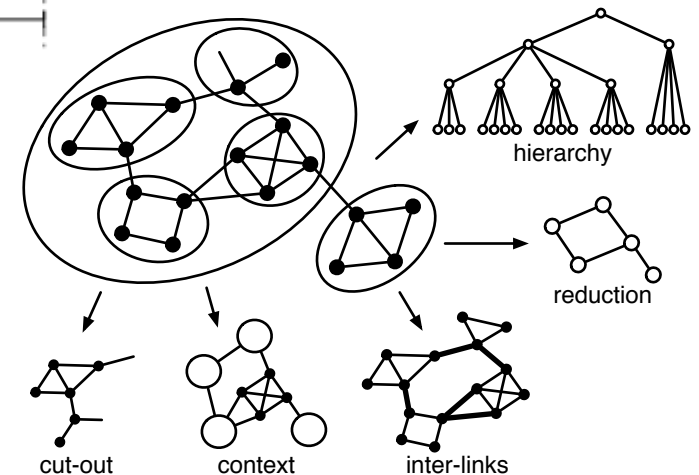
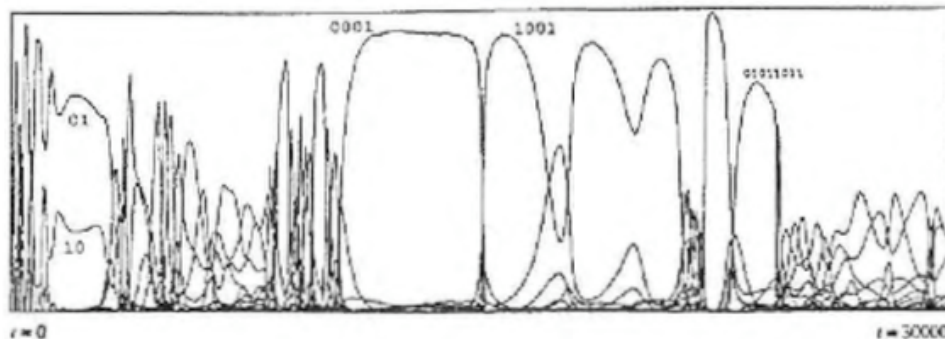
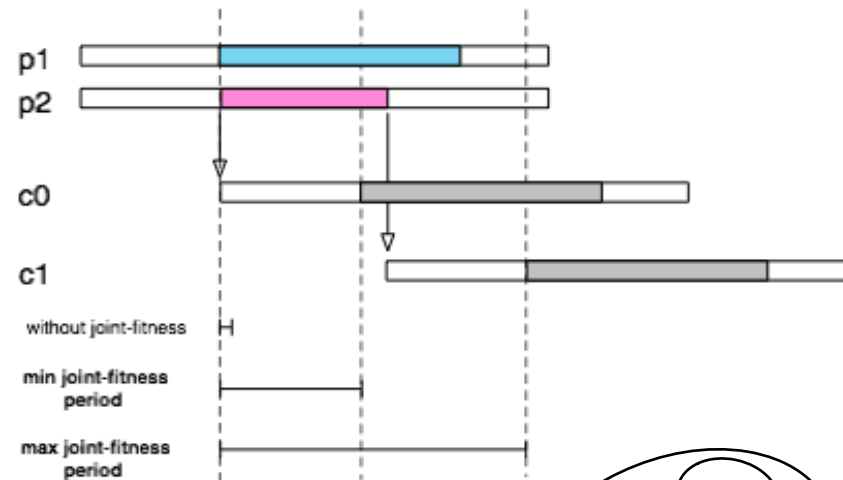
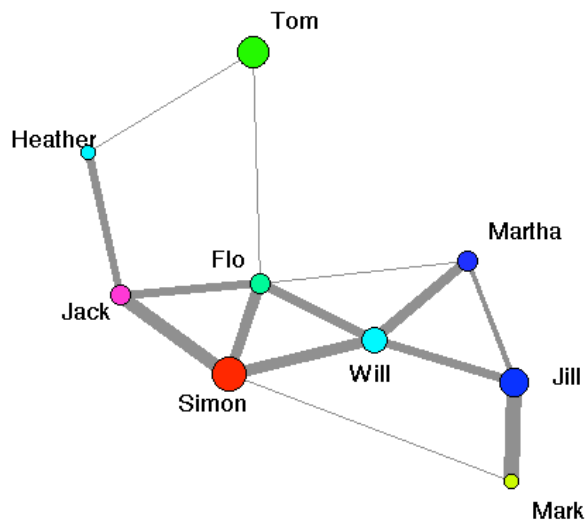


# Why is Economics not an Evolutionary Science?

## Systems Biology and Systems Economy



## Agenda

- A. Asking the question
- B. A few key differences between Economic Biology and 'Mechanics'
- C. Focus i: sparse networks
- D. Focus ii: co-evolution, adaptation and fitness landscapes
- E. Methodological options
- F. An example
- G. Some hurdles to the Economic Biology paradigm

# Veblen on the 'received formulation'

*In all the received formulations of economic theory, whether at the hands of English economists or those of the Continent, the human material with which the inquiry is concerned is conceived in hedonistic terms; that is to say, in terms of a **passive and substantially inert and immutably given human nature**.*

human nature is  
exogenously defined  
in purely hedonistic  
terms

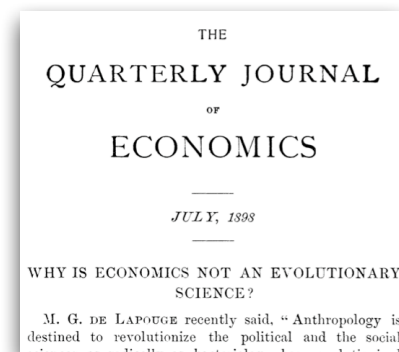
*... The hedonistic conception of man is that of a lightning calculator of pleasures and pains, who oscillates like a homogeneous globule of desire of happiness under the impulse of stimuli that shift him about the area, but leave him intact. He has neither antecedent nor consequent. **He is an isolated, definitive human datum, in stable equilibrium except for the buffets of the impinging forces that displace him in one direction or another.** Self-poised in elemental space, he spins symmetrically about his own spiritual axis until the parallelogram of forces bears down upon him, where-upon he follows the line of the resultant. When the force of the impact is spent, he comes to rest, a self-contained globule of desire as before. Spiritually, the hedonistic man is not a prime mover. He is not the seat of a process of living, except in the sense that he is subject to a series of permutations enforced upon him by circumstances **external and alien to him**.*

so ... mankind is a  
passive responder

so ... the forces he faces are  
not of his making: they are  
'external', 'alien' to him

he 'tends' to return to equilibrium

**Thorstein Veblen, *QJE*, 1898, pp. 389-390**



# ... a different view of mankind?

*... it is the characteristic of man to **do something**, not simply to suffer pleasures and pains through the impact of suitable forces. He is not simply a bundle of desires that are to be saturated by being placed in the path of the forces of the environment, but rather **a coherent structure of propensities and habits which seeks realization and expression in an unfolding activity**. According to this view, human activity, and economic activity among the rest, is not apprehended as something incidental to the process of saturating given desires. **The activity is itself the substantial fact of the process**, and the desires under whose guidance the action takes place are circumstances of temperament which determine the specific direction in which the activity will unfold itself in the given case. These circumstances of temperament are ultimate and definitive for the individual who acts under them, so far as regards his attitude as agent in the particular action in which he is engaged.*

an 'unfolding activity'  
arising from  
preferences and  
habits

individual activity  
builds the general  
'process'

*But, in the view of the science, they are elements of the **existing** frame of mind of the agent, and are the **outcome of his antecedents and his life up to the point at which he stands**. They are the products of his hereditary traits and his past experience, cumulatively wrought out under a given body of traditions, conventionalities, and material circumstances; and they afford the point of departure for the next step in the process. **The economic life history of the individual is a cumulative process of adaptation of means to ends that cumulatively change as the process goes on, both the agent and his environment being at any point the outcome of the past process. His methods of life today are enforced upon him by his habits of life carried over from yesterday and by the circumstances left as the mechanical residue of the life of yesterday.***

the landscape is  
constantly changing

so ... adaptation

so ... path-dependency

Thorstein Veblen, *QJE*, 1898, pp. 390-391

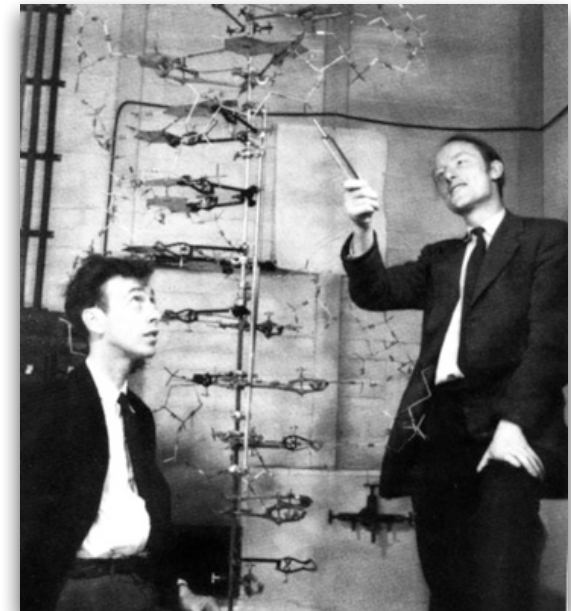
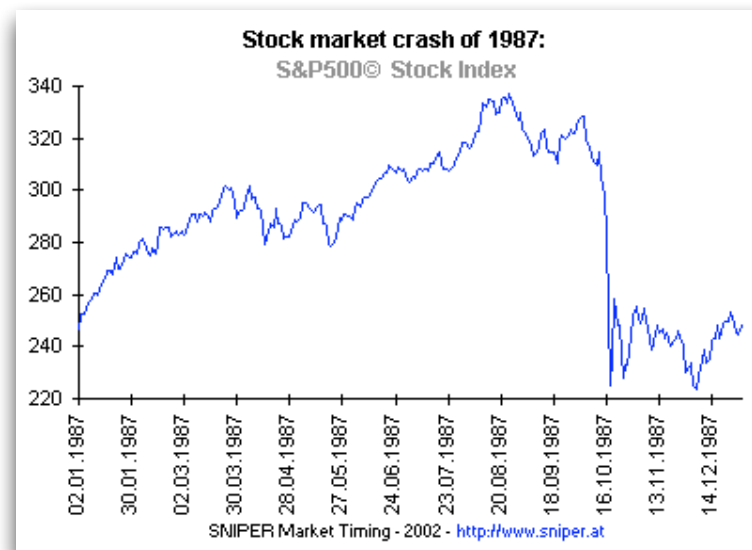
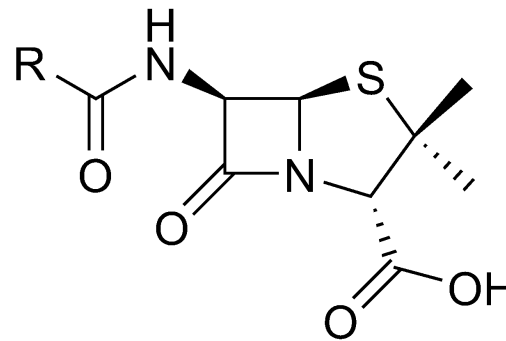


# 'Marginal economics' versus 'Thresholds/Criticality'

*[W]hat we are about to consider is that kind of change arising from within the system which so displaces its equilibrium point that the new one cannot be reached from the old one by infinitesimal steps. Add successively as many mail coaches as you please, you will never get a railway thereby.*

'abrupt' changes,  
criticality, thresholds,  
regime-change  
(structural breaks)

Joseph Schumpeter, (1934) p. 64, fn 1.

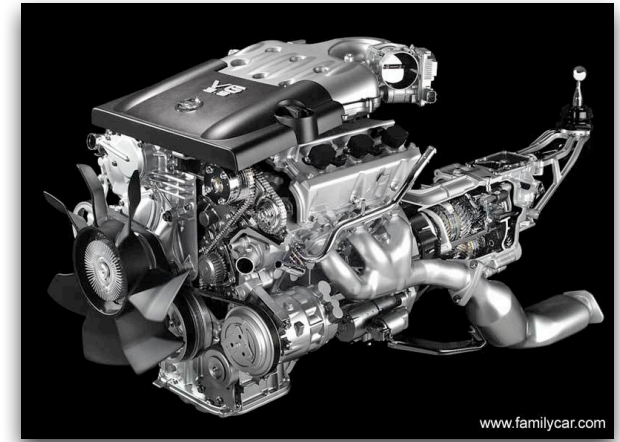


# 'Mechanics' versus 'Economic Biology'

*The Mecca of the economist lies in **economic biology** ... But biological conceptions are more complex than those of mechanics; a volume on Foundations must therefore give a relatively large place to **mechanical analogies**, and frequent use is made of the term '**equilibrium**' which suggests something of a static analogy.*

*Alfred Marshall, **Principles of Economics**, 1948, p.xiv*

the dominance of  
'equilibrium'  
thinking ... (because it  
is less complex)





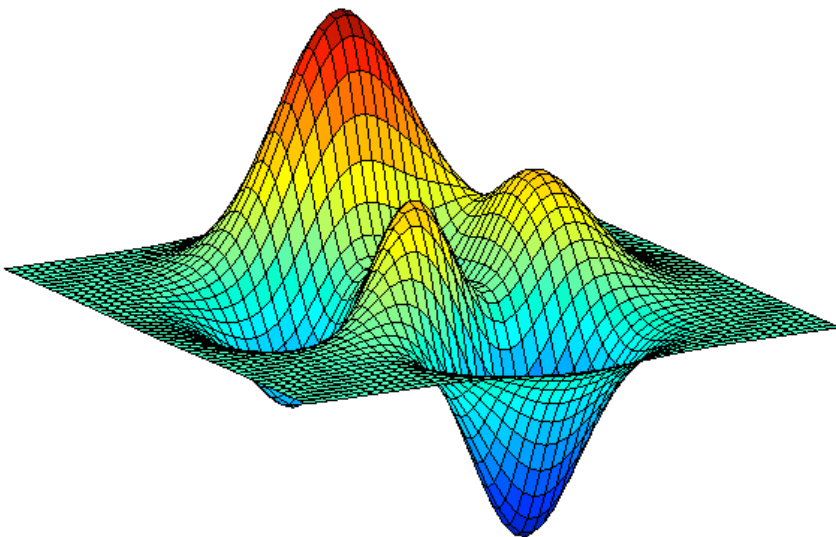
# 'Optimisation' versus 'Adaptation'

*Few economists confuse the formal static or dynamic equilibrium theory with the reality. Most readily acknowledge that at least some economic situations need to be understood as involving **significant elements of novelty**, so that the actors should be regarded as **searching for a best action**, as contrasted with actually having found it. In their analysis of certain economic phenomena, for example technical advance, many economists recognize that frequent or continuing shocks, generated internally as well as externally, may make it hazardous to assume that the system ever will get to an equilibrium; thus the fixed or moving equilibrium in the theory must be understood as an "attractor" rather than a characteristic of where the system is.*

**Richard R Nelson, JEP 1995, p.49**

novelty ... implies a changing optimisation landscape: continual search, not 'finished' search

the system does not ever reach 'equilibrium' (if it exists), but orbits near or far from it perpetually



# Key elements of 'Economic Biology'

## Evolutionary thinking

*Economics happens when actors interact*

But everything is dynamic:

// the **pattern** of interactions (network)

// the **type** of interactions (innovations)

// the **preferences** of the agents

// the **information** available

So ...

=> The 'fitness' landscape is also **dynamic**

=> The action of agents is not static (or even dynamic)

optimisation, but **adaptation**

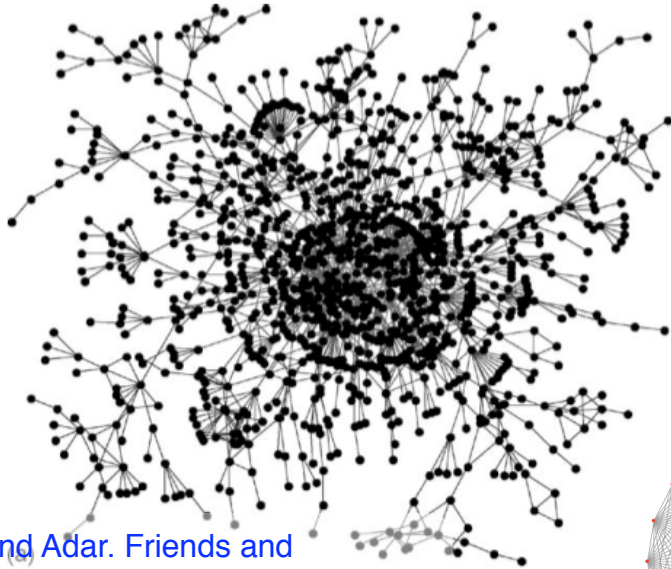
=> There is no stasis, no equilibrium, but only

**'unfolding change'**

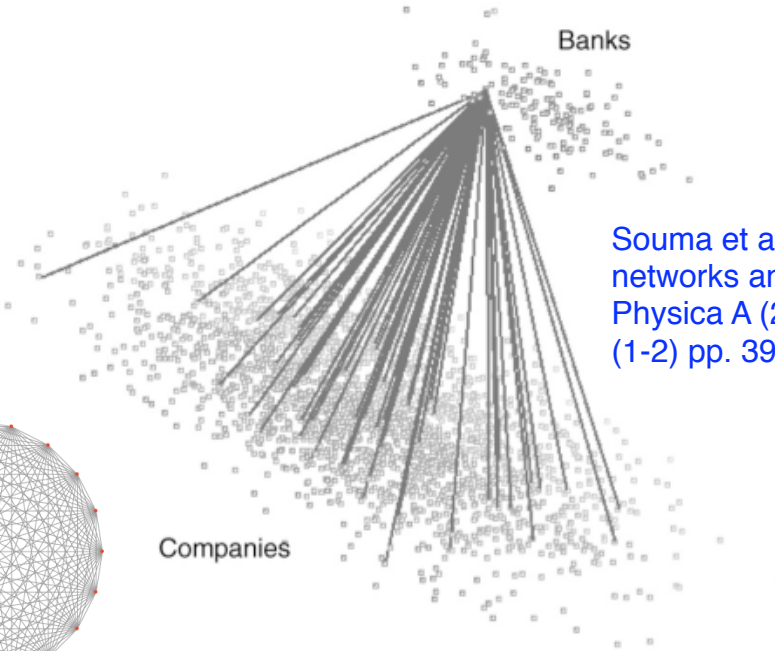
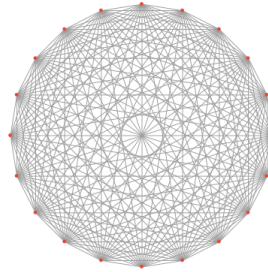
*The economic life history of the individual is a **cumulative process of adaptation of means to ends that cumulatively change as the process goes on**, both the **agent** and his **environment** being at any point the outcome of the past process. His methods of life today are enforced upon him by his habits of life carried over from yesterday and by the circumstances left as the mechanical residue of the life of yesterday.*

**Veblen**

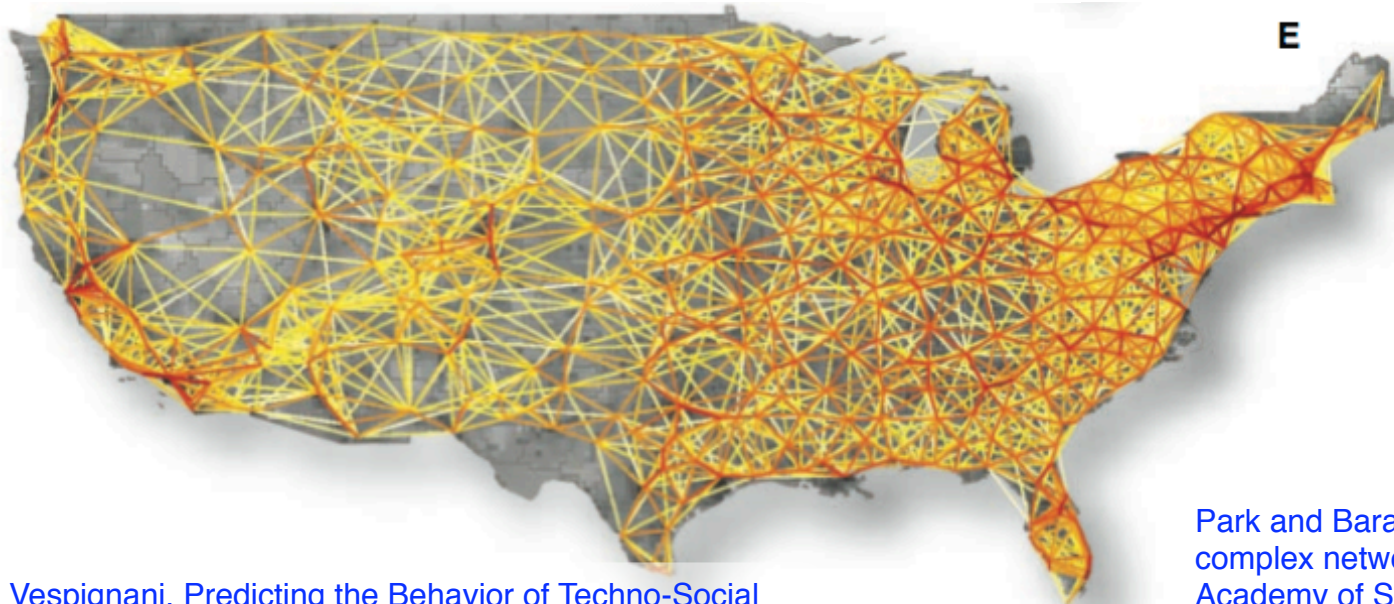
# Economic networks are not complete graphs



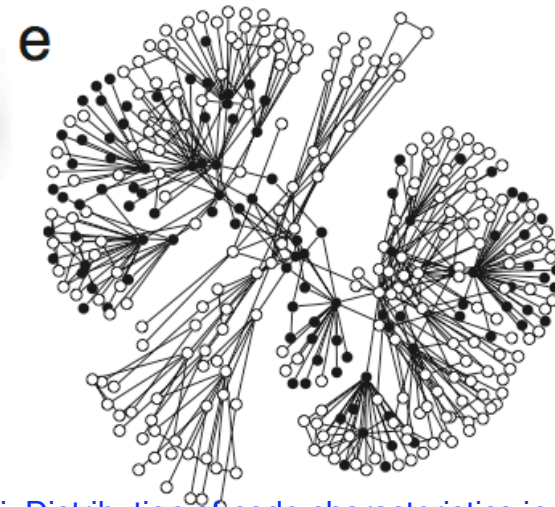
Adamic and Adar. Friends and Neighbors on the Web. *Social Networks* (2003) vol. 25 pp. 211-230



Souma et al. Complex networks and economics. *Physica A* (2003) vol. 324 (1-2) pp. 396-401



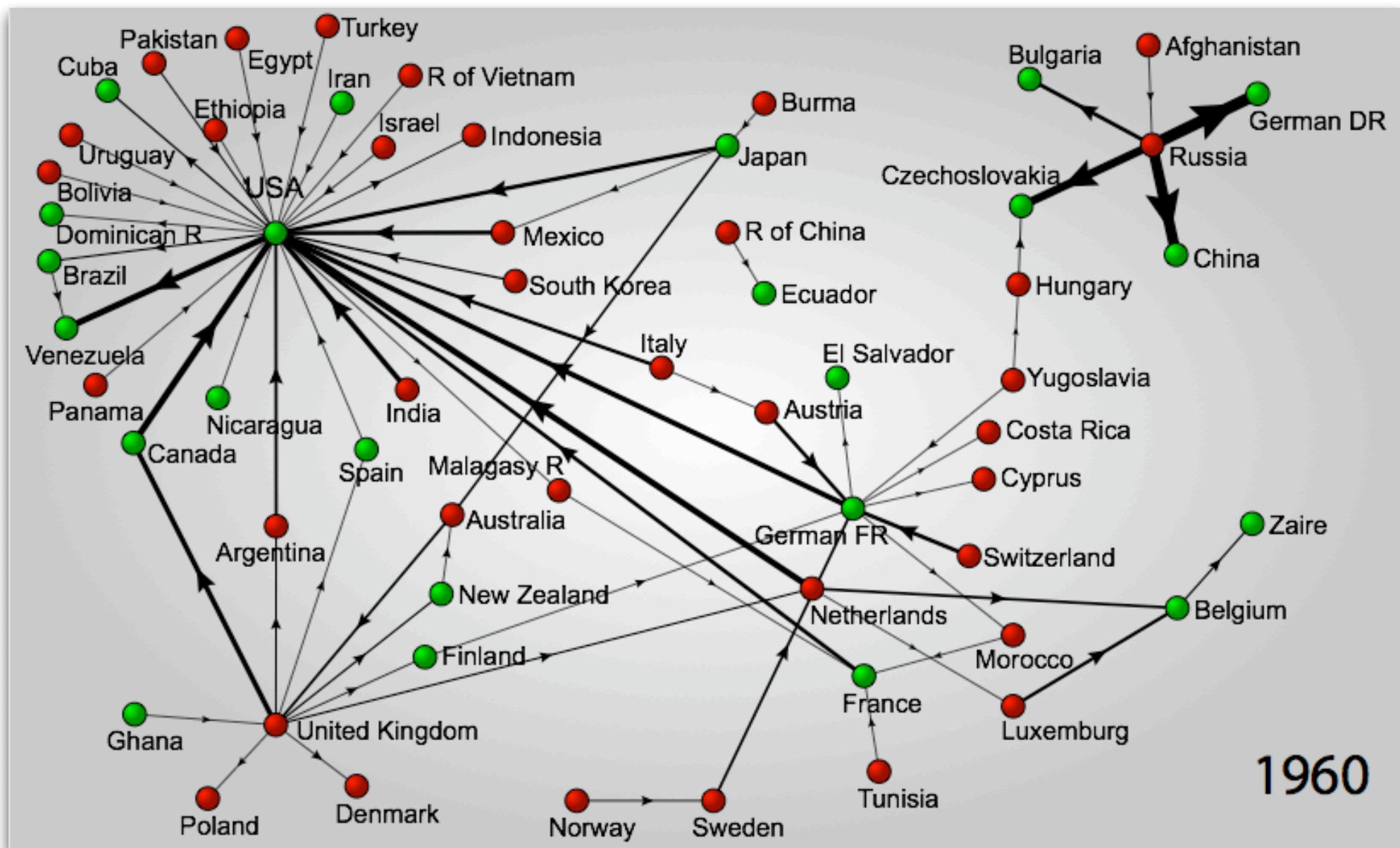
Vespignani. Predicting the Behavior of Techno-Social Systems. *Science* (2009) vol. 325 (5939) pp. 425



Park and Barabási. Distribution of node characteristics in complex networks. *Proceedings of the National Academy of Sciences* (2007) vol. 104 (46) pp. 17916-17920

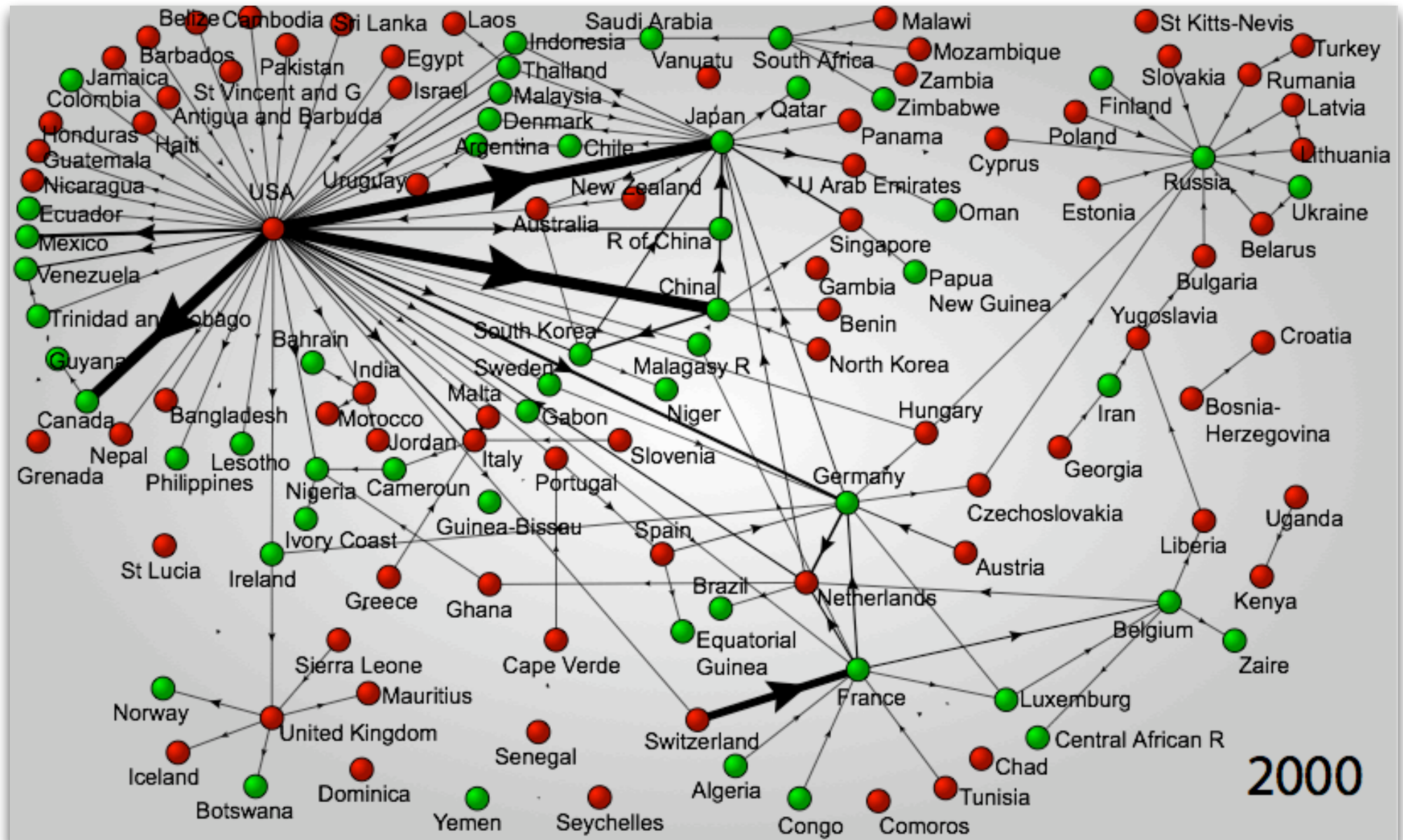


# Sparse networks: trade imbalances 1960



Serrano, M.A., Boguna, M., Vespignani, A., Patterns of dominant flows in the world trade web, Journal of Economic Interaction and Coordination 2(111) (2007)

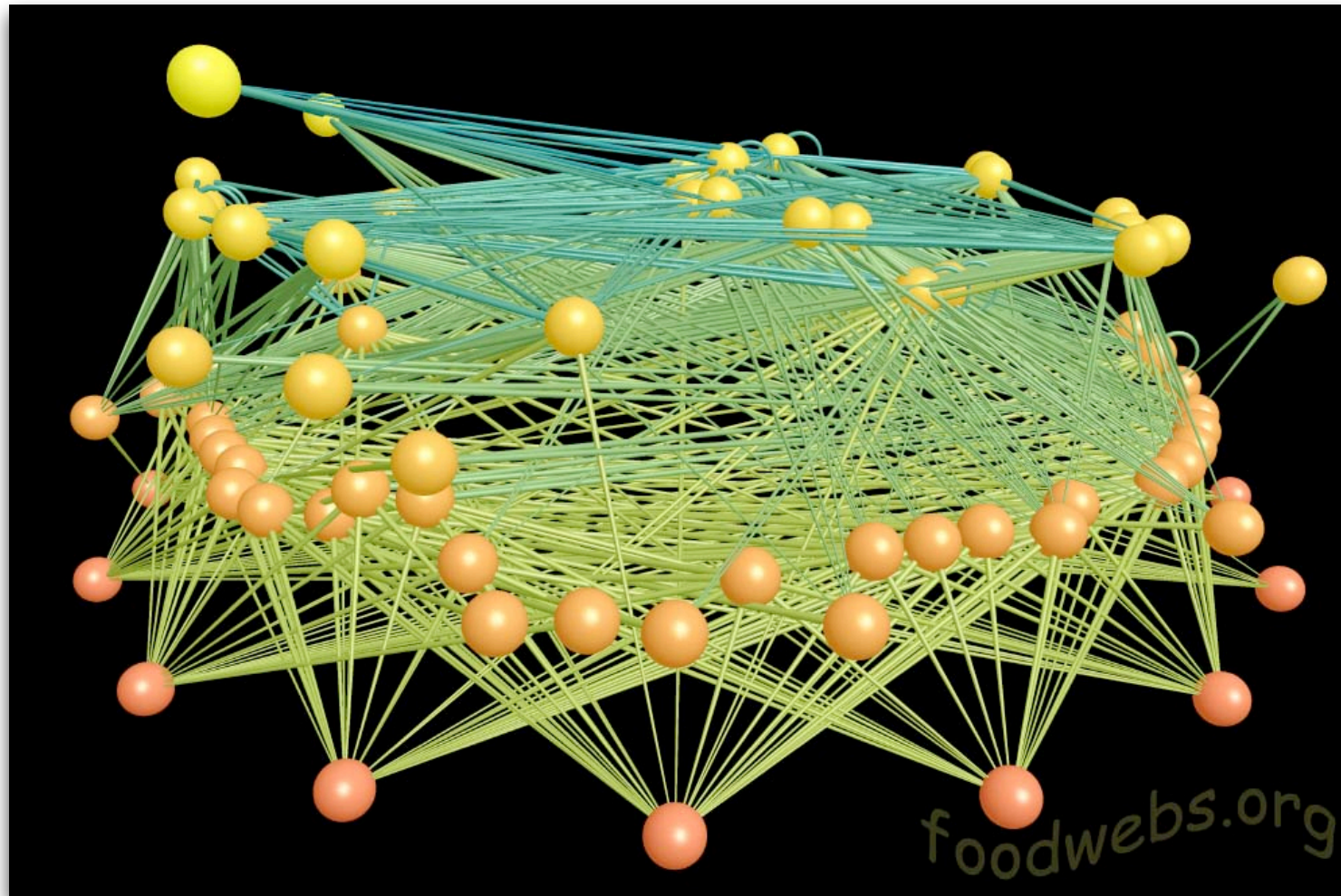
# Sparse networks: trade imbalances 2000



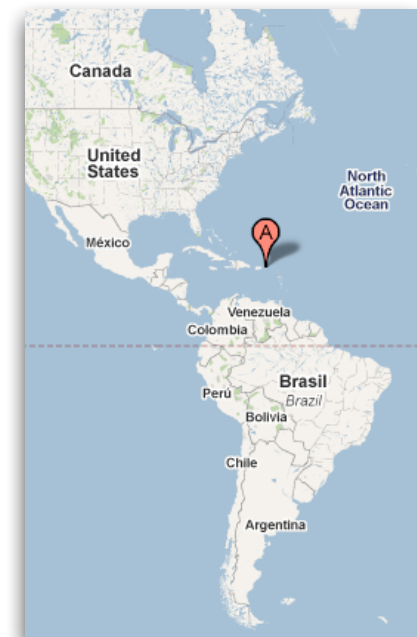
Serrano, M.A., Boguna, M., Vespignani, A., Patterns of dominant flows in the world trade web, Journal of Economic Interact



# Biological Economics: recall food-webs



*Virgin Islands  
Shelf Complex  
Food Web  
(Puerto Rico)*

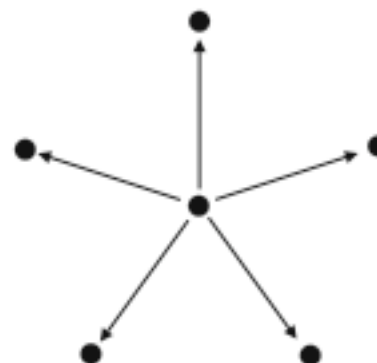


Dunne, J.A., R.J. Williams, N.D. Martinez. 2004. Network structure and robustness of marine food webs. Marine Ecological Press Series, vol. 273, pp. 291-30; Image produced with FoodWeb3D, written by R.J. Williams and provided by the Pacific Ecoinformatics and Computational Ecology Lab ([www.foodwebs.org](http://www.foodwebs.org), Yoon et al. 2004).



# Network research: in the lab (small n)

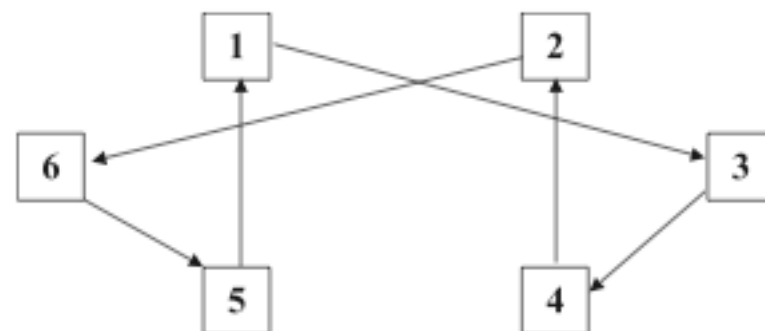
- Corbae and Duffy. Experiments with network formation. *Games and Economic Behavior* (2008) vol. 64 (1) pp. 81-120
- Charness et al. Bargaining and network structure: An experiment. *Journal of Economic Theory* (2007) vol. 136 (1) pp. 28-65
- Cassar. Coordination and cooperation in local, random and small world networks: Experimental evidence. *Games and Economic Behavior* (2007) vol. 58 (2) pp. 209-230
- Berninghaus et al. Evolution of networks - an experimental analysis. *Journal of Evolutionary Economics* (2007) vol. 17 (3) pp. 317-347
- Berninghaus et al. A network experiment in continuous time: The influence of link costs. *Experimental Economics* (2006) vol. 9 (3) pp. 237-251
- Callander and Plott. Principles of network development and evolution: an experimental study. *Journal of Public Economics* (2005) vol. 89 (8) pp. 1469-1495
- Corominas-Bosch. Bargaining in a network of buyers and sellers. *Journal of Economic Theory* (2004) vol. 115 (1) pp. 35-77



a) Center-sponsored star



b) Periphery-sponsored star



# Network research: computational, empirical



Organization, learning and cooperation<sup>☆</sup>

Jason Barr<sup>a,\*</sup>, Francesco Saraceno<sup>b,1</sup>

J Evol Econ (2009) 19:379–396  
DOI 10.1007/s00191-008-0117-5

REGULAR ARTICLE

**Reciprocity in evolving social networks**

Tackseung Jun · Rajiv Sethi



Pushing Networks to the Limit

PERSPECTIVE

**Scale-Free Networks: A Decade and Beyond**

Albert-László Barabási



nature

Vol 441|25 May 2006|doi:10.1038/nature04605

LETTERS

**A simple rule for the evolution of cooperation on graphs and social networks**

Hisashi Ohtsuki<sup>1,2</sup>, Christoph Hauert<sup>2</sup>, Erez Lieberman<sup>2,3</sup> & Martin A. Nowak<sup>2</sup>

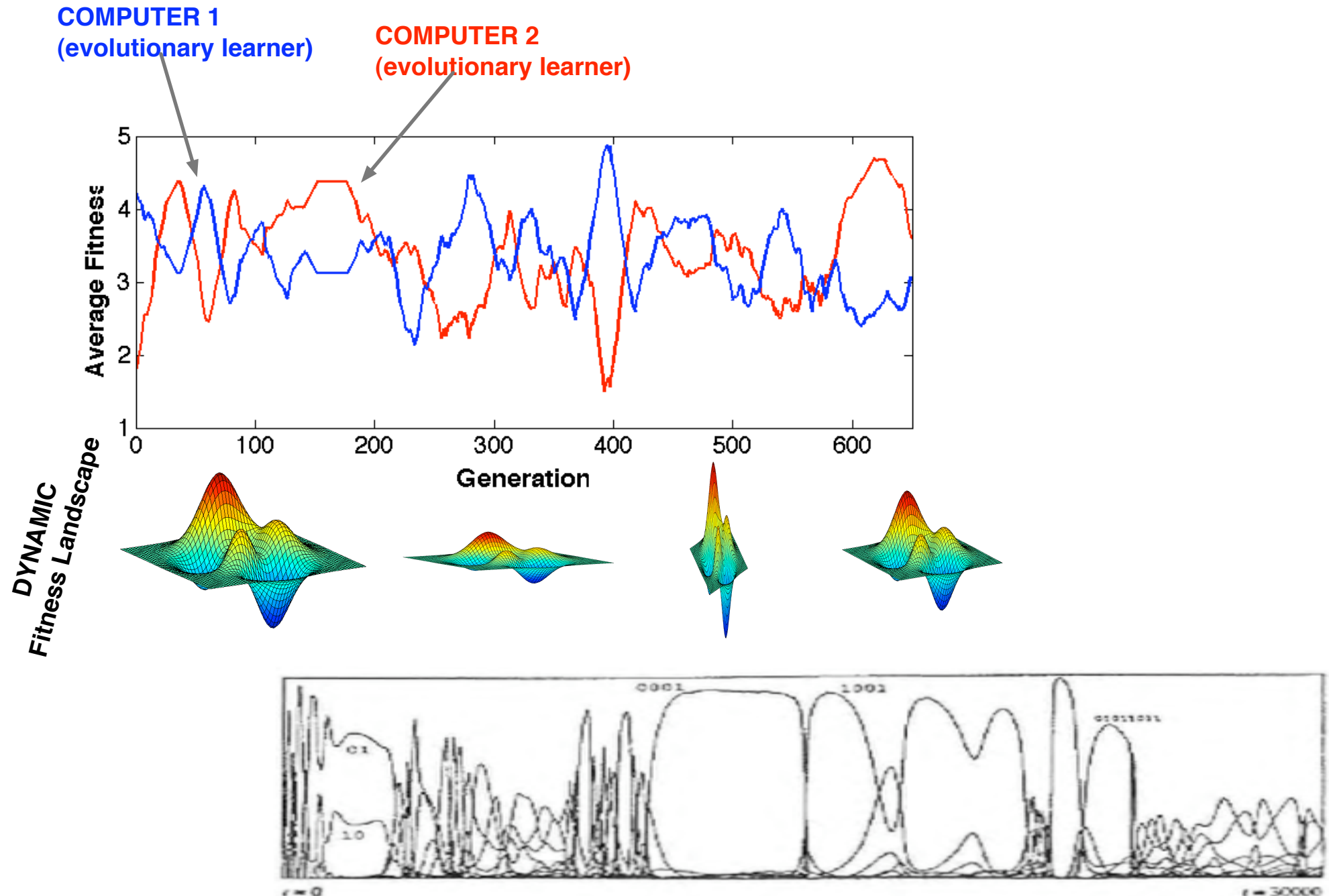
OPEN ACCESS Freely available online

PLoS one

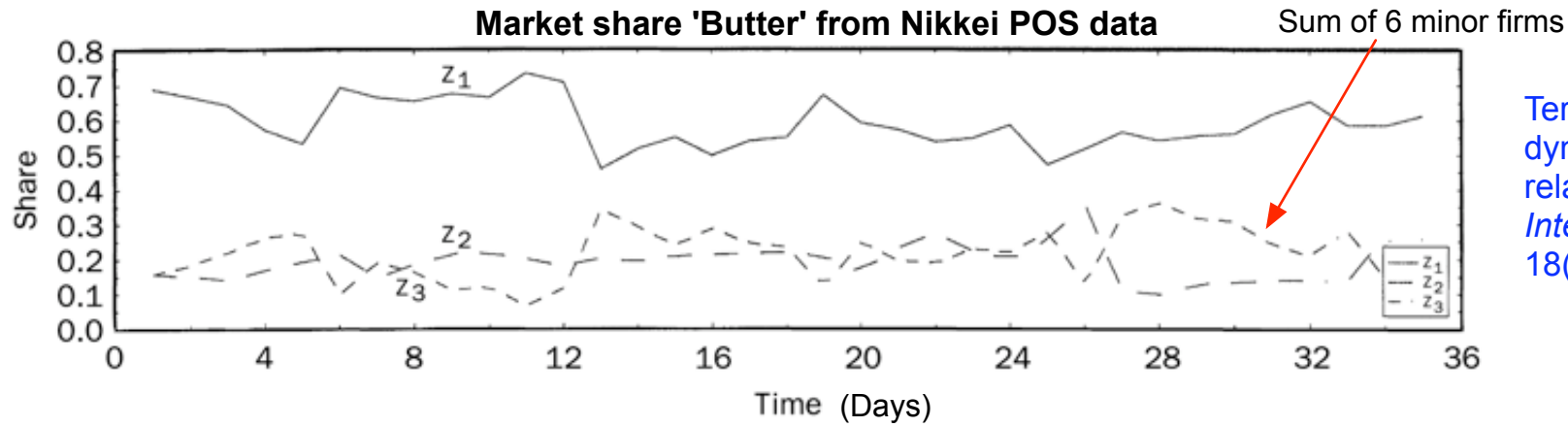
**Dynamics of Person-to-Person Interactions from Distributed RFID Sensor Networks**

Ciro Cattuto<sup>1\*</sup>, Wouter Van den Broeck<sup>1</sup>, Alain Barrat<sup>1,2</sup>, Vittoria Colizza<sup>1</sup>, Jean-François Pinton<sup>3</sup>, Alessandro Vespignani<sup>4,5,6</sup>

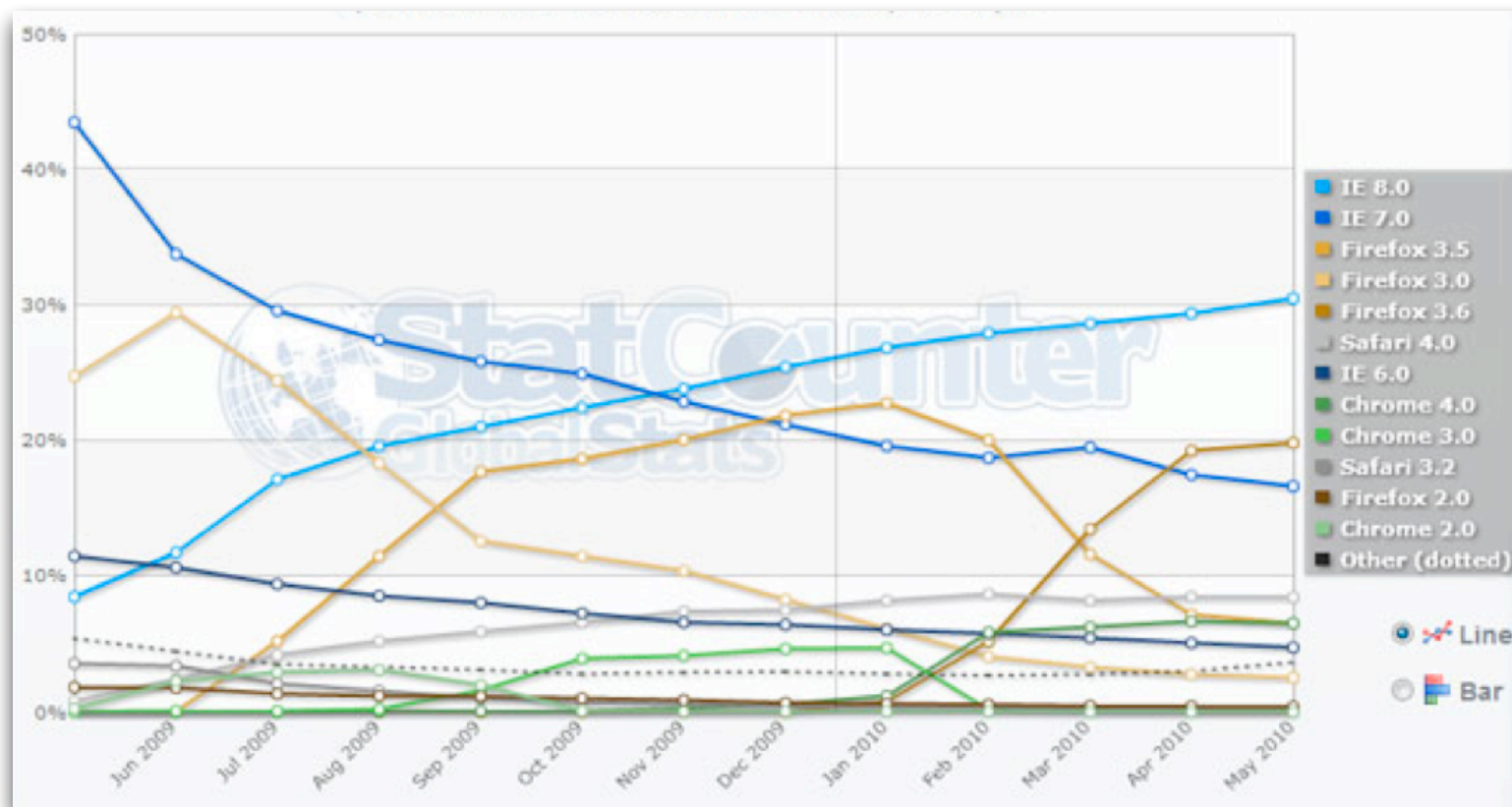
# Co-evolution and fitness landscapes



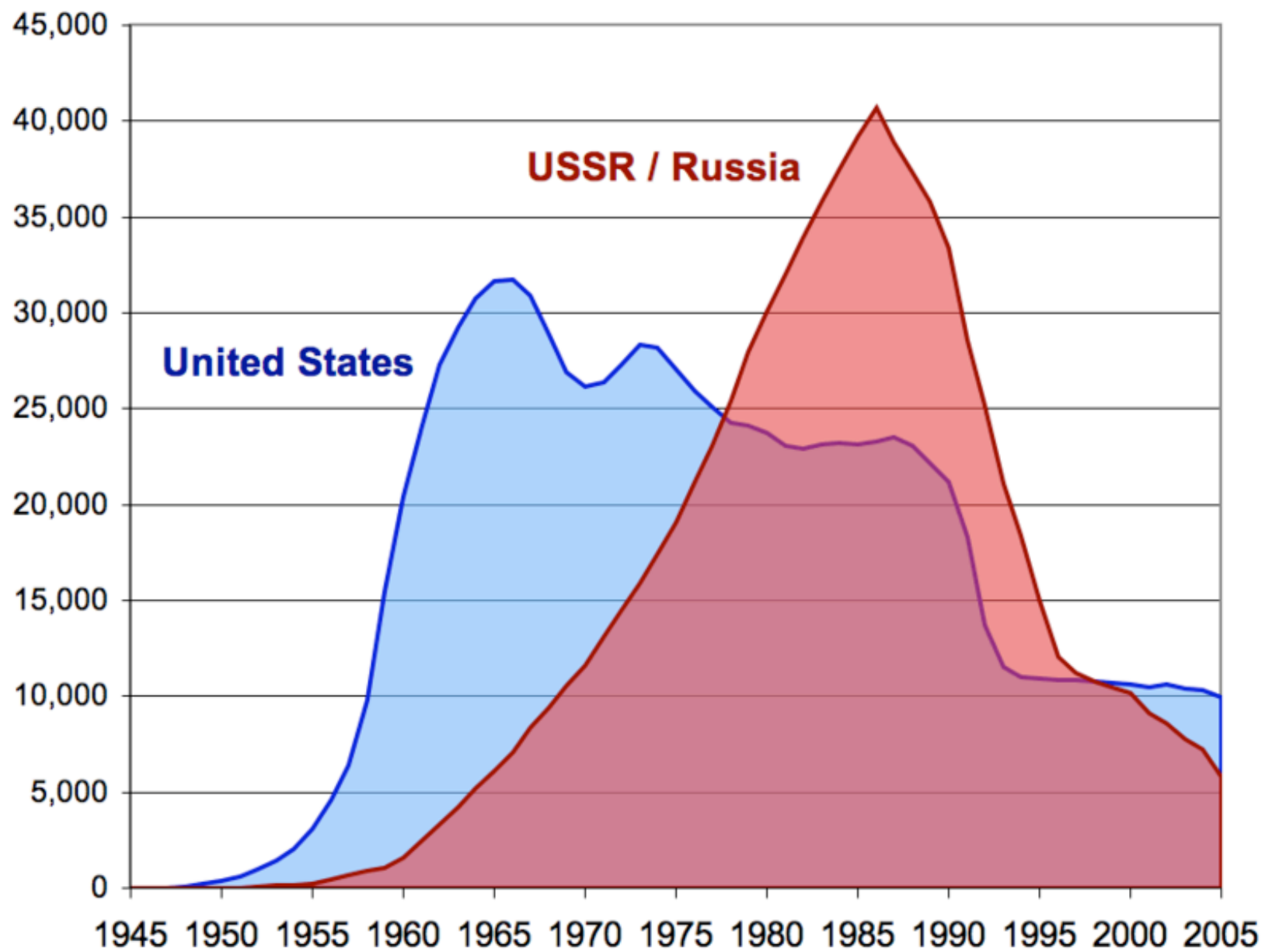
# Co-evolution examples: butter, browsers and ...



Terui, N., Forecasting dynamic market share relationships, *Marketing Intelligence & Planning*, 18(2), 2000:67-77

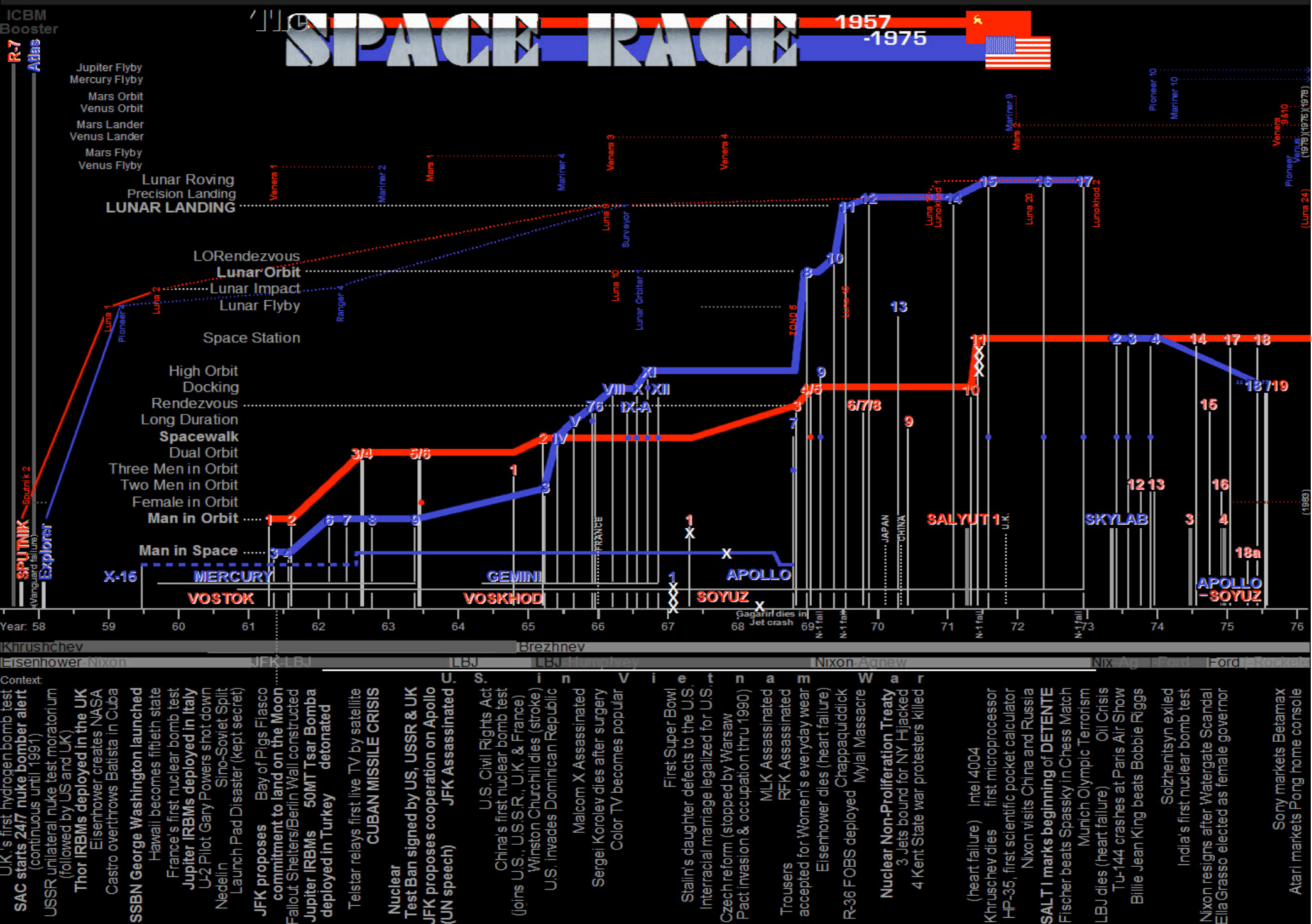


# ... bombs





# ... and space technology



# Dealing with complexity: our current methods

*In today's high-tech age, one naturally assumes that US President Barack Obama's economic team and its international counterparts are using sophisticated quantitative computer models to guide us out of the current economic crisis. They are not.*

*The best models they have are of two types, both with fatal flaws. Type one is econometric: empirical statistical models that are fitted to past data. These successfully forecast a few quarters ahead as long as things stay more or less the same, but fail in the face of great change. Type two goes by the name of 'dynamic stochastic general equilibrium'. These models assume a perfect world, and by their very nature rule out crises of the type we are experiencing now.*

**J. Doyne Farmer & Duncan Foley, Nature 460(7256), p. 685, 2009**

econometric  
forecasting tools fail  
with large structural  
change

CGE models cannot  
produce crisis events  
(they are  
'computable' ...  
therefore linear/  
solvable)

Vol 460 | 6 August 2009

nature

## OPINION

### The economy needs agent-based modelling

The leaders of the world are flying the economy by the seat of their pants, say **J. Doyne Farmer** and **Duncan Foley**. There is, however, a better way to help guide financial policies.

# So how to model 'economic biology'?

## A Checklist



1. Models 'agents' with **heterogeneity**
2. Agents '**do something**' and are the basis for all events/aggregates
3. Information and contact networks are **sparse** (not complete)
4. Agents **adapt/learn/change** over time, thus causing the environment to likewise change (via aggregates)
5. Open-ended, non-equilibrium (non-'solvable') dynamics.

## Implications

1. Will **not be analytically tractable** (most of the time)
2. Will be **heavily path-dependant** ... so: will need Monte Carlo style simulations (i.e. non-ergodic systems)
3. Will need **computational help** to deal with many interactions and structures
4. Will need to be **validated/calibrated** and **parsimonious** (to increase intelligibility)



# Two possible methods

## Dynamical systems

- *A system of non-linear equations and interactions*
- *Calculated numerically (no analytical solution likely)*
- *Work with 'population' or ('sub-population') level of aggregation*
- *'Mean-field' approximation to full-blown agent-simulation*

## Agent-Based Models (ABMs)

- *A system of many individual 'agents' (modules of computer code)*
- *Sparse interactions and information networks modeled explicitly*
- *Adaptive learning modeled explicitly*
- *Aggregate time-series obtainable from integrals over agents*
- *No central controller, no over-riding 'tendency', no 'philosopher' -- agents do, learn, change, adapt*

# Example

## Endogenous Business Cycles with an Evolutionary ABM

### Firm Innovations/Learning:

- intra-, or inter-firm learning by local-search
- form expectations over future demand

### Consumer preferences:

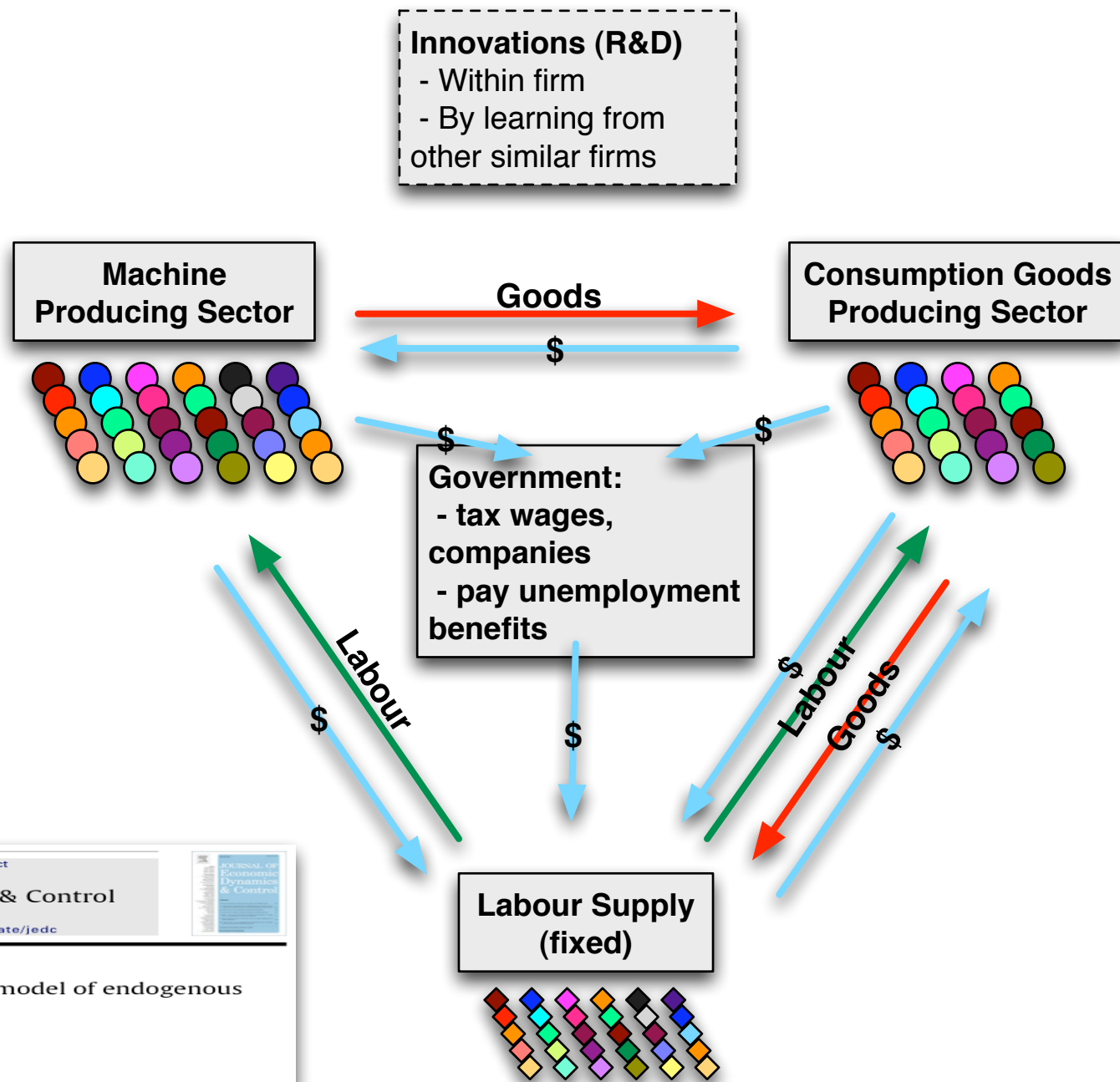
- adaptive via replicator dynamics based on quality and price of consumption goods produced, but imperfectly informed, so not immediate switching

### Credit market

- firms face imperfect credit market, constrained by own finance position

### Economic 'engines':

- 'Keynesian': fiscal policy (taxation level, unemployment benefits)
- 'Schumpeterian': Creative destruction via innovation



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journal homepage: [www.elsevier.com/locate/jedc](http://www.elsevier.com/locate/jedc)



Schumpeter meeting Keynes: A policy-friendly model of endogenous growth and business cycles

Giovanni Dosi<sup>a,b,\*</sup>, Giorgio Fagiolo<sup>a</sup>, Andrea Roventini<sup>c,a</sup>

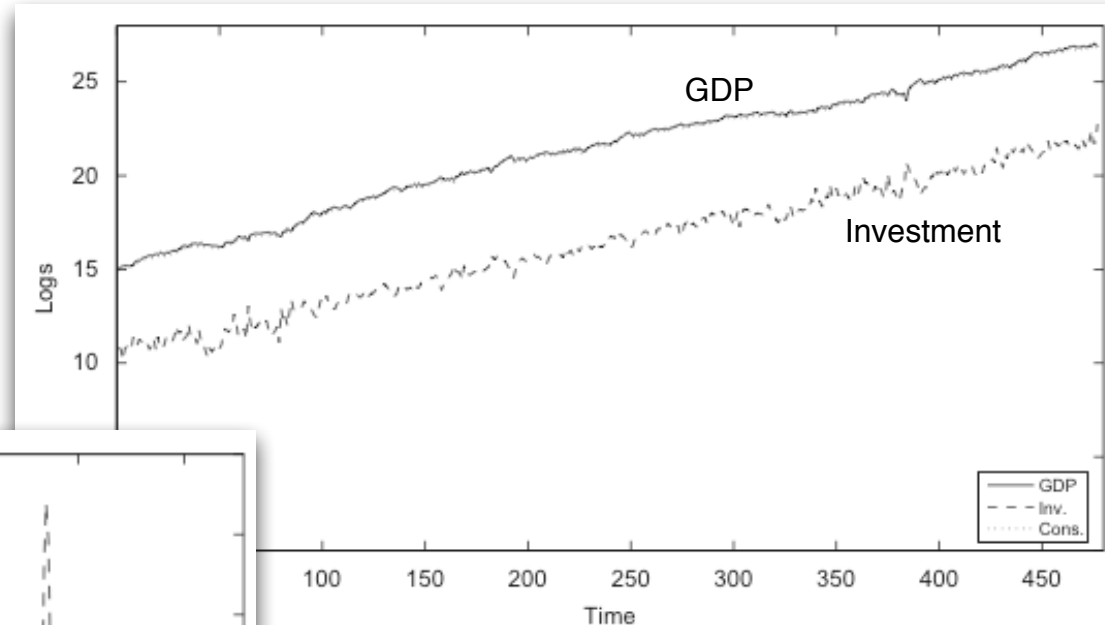
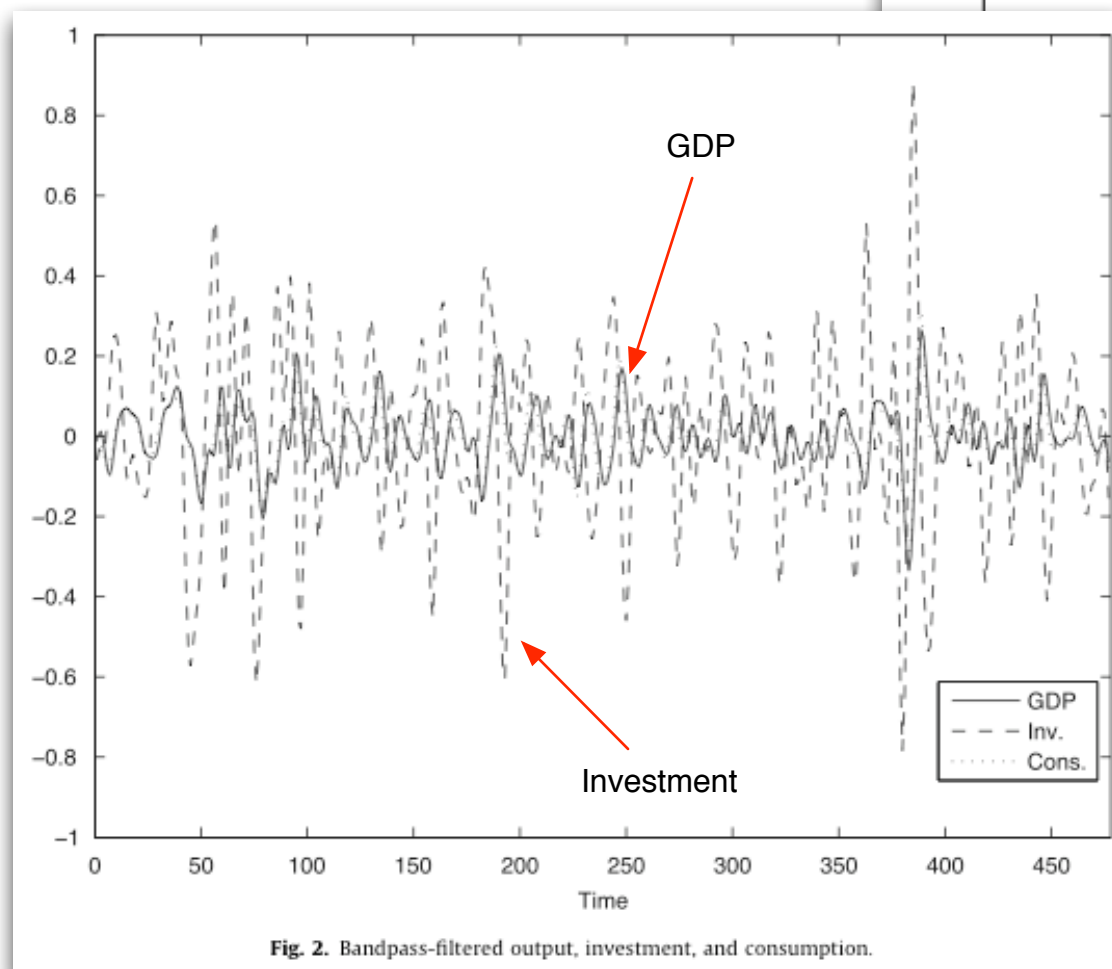
<sup>a</sup> Laboratory of Economics and Management, Sant'Anna School of Advanced Studies, Pisa, Italy

<sup>b</sup> MIOIR, University of Manchester, UK

<sup>c</sup> Department of Economics, University of Verona, Italy

# Sustained growth and endogenous business cycles

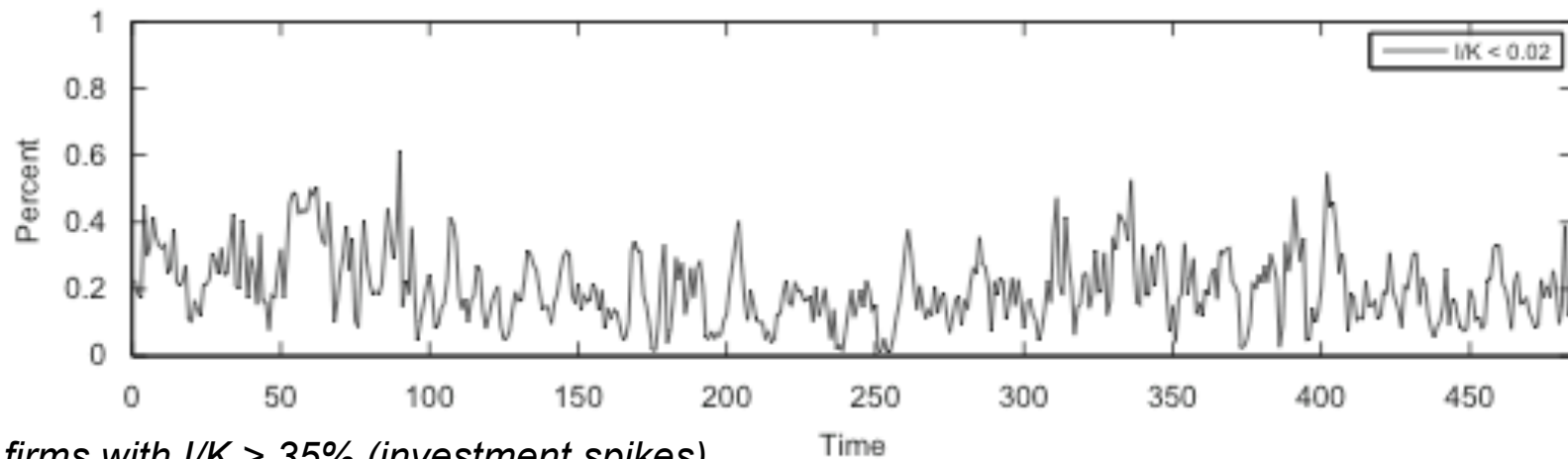
*De-trended output: clear business cycles*



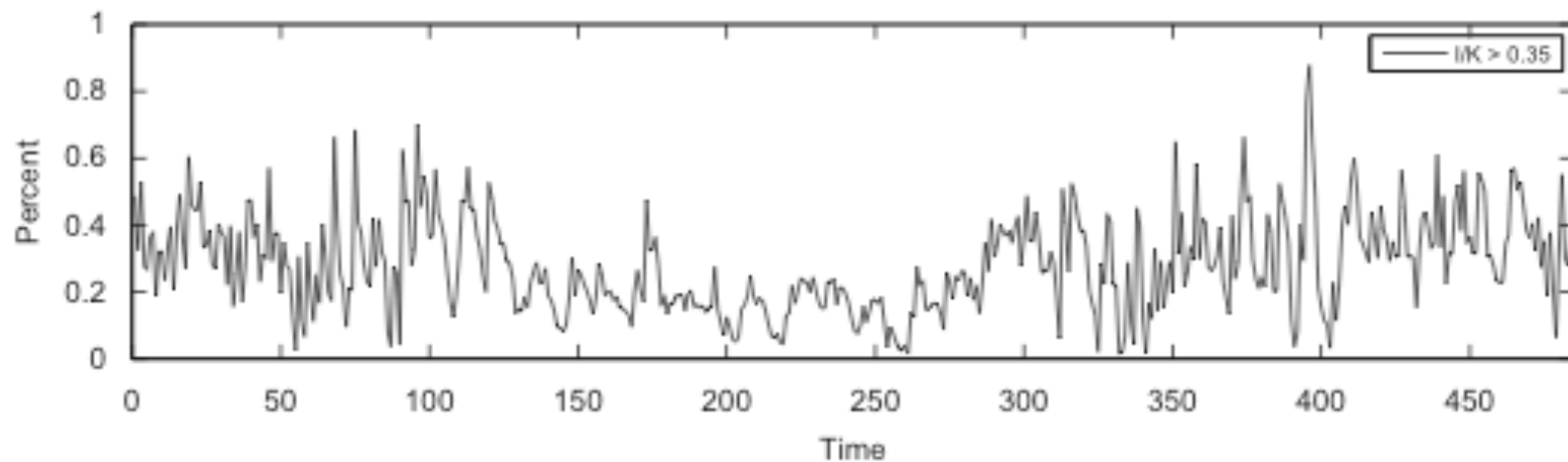
**C, I procyclical and more volatile than GDP**

# Investment 'lumpiness'

*Fraction of firms with  $I/K < 2\%$  (zero investment)*



*Fraction of firms with  $I/K > 35\%$  (investment spikes)*



**Fig. 6.** Investment lumpiness. First panel: share of firms with (near) zero investment; second panel: share of firms with investment spikes.

# Validation & Findings

## Approach

- *Run 100 Monte Carlo experiments of a 'baseline' economy*
- *Compare model outputs to 13 stylized facts (inc. 'Micro' and 'Macro' facts)*
- *Check for robustness by changing to low/high key policy parameters*

## Interesting findings

- *Authors express 'deep doubts' about traditional division between 'long-run' and 'short-run' variables*
  - *Technology innovations impact on many time-scales*
  - *Schumpeterian only economy (no fiscal policy) leads to high average unemployment, low growth*
  - *Keynesian policies reduce output volatility and unemployment rates (and long-run growth by preventing stagnant resting state)*
- ... many extensions*

# What hurdles prevent Economic Biology?

## I can think of a few ...

1. *Linear vs. non-linear thinking*
2. *Undergraduate teaching is not systems teaching, but 'micro' and 'macro'*
3. *Available materials (text books, software)?*
4. *Publication traps*
5. *Field lock-in*

# Hurdle 1: it's a linear (mental) world ...

*... but almost all of our analytical education is solvable cases of linear systems*

*Most 'systems' problems are nonlinear in nature*

<i>Type of Equations</i>	<i>Linear</i>			<i>Nonlinear</i>		
<i>Equations</i>	<i>One equation</i>	<i>Several equations</i>	<i>Many equations</i>	<i>One equation</i>	<i>Several equations</i>	<i>Many equations</i>
<i>Algebraic</i>	Trivial	Easy	Possible	Very difficult	Very difficult	Impossible
<i>Ordinary Differential</i>	Easy	Difficult	Essentially impossible	Very difficult	Impossible	Impossible
<i>Partial Differential</i>	Difficult	Essentially impossible	Impossible	Impossible	Impossible	Impossible

*... but computational, numerical solutions exist in these cases*

# Hurdle 2: you teach what you were taught

*... Like other men, the economist is an individual with but one intelligence. He is a creature of habits and propensities given through the antecedents, hereditary and cultural, of which he is an outcome; and the habits of thought formed in any one line of experience affect his thinking in any other.*

**Thorstein Veblen, *QJE*, 1898, pp. 395**

ECC1000 Principles of microeconomics  
ECC1100 Principles of macroeconomics  
ECC2000 Intermediate microeconomics  
ECC2010 Intermediate macroeconomics  
ECC2300 Current issues in macroeconomic policy  
ECC2360 Environmental economics  
ECC2400 Current issues in applied microeconomics  
ECC2410 Introductory econometrics  
ECC2440 Mathematics for economics and business  
ECC2450 Sports economics  
ECC2600 Behaviour, rationality and organisation ●  
ECC2700 Economic issues in health and health care  
ECC2800 Prosperity, poverty and sustainability ●

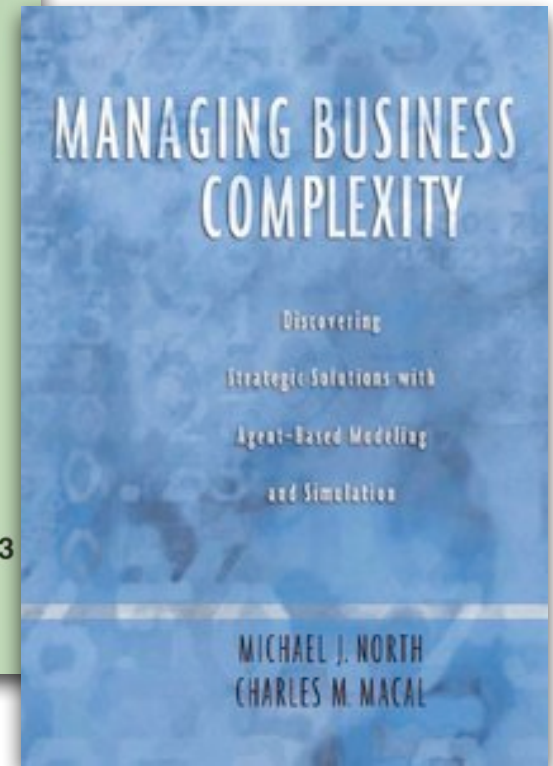
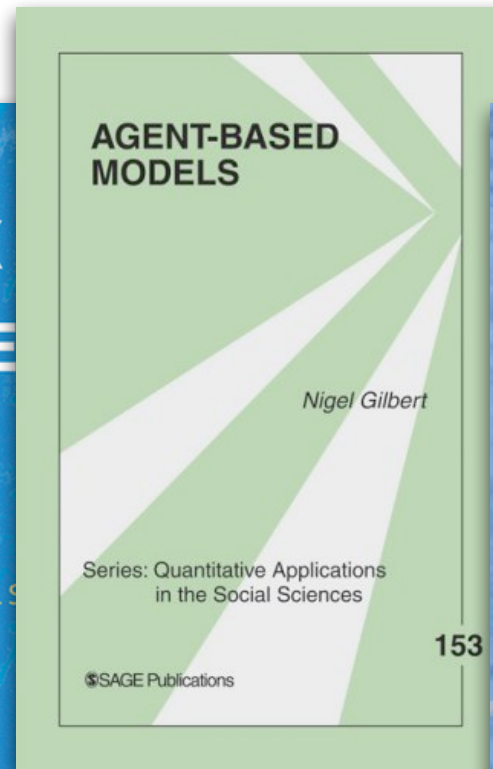
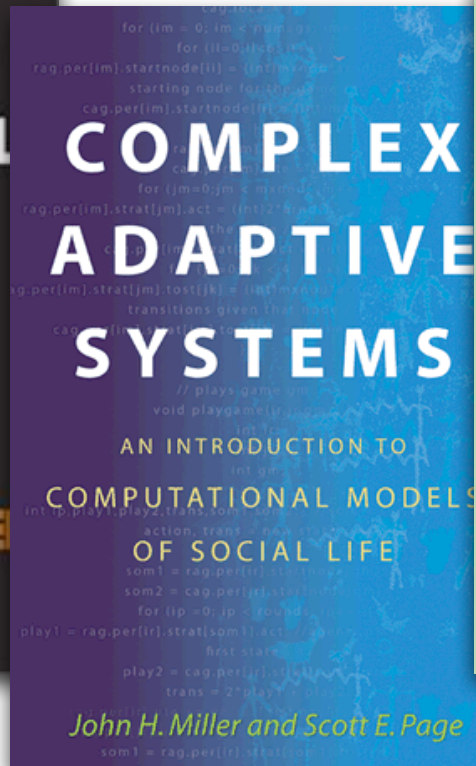
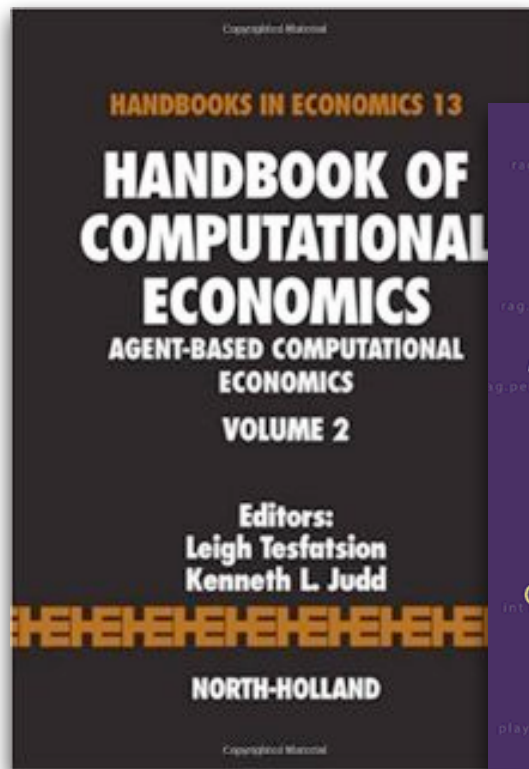
ECC3410 Applied econometrics  
ECC3640 Economics of climate change  
ECC2890 Economic development of East Asia  
ECC3650 Applied general equilibrium economics  
ECC3660 Monetary economics  
ECC3670 Economics of developing countries  
ECC3690 International economics  
ECC3710 Labour economics  
ECC3800 History of economic thought  
ECC3810 Public finance  
ECC3830 Competition and regulation  
ECC3840 Mathematical economics ●  
ECC3860 Integrated economic modelling ●



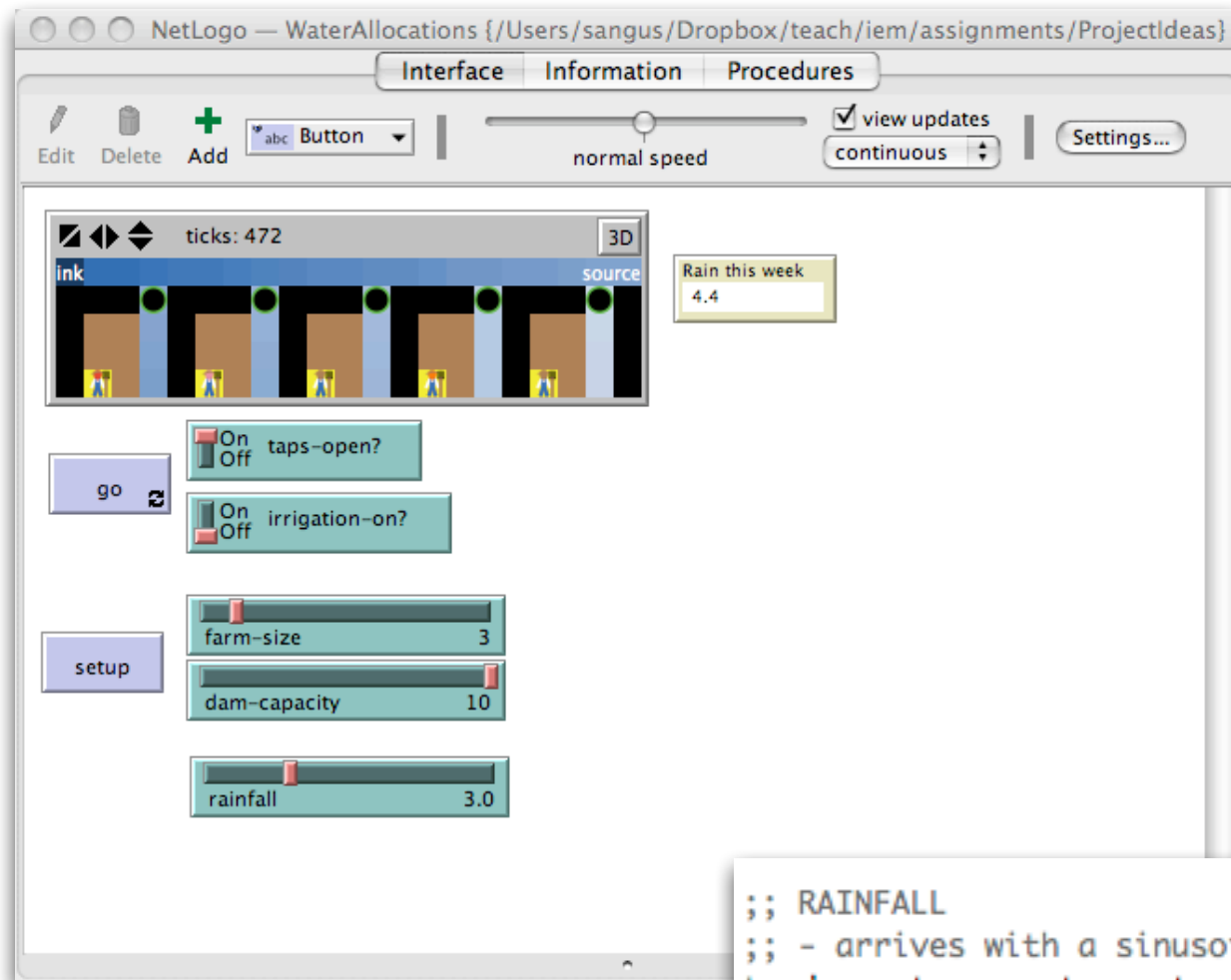
# Our teaching: what could be done?

<b><i>First year</i></b>	<b><i>ECC100 Intro to non-linear dynamics ETC101 Intro to Computational Economics (NetLogo)</i></b>
<b><i>Second year</i></b>	<b><i>ECC200 Intermediate Dynamics (chaos, evolutionary operators) ECC201 Economic Learning &amp; Behaviour</i></b>
<b><i>Third Year</i></b>	<b><i>ECC300 Applied Economic Biology (IEM) ECC301 Validation &amp; Calibration Methods</i></b>

# Hurdle 3: no materials? ... Not true.



# NetLogo: ready to use



```
;; RAINFALL
;; - arrives with a sinusoidal distribution based on the week of t
to do-upstream-water-entry
  ask patches with [plabel = "source"] [
    set week-rainfall (rainfall * (1 + sin (ticks / 52 * 360)))
    set water-level water-level + week-rainfall
  ]
end
```

## Hurdles 4: getting published

*The well-worn paths are easy to follow and lead into good company. Advance along them visibly furthers the accredited work which the science has in hand. Divergence from the paths means tentative work, which is necessarily slow and fragmentary and of uncertain value.*

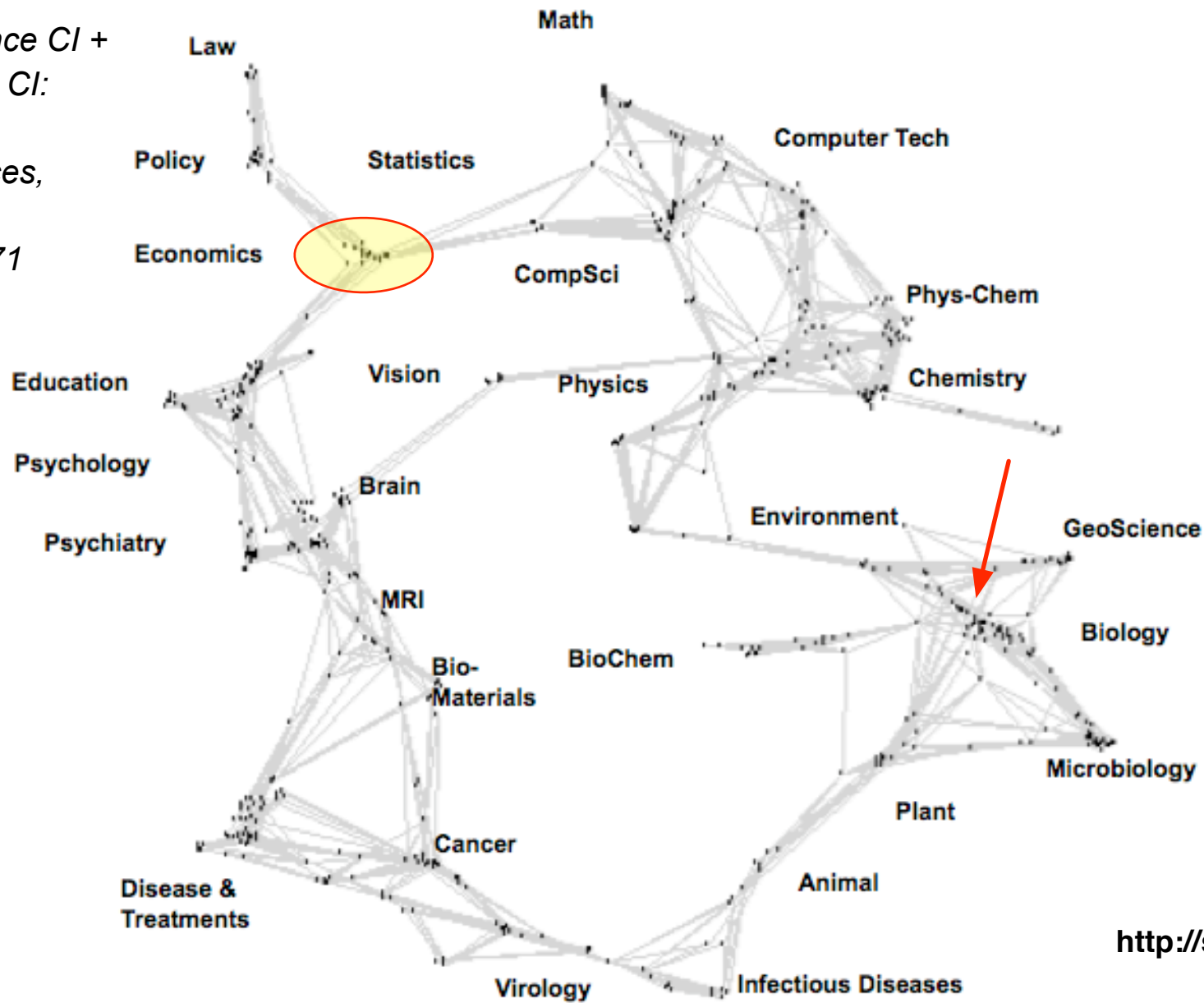
**Thorstein Veblen, *QJE*, 1898, pp. 395**

*However, despite the upsurge in ABM research witnessed in the past 15 years, the methodology is still left aside in a standard economist's toolbox. **Among the top 20 economic journals we were able to find only eight articles based on ABM.** This number is to be compared with the 26,698 articles that were published since the seminal work of Arthur (1988) in the top 20 journals considered. **Agent-based modeling thus counts for less than 0.03% of top economic research.** It seems to be confined only in specialized journals like the *Journal of Economic Dynamics and Control*, ranking 23rd, the *Journal of Artificial Societies and Social Simulation*, and *Computational Economics*, which are not even ranked. A notable exception is the *Journal of Economic Behavior and Organization*, ranked 32, which sometimes publishes research in ABM.*

**Roberto Leombruni, Matteo Richiardi, *Physica A*, 2005, v355, p.104**

# Hurdles 5: there's a hole in the middle (of science)

Combine Science CI +  
Social-Science CI:  
1.07M papers,  
24.5M references,  
7,300 journals,  
Clustering -- 671  
clusters



<http://scimaps.org/>

Kevin W. Boyack, Katy Börner, & Richard Klavans (2007). Mapping the Structure and Evolution of Chemistry Research. 11th International Conference on Scientometrics and Informetrics. pp. 112-123.



# The last word ...

*The later method [the evolutionary approach] of apprehending and assimilating facts and handling them for the purposes of knowledge may be better or worse, more or less worthy or adequate, than the earlier; it may be of greater or less ceremonial or aesthetic effect; we may be moved to regret the incursion of underbred habits of thought into the scholar's domain. But all that is beside the present point.*

*Under the stress of modern technological exigencies, men's everyday habits of thought are falling into the lines that in the sciences constitute the evolutionary method; and knowledge which proceeds on a higher, more archaic plane is becoming alien and meaningless to them. The social and political sciences must follow the drift, for they are already caught in it.*

*Thorstein Veblen  
University of Chicago  
1898*