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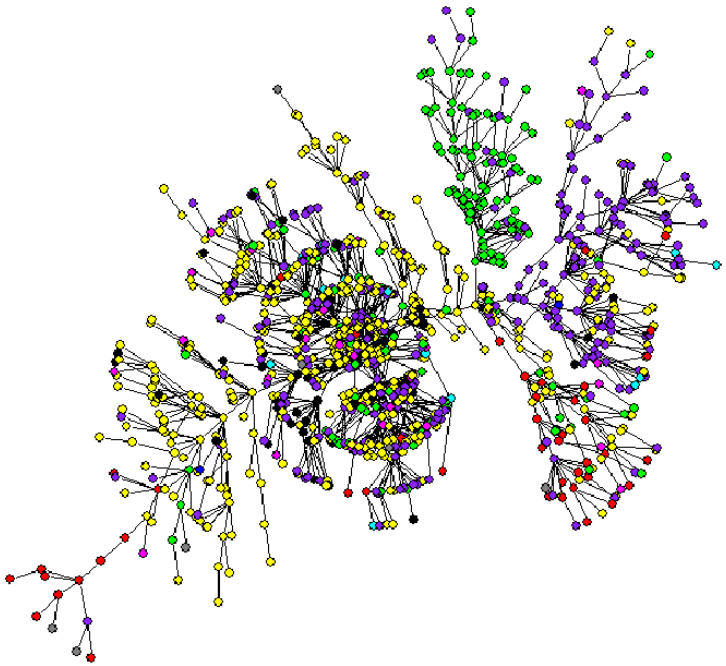
Networks in Finance



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Istituto Nazionale
Fisica per la Materia

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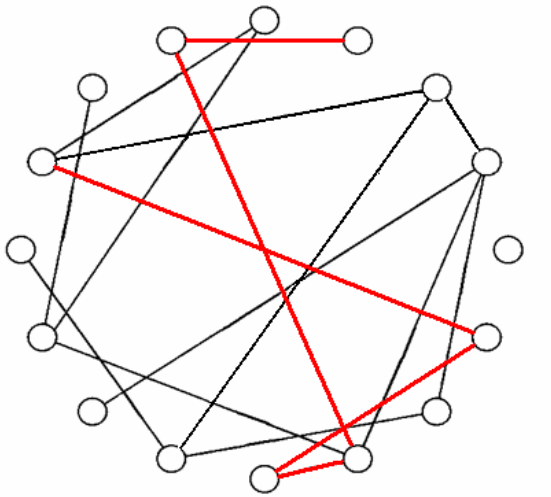
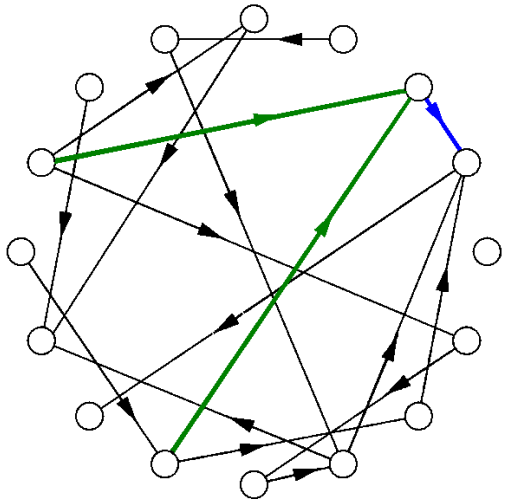
7 Santa Fé Institute

• Graph Topology

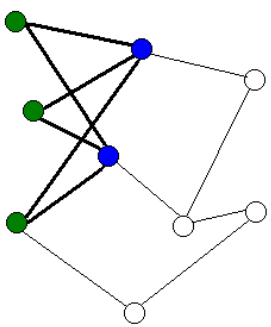


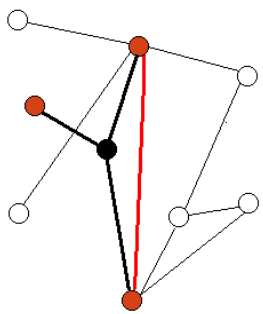
A **Graph *G(v,e)*** is an object composed by ***v*** *vertices* and ***e*** *edges*

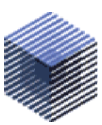
Edges can be oriented →



· Degree k (In-degree k_{in} and out-degree k_{out}) = number of edges (oriented) per vertex
· Distance d = number of edges amongst two vertices (in the connected region !)
· Diameter D = Maximum of the distances (in the connected region !)
· Clustering = cliques distribution, or clustering coefficient



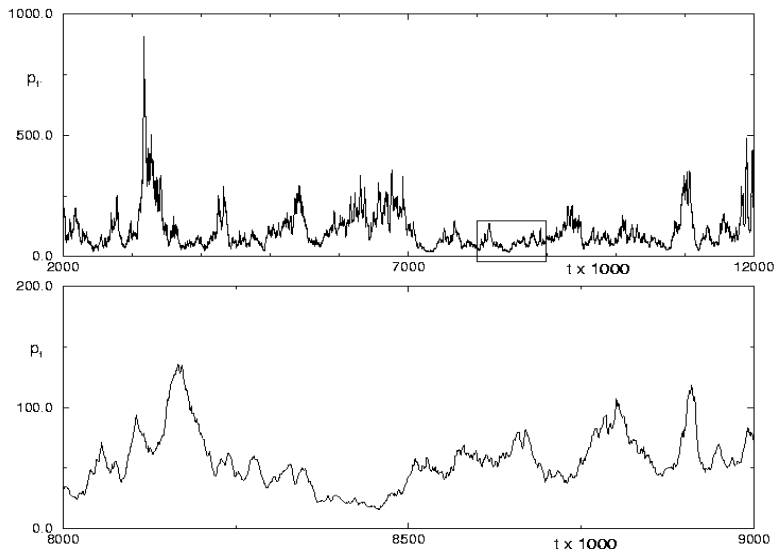




Economics and Finance

Probably the most complex system is human behaviour!

Even by considering only the trading between individuals, situation seem to be incredibly complicated.



Econophysics tries to understand the basic "active ingredients" at the basis of some peculiar behaviours.

For example price statistical properties can be described through a simple model of agents trading the same stock.

"**A Prototype Model of Stock Exchange**"

Europhysics Letters, **40** 479 (1997)**,** G. C., M. Marsili, Y.-C. Zhang.

- **Why networks ?**

Some of the phenomena in finance can be described by means of graphs

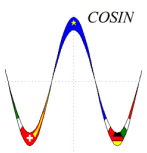
- Stock price correlations
  - J.-P. Onnela, A. Chackraborti, K. Kaski, J. Kertész, A. Kanto
    http://xxx.lanl.gov/abs/cond-mat/0303579 and http://xxx.lanl.gov/abs/cond-mat/0302546
  - G. Bonanno, G. Caldarelli, F. Lillo and R. N. Mantegna *http://xxx.lanl.gov/abs/cond-mat/0211546*

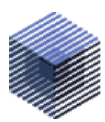
- Board of Directors
  - M. E. J. Newman, S. H. Strogatz and D. J. Watts, *Phys. Rev. E* **64**, 026118 (2001).
  - S. Battiston, E. Bonabeau and G. Weisbuch *http://xxx.lanl.gov/abs/cond-mat/0209590* (2002).

- Portfolio composition
  - Next slides…

Through this new description we can

- Discover new features
- Validate Models





- **Stock Price Correlations**

$$r_i(\tau) = \ln P_i(\tau) - \ln P_i(\tau - 1)$$

Logarithmic return of stock *i*

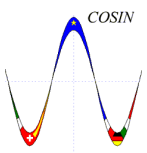
$$\rho_{i,j} = \frac{\langle r_i r_j \rangle - \langle r_i \rangle \langle r_j \rangle}{\sqrt{\left(\langle r_j^2 \rangle - \langle r_j \rangle^2\right)\left(\langle r_i^2 \rangle - \langle r_i \rangle^2\right)}}$$

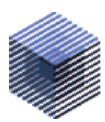
Correlation between returns (averaged on trading days)

$$d_{i,j} = \sqrt{2(1 - \rho_{i,j})}$$

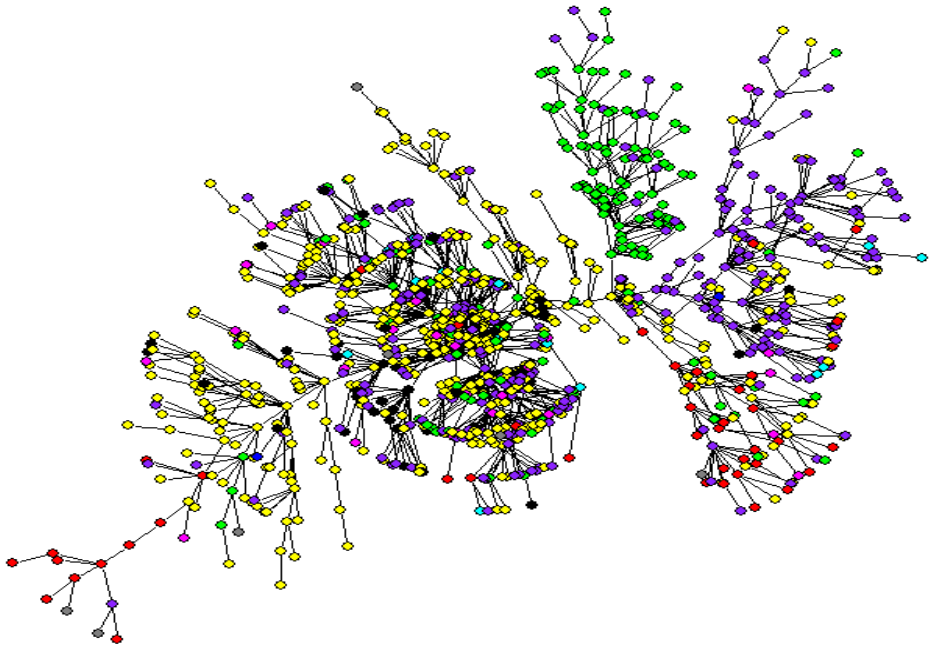
Distance between stocks *i, j*

A tree (a graph with no cycle) can be constructed by imposing that the sum of the (N-1) distances is the minimum one.





Real Data from NYSE



Correlation based minimal spanning trees of real data from daily stock returns of 1071 stocks for the 12-year period 1987-1998 (3030 trading days). The node colour is based on Standard Industrial Classification system.
The correspondence is:

red for mining

cyan for construction

yellow for manufacturing

green for transportation, communications, electric,gas and sanitary services

light blue for public administration

magenta for wholesale trade

black for retail trade

purple for finance and insurance

orange for service industries

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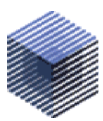
"**Topology of correlation based..**" http://xxx.lanl.gov/abs/cond-mat/0211546
G. Bonanno, G. C. , F. Lillo, R. Mantegna

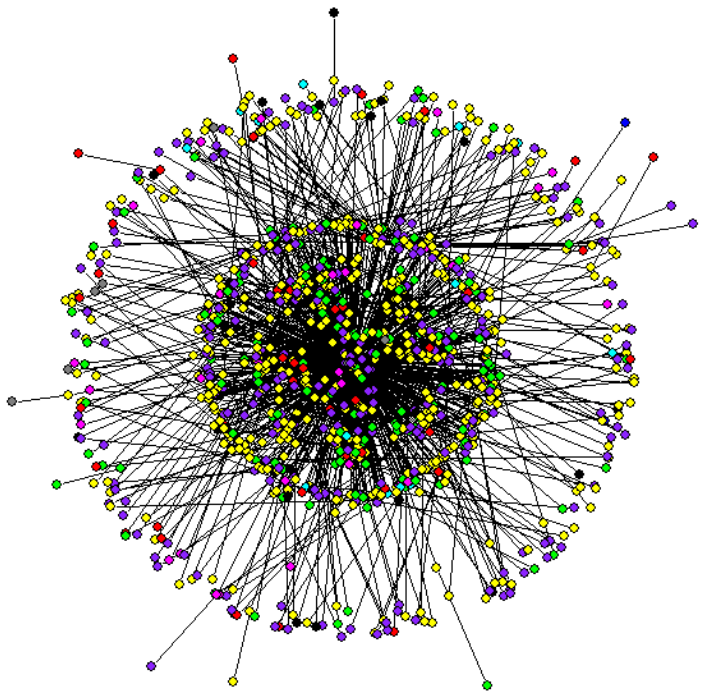


Data from Capital Asset Pricing Model

In the model it is supposed that returns follow

$$r_i(t) = \alpha_i + \beta_i r_M(t) + \varepsilon_i(t)$$

$r_i(t)$ = return of stock i
$r_M(t)$ = return of market (Standard & Poor's)
α_i, β_i = real parameters
ε_i, = noise term with 0 mean



Correlation based minimal spanning trees of of an artificial market composed by of 1071 stocks according to *the one factor model*.
The node colour is based on Standard Industrial Classification system. The correspondence is:

red for mining

green for transportation, communications, electric,gas and sanitary services

black for retail trade

cyan for construction

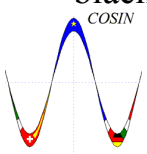
light blue for public administration

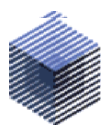
purple for finance and insurance

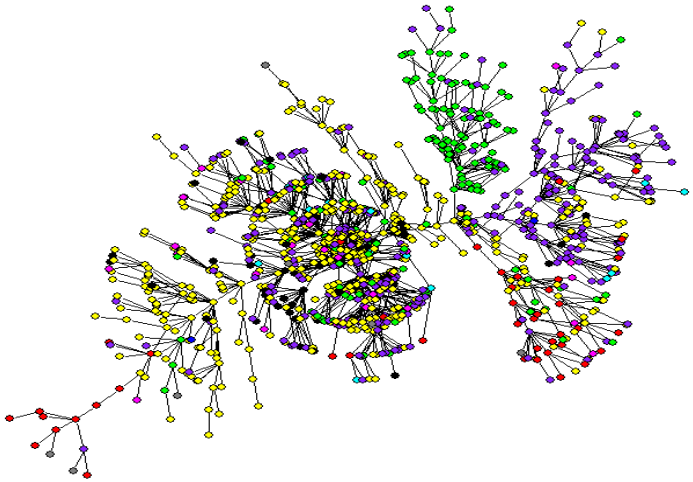
yellow for manufacturing

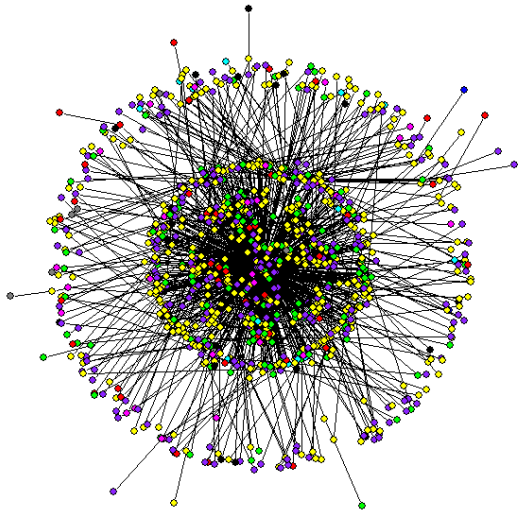
magenta for wholesale trade

orange for service industries







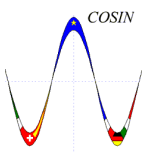


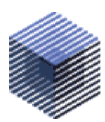
Without going in much detail about degree distribution or clustering of the two graphs

We can conclude that:

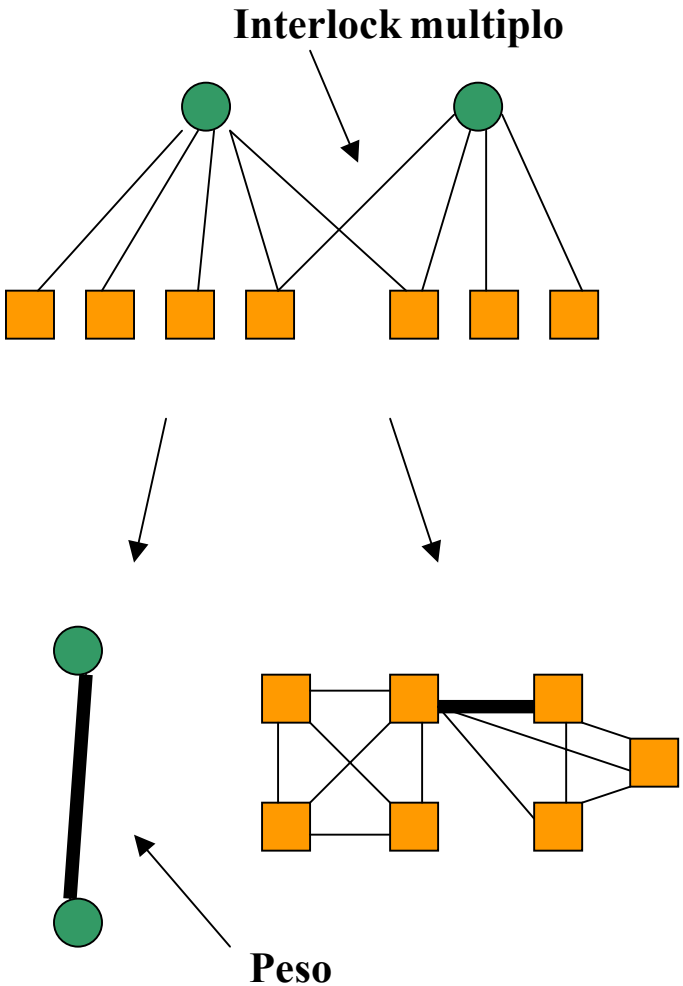
the topology of MST for the real and an artificial market are greatly different.

Real market properties are not reproduced by simple random models





Rete dei consigli di amministrazione italiani



Grafo bipartito:

- nodi di due classi (società e amministratori),
- archi fra nodi di classi diverse.

Proiezioni

Collegamento fra due società (amministratori) se hanno un amministratore (società) in comune.

Peso.

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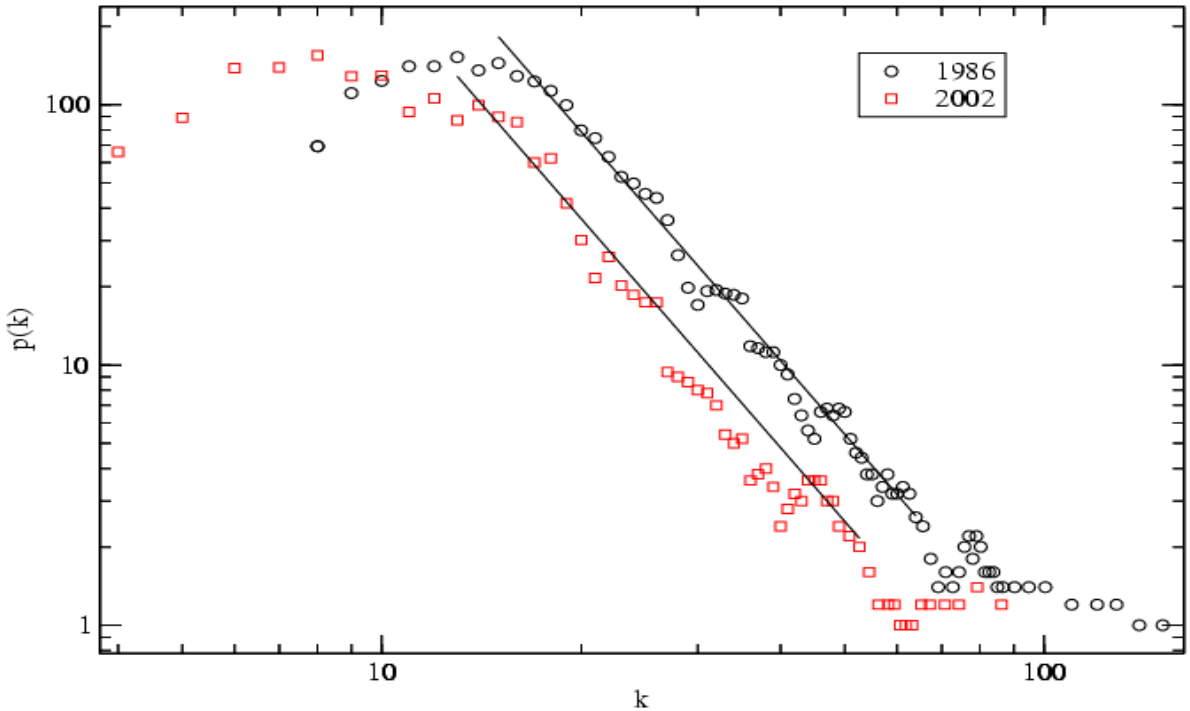
L'invarianza di scala

La rete esibisce invarianza di scala rispetto a diverse grandezze.

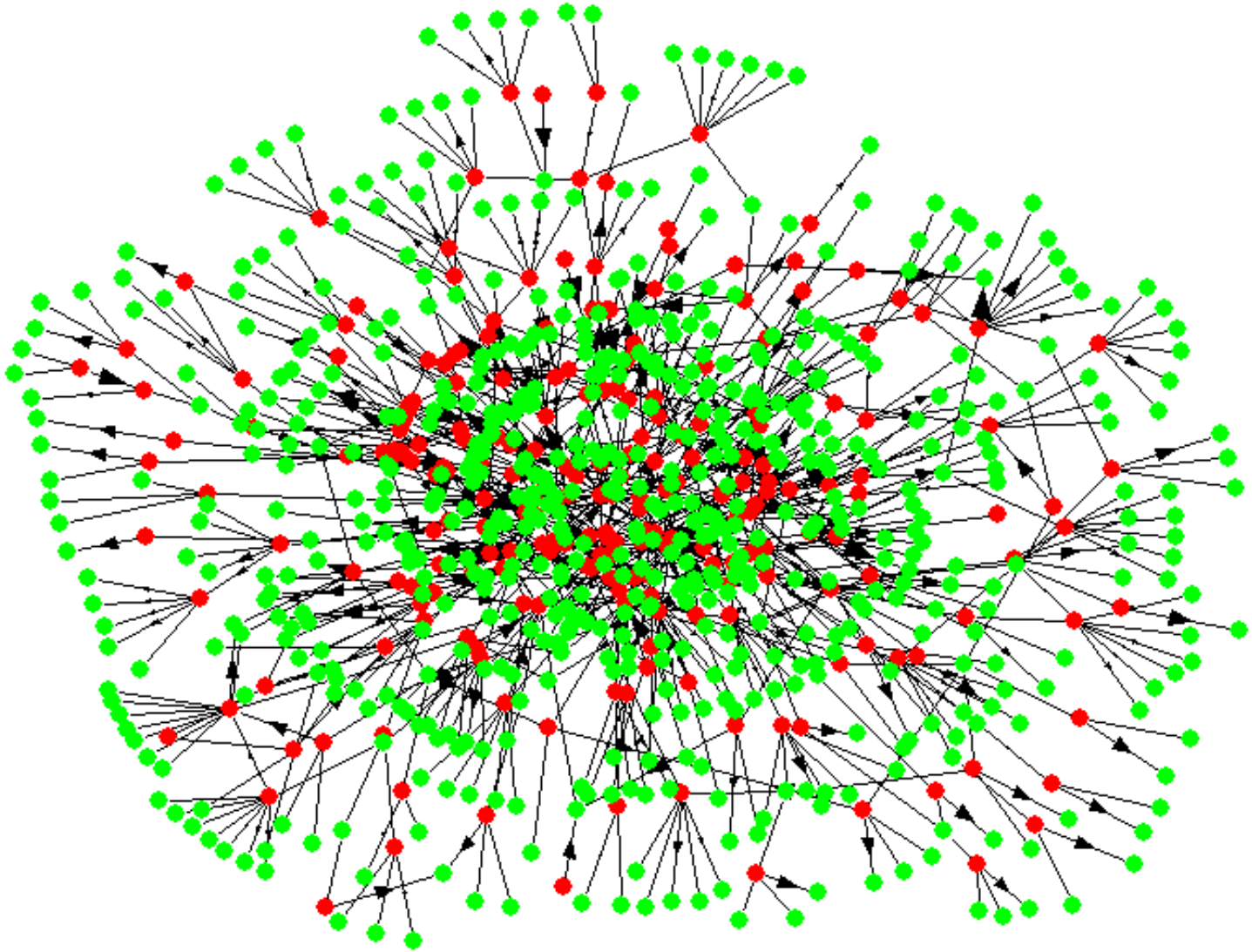


(rete degli amministratori)

$$P(k) \propto k^{-\gamma}$$

$$\gamma = 2.92 \pm 0.08$$

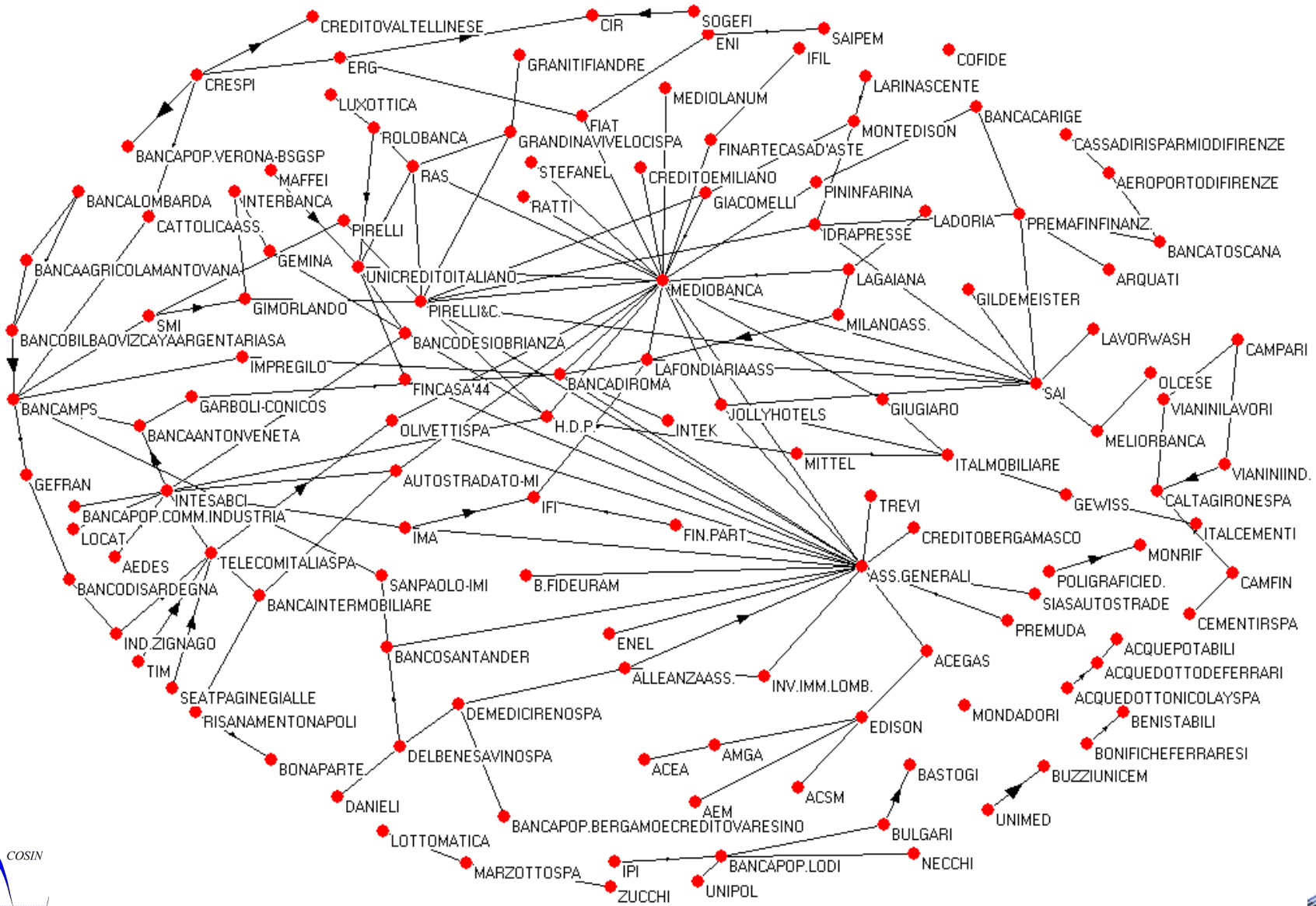
- **Portfolio Composition**

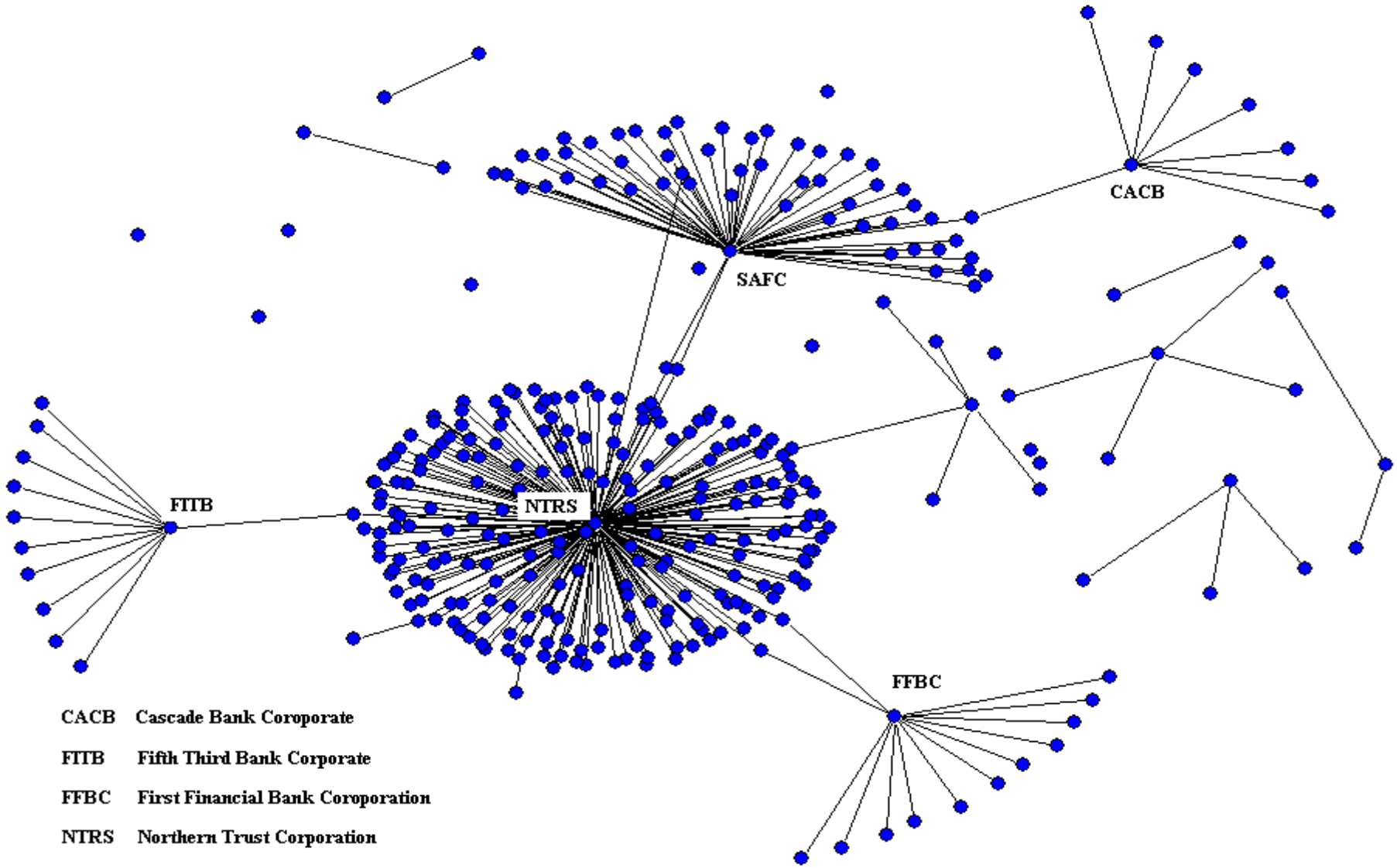


Investors or Companies not traded at Borsa di Milano (Italy)

Companies traded at Borsa di Milano (Italy)

- **Portfolio Composition**





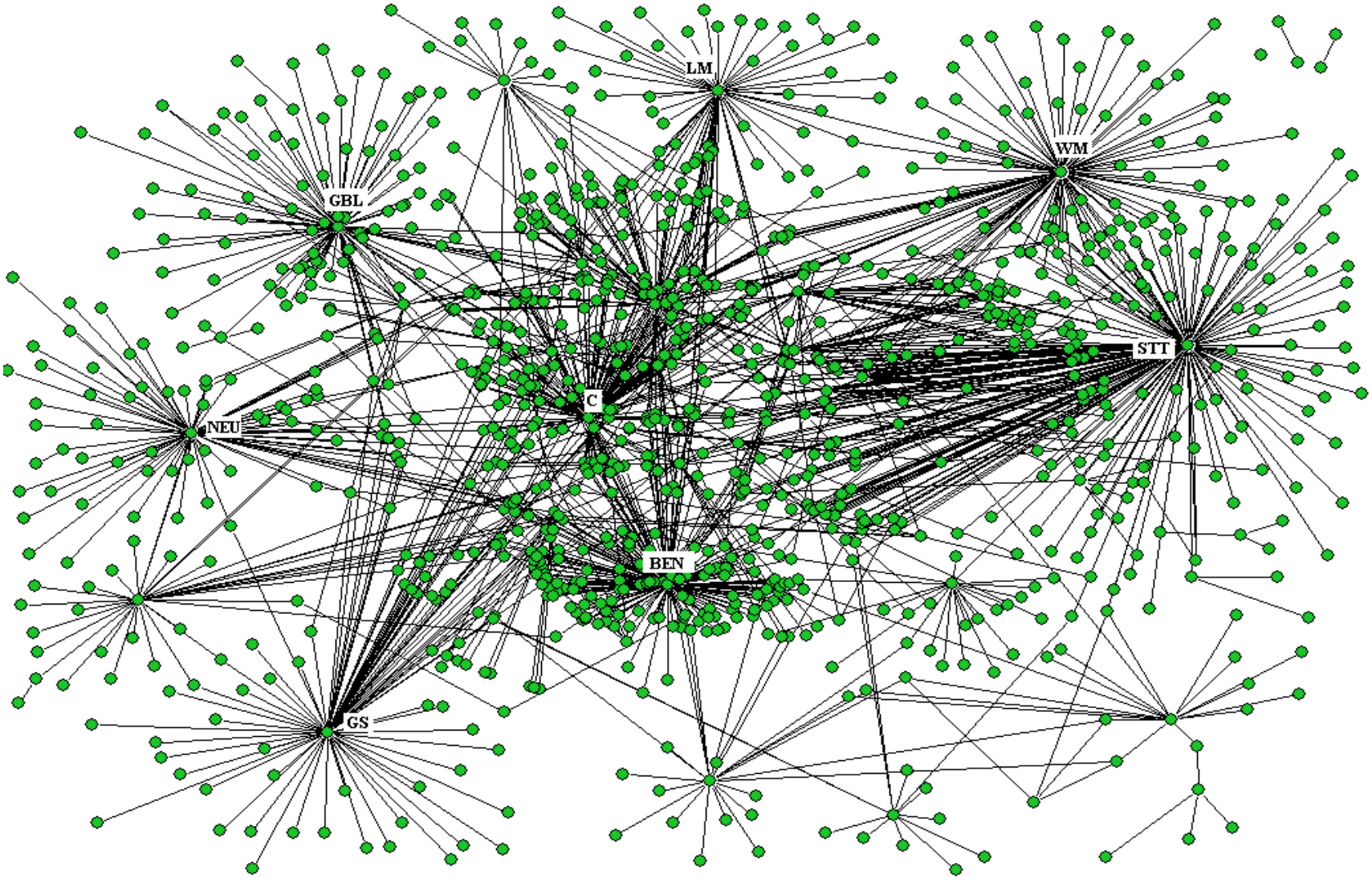
CACB Cascade Bank Coroporate

FITB Fifth Third Bank Corporate

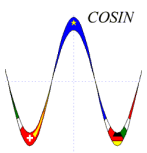
FFBC First Financial Bank Coroporation

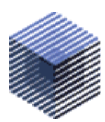
NTRS Northern Trust Corporation

SAFC Safeco Corporation



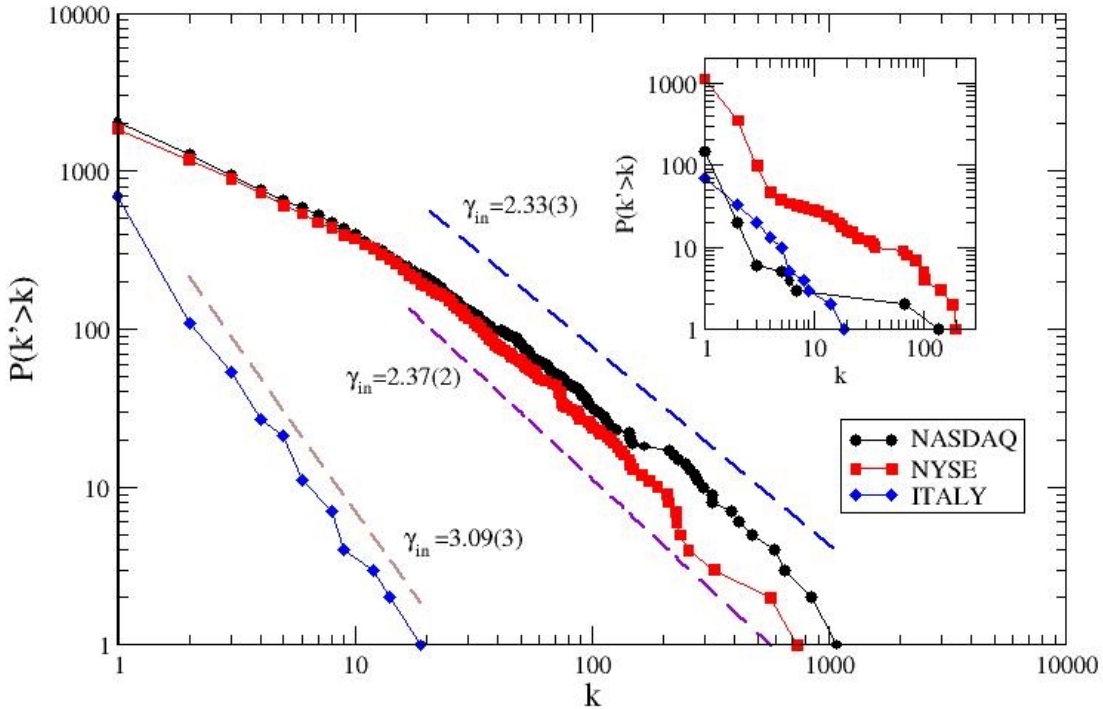
BEN Franklin Res Inc C Citygroup GS Goldman Sachs GBL Gabelli Asset Man LM Legg Mason INC NEU Neuberger Bergman STT State Street WM Washington Mutual





Cumulative in-degree distribution (portfolio diversification)

$$P(k) \propto k^{-\gamma}$$

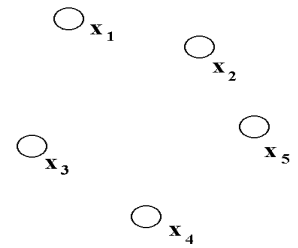


Sharp contrast with the Portfolio Composition predicted by the CAPM model:

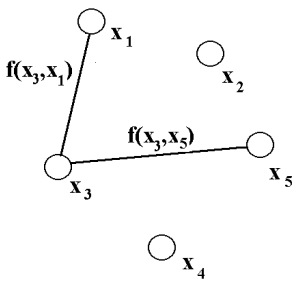
*The optimal portfolio spans all **M** assets in the market, with weights proportional to their market capitalization:*

$$k_i = M \qquad \forall i$$

Can we reproduce the observed heterogeneity by means of a simple network model?



Each investor/asset has a 'fitness' (wealth/performance) drawn from a probability distribution $\rho(x)$



Edges are drawn with probability $f(x_i,x_j)$

Suppose: $f(x_i,x_j)=g(x_i)h(x_j)$

Then we expect a wealth-dependent portfolio diversification:
$k(x) \propto g(x)$

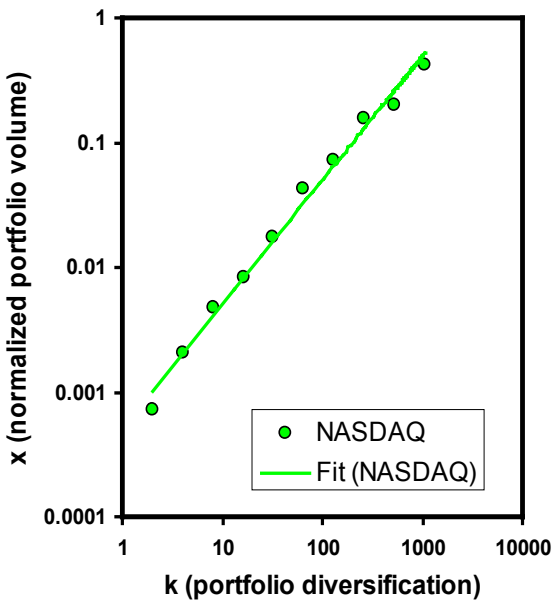
G.C, A. Capocci, P. De Los Rios, M.A. Munoz *PRL* **89**, 258702 (2002).

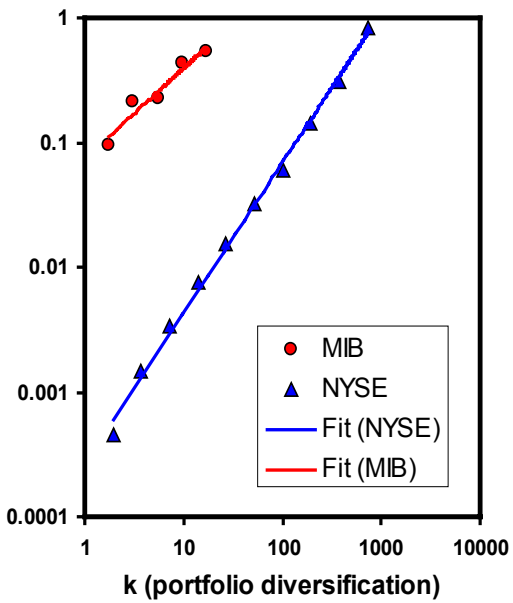
If we choose x_i as the total number of shares that *i* wants to invest, we can measure both $g(x)$ and $\rho(x)$ directly.

x=portfolio volume (total shares held)

k=portfolio diversification (number of different assets)

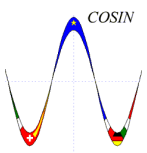
$$x(k) \propto k^{1/\beta}$$

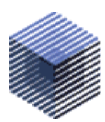




$$k(x) \propto x^{\beta}$$

$$\begin{cases} \beta_{Nasdaq}=1 \text{ (linear)} \\ \beta_{Nyse}=0.86 \text{ (sublinear)} \\ \beta_{Mib}=1.41 \text{ (superlinear)} \end{cases}$$



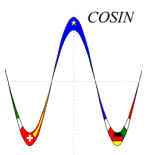


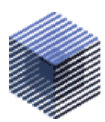
- **Conclusions (?)**

Financial Networks can help

- In distinguishing behaviour of different markets
- In visualizing important features as the chain of control
- In testing the validity of market models

They might be an example of scale-free networks even more general than those described by growth and preferential attachment.





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COevolution and Self-organisation In dynamical Networks

RTD Shared Cost Contract IST-2001-33555

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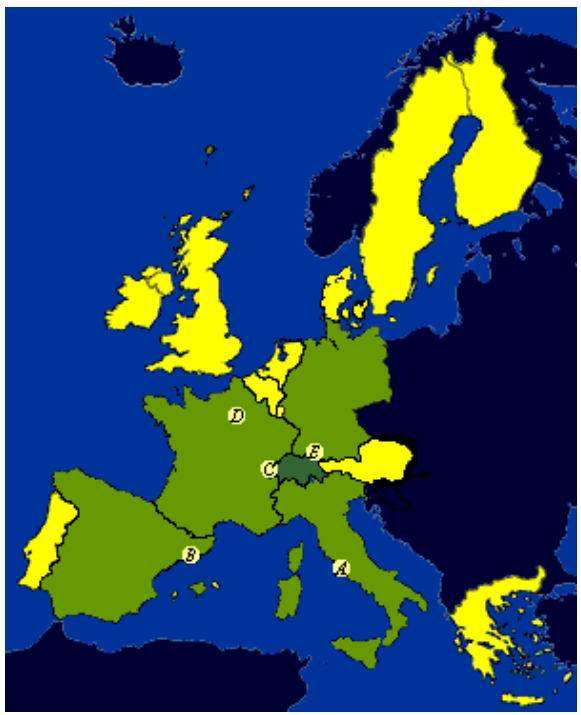

- **Nodes** 6 in 5 countries
- **Period of Activity**: April 2002-April 2005
- **Budget:** 1.256 M€
- **Persons financed**: 8-10 researchers
- **Human resources**: 371.5 Persons/months

EU countries

Non EU countries

EU COSIN participant

Non EU COSIN participant

MIDTERM CONFERENCE COSIN (FET Open Project IST-2001-33555)

Conference on Growing Networks and Graphs in Statistical Physics, Finance, Biology and Social Systems

Roma 1-5 September 2003

Aule S. Pietro in Vincoli, Facoltà di Ingegneria, Università di Roma "La Sapienza" v. Eudossiana 18

http://www.cosin.org/midterm.html

Tentative List of Speakers

L. Adamic *(HP Palo Alto)*
A.-L. Barabási *(Notre Dame)*
W. R. Cheswick *(Lumeta)*
A. Erzan *(Istanbul Univ.)*
R. Mantegna *(Palermo)*
F. Menczer* *(Iowa Univ.)*
A. M. Spaccamela *(Roma)*
D. Wagner *(Konstanz Univ.)*
L. Amaral *(NorthWestern Univ.)*
B. Bollobas *(Memphis)*
P. De Los Rios *(IPT, Lausanne)*
B. Kahng *(Seoul Univ.)*
N. Martinez* *(S. Francisco Univ.)*
J. J. Mendes *(Porto)*
H. E. Stanley *(Boston Univ.)*
G. Weisbuch *(ENS)*
A. Arenas *(Univ. Tarragona)*
A. Broder* *(Altavista)*
S. Dorogotsev *(Porto)*
J. Kertesz *(Eotvos Institute)*
S. Maslov *(Brookhaven)*
R. V. Solé *(UPF Barcelona)*
Z. Toroczkai *(LANL)*
Y.-C. Zhang *(Fribourg)*

Registration

Details about registration forms, contribute submissions, accommodation and tentative programme at web site http://www.cosin.org/midterm.html or e-mail Ms. Francesca Consales consales@pil.phys.uniroma1.it