

# **Exploration into the network structure of the Economy**

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# Assumptions in economic/statistical models are questioned

- Enterprises are perfectly rational and tend to behave in similar ways to each other
- The economy settles into a balanced “equilibrium” state
- The detailed institutional structures and interconnections of the system do not generally matter for policy

# The global financial crisis

2010, ECB President Jean-Claude Trichet:

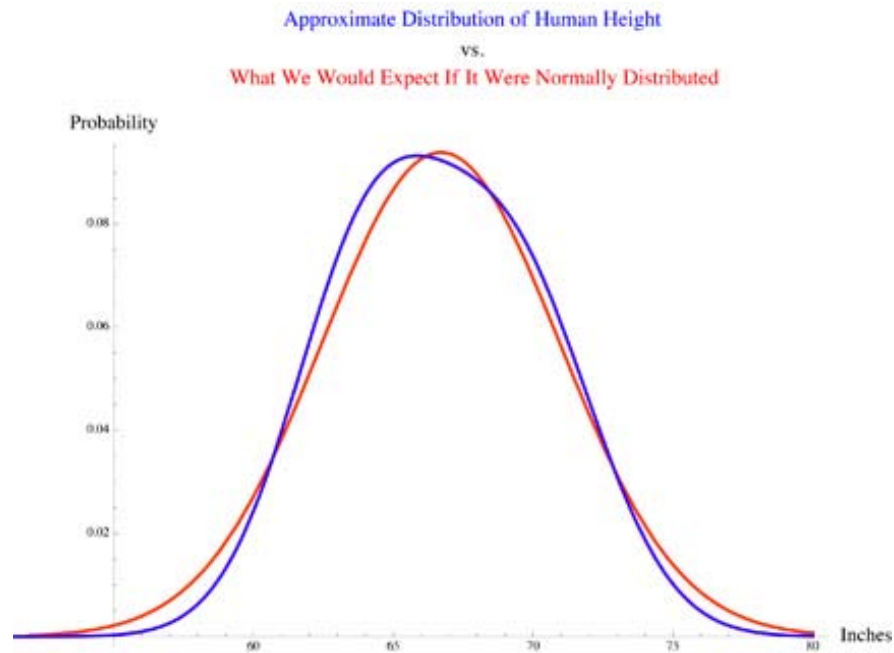
“In the face of the crisis, we felt abandoned by  
conventional tools”

Is there a problem with current statistics?

# Normal distribution often taken for granted

- 1830 Adolphe Quetelet “l’homme moyen” (the average man)
- 1890 Alfred Marshall concept of “representative firm”
- Nowadays “representative agent” typical decision-maker
  - A model contains representative agents while agents may differ individually but act in such a way that the sum of their choices is mathematically equivalent to the decision of a (random) subset of agents.
- Normal distribution expected to be omnipresent

# Distributions in the real world: normal



example: human height

# Distributions in the real world: power law

- Income and wealth distribution
- Word frequency
- Size distribution of galaxies, stars
- Populations of cities
- Frequency and severity of terrorist attacks
- Size distribution of establishments
- Returns in financial markets

Often thought to be results of stochastic processes

# What's special about power laws?

- A power-law  $x^{-a}$  has a:
  - well-defined mean when  $a > 2$
  - finite variance when  $a > 3$

Empirical estimates of mean and variance can converge very slowly due to the regular appearance of extremely large values.

Incorrect to apply traditional statistics that are based on variance and standard deviation

Frequency of extremely rare events like stock market crashes and large natural disasters = much higher than calculated under assumption of normal distribution

# What's special about power laws?

- Scale invariance: the relative likelihood between small and large events is the same, no matter what choice of “small” we make
- Power laws suggest that variations are controlled by interactions among the parts of a system rather than by unconnected chance events, which produce the normal distribution
- Hence the importance of looking at the interdependencies and interactions between the units in a population i.e. the network properties

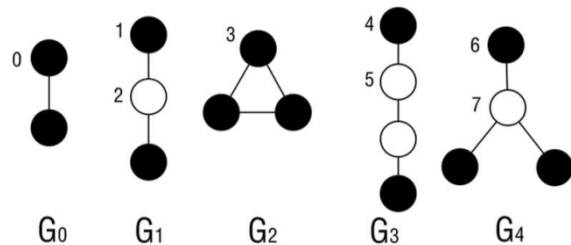


# statistical analysis of network data (1)

- Global properties:
  - Size: usually the number of nodes ( $N$ )
  - Average degree: degree  $k$  of a node is the number of edges connected to it
  - Average path length: average shortest distance between any two nodes in the network
  - Clustering coefficient: the degree to which nodes tend to cluster together

# statistical analysis of network data (2)

- local properties
  - Motif: a small over-represented partial subgraph in a real network.
    - May reflect functional properties
  - Graphlet: small sub-graphs. Graphlet degree vectors (signatures) are compared
    - Used to predict properties of uncharacterised nodes



# statistical analysis of network data (3)

- Comparison between theoretical models and real networks
  - 50's: (Erdős-Rényi) edges distributed randomly
  - 1999 (Barabási-Albert) new nodes attach preferentially to well connected nodes → scale free distribution of connectivities
  - Hidden variable hypothesis: nodes have an intrinsic quality that determines connection probability
- = to understand the dynamics of network formation

# Markets are networks

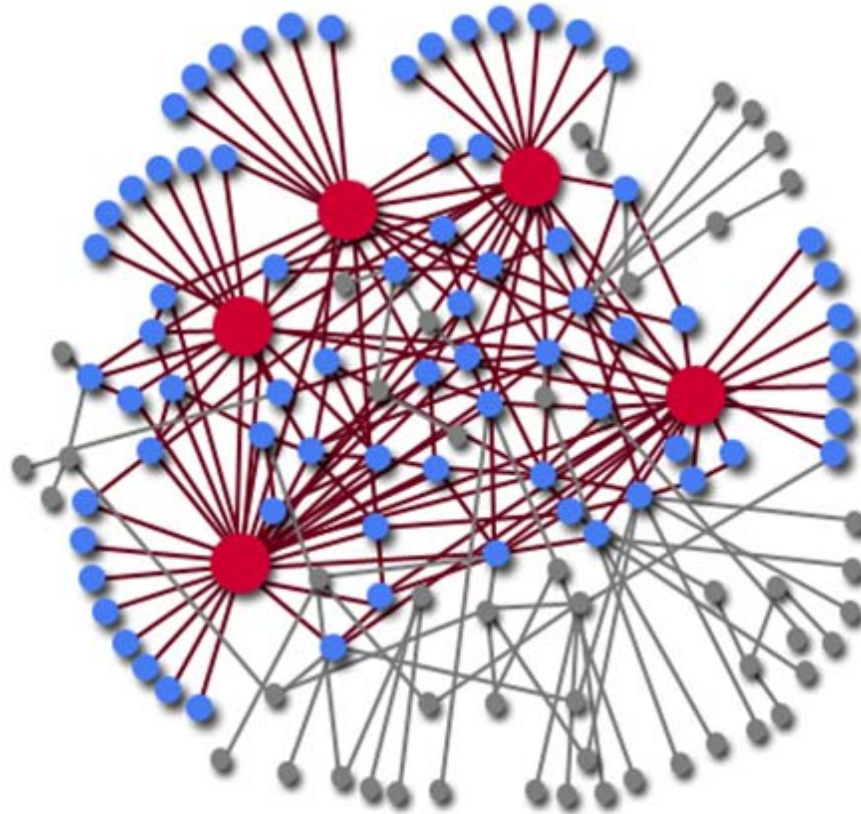
- Network approach has been applied successfully in the study of financial markets
  - Trendfollowing on stock market, risk analysis
- Firms or enterprises as market players:
  - 30's: mechanisms that lead to power law distribution in firm size
  - Search for factors behind differences in growth
  - Customer – Supplier networks
  - Control/ownership relations

# Heterogeneous Interacting Agents

The environment in which we produce statistics has changed

- The assumptions of the rational agent model in economics are widely questioned
- In other domains (physics, biology,..) tools were developed for analyzing systems with heterogeneous interacting agents
- Technical possibilities for handling and analyzing data have changed

# Thank You



Netztopologie nach Albert-László Barabási:

5 Hubs (rot) reichen aus, um 60% der Knoten (blau) direkt zu erreichen.