A perspective on physics, emergence and economics

A growth area for non-equilibrium science

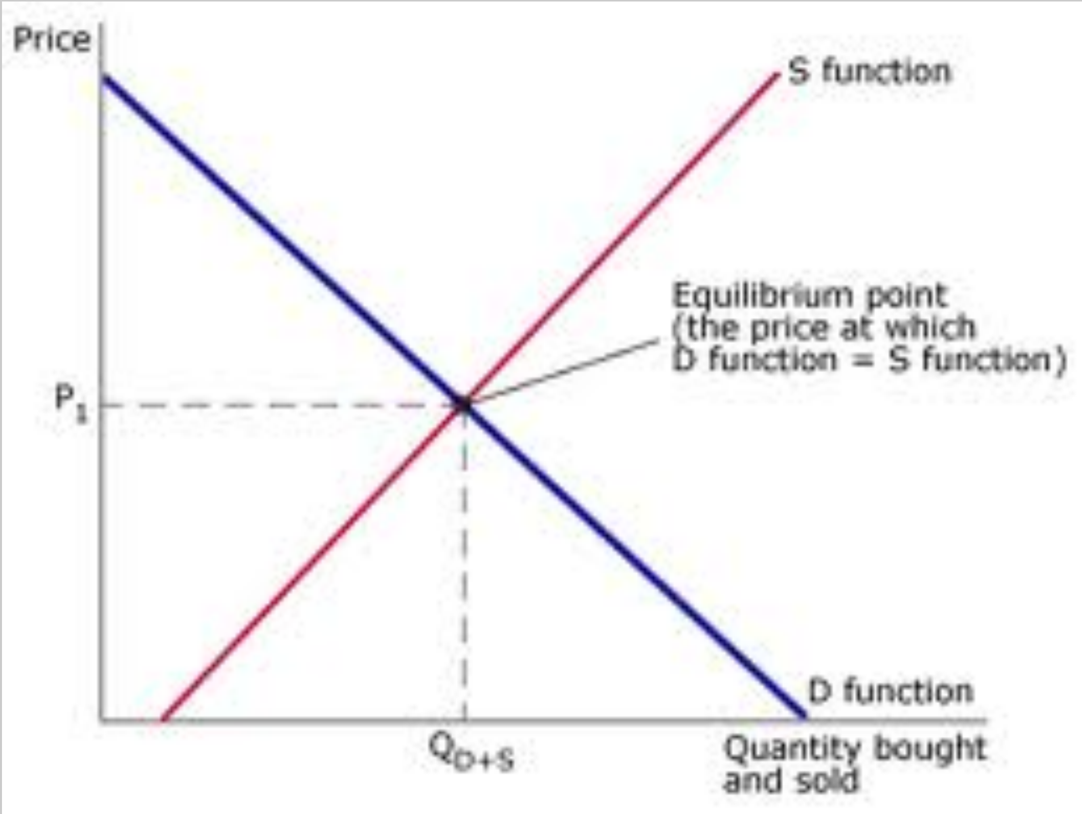
“Economics is a discipline for quiet times. The profession... has no grip on how the abnormal grows out of the normal... like weather forecasters who don't understand storms.”

Will Hutton
The Observer

Meteorologists, of course, see storms as the result of ordinary physics, not “shocks” to the atmosphere

Economic and financial history is as tumultuous, unpredictable and unruly as the weather, but...

Economics instead sees reality as reflecting an simple self-correcting “equilibrium”



The economic balance is occasionally disturbed by outside “shocks,” which cause crises and other dramatic events.

Does economics suffer from physics envy?

Andrew Lo

Albert Einstein (1915):

$$R_{\mu\nu} - \frac{1}{2} R\, g_{\mu\nu} + \Lambda\, g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

Robert Lucas (1972):

$$U'\left(\sum_j Y_j\right) p_i(y) = \beta \int U'\left(\sum_j Y'_j\right)\left(y'_i + p_i(y')\right) dF(y', y),$$

Or maybe:
Economists have envied the
wrong kind of physics?

They've preferred analyses of equilibrium balance,
and downplayed **instability** and disequilib**rium**

The Last 20 Years

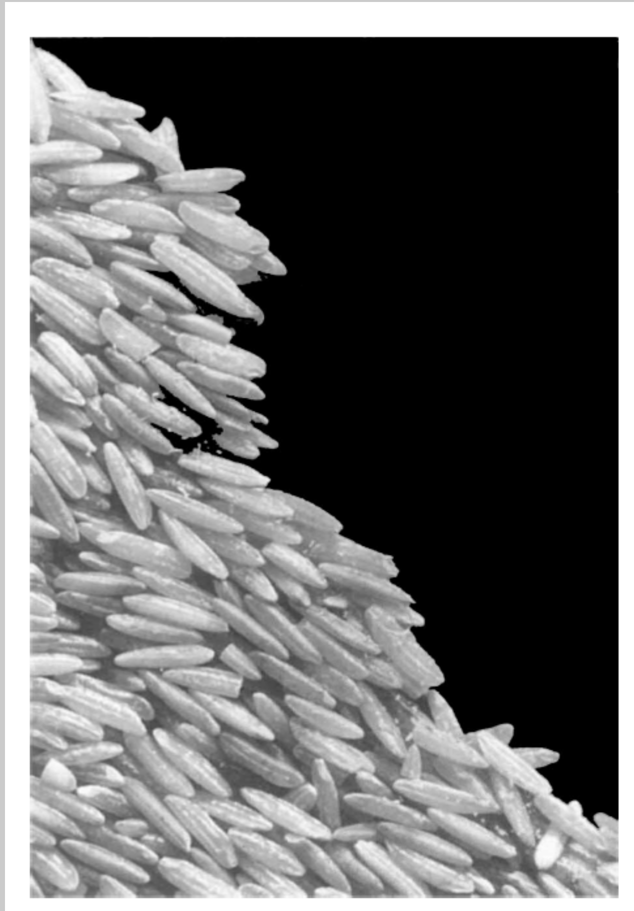
Some history... why would physicists study sand piles? … or even worse, rice piles?

Avalanche dynamics in a pile of rice

Vidar Frette*, Kim Christensen, Anders Malthe-Sørenssen, Jens Feder, Torstein Jøssang & Paul Meakin

Department of Physics, University of Oslo, PO Box 1048, Blindern, N-0316 Oslo, Norway

Nature 379, 49 (1996)



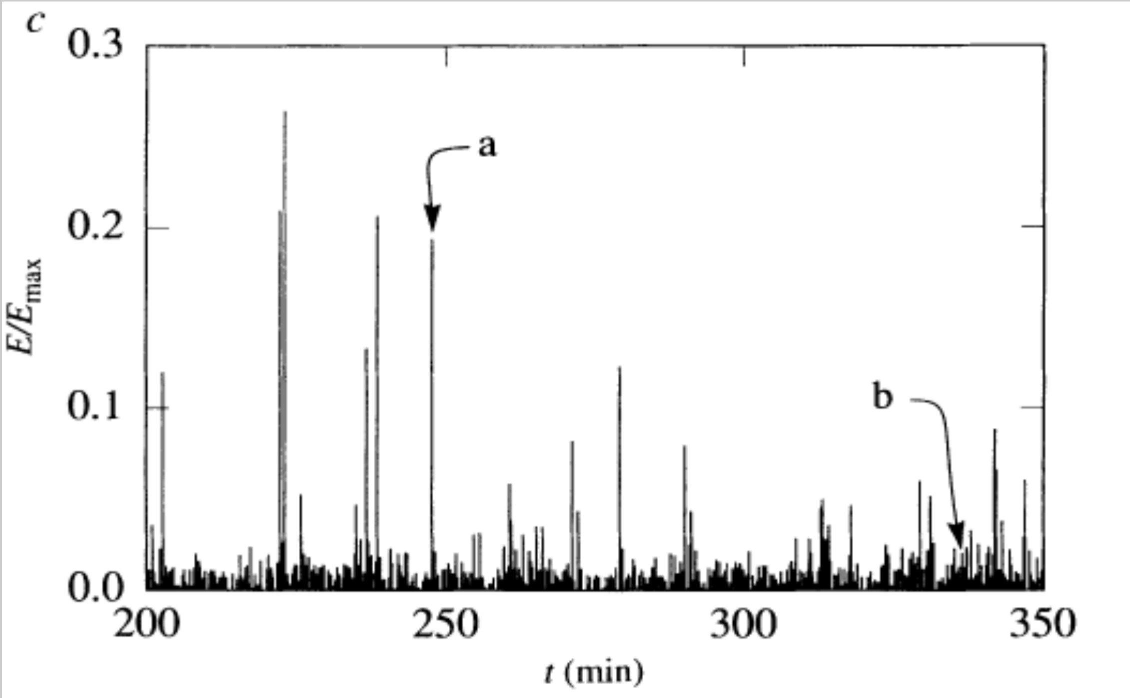
Drop grains one-by-one onto a pile

What happens?

Surprise – the response to one additional grain has no typical scale, but is scale invariant!!

There is no 'typical'

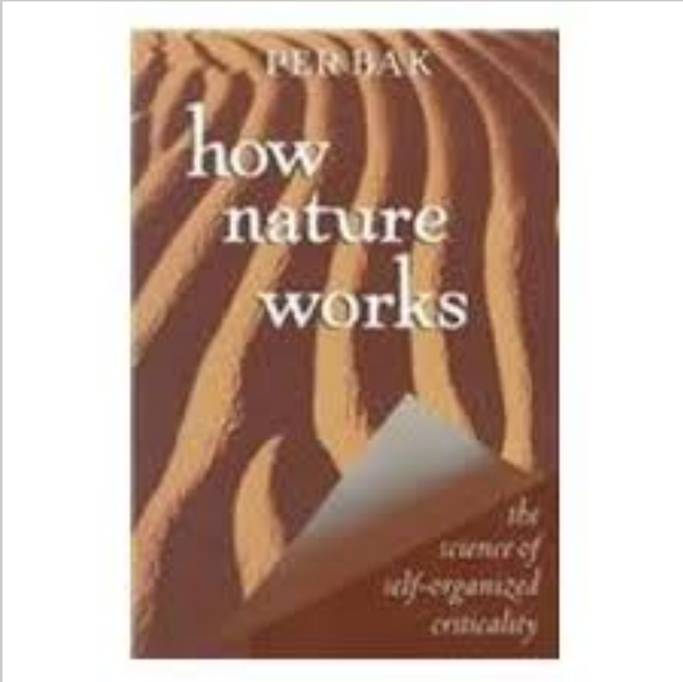
Energy released



The response is wildly unpredictable; there's no clear link between the scale of cause and effect.

A philosophical experiment: big events don't need big causes

A bold idea – perhaps lots of things in the world work this way...



Per Bak
(1996)

The emerging insight:
physics is not about physical stuff, but about organization and change quite generally

WHY (more generally)?

Because physics shows hints of "universality" from many directions:

- critical phenomena
- dynamical systems theory
- pattern formation out of equilibrium
- mechanisms behind fractal scaling laws (stochastic growth, etc.)

Possibilities and promise:

- that similar patterns and categories of phenomena may hold across very different fields.

Significant progress over two decades:
some randomly chosen examples

Beautiful, fairly complete explanations
of many unusual natural phenomena (including
landscapes, rough surfaces, etc).

Significant progress over two decades:
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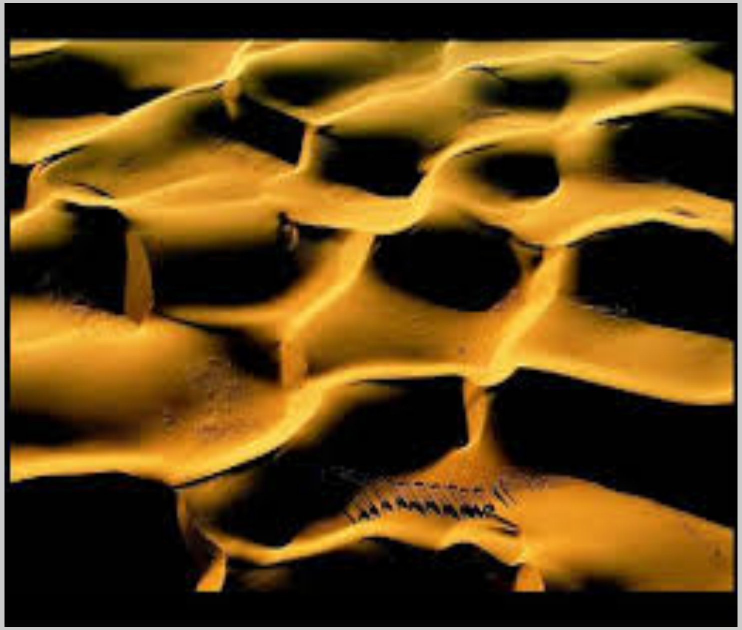
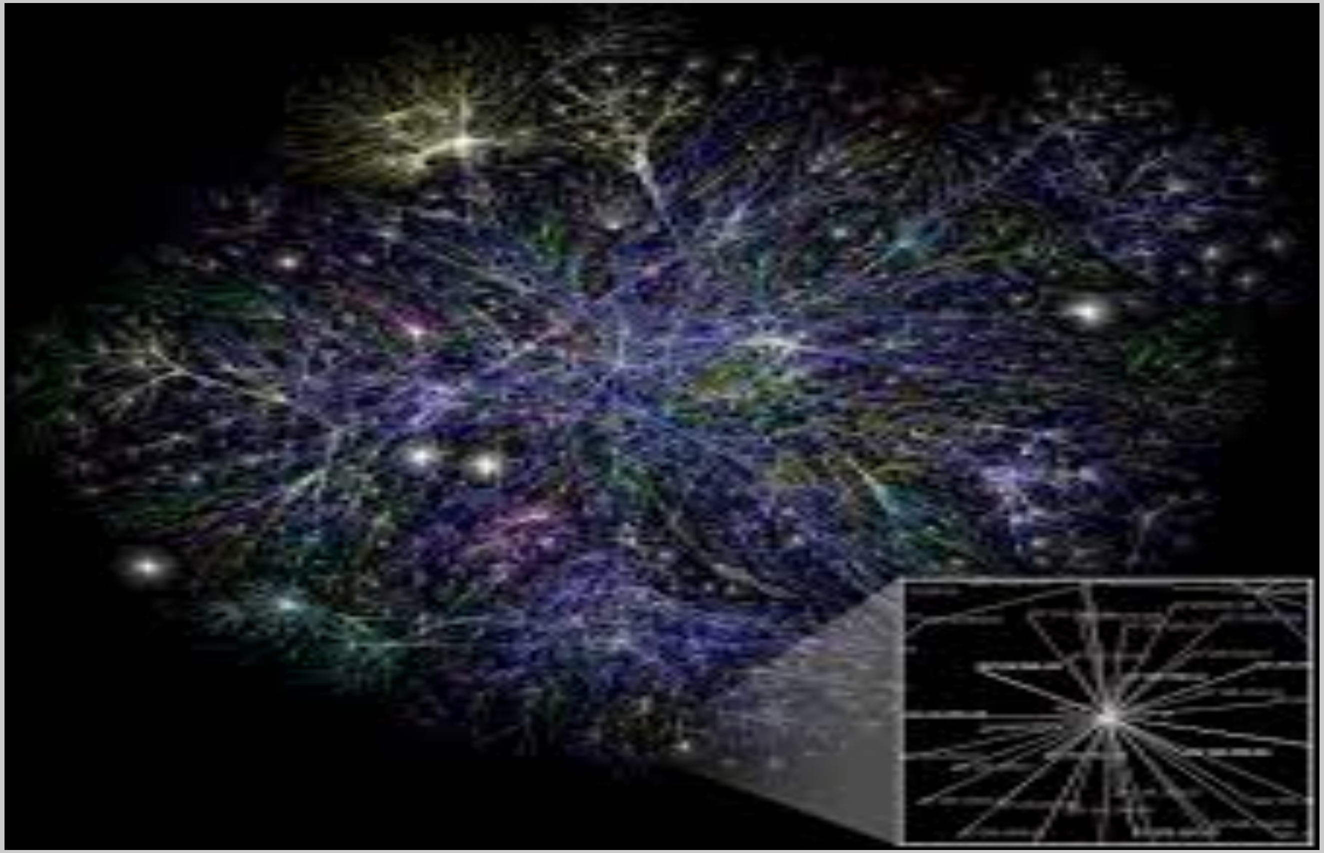


Beautiful, fairly complete explanations
of many unusual natural phenomena (including
landscapes, rough surfaces, etc).

Significant progress over two decades: some randomly chosen examples

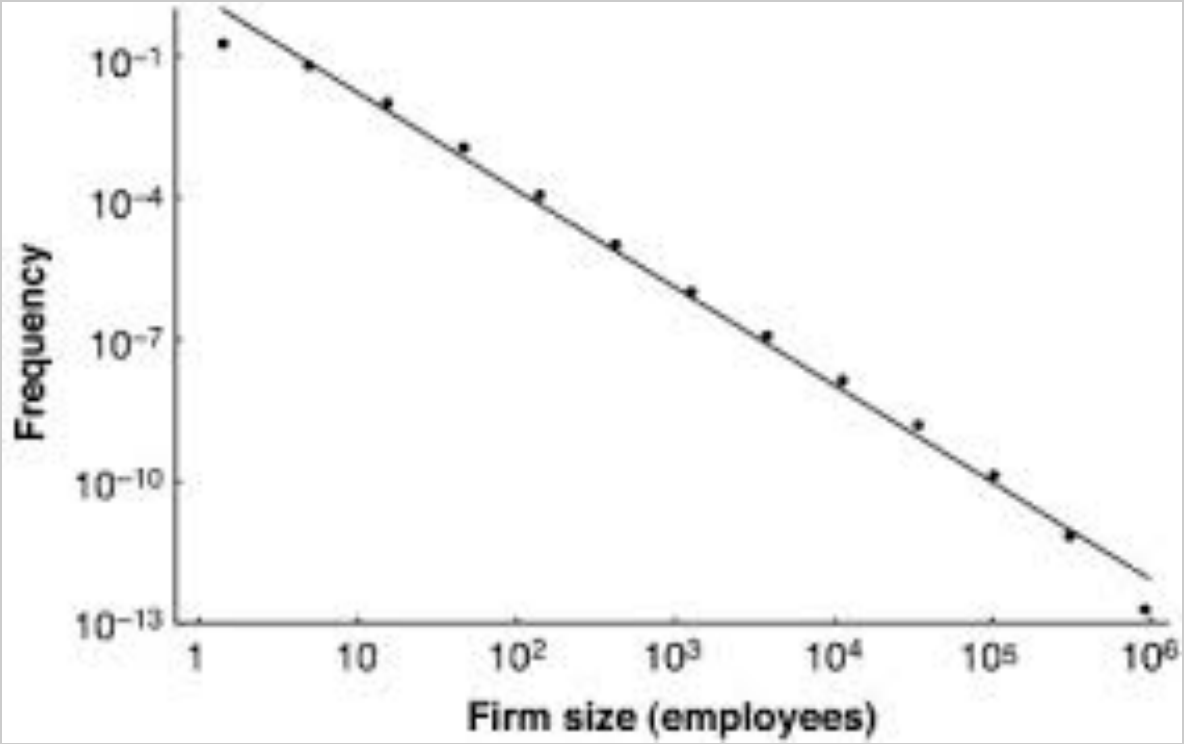
SOC-type theories plausibly “explain” why earthquakes are very difficult to predict

Significant progress over two decades: some randomly chosen examples



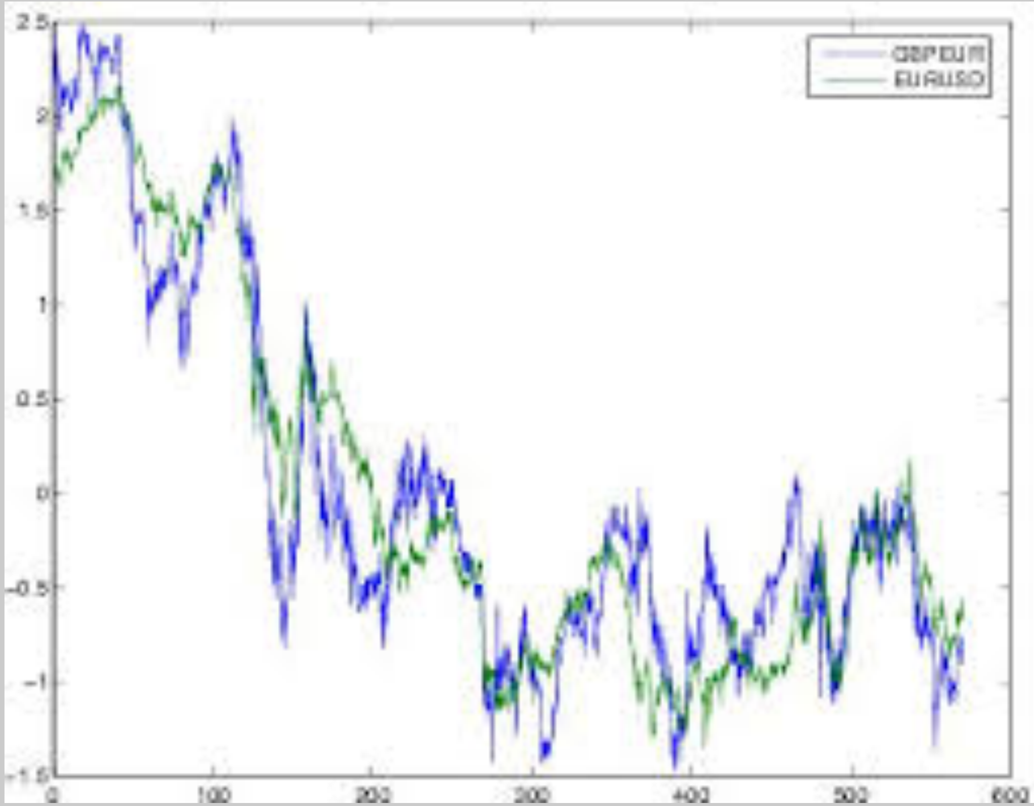
Multiplicative stochastic growth models account well for basic features of the structure of the Internet

Significant progress over two decades: some randomly chosen examples



Simple growth models account for empirical scaling of business firms by size (Rob Axtell)

Significant progress over two decades:
some randomly chosen examples



Empirical characterization of scaling
laws in financial time series

History since mid-1990s: Physics-inspired models of markets as "ecologies" of interacting strategies

"You physicists have a Tarzan mentality!"

If "econophysics" hasn't resolved policy puzzles, what good is it?

thesis

What has econophysics ever done for us?

The modern trend for physicists to work on problems in finance and economics began in the early 1990s and has gained momentum ever since. In the past few years, however, this field of 'econophysics' has come in for some strong criticism. Physicists, critics say, have mostly just re-discovered things that others already knew, and failed to build any valuable theory with explanatory power.

Is it true? Has econophysics really

Has econophysics really degenerated into irrelevance? It doesn't seem that way to me.

surprising qualitative features of markets; for

in economics holds that the sharing of risks between financial institutions — through derivatives and other instruments — should both make individual firms safer and the entire banking system more stable. However, a collaboration of economists and physicists has showed that too much risk sharing in a network of institutions can decrease stability. An overconnected network makes it too easy for trouble to spread.

Nature Physics, June 2013

Answer: has helped to clarify very basic issues.
Helping economics establish *different* foundations

Success stories:

- Pinned down universal properties of financial time series. Large price movements follows inverse cubic power law. Volatility clustering in all markets; large movements cluster like earthquakes.
- Developed dynamically “realistic” models of markets as ecologies of interacting, learning agents. No equilibrium. Life-like dynamics emerge naturally.
- Identified interesting phase transitions in market dynamics as a result of crowding of strategies (minority game, etc.).

What's going on? A metaphor

Economics of
the future

??

Traditional economics
is stuck

Physicists are
working over
here

Some VERY RECENT advances

Probing market instabilities

Everyone knows... leverage amplifies interactions

"The whole building is about to collapse... Only potential survivor, the Fabulous Fab… standing in the middle of all these complex, highly leveraged, exotic trades he created without necessarily understanding all of the implications of those monstruosities [sic]!!!"

Leverage Causes Fat Tails and Clustered Volatility

By Stefan Thurner, J. Doyne Farmer and John Geanakoplos*

- An “experiment” in financial instability; explores what we ought to expect as normal

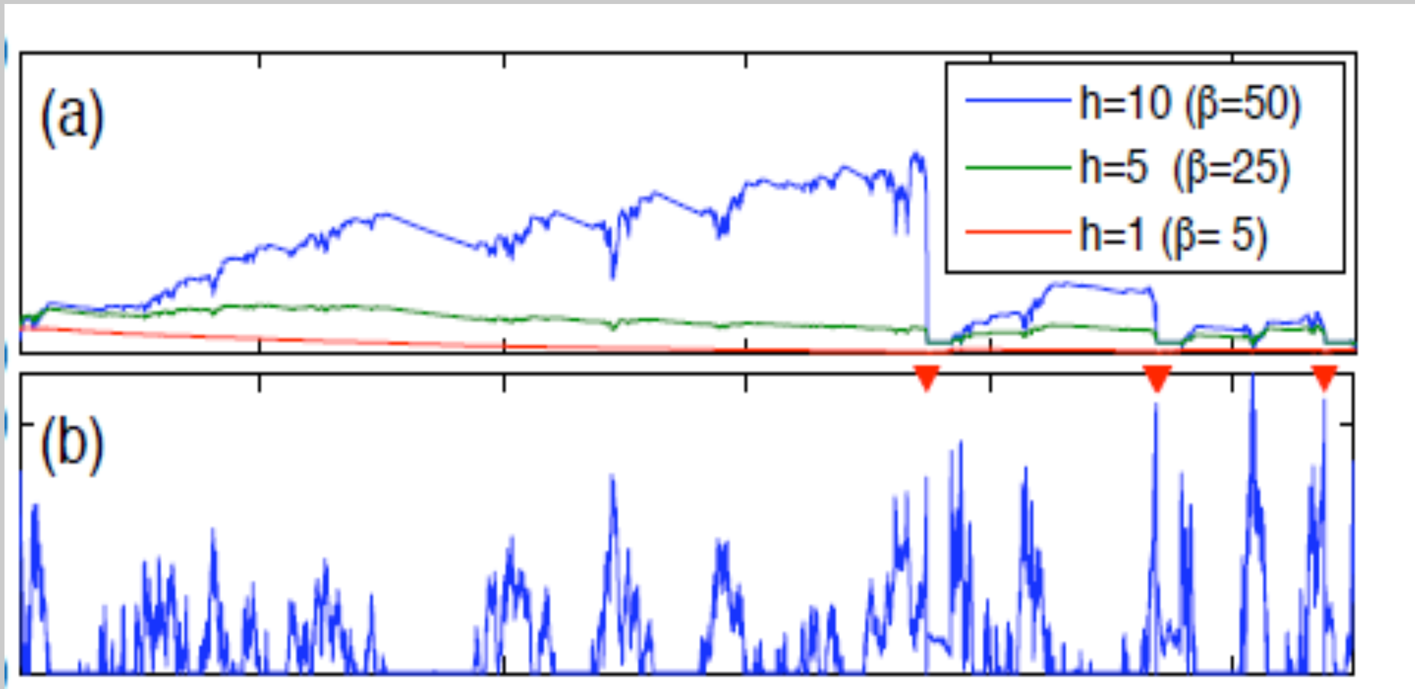
- Uses computation to probe dynamics: finds instability past a leverage threshold

The typical outcome:

A leverage “arms race” pushes the market past a stability threshold, beyond which a crash becomes certain

Funds' Wealth

Mean leverage



time

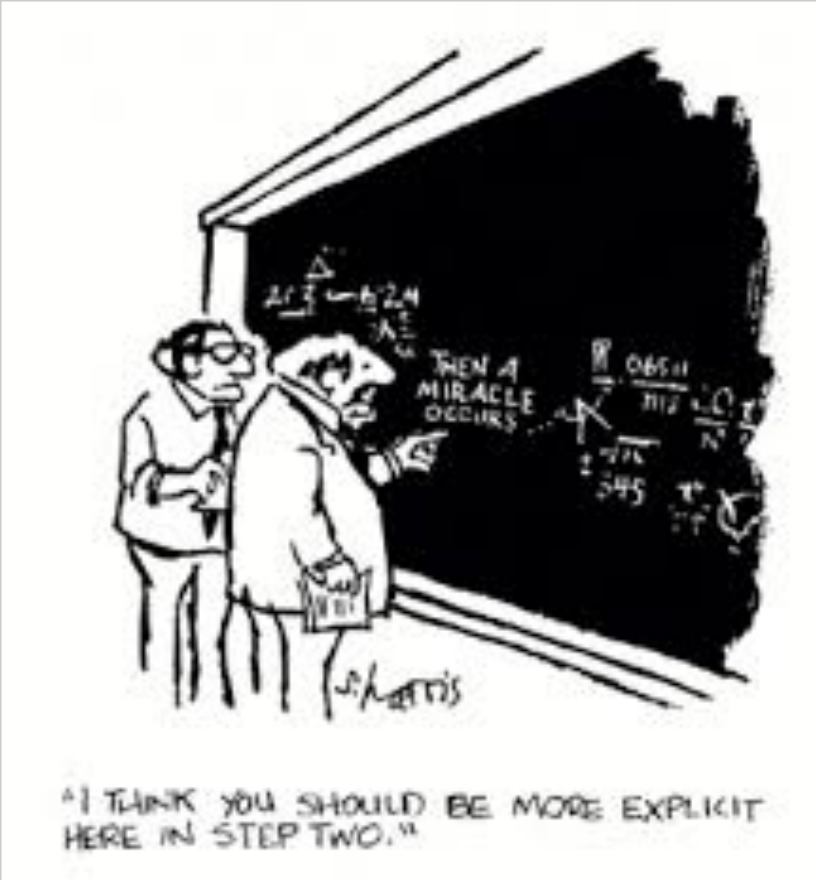
Other recently discovered sources of instability on the road to the "nirvana" of market efficiency:

1) increasing speed of trading (causing crowding of strategy space)
2) increasing density of network interdependence (derivatives!!)

*** Markets breakdown in many ways ***

We currently only know a few

Next 20 Years: Challenges (in economics):



Our understanding of macroeconomics is **very** rudimentary

Example: “rational expectations”

A reassuring claim:

“...rational expectations is not a strong assumption, because most macro models under learning converge to the rational expectations equilibrium anyway”

A body of research – the “learning literature” – goes back to Thomas Sargent and others. [See, for example, George W. Evans & Seppo Honkapohja, "Learning as a Rational Foundation for Macroeconomics and Finance," (2013)]

Hence, it seems that the rational expectations paradigm really is robust; its conclusions rest on solid ground.

BUT: what *kind of learning* are we talking about?

How do agents in these models learn their expectations? Several assumptions:

1. The economy's equations of motion take a simple form.

2. The agents ALREADY KNOW the correct form of these equations; they only remain ignorant of the values of a few parameters.

3. Agents learn the right parameters by trial and error.

Conclusion: under “learning”, macro models often converge to the RE equilibrium!!

Welcome changes:

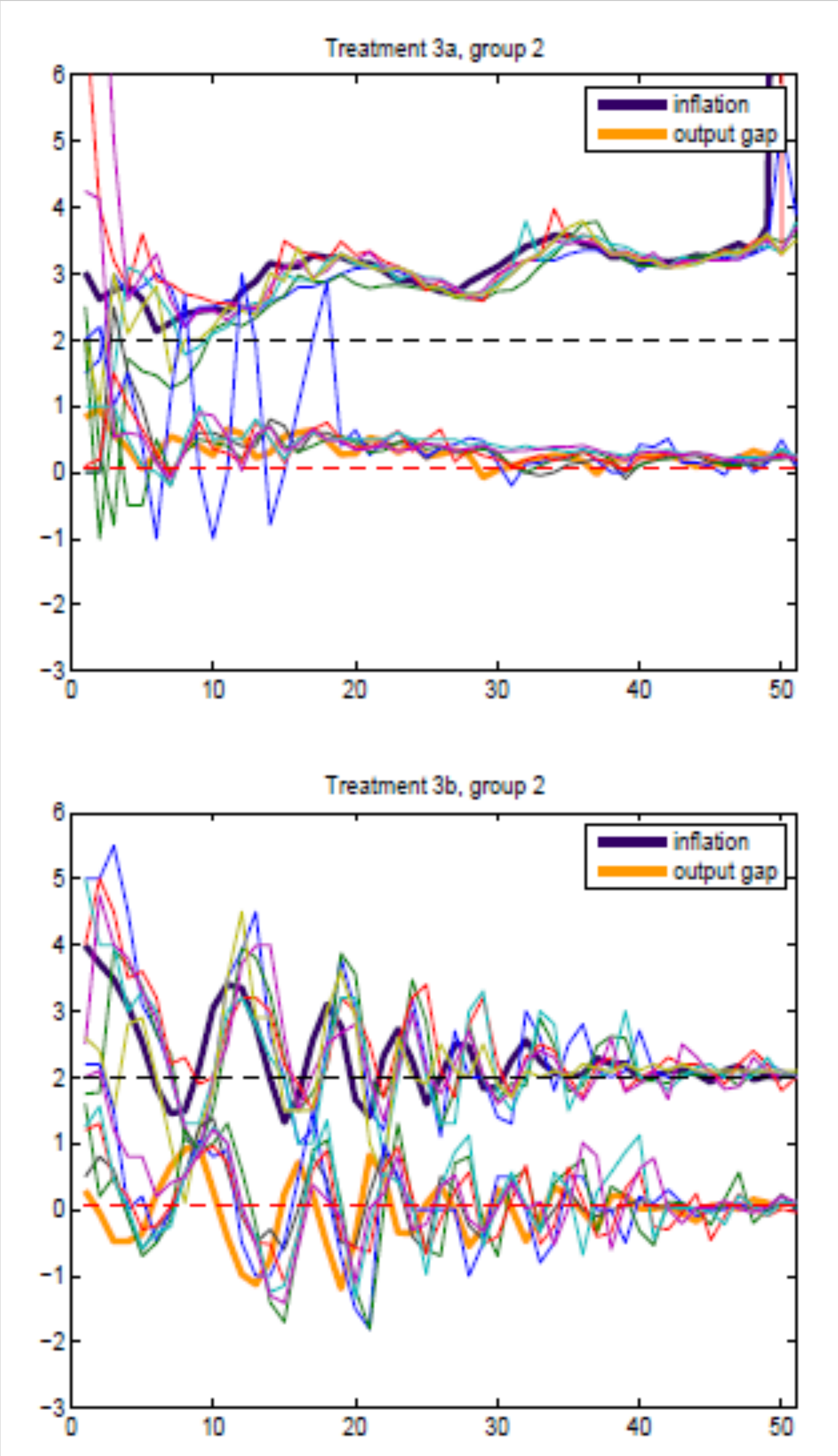
Individual Expectations and Aggregate Macro Behavior

Tiziana Assenza[a,b] Peter Heemeijer[c]

Cars Hommes[b,d] Domenico Massaro[b]

January 5, 2013

Runs experiments: people form their expectations in an unrestricted way, without knowing the equations of motion of the economy. What happens?



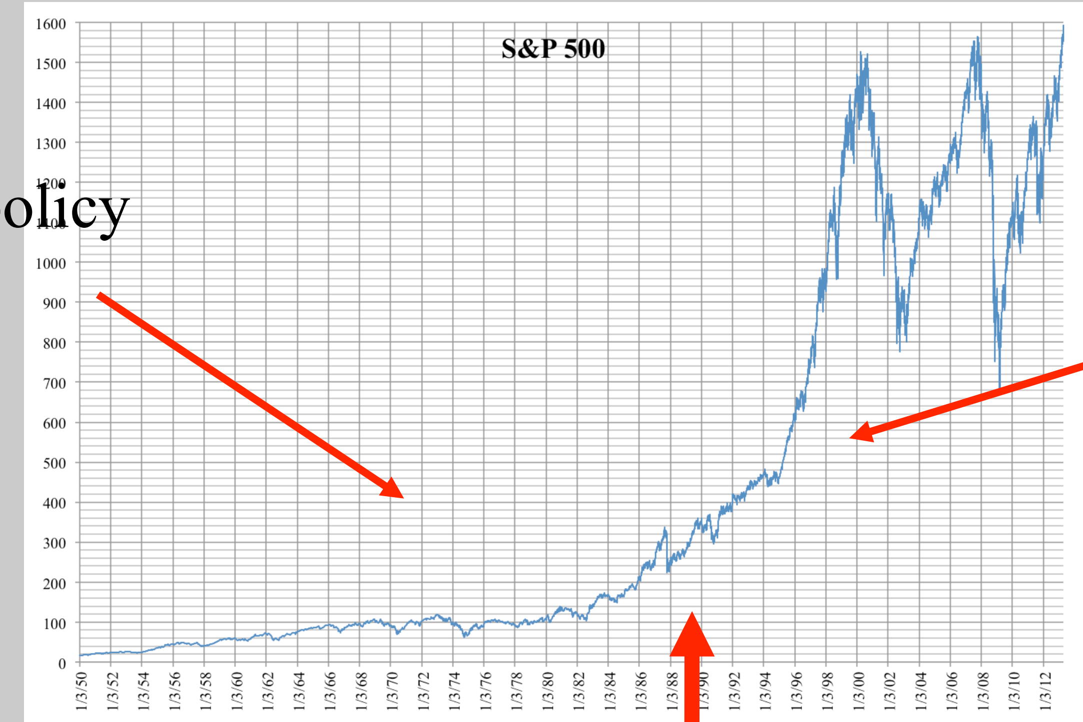
Inflation and output time series in two different experiments.

Even when results do converge to the rational expectations case, it takes A VERY LONG TIME

Allowing diversity means accepting greater uncertainty (**will certainly expand with social interaction**)

By trying to manage expectations are actually we causing MORE instability?

Era of policy secrecy



Era of policy transparency

2015

1970

Beginning of transparent monetary policy and "forward guidance"

John Coates, "The biology of risk", *New York Times*, 7 June 2014

Coincidence? Or not?

We still don't really understand the "Invisible Hand"!

The Emergence of Economic Organization

by

Peter Howitt

The Ohio State University

and

Robert Clower

The University of South Carolina

Journal of Economic Behavior & Organization,
Volume 41, 55-84 (2000)

Thank you for listening!