Economics from a physics point of view

Complex Systems Summer School
June 30, 2015

J. Doyne Farmer

Mathematical Institute and

Institute for New Economic Thinking at the Oxford Martin School

External professor, Santa Fe Institute

Institute for New Economic Thinking AT THE OXFORD MARTIN SCHOOL

Overview of lectures

1. Agent-based modeling of the economy: The vision, the problems, and the reality
2. A physicist's perspective on economics:
   - The perils of scientific cross-dressing, or
   - a case study in how to have an unusual career
3. Toward an evolutionary theory of technological change
   - with a few metaphysical remarks about progress

Questions Sander challenged us with

- Did science choose you or did you choose it?
- How did you end up in interdisciplinary research?
- What was your career like?
- Is it hard to get funding, did you ever feel you had to compromise on interest, subject or even integrity?
- Did being a scientist change your view on life and the world in general, and in what sense?
- How is science going to help solving the world's most pressing problems?
- What are the scientific problems you would like to solve personally, but also what would you hope could be achieved in your lifetime by the community you are part of?

A physicist's perspective on economics

The perils of intellectual cross-dressing

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What was your career like?

- I will give an overview in this lecture, as background to why I have taken on the challenge of building a quantitative agent-based model of the economy.

Do you recognize this man?

Did science choose you
or did you choose it?

My mentor:

Tom Ingerson

How did you end up in interdisciplinary research?

(I started in physical cosmology)

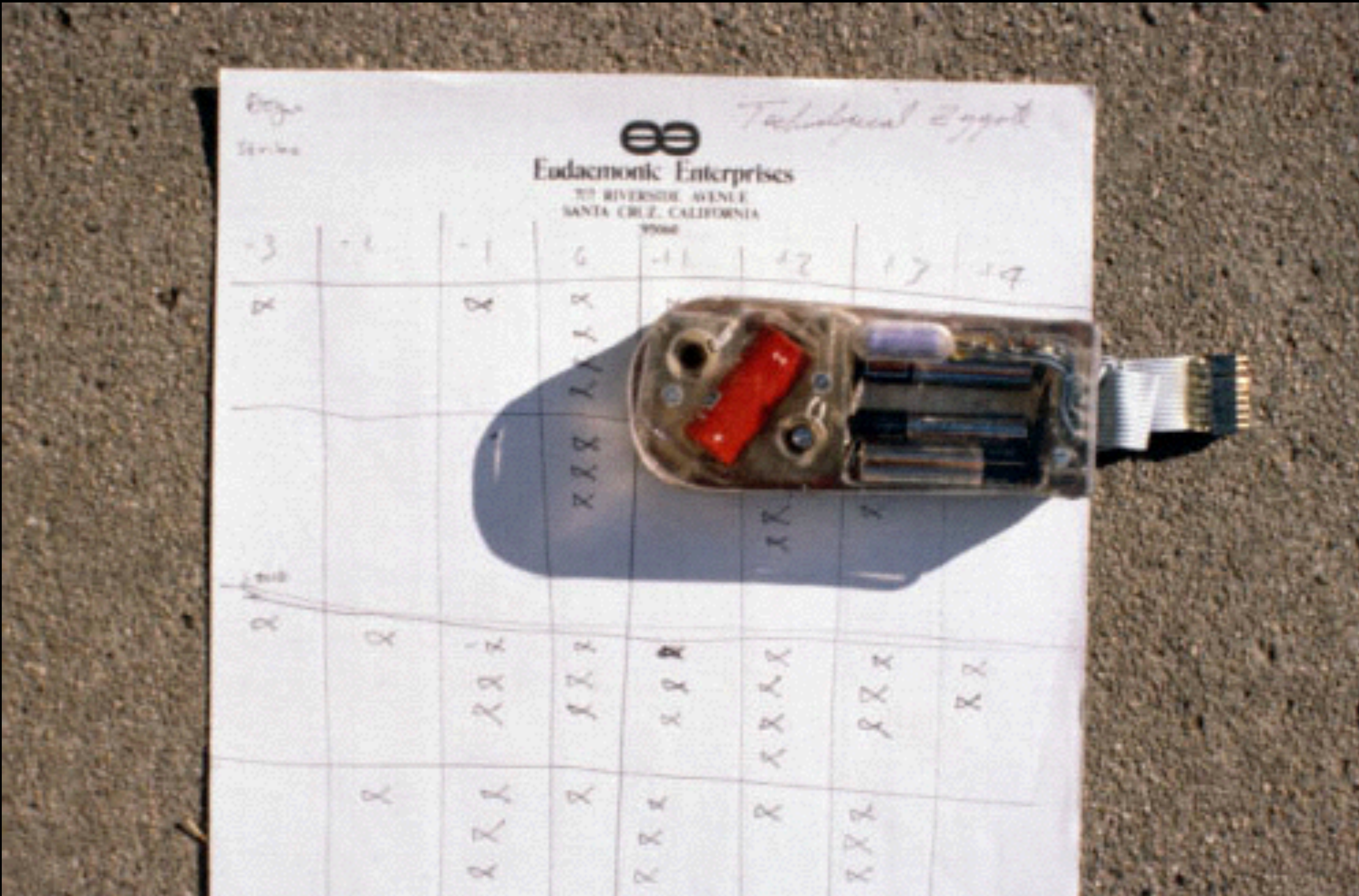
Rolling ball on a circular track with counter-spinning inside track

Roulette

- Classical physics problem Newton could have solved.
  - Measuring position and velocity at a given time determines future motion. Wind resistance is main force

$$\text{rate of change of velocity} = \text{constant} \times (\text{velocity})^2$$

  - complication due to tilt
- Motion of ball on perfect track isn't chaotic; prediction is difficult because of:
  - circularity of wheel (like taking remainder in long division)
  - imperfections in track and ball creates "turbulence"
  - bouncing on cups (this is chaotic)


Eudaemonic Enterprises
RIVERSIDE AVENUE
SANTA CRUZ, CALIFORNIA

VOLUME 45, NUMBER 9 PHYSICAL REVIEW LETTERS 1 SEPTEMBER 1980

Geometry from a Time Series

N. H. Packard, J. P. Crutchfield, J. D. Farmer, and R. S. Shaw
Dynamical Systems Collective, Physics Department, University of California, Santa Cruz, California 95064
(Received 13 November 1979)

It is shown how the existence of low-dimensional chaotic dynamical systems describing turbulent fluid flow might be determined experimentally. Techniques are outlined for reconstructing phase-space pictures from the observation of a single coordinate of any dissipative dynamical system, and for determining the dimensionality of the system's attractor. These techniques are applied to a well-known simple three-dimensional chaotic dynamical system.

PACS numbers: 47.25.-c

FIG. 1. (x,y) projection of Rossler (Ref. 7).

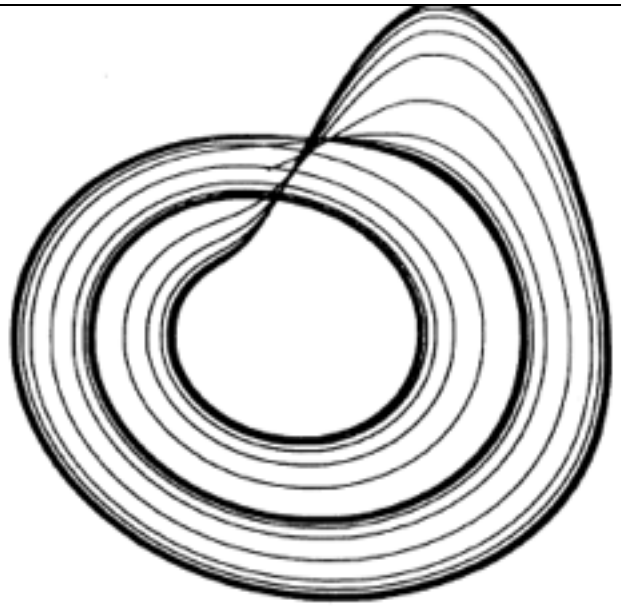
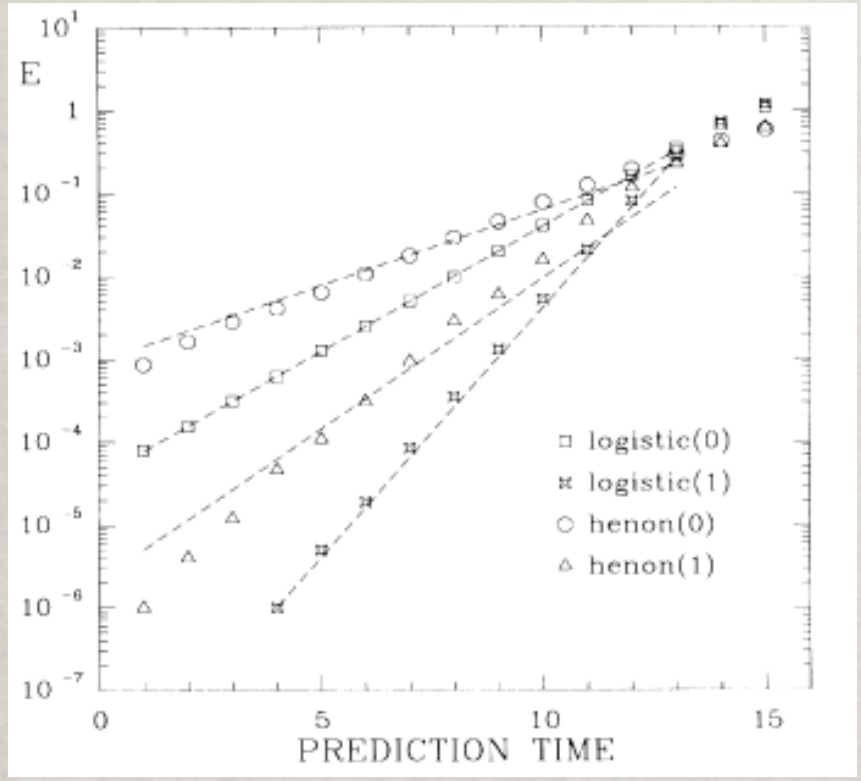


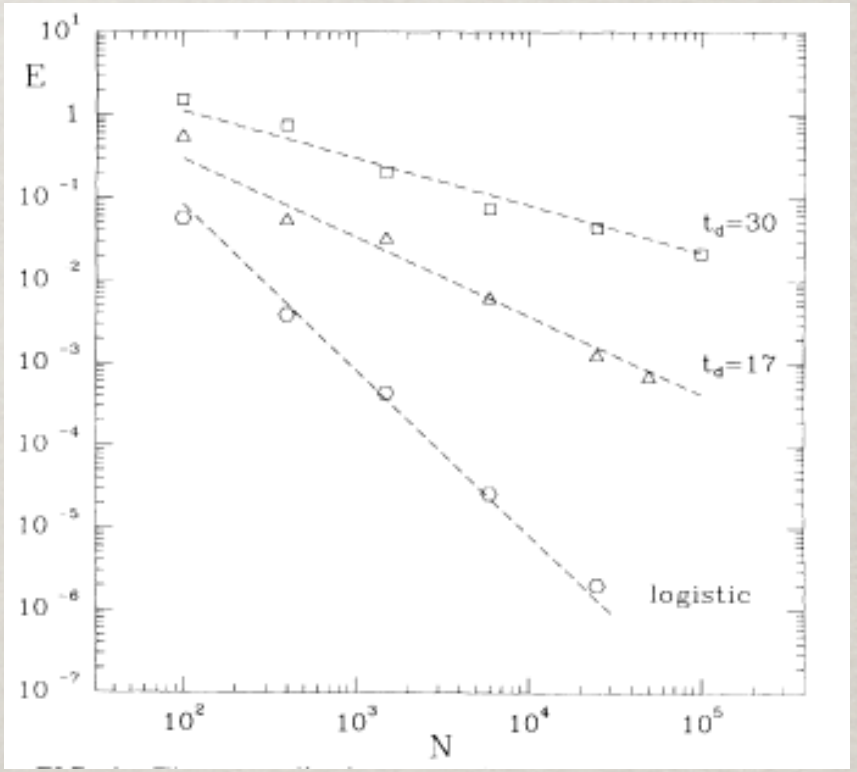
FIG. 2. $(x,\dot{x})$ reconstruction from the time series.

Predicting chaotic time series

(farmer and Sidorowich, 1987)

$$E \approx Ce^{(m+1)\lambda_1 T} N^{-(m+1)/D}$$





The early days of complex systems

Metadynamics papers

- Farmer, J.D., S. Kauffman, N. Packard. "Autocatalytic Replication of Polymers." *Physica D* (1986).
- Farmer, J. D., N. H. Packard, A. Perelson. "The Immune System, Adaptation, and Machine Learning." *Physica D* (1986)
- Bagley, R. J., and J. D. Farmer. "Spontaneous Emergence of a Metabolism." In *Artificial Life II* (1991).
- Bagley, R. J., J. D. Farmer, and W. Fontana. "Evolution of a Metabolism." In *Artificial Life II* (1991).

Metadynamics
(with Norman Packard)

- A *metadynamics* model is a dynamical systems model on a dynamic network. The dynamics induce changes in the network, which in turn induces changes in the dynamical system.
- For example, consider modeling a potentially infinite set of possible chemical reactions.
  - Chemical kinetics are solved on a network of dominant reactions. This network is defined by the set of existing chemical species, which can themselves change through time. As they change, they change the network.
- Key idea: Evolution toward the adjacent possible (Kauffman).

Efficient markets theory

- No arbitrage: It is not possible to make a consistent profit from trading in financial markets without inside information.

Prediction Company

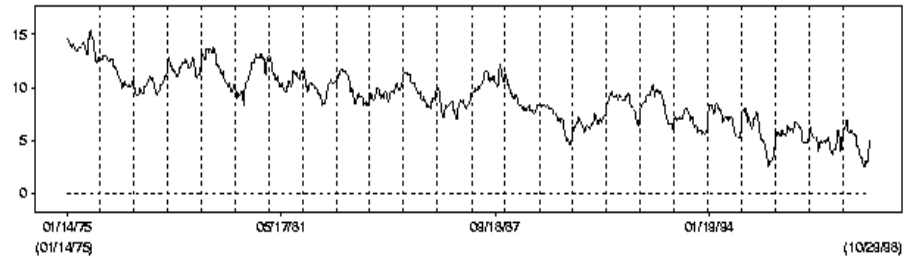
- One of the earliest purely quantitative funds
- Founded by Norman Packard and I in 1991
- Completely automated trading
- I left in 1999, sold to UBS in 2006
- Volcker rule — recently sold to Millenium.

- Basic idea: Find reproducible patterns in financial time series to create a "financial cerebellum"

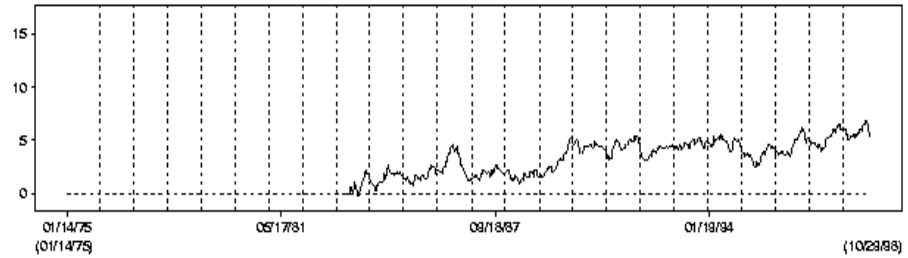
Market efficiency?

Strength of two proprietary predictive signals (1975 - 1998), (measured as smoothed average % correlation between signal and future weekly return)

Signal 1:



Signal 2:



My vision

- Real time tandem simulation of economies of the major countries of the world.
- Inputs directly from internet.
- Coupled to other social models?
- Used by central banks
- Teams focusing on each component, e.g. households, firms, banks, …

Is it hard to get funding, did you ever feel you had to compromise on interest, subject or even integrity?

Scientific method in economics

The epistemology of economics is quite different from that used in natural sciences, particularly in regard to the approach for accumulating and explaining empirical facts.

Hypotheses Non Fingo, Journal of Economic Methodology, 2013

Mainstream economic theory

- Representative agents
- Ad hoc choice of utility function
- Equilibrium: Each agent maximizes utility, taking all of the others into account. Fixed point.
- Solve in closed form.
- Traditional: perfect rationality, full information, no institutional constraints, …
- Current research: relax “perfect” assumptions one at a time.

Consequences

- Monolithic concept of theory: Selfish optimization of preferences.
- Disjointed culture for models <=> data.
- Math vs. science
- Failure to use computers for simulation
- Lack of appreciation for complex systems
- Rational expectations equilibrium, representative agents, ...

How to change economics?

Demonstrate that methods emerging from alternative epistemologies are more successful at explaining and predicting empirical phenomena.

- Determine which theories have empirical backing
- Catalogue empirical laws
- Develop phenomenological theories matching data
- Agent-based models

Purpose of my professional life at present: Show success of complex systems point of view in economics.