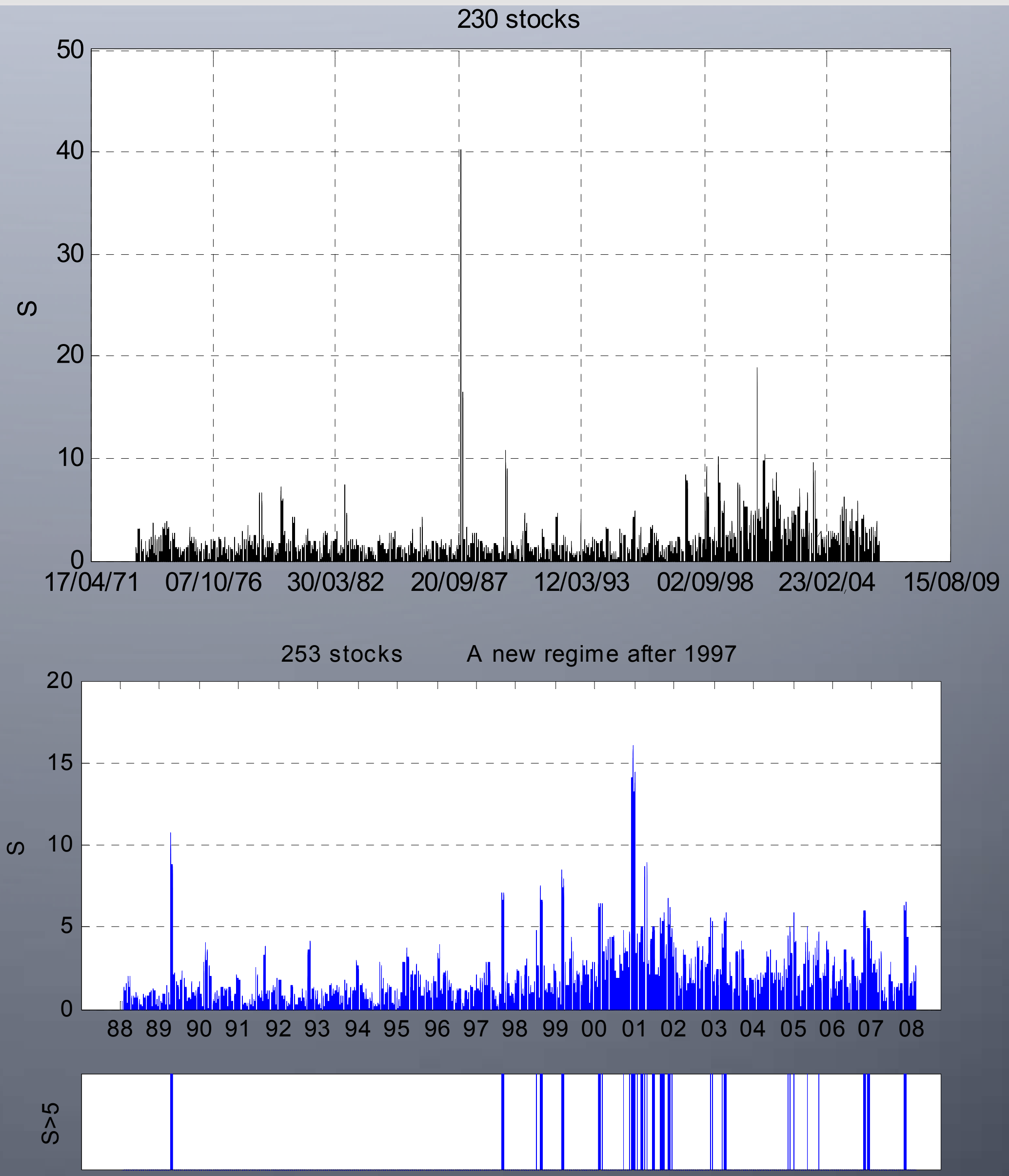
Structure index

Shape distorsions

Structure index

λ : actual
λ': random

$$S_t = \sum_{i=1}^{6} \left(\frac{\lambda_t'(i)}{\lambda_t(i)} - 1 \right)$$



After 1997 there are many periods with market distorsions

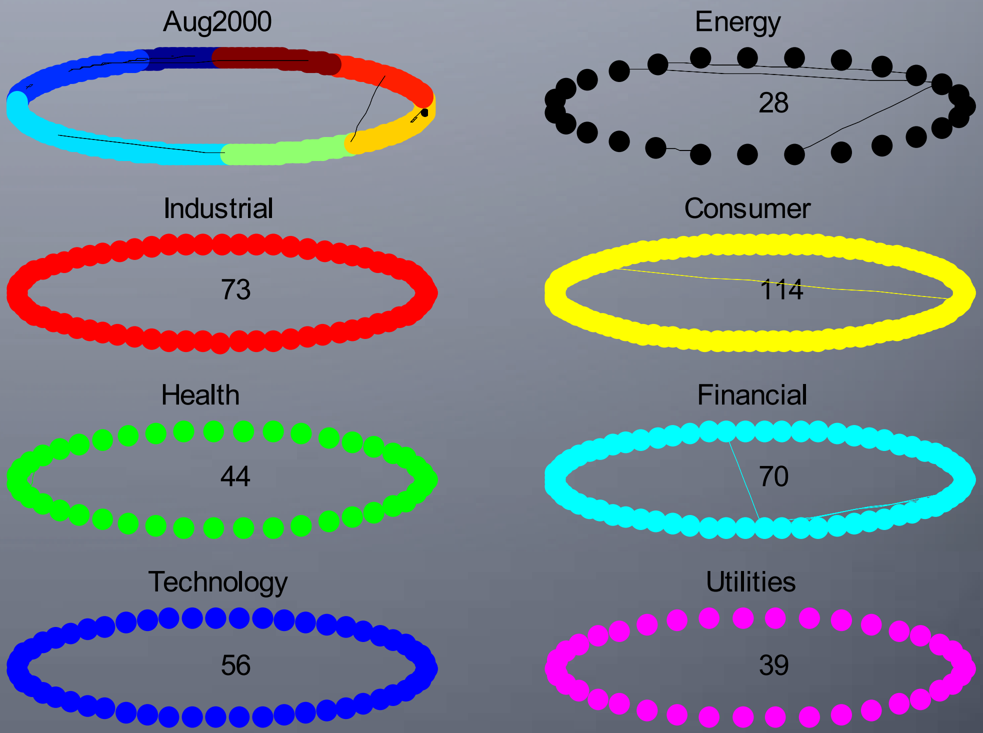
Stock market networks

The market networks are weighted and fully connected

1. **hierarchical clustering**
2. **minimal spanning tree**
3. **L_D^6 smaller distance in R^6 which insures network connectivity**
4. **Then**

$$d^6{}_{i,j} \le \frac{L_{D^6}}{2} \Rightarrow b_{i,j} = 1$$

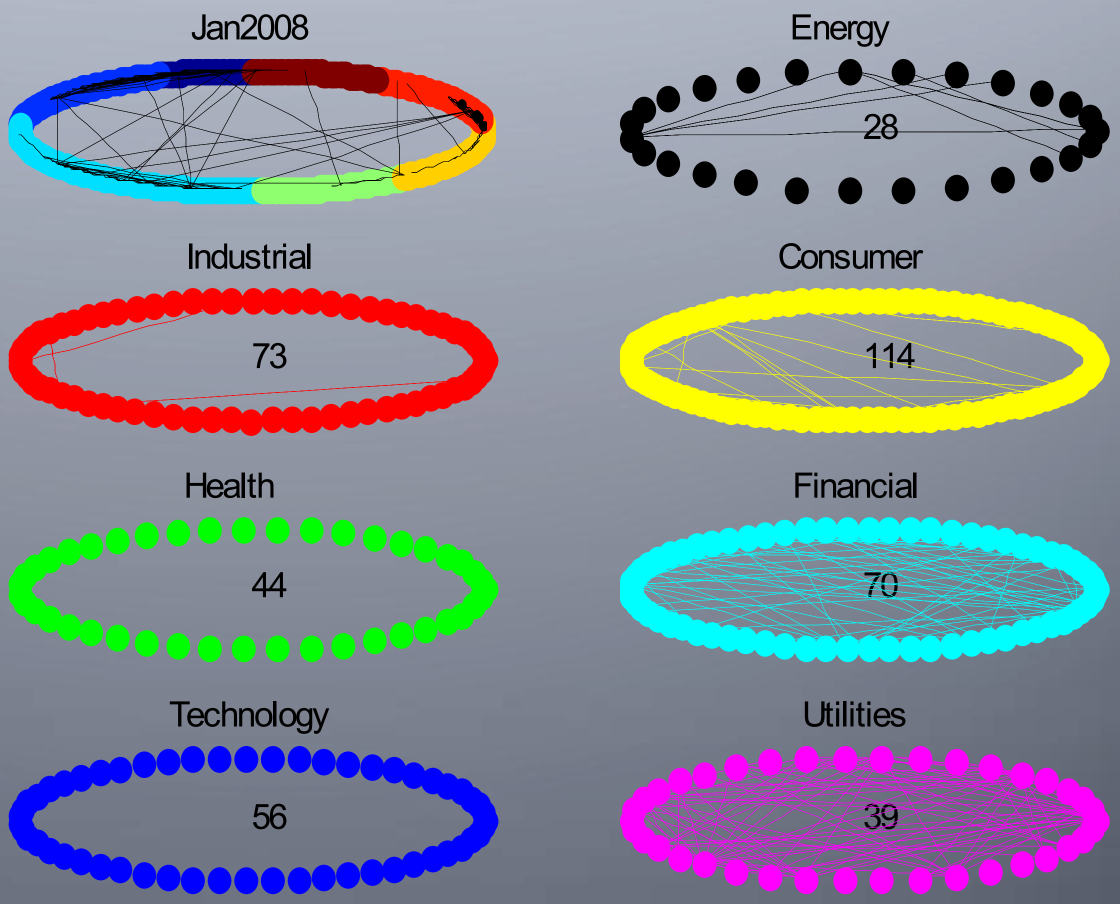
$$d^6{}_{i,j} > \frac{L_{D^6}}{2} \Rightarrow b_{i,j} = 0$$



Normal periods have few links

Stock market networks

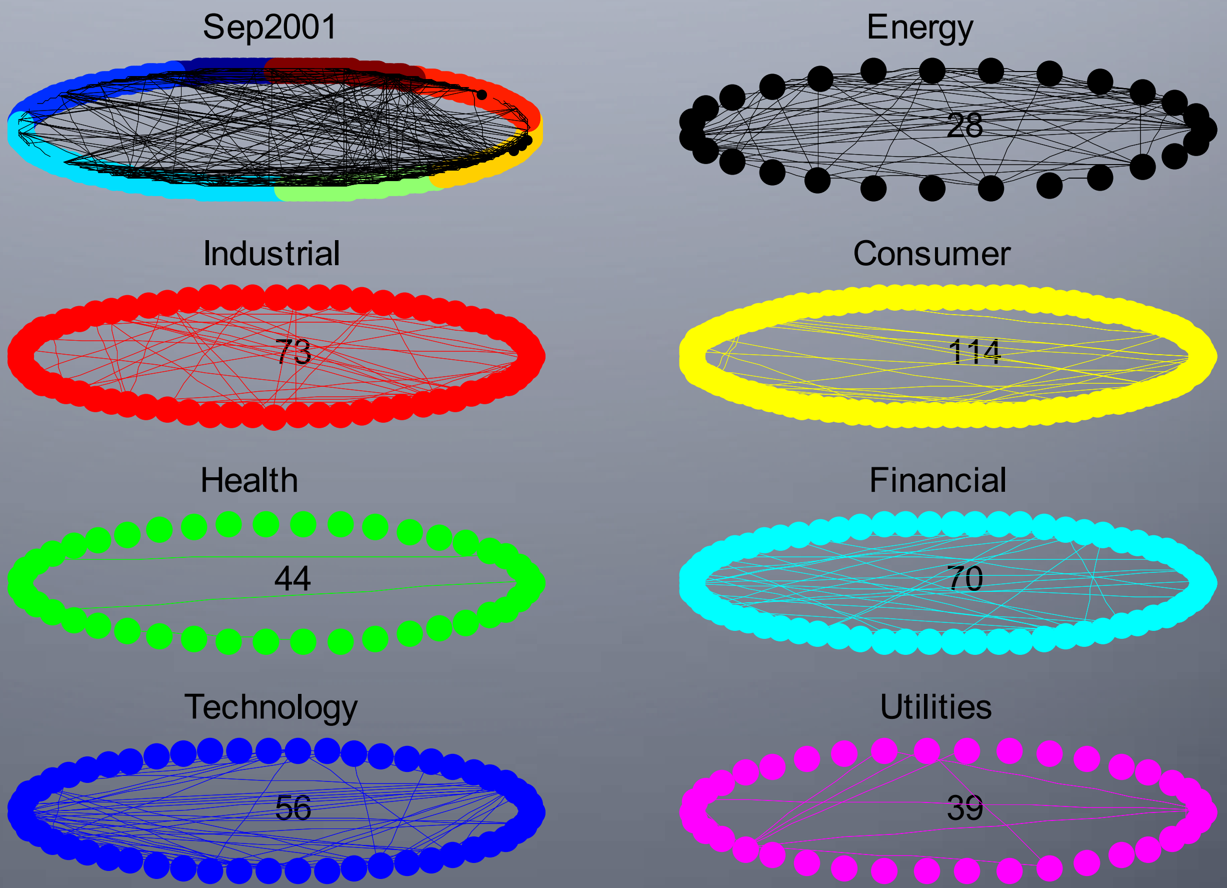
During the crisis the agents display higher correlations



Crisis periods: increase of the number of links, mostly inside the sectors

Stock market networks

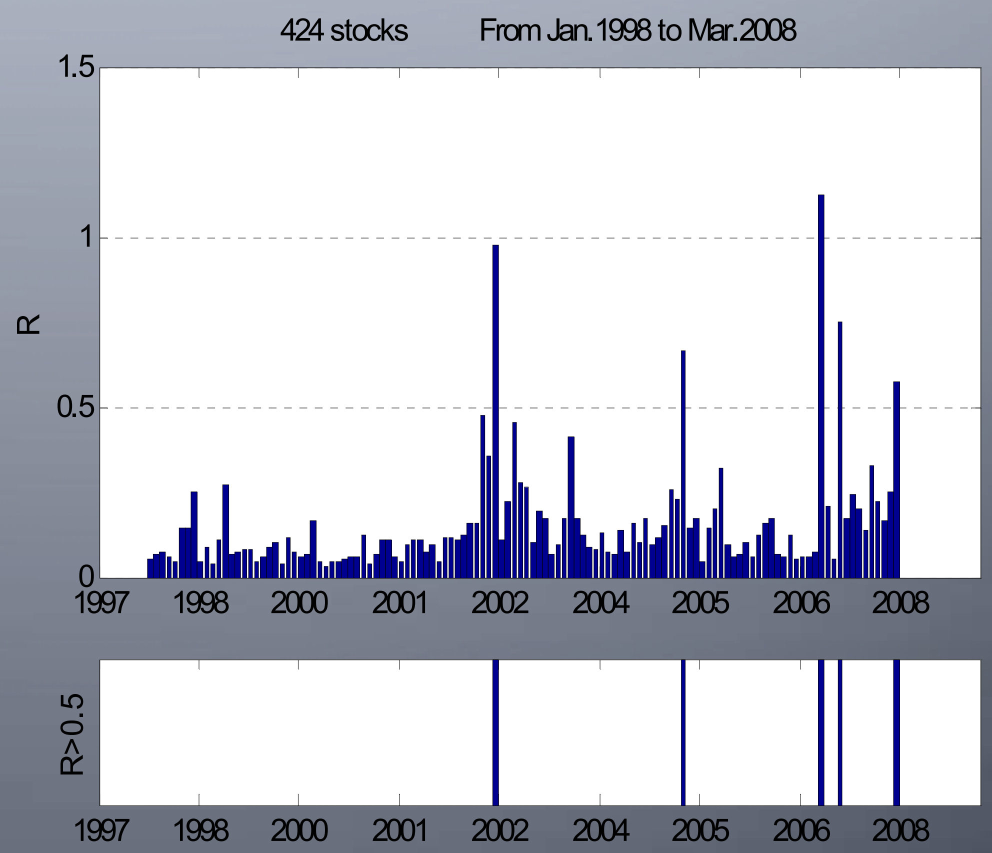
In some crisis: general increase of the number of links in all sectors



Strong versus weak links

1. hierarchical clustering
2. minimal spanning tree
3. L_D^6
4. Strong-weak ratio

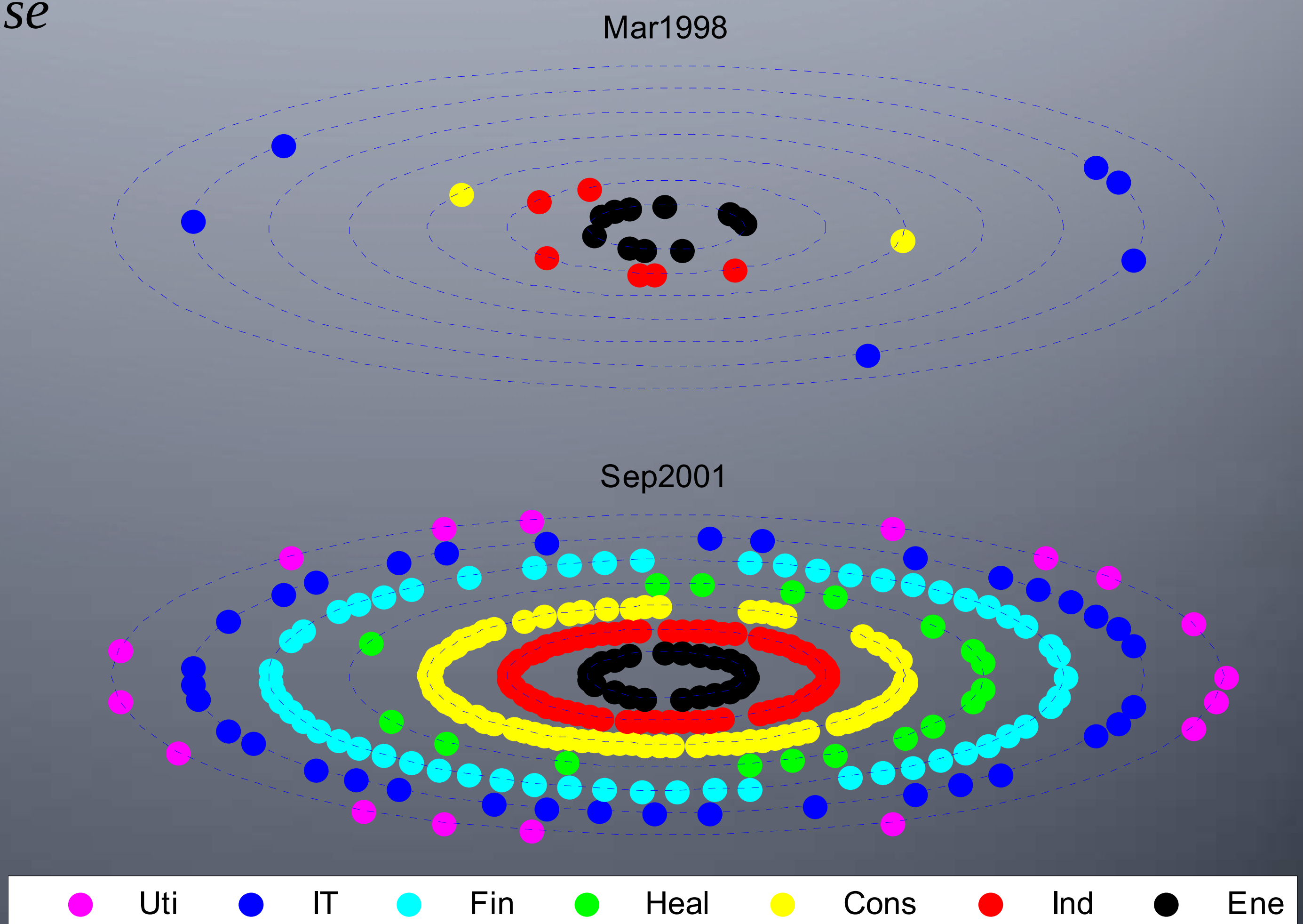
$$R_t = \frac{\sum\limits_{d_t^6(i,j) \le L_{D^6}} d_t^6(i,j)}{\sum\limits_{d_t^6(i,j) > L_{D^6}} d_t^6(i,j)}$$



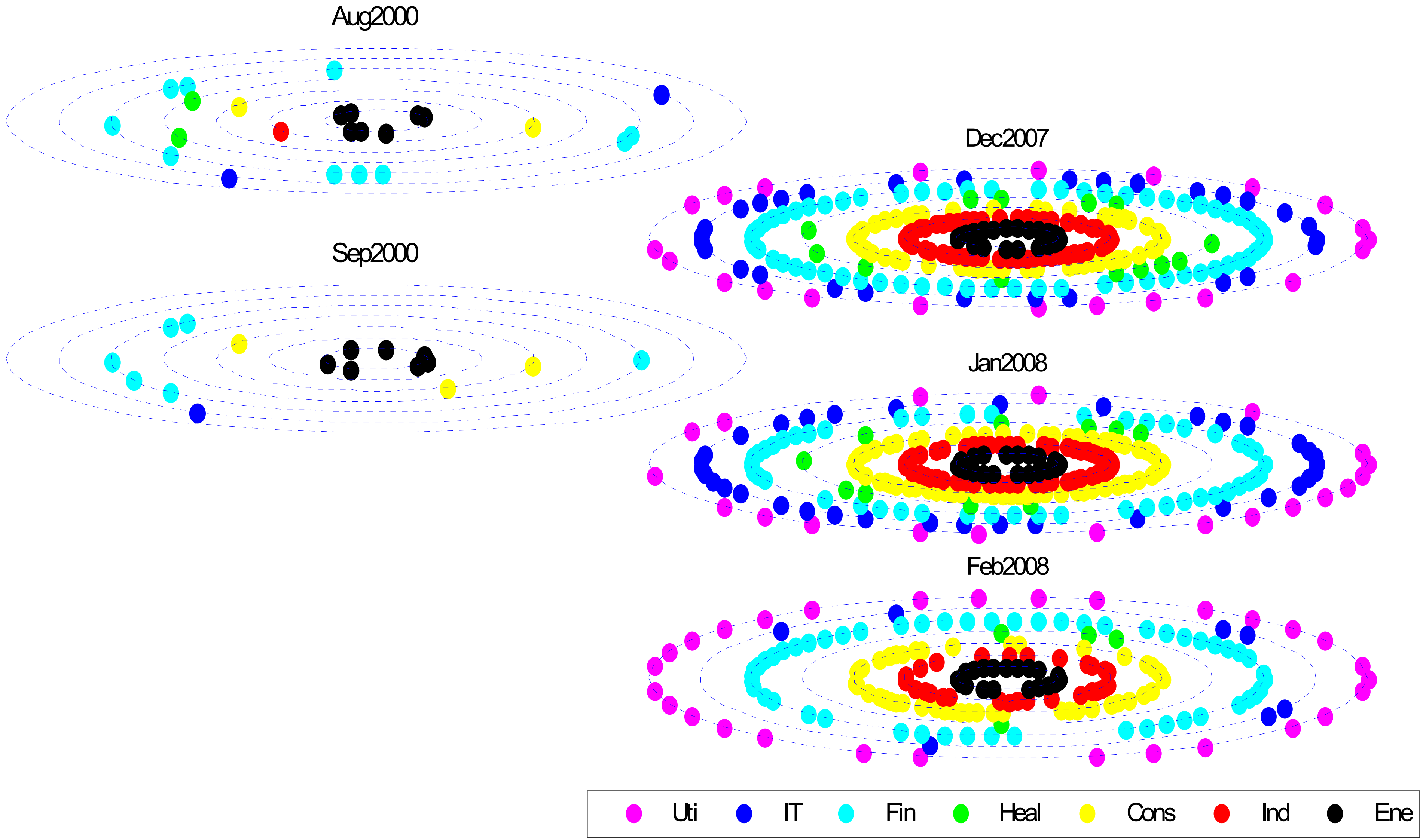
Synchronization (states)

$$s_i = 1 \Leftrightarrow \exists \quad d_t^6(i,j)_{\leq} \frac{L_{D^6}}{2}$$

$$s_i = 0 \quad otherwise$$



States



Aug2000
Sep2000
Dec2007
Jan2008
Feb2008
Uti
IT
Fin
Heal
Cons
Ind
Ene