

Economy from the Perspective of Complex Systems

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THE CENTURY OF COMPLEXITY?

I think the next century will be the century of complexity.”
Stephen Hawking (Complexity Digest 2001.10 March-05-2001)

20th century sciences: mechanistic reductionism

Understanding any system: study of the whole by reduction to its parts.

Knowledge of the parts was thought to yield full understanding of the whole.

Science of Complexity: study of organization principles

Holistic studies: the properties and behavior of *intact* system + environment



KALAMAZOO COLLEGE

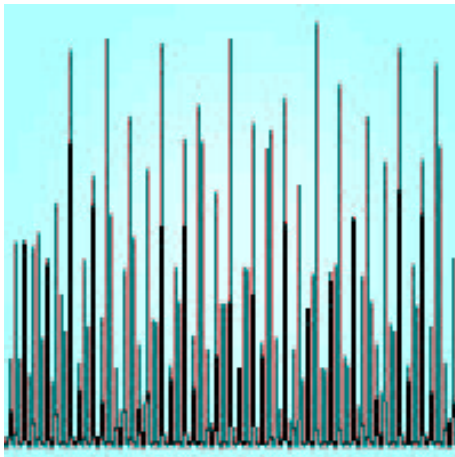
PROSPECTIVES ALUMNI STUDENTS & STAFF VISITORS



**Center for
Complex Systems Studies**

COMPLEXITY: WHAT WE ARE TALKING ABOUT?

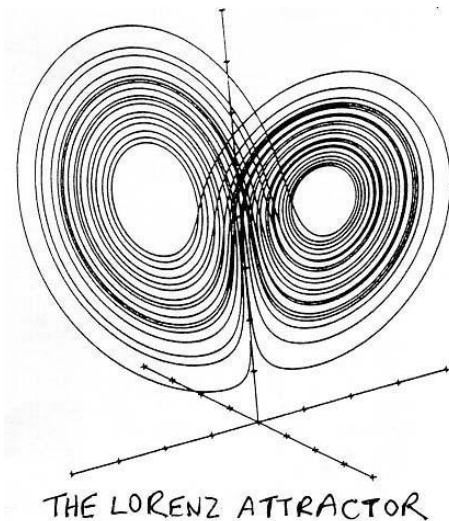
Temporal complexity



Chaotic patterns



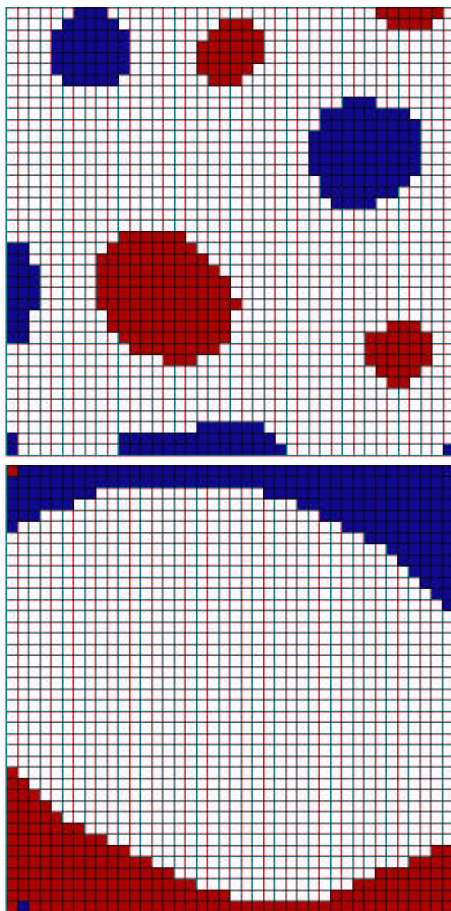
Lorenz:
unpredictability



Lorenz attractor

Spatial complexity

Schelling's segregation model



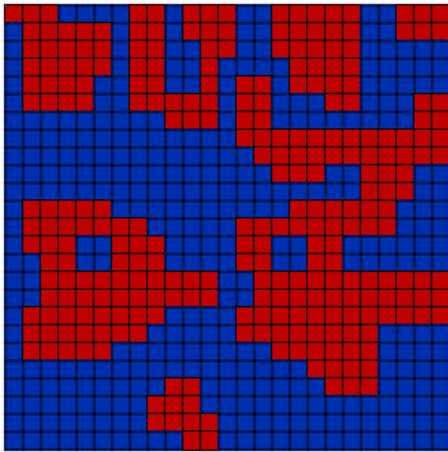
Segregation-1

Segregation-2

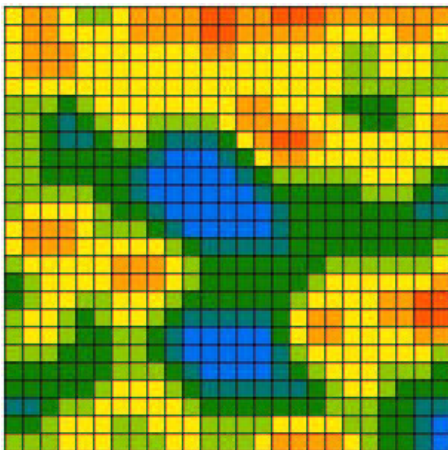
Ghettos emerge from a simple neighborhood rule

Spatial complexity

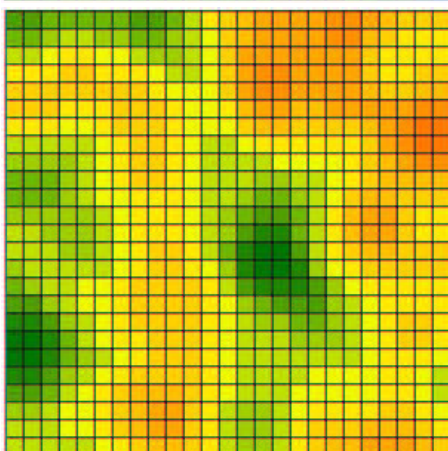
Distribution of opinions



2 possible opinions



10 possible opinions

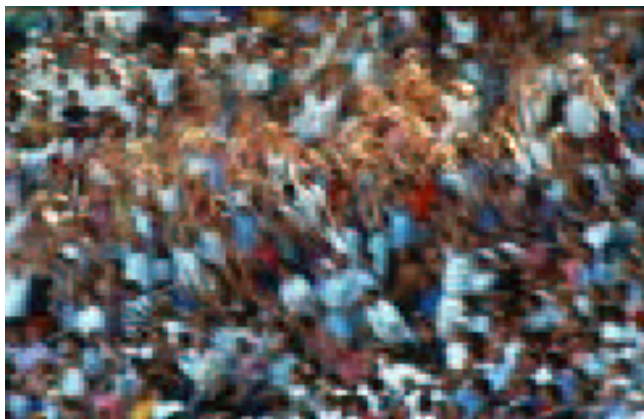


30 possible opinions

Spatiotemporal complexity

People: an excitable media performing the Mexican wave

I. Farkas, D. Helbing, T. Vicsek, Nature 419, 131 (2002)



Mexican wave:

La Ola

The Mexican wave (or La Ola), sweeping through a crowd of spectators. A few dozen fans leap up with their arms raised and then sit down as people in the next section jump to their feet to repeat and propagate the motion.

Spatiotemporal complexity

Statistical theory of **Collective** (physical-chemical) systems → to human behavior

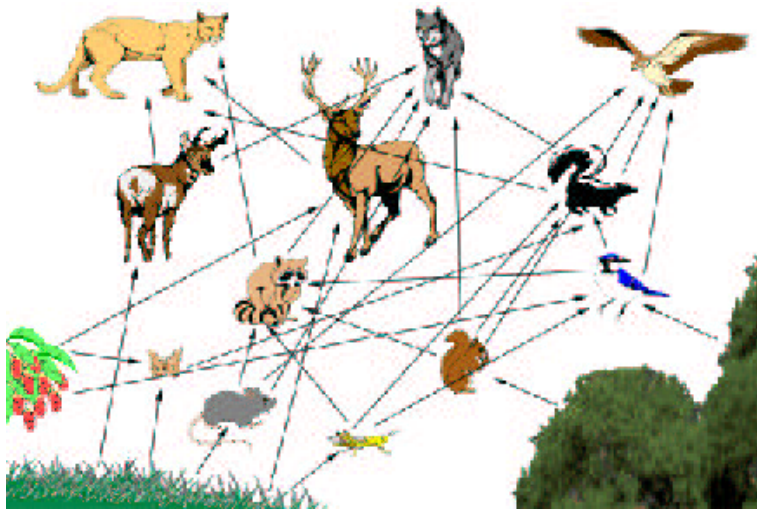
States: excitable - standing - waving - passive (refractory)

Model: the weighted concentration of active people within a given radius around a person is above the person's threshold, then that person becomes activated.

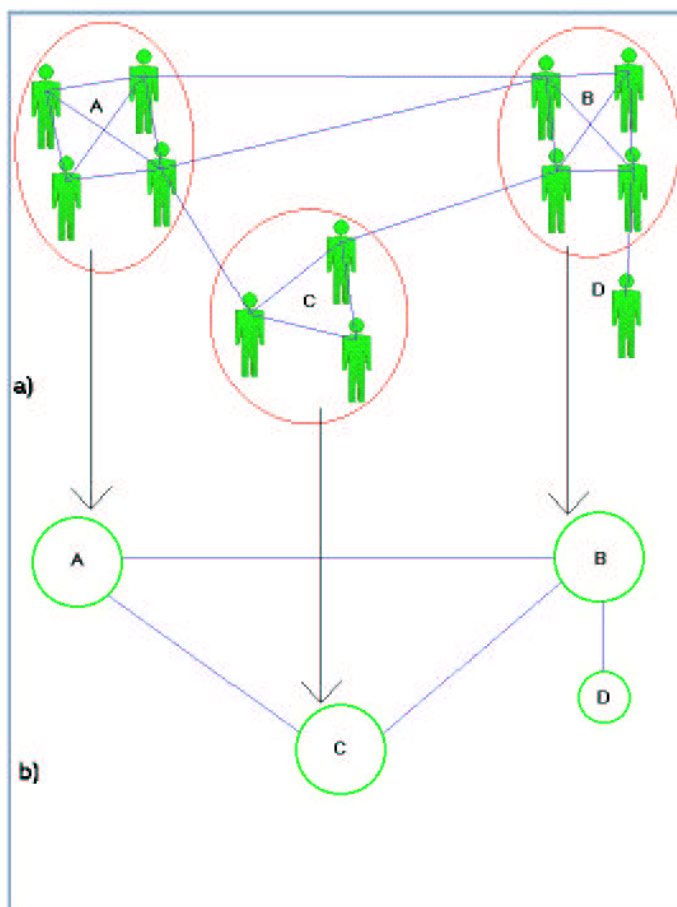
Activation decrease exponentially with distance and change linearly with the cosine of the direction, so that people on the left of an individual have an influence that is stronger than those on the right. The direction of the wave's motion is determined by this anisotropy because of the breakdown of spontaneous symmetry in the early stages as a result of anticipation and anisotropic perception (as most people are right-handed).

Conditions of triggering a wave; characteristic size and time.

Organizational complexity



Food web



Social network

ECONOMICS AND COMPLEXITY: THE PROMISE

Why a New Approach is Needed ?

- *Neoclassical economics*
 - * Behavioral model for people:
 - : Fully-informed
 - : Rational
 - * People interact only indirectly with one another (through markets)
 - * Focus on equilibrium outcomes
- *Complexity approach*
 - * People are adaptive
 - * They interact directly with one another
 - * Focus on dynamics
 - * Methodology: equation vs. agent-based modeling ?

W. Brian Arthur

"Complexity and the Economy," Science, 2 April 1999, 284, 107-109

<http://www.santafe.edu/~wba/Papers/Papers.html>

CONTROLLING CHAOS IN ECONOMICAL MODELS

J.A. Holyst and K. Urbanowicz:

Chaos control in economical model by time-delayed feedback method; Physica A, 287, 587-598 (2000)

Chaos in a simple micro-economical model of two competing firms

Two firms X and Y competing on the same market of goods. The firms perform active investment strategies, i.e., their temporary investments depend on their relative position on the market.

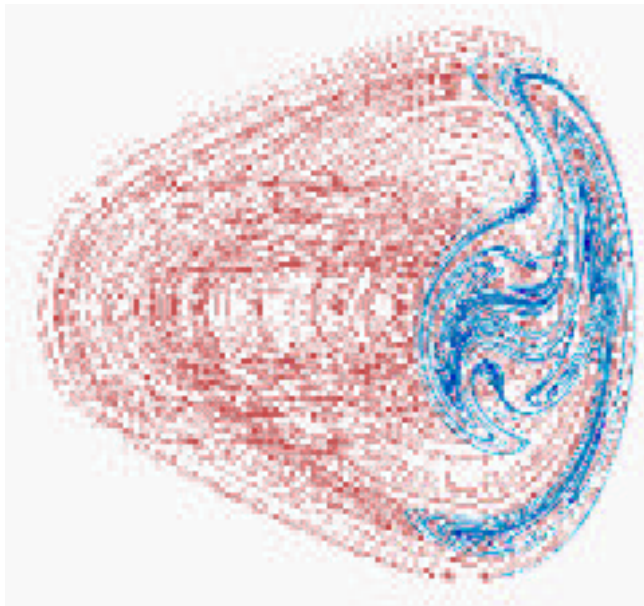
The strategies are asymmetric:

firm X invests more when it has an advantage over the firm Y;

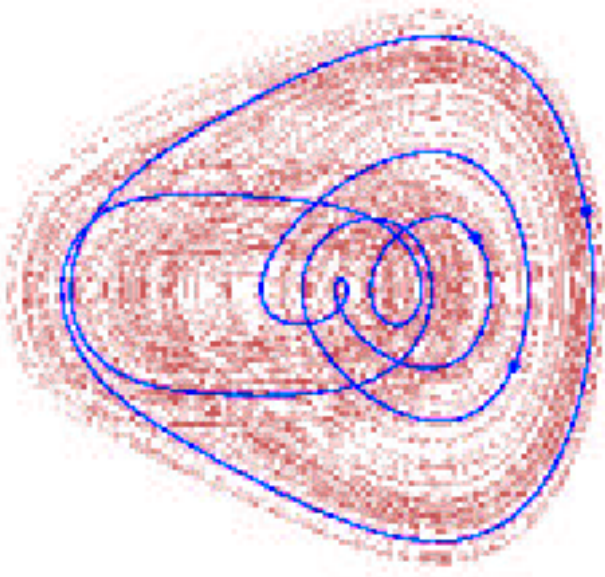
firm Y invests more if it is in a disadvantageous position compared to the firm X

+ chaos may occur

+ chaos can be suppressed by changing the investment sizes



Chaos



3-periodicity

ECONOPHYSICS

Econophysics tries to apply physics methods to theoretical economics with the optimism of the physicists

<http://www.unifr.ch/econophysics/>

- deals with real market data

derive empirical laws

- construct phenomenological theories

obvious drawback: interacting units in economics are 'thinking agents' with adaptive strategies;
and not 'mindless' particles obeying simple microscopic laws

MINORITY GAME

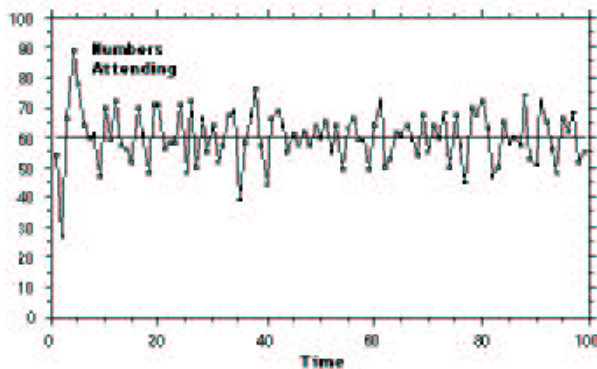
A minority game (MG) is a repeated game where N (odd) players have to choose one out of two alternatives (say A and B) at each time step. Those who happen to be in the minority win. Although being rather simple at first glance this game is subtle in the sense that if all players analyze the situation in the same way, they all will choose the same alternative and will lose. Therefore, players have to be HETEROGENOUS. Moreover, there is a frustration since not all the players can win at the same time: this is an essential mechanism for modelling competition.

MG is an abstraction of the famous El-Farol's bar problem (Brian W. Arthur, Am. Econ. Assoc. Papers and Proc 84, 406, (1994)): 100 people would like to go to a bar (El Farol) which is too crowded if there are more than 60 people.

Minority game

MG is simply a game with artificial agents with partial information and bounded rationality. (Herbert Simon is cited very rarely in the econophysics literature.) Decisions: based on the knowledge of the M last winning alternatives, called histories. Take all the histories and fix a choice (A or B) for each of them : you get a strategy, which is like a theory of the world.

Inductive strategies; mental schemes, hypotheses or behavioral rules



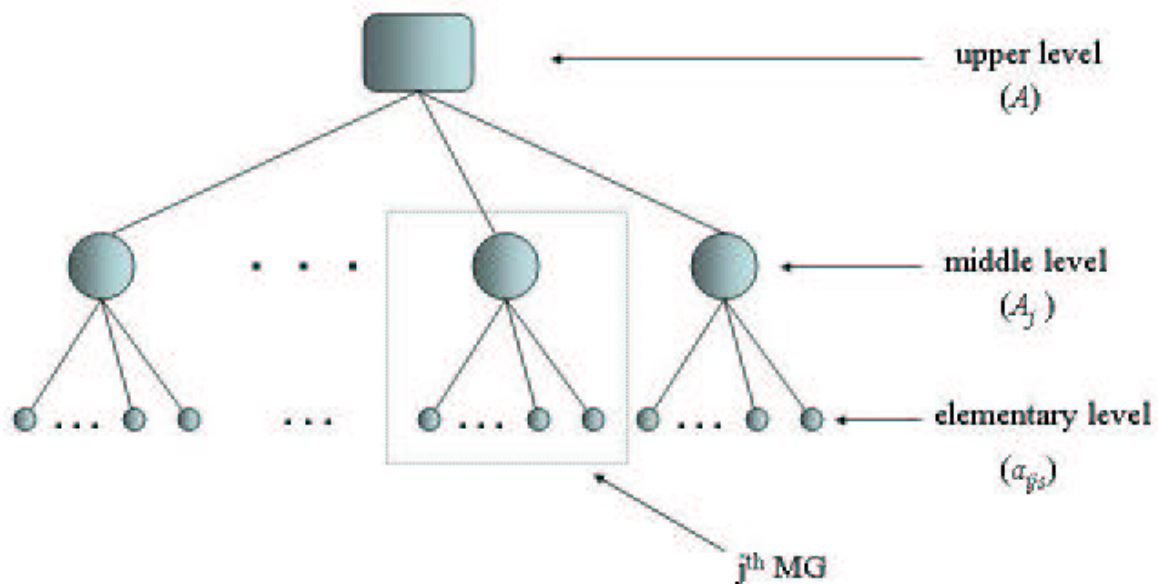
Bar Attendance in the
first 100 Weeks

MG: very crude model of financial markets: minority mechanism is found in markets.

Stock market as a complex adaptive system

Hierarchically Organized Minority Games

The individual MGs will form a group, and individual players within each MG will make decisions which depend on the average behavior of their own and other MGs. Calculations show that under certain conditions the elements of the individual MGs 'know' much more about each other than one would expect.



FROM SOCIAL NETWORKS TO ECONOMIC NETWORKS

- *Acquaintanceship Networks*

Milgram, Stanley. "The Small World Problem." 1967.

It took a median of 5 intermediate friends to go from the starter to the target person

What is the probability that any two people, selected arbitrarily from a large population, will know each other?

What is the length of the shortest chain of acquaintances between two people chosen at random?

- *Hollywood Universe*

Find the shortest path from any actor to Kevin Bacon, using the association rule

Unlike society in general, film actor associations are well documented

- *Collaborative graphs*



Paul Erdős
(1913-1996)

FROM SOCIAL NETWORKS TO ECONOMIC NETWORKS

The Erdős Number Project

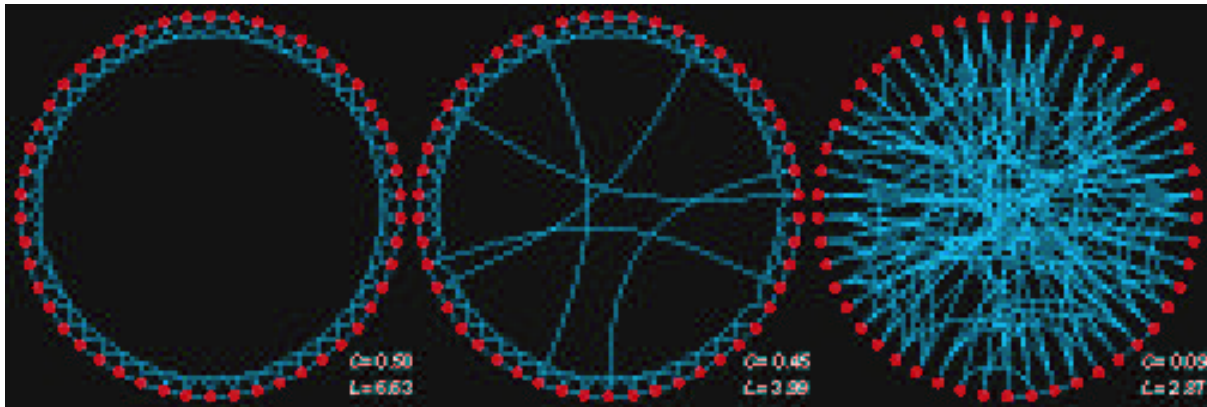
<http://www.oakland.edu/~grossman/erdoshp.html>

E. n 0	1	person
E. n 1	502	people
E. n 2	5713	people
E. n 3	26422	people
E. n 4	62136	people
E. n 5	66158	people
E. n 6	32280	people
E. n 7	10431	people
E. n 8	3214	people
E. n 9	953	people
E. n 10	262	people
E. n 11	94	people
E. n 12	23	people
E. n 13	42	people
E. n 14	7	people
E. n 15	1	person
E. n 16	0	people

Average Erdős number: 4.69

FROM SOCIAL NETWORKS TO ECONOMIC NETWORKS

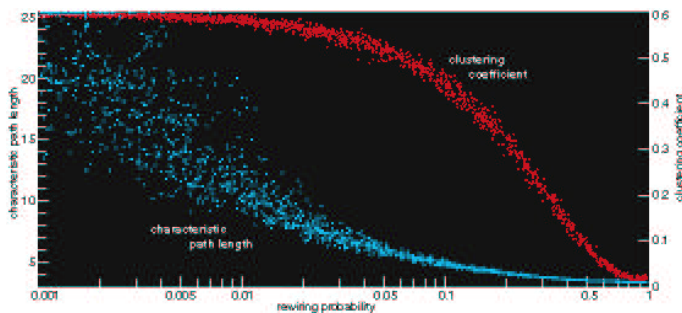
REGULAR, RANDOM and REAL WORLD GRAPHS



lattice-like (several neighbors)

regular + random effects

random

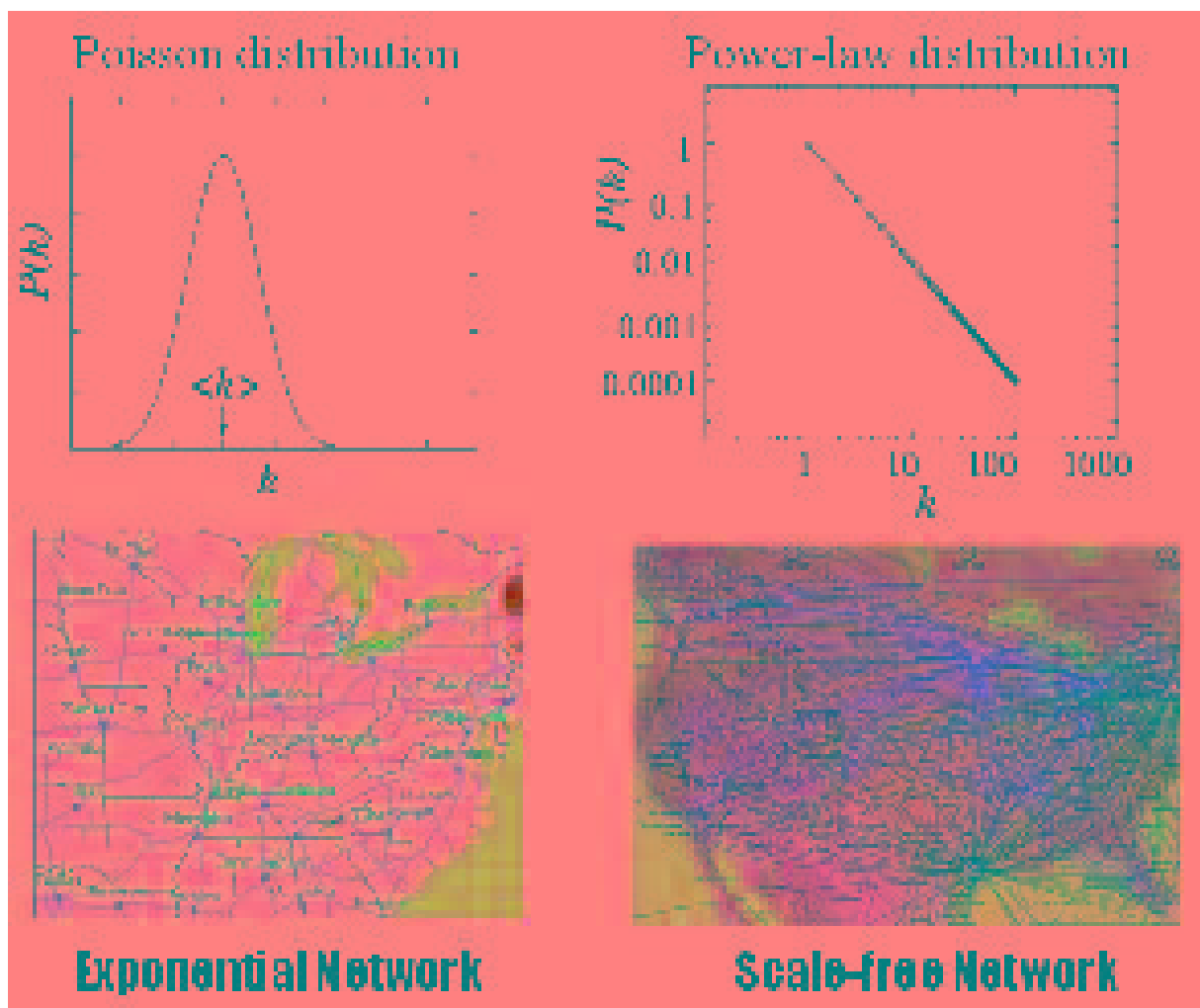


small world graphs

FROM SOCIAL NETWORKS TO ECONOMIC NETWORKS

Power-law distribution - Scale-free distribution

(Success story on the topology of WWW: Barabasi)

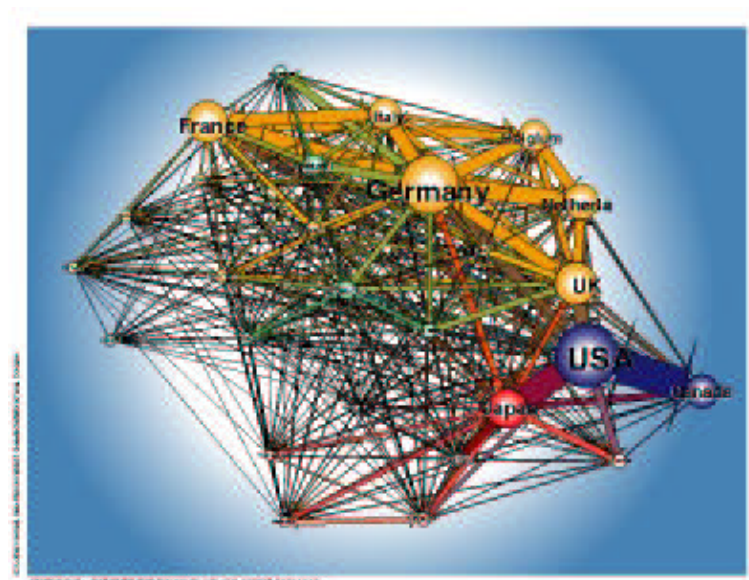


FROM SOCIAL NETWORKS TO ECONOMIC NETWORKS

OECD Statistics on International Trade in Services, Partner Country Data and Summary Analysis, 1999-2000

OECD statistics of trade in services broken down by partner country. It is a response to a growing interest in trade in services partly due to their increasing importance in economic production and partly driven by increased data needs to inform trade negotiations.

<http://www.oecd.org/pdf/M00032000/M00032981.pdf>



OECD

FROM SOCIAL NETWORKS TO ECONOMIC NETWORKS

Paper of the month in Econophysics:

M. Angeles Serrano, Marian Boguna: Topology of the World Trade Web

<http://xxx.lanl.gov/pdf/cond-mat/0301015/>

Analysis of International Trade Center:

<http://www.intracen.org/menus/countries.htm>

import - export list; the forty more important exchanged merchandises (2000)

vertices: countries (179) directed links: import/export relations (7510)

average degree: 30.9

$k > 20$: power law distribution

else: Poisson distribution ("random evolution")

Message: Developmental mechanisms are different !!!

AGENT-BASED MODEL OF THE TIMING OF RETIREMENT

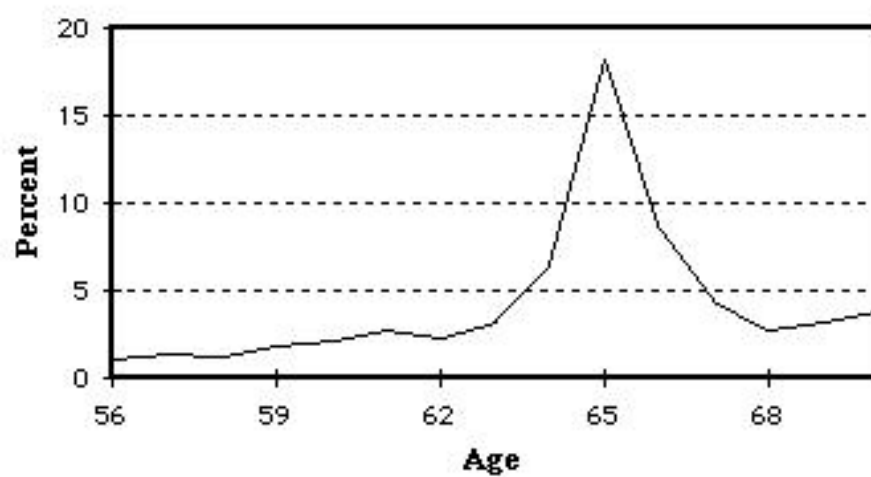
Axtell and Epstein (The Brookings Institution):

Coordination in Transient Social Networks: An Agent-Based Computational Model of the Timing of Retirement

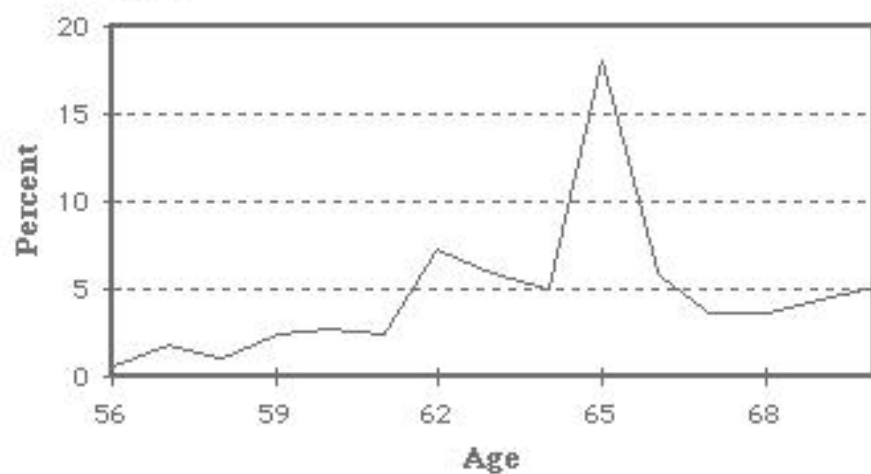
1961: minimum age at which workers could claim social security benefit: 65 -> 62

fully-informed rational behavior: instantaneous shift

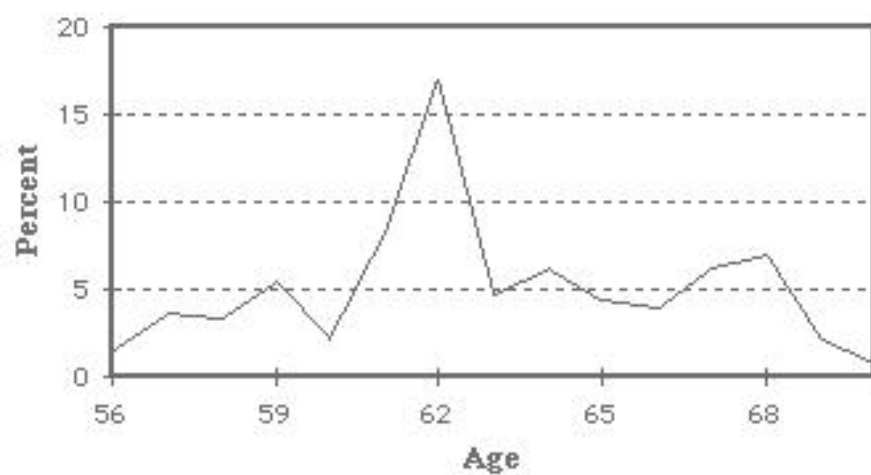
1960



1970



1995-96

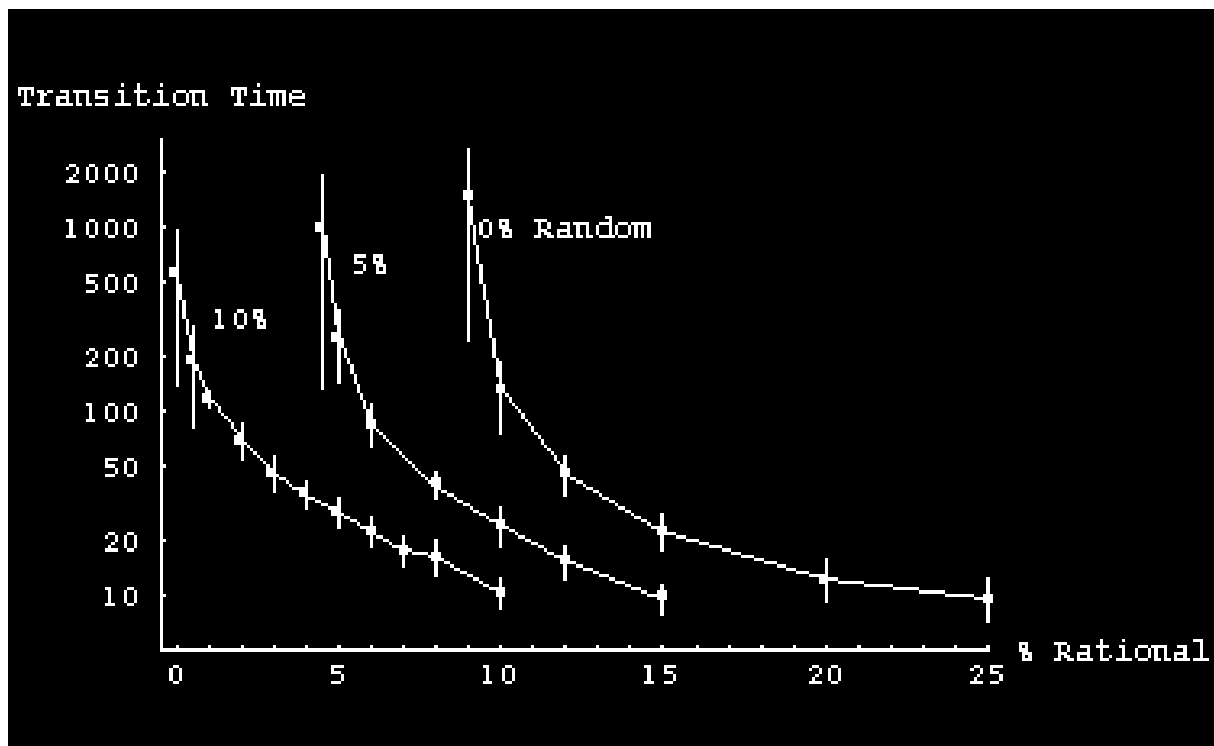


Agents-based simulation: different strategies:

(Game theory + social network theory)

'rationals,' 'randoms,' and 'imitators.'

(Heterogenous) Imitators behaviour \leftarrow their social network



For a given fraction of rationals:

transition time decreases as the proportion of randoms increase ...

similar simulations ...