Climate Change and the New Economics

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McKinsey Global Institute

European Climate Forum
Annual Conference
Universidad de Alcalá, Madrid
1-2 April, 2008

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“The ideas of economists and political philosophers, both when they are right and when they are wrong, are more powerful than is commonly understood. Indeed, the world is ruled by little else.”

John Maynard Keynes
Today’s discussion

• The three most stunning empirical facts in economics
• Characterizing the economy – what is it?
• The economy as an evolving complex system
• What does it mean for addressing climate change?
Today’s discussion

• The three most stunning empirical facts in economics
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Fact no. 1 – wealth has grown explosively

World GDP per capita, constant 1992 US$

Fact no. 2 – complexity has grown explosively

From . . .

10^2 SKU economy

To . . .

10^{10} SKU economy

• Wal-Mart 100,000 SKUs
• Cable TV 200+ channels
• 275 breakfast cereals
Fact no. 3 – no one is in charge
Today’s discussion

• The three most stunning empirical facts in economics

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Traditional economics cannot explain key characteristics of the economy.

Economy viewed as an equilibrium system . . .

. . . but such a system cannot

• Grow explosively
• Create novelty
• Spontaneously self-organize
The accidental history of equilibrium in economics

THE ELEMENTS OF STATICS
BY LOUIS POINSOT
1803

TREATISE ON NATURAL PHILOSOPHY
BY SIR WILLIAM THOMPSON
AND PETER GUTHRIE TAIT
1867

Léon Walras

William Stanley Jevons
A different explanation – the economy is a ‘complex adaptive system’

Complex

Many interacting agents and organizations of agents

Adaptive

Designs and strategies evolve over time

System

Macro patterns emerge from micro behavior
Dynamics

Traditional – fixed point attractors

Complexity – dynamic attractors
Agents

Traditional – perfect rationality
- Deductive logic
- Self-interest
- Perfect information
- Infinite computational power
- No errors, biases
- No learning

Complexity – realistic rationality
- Inductive rules of thumb
- Strong reciprocity
- Imperfect information
- Finite computing power
- Errors, biases
- Learning over time
Networks

Traditional – networks don’t matter

• Interactions – only via markets
• Information – prices, quantities
• Institutions – Walrasian auctions

Complexity – network structures matter

• Interactions – via networks
• Information – anything
• Institutions – bilateral trade, posted prices, corporations, etc.
Emergence

Traditional – assumes linear additivity

- Macroeconomic behavior
  - Time
  - Representative "super agent"
  - Individual agents

Complexity – non-linear interactions create emergent patterns
Evolution

Traditional – no endogenous theory of innovation

“Add successfully as many mail coaches as you please, you will never get a railway thereby”

Joseph Schumpeter

Complexity – innovation as evolutionary search
## A paradigm shift

<table>
<thead>
<tr>
<th>Dynamics</th>
<th>Traditional economics</th>
<th>Complexity economics</th>
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<tbody>
<tr>
<td></td>
<td>Economies are closed, static, linear systems in equilibrium</td>
<td>Economies are open, dynamic, non-linear systems far from equilibrium</td>
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<table>
<thead>
<tr>
<th>Agents</th>
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<tbody>
<tr>
<td></td>
<td>Homogeneous agents</td>
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<tr>
<td></td>
<td>• Only use rational deduction</td>
</tr>
<tr>
<td></td>
<td>• Make no mistakes and have no biases</td>
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<tr>
<td></td>
<td>• Are already perfect, so why learn?</td>
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<tr>
<td></td>
<td>Heterogeneous agents</td>
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<tr>
<td></td>
<td>• Mix deductive/inductive decision-making</td>
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<tr>
<td></td>
<td>• Subject to errors and biases</td>
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<td>• Learn and adapt over time</td>
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<thead>
<tr>
<th>Networks</th>
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<tbody>
<tr>
<td></td>
<td>Assume agents only interact indirectly through market mechanisms</td>
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<td>Explicitly account for agent-to-agent interactions and relationships</td>
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<tr>
<th>Emergence</th>
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<td></td>
<td>Treats micro and macroeconomics as separate disciplines</td>
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<td></td>
<td>No distinction between micro- and macroeconomics; macro patterns emerge from micro behaviors and interactions</td>
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<tr>
<th>Evolution</th>
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<tbody>
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<td></td>
<td>Contains no endogenous mechanism for creating novelty or growth in order and complexity</td>
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<tr>
<td></td>
<td>Evolutionary process creates novelty and growing order and complexity over time</td>
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</tbody>
</table>
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Long history of evolutionary ideas in economics (and vice versa)

1838
- Malthus
- Darwin
- Mandeville
- Marx
- Spencer
- Marshall
- Menger
- Veblen
- Schumpeter
- Hayek
- Nelson and Winter

1982

Problem
- Driven from a metaphor with biology
- Not built on a general computational view of evolution
We are accustomed to thinking of evolution in a biological context.
Evolution is a search algorithm for ‘fit designs’

Create a variety of experiments

Select designs that are ‘fit’

Amplify fit designs, de-amplify unfit designs

Repeat
Evolution creates complexity from simplicity

Information World

1 0 1 1 0 0 1 1

Physical World

Rendering of design

Variation, selection, amplification

Feedback on fitness

Design encoded in a schema

Interactor in an environment

Order, complexity

Entropy

Entropy
Who designed the modern bicycle?
The reality – evolution through ‘deductive-tinkering’
Technologies evolve
Economic evolution occurs in three ‘design spaces’

Physical technologies

Business plans

Social technologies
Business plan evolution works at three levels

**Individual minds**

A?
B?
C?
D?
E?

**Organizations**

A?
B?
C?
D?
E?
B+D+E?

**Markets**

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WATERSTONES

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What would economic evolution look like?

- Bursts of innovation/punctuated equilibrium
- Spontaneous self organization
- Decreasing local entropy/increasing order
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Climate change requires new economic methodologies

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<th>To</th>
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<tr>
<td>• Cost-benefit analysis</td>
<td>• Risk models that account for fat tails and time irreversibility</td>
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<tr>
<td>• Utility view of time preference</td>
<td>• Hyperbolic discounting</td>
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<tr>
<td>• Perfect rationality view of behavioral change</td>
<td>• Cognitively realistic view of behavioral change</td>
</tr>
<tr>
<td>• Static view of technology and institutions</td>
<td>• Evolutionary view of technology and institutions</td>
</tr>
<tr>
<td>• No physical constraints</td>
<td>• Constrained by energy and entropy</td>
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<tr>
<td>• General equilibrium models</td>
<td>• Agent-based models that capture time dynamics, nonlinearities</td>
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How might a ‘complexity economist’ think about climate change?

- Export higher entropy
- Decreasing entropy
- Creation of “fit order”, e.g. wealth
- Economic growth

Energy
A carbon productivity ‘revolution’ is required – three times faster than the Industrial Revolution

Index (Year 0 = 1)

Carbon productivity growth required 2008-2050

US labor productivity growth 1870–1995

Years
McKinsey cost curve shows where opportunities exist for improving carbon productivity

Cost of abatement, 2030
EUR/tCO₂e

- Insulation improvements
- Fuel-efficient commercial vehicles
- Lighting systems
- Air-conditioning
- Water heating
- Fuel-efficient vehicles
- Industrial non-CO₂
- Sugarcane biofuel
- CCS EOR; New coal
- Industrial feedstock substitution
- Forestration
- Wind; low pen.
- Co-firing biomass
- CCS; new coal
- CCS; coal retrofit
- Coal-to-gas shift
- Avoid deforestation, America
- Avoided deforestation, Asia
- Biodiesel
- Industrial CCS
- Abatement GtCO₂e/year
- Industrial motor systems
- Waste
- Stand-by losses
- Livestock/soils
- Nuclear
- CCS EOR; New coal
- Forestration
- Industrial non-CO₂
- Airplane efficiency
- Industrial non-CO₂
- Stand-by losses

Source: Vattenfall and McKinsey analysis

Cost of abatement, 2030
EUR/tCO₂e
Harnessing economic evolution in climate policy?

- Set GHG limits as constraint in economic fitness function
- Improve carbon information
- Create incentives/institutions for “portfolios” of technology experiments—do not pick winners
- Address market failures (e.g. energy efficiency)—markets necessary but not sufficient
- Harness what is known about behavior (e.g. strong reciprocity)
- Other???
Final thought…

“Evolution is cleverer than we are”

Orgels’ second law
Thank you