

Ecological Complexity Economics?

Models, Natural Science Ideas, and Utopias

by

Yannick Oswald

@



**Rethinking
Economics**
Switzerland

Unil.

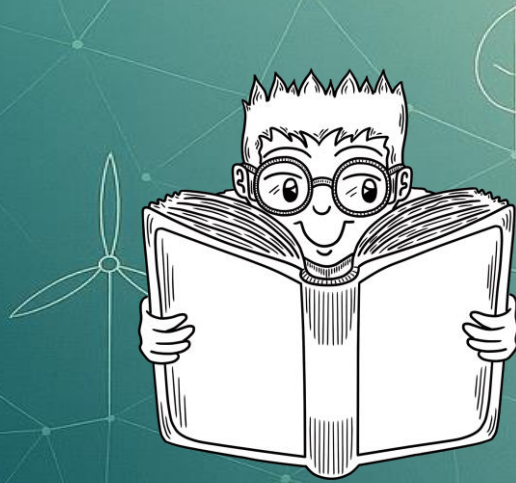
What is this talk about?

A ***personal view*** on two schools of economics:

Ecological Economics and

Complexity Economics

and their models



Agenda

- **Introduction**
- **Ecological Economics**
- **Complexity Economics**
- **The vision: Ecological Complexity Economics?**

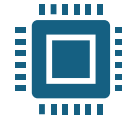
About myself..



**M.Sc. In
Sustainable
Development**



**PhD in Ecological
Economics in
Leeds, UK**



**PostDoc in *agent-
based modelling*
and data science
in Leeds**



**PostDoc in Ecological
Economics and
modelling in
Lausanne (*Now*)**



***Strong interests in
mathematics and
natural science***

Why do we need to rethink economics?

A look at the Nobel Prize Earlier Years

Thematic restrictions?

“No Nobel Memorial Prize for economics has ever been awarded related to the topic (inequality) (as of January 2022), contrasting with four prizes for contributions to economic growth theory.”

– *from my PhD*

A look at the Nobel Prize 2025

Methodological homogeneity!

Many topics, similar equilibrium frameworks

$$Y_t = \frac{1}{\alpha} L_t^{1-\alpha} \int_0^1 q_t(\nu)^{1-\alpha} y_t(\nu)^\alpha d\nu,$$

Aghion and Howitt (1992), A model of growth through creative destruction.

<https://www.nobelprize.org/uploads/2025/10/advanced-economicsciencesprize2025.pdf>

Many other reasons – I know!

- Unempirical first semesters
 - Not inclusive of Global South/Decolonial perspectives
 - Neglected aspects of economy such as care work
- And and

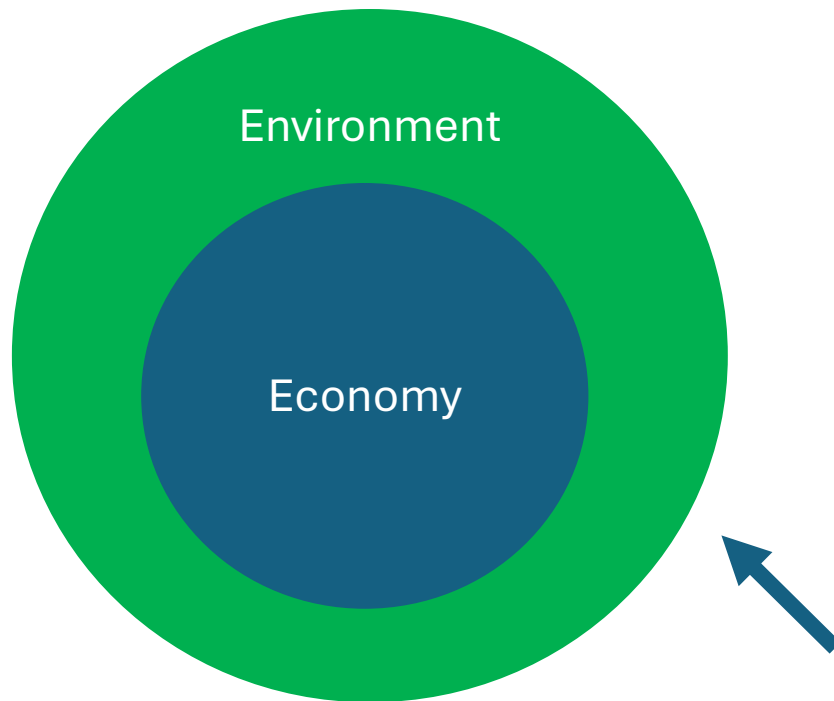
But also we need to continue thinking new schools of economics – there is no consensus!

A look at the book

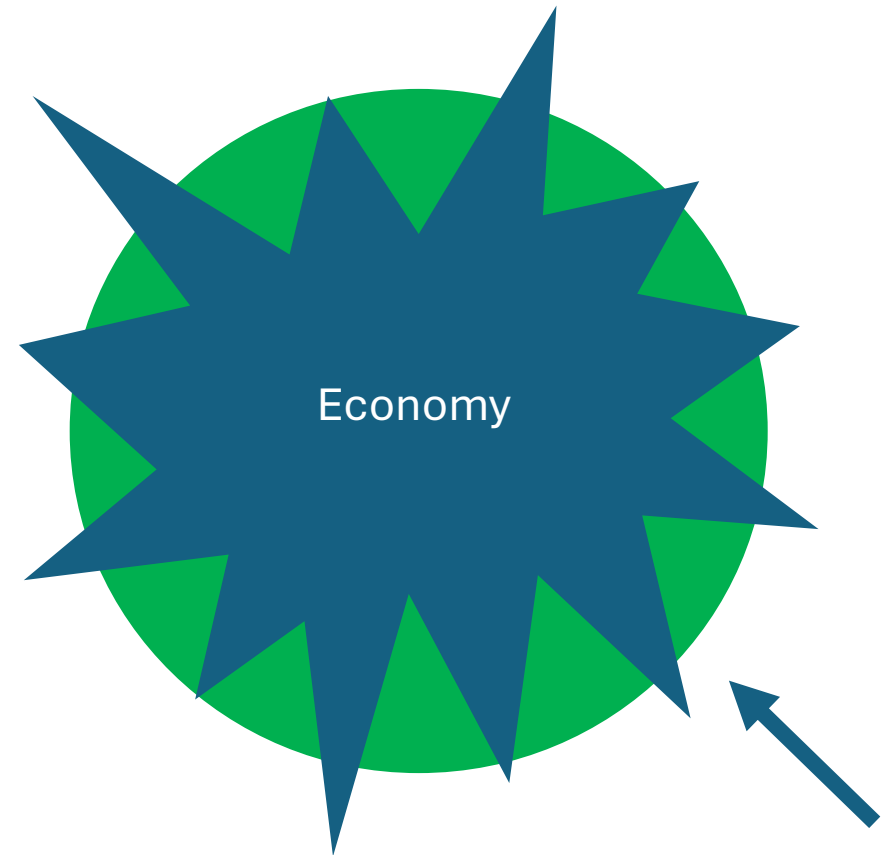
Economy Studies: A Guide to Rethinking Economics Education

	Austrian School	Behavioural Economics	Classical Political Economy	Complexity Economics	Cultural Approach	Ecological Economics	Evolutionary Economics	Feminist Economics	Field Theory	Historical School	Institutional Economics	Marxian Political Economy	Neoclassical Economics	Post-Keynesian Economics	Social Network Analysis	Structuralist Economics	Other	
■	+		+	+			□			+		+	■	■			+	Governments
□												+	□	■			+	Business Cycles
+											■						+	Consumption
		+	■			+	+			■	□	+	+			+		Economic Development
		+		□	+								■	■				Finance
			+				□		■		■		+		+		+	Firms
								■				+	■					Households
	+	+		+				□				■	■	+			+	Inequality
													■	■		□	+	International Trade
					□			+				■	■		+			Labour
	+	+	■		□				+				■					Markets
					□					+				■				Money
			□			■					+		■				+	Nature

Ecological Economics



What would be good.



What is happening.

Biophysical quantities

- **Energy Instead of GDP**
- **Carbon emissions, water footprints and so forth.**



Considers absolute constraints => urgency

Carbon budget for 2°C

900 GtCO₂

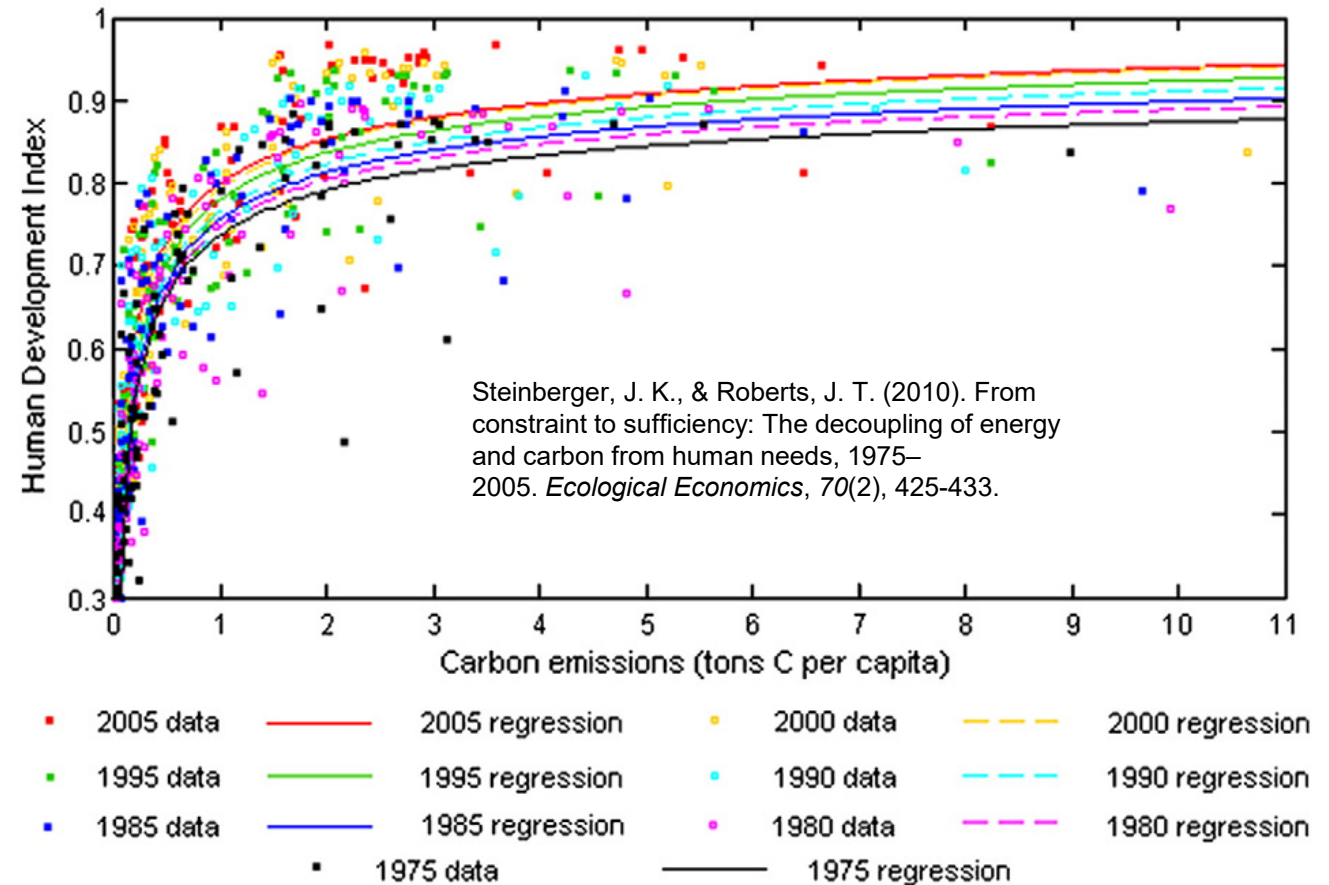
(with 83% probability)

Yearly global emissions
~ 53.2 gigatonnes (GtCO₂eq)

900/50 ~ 18 years left to “save the world”!?

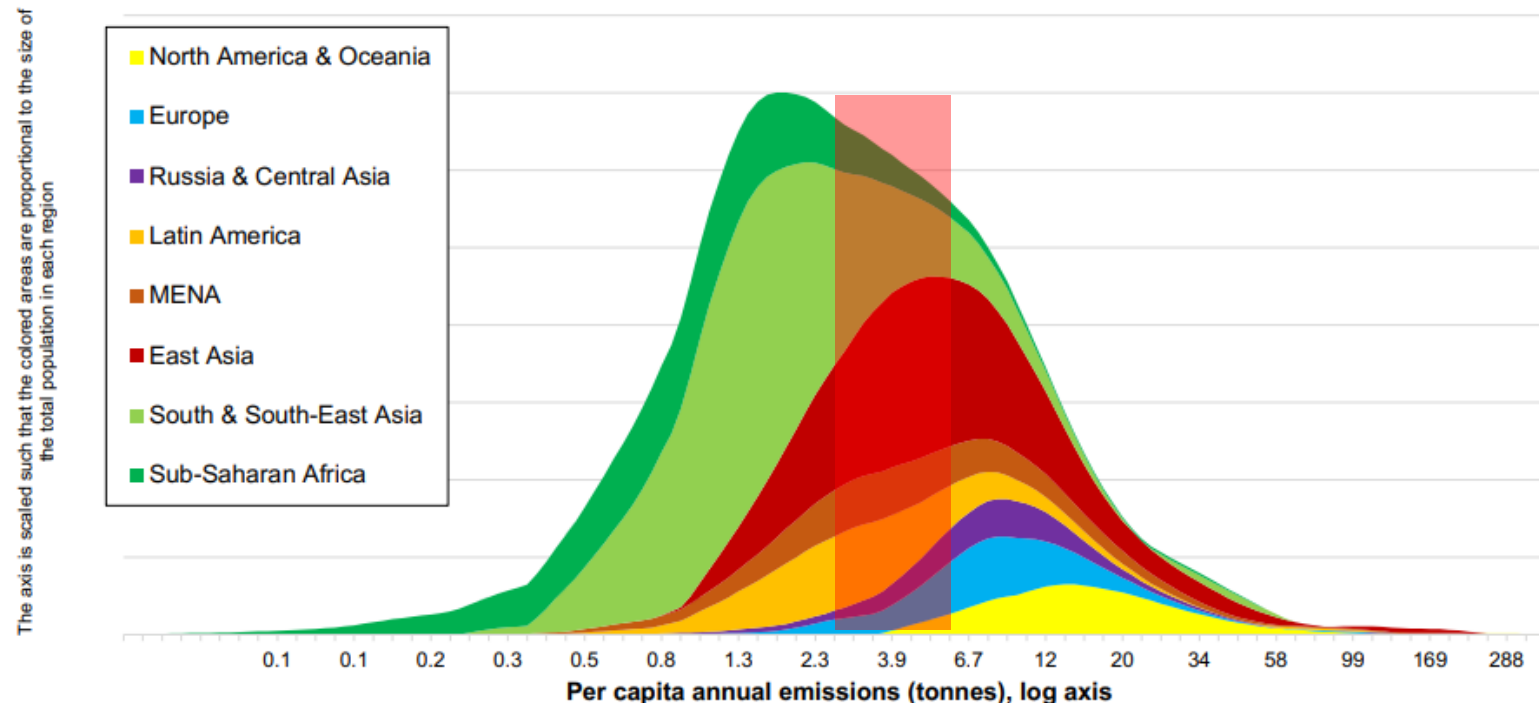
https://en.wikipedia.org/wiki/Carbon_budget

Diminishing Returns In Well-being Metrics



Diminishing returns impose distributional problem

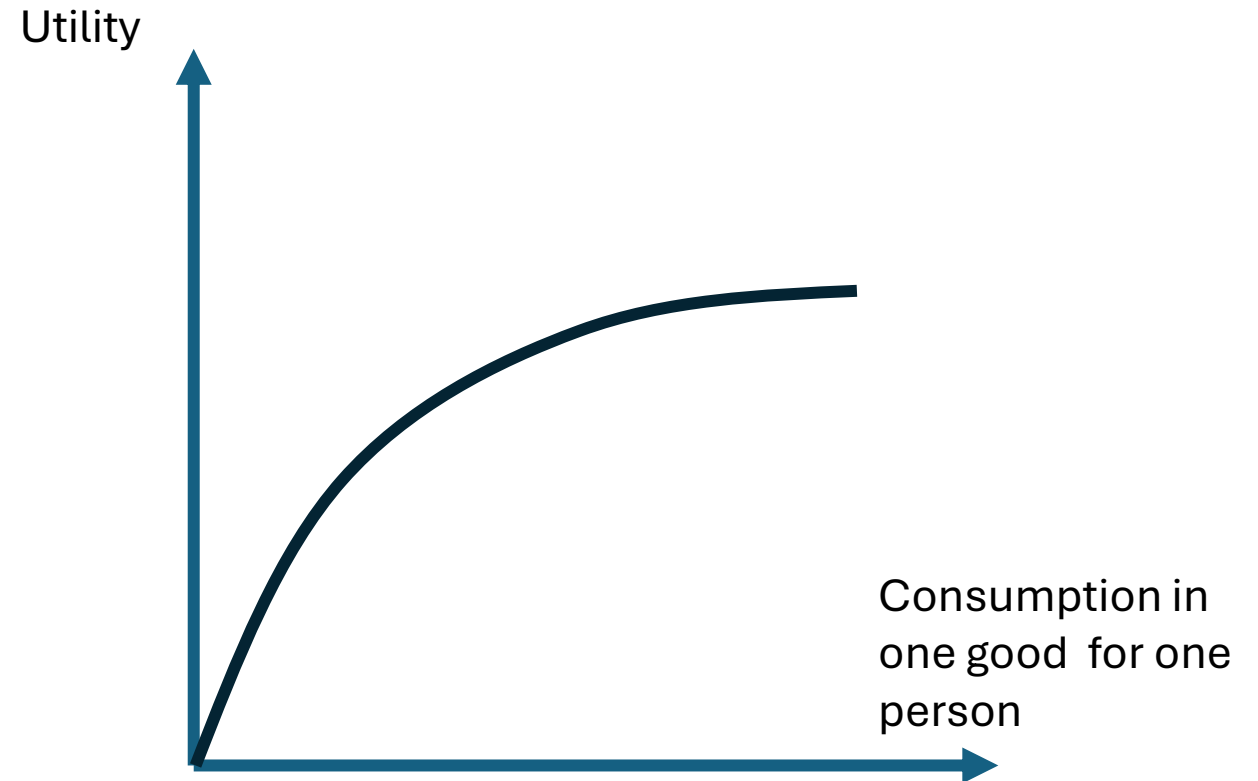
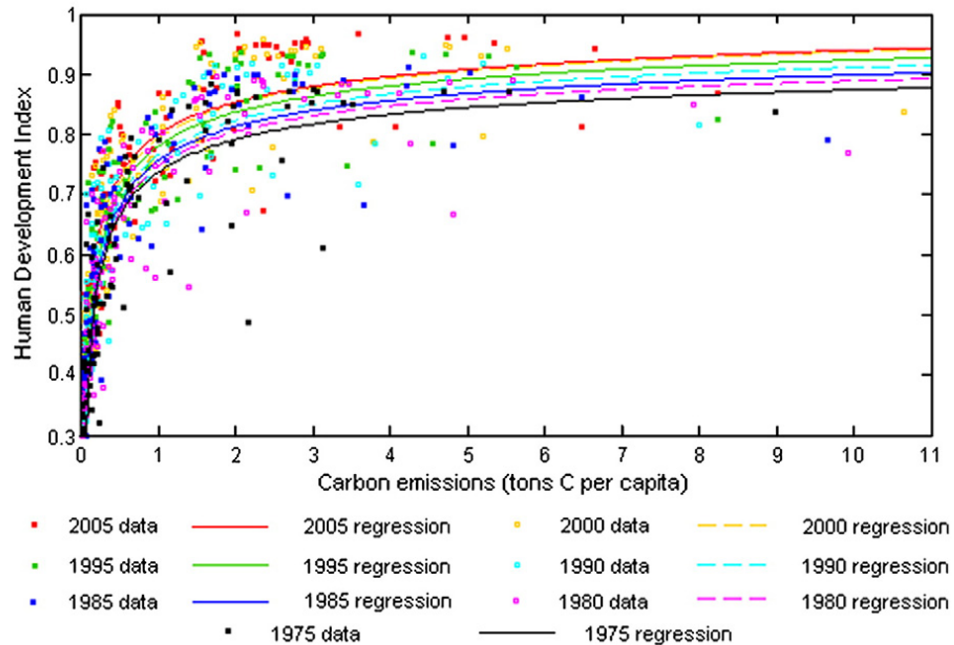
(b) Group share (%) in world total emissions



Chancel, L. (2022). Global carbon inequality over 1990–2019. *Nature Sustainability*, 5(11), 931-938.

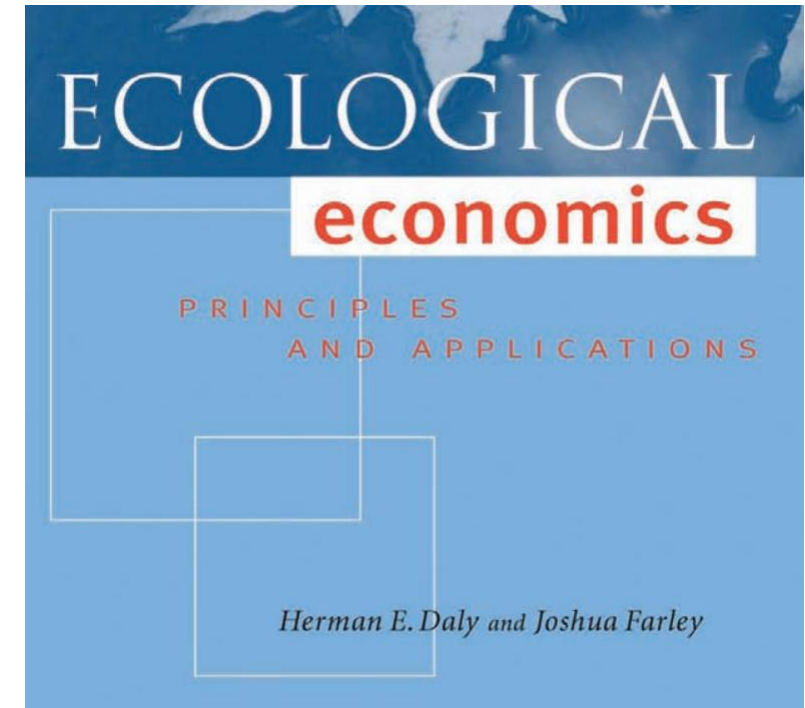
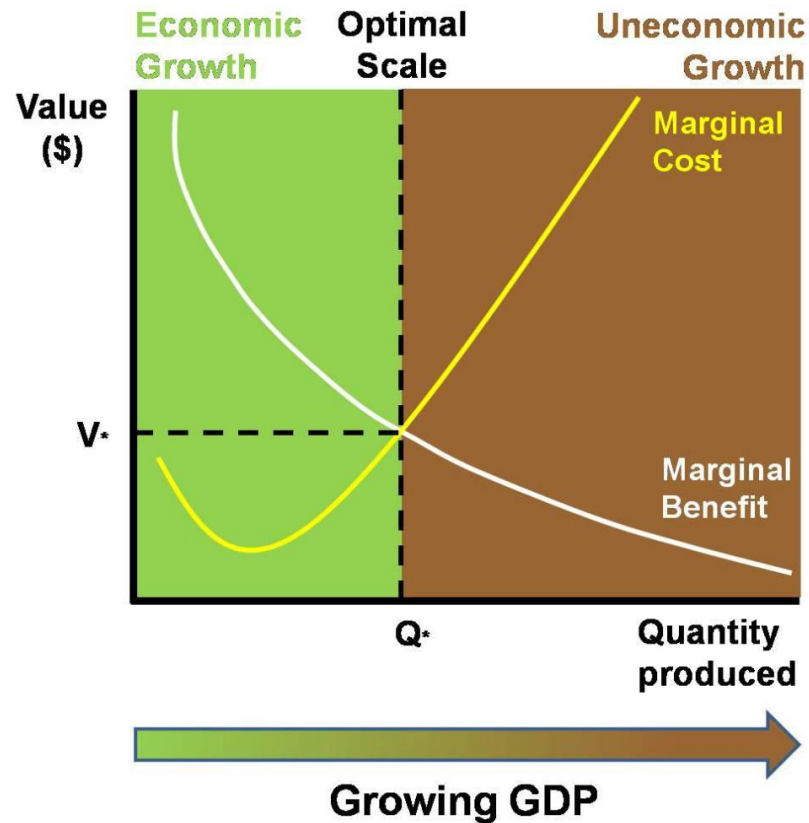
Reflections on the said so far (1)

– More Marginal Analysis? Optimization?



Reflections on the said so far (2)

– more marginal analysis? Micro to Macro?



Computational thought experiments

Global Sustainability

cambridge.org/sus

Long Form Research Paper

Cite this article: Oswald Y, Steinberger JK, Ivanova D, Millward-Hopkins J (2021). Global redistribution of income and household energy footprints: a computational thought experiment. *Global Sustainability* 4, e4, 1–13. <https://doi.org/10.1017/sus.2021.1>

Global redistribution of income and household energy footprints: a computational thought experiment

Y. Oswald¹ , J.K. Steinberger^{1,2}, D. Ivanova¹  and J. Millward-Hopkins¹

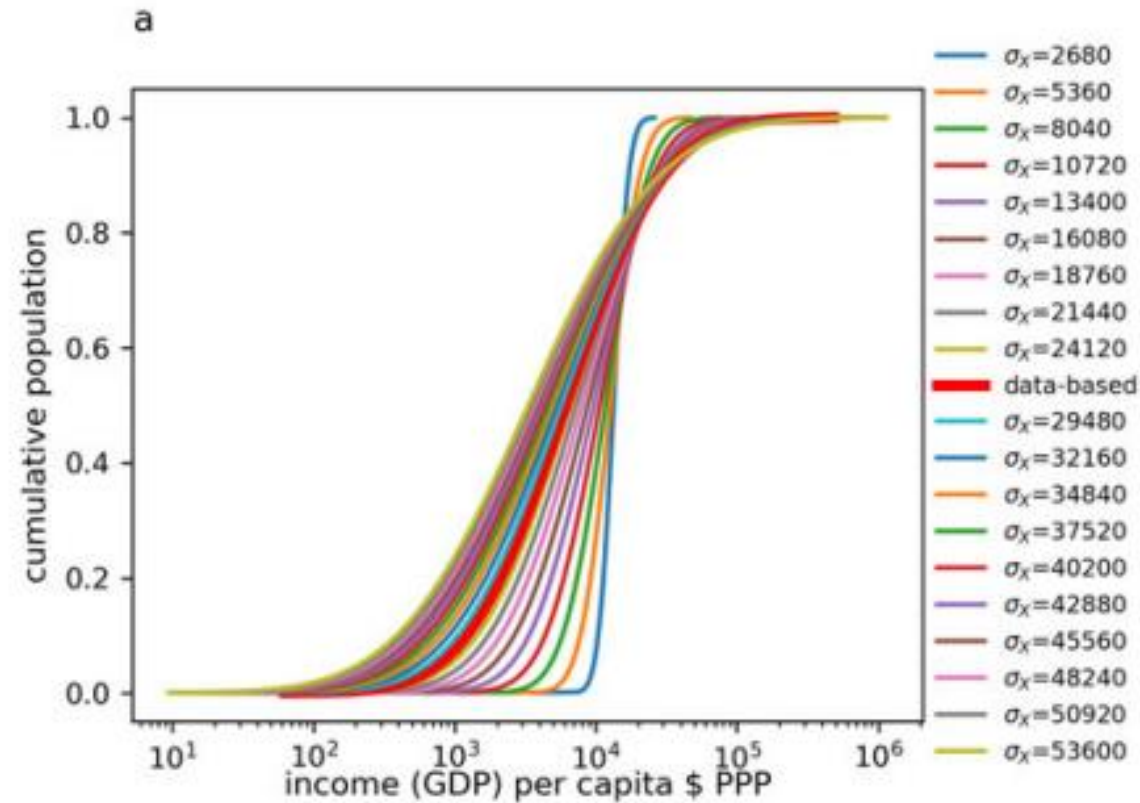
¹Sustainability Research Institute, School of Earth and Environment, University of Leeds, Leeds LS2 9JT, UK and

²Institute of Geography and Sustainability, Faculty of Geosciences and Environment, University of Lausanne, Lausanne, Switzerland

Non-technical summary. Global income inequality and energy consumption inequality are related. High-income households consume more energy than low-income ones, and for

What if the global income distribution would be different?

Effects on energy consumption

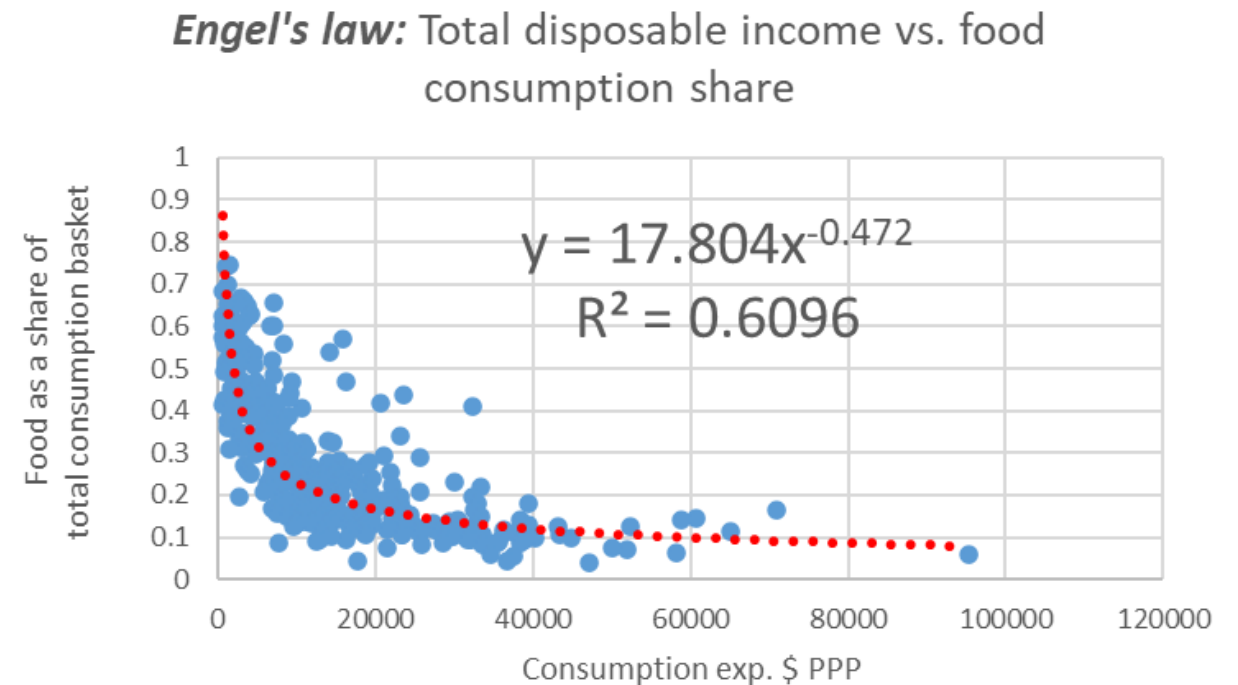
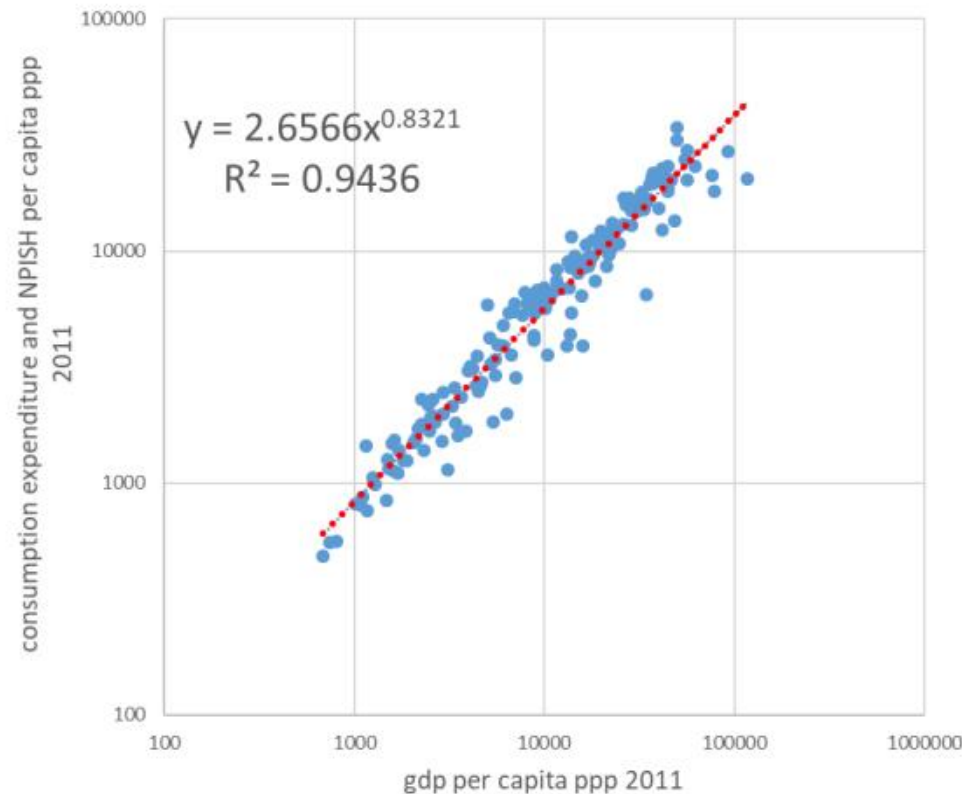


Heavy assumptions necessary?

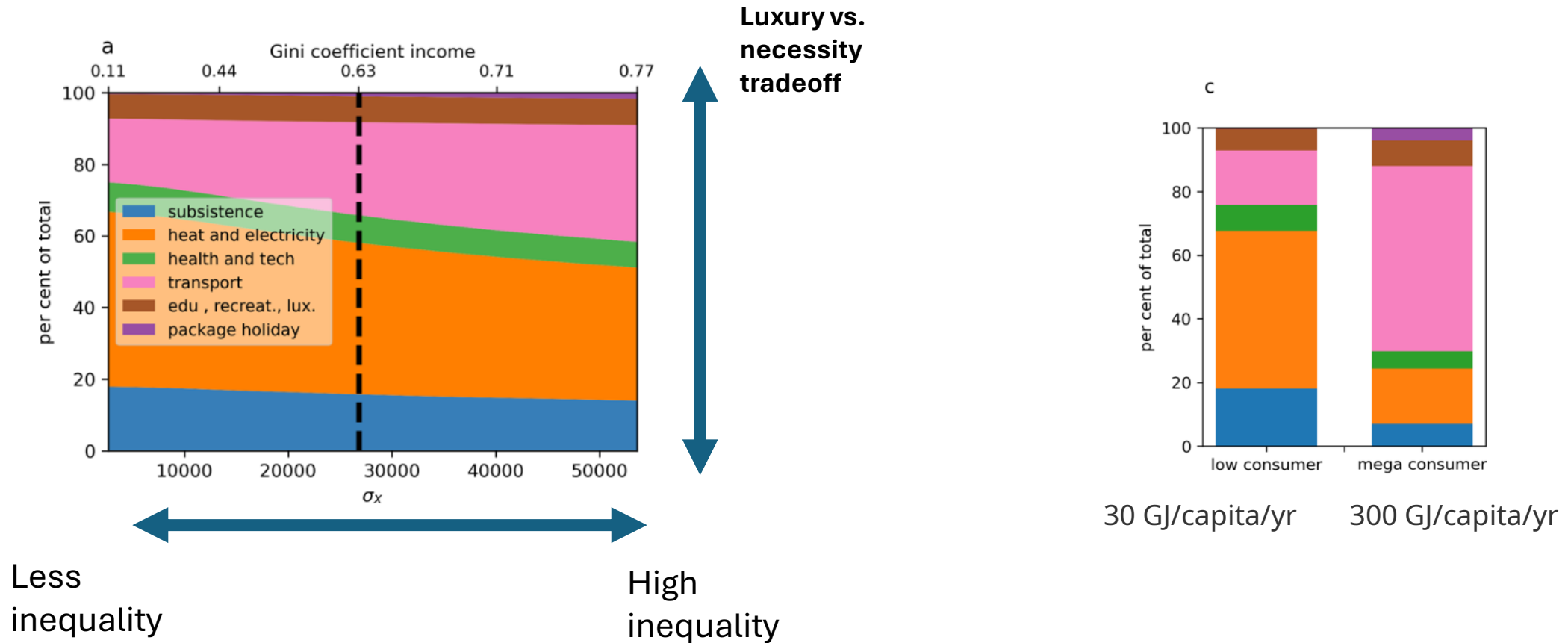
Table 1. Major assumptions of the model

Number	Assumption
1	Constant world GDP
2	Constant population
3	GDP per capita is distributed as income per adult equivalent
4	GDP per capita and expenditure per capita are correlated by a power law
5	Household expenditure is distributed over 14 consumption categories
6	The budget share per consumption category is determined by constant income elasticities of demand
7	Constant and homogenous technology

Empirical grounding of assumptions



Results of this thought experiment – A more equal world consumes energy differently



Reflections on Ecological Economics

- In a way a bit like neoclassical economics, yet completely different
- A utopian world imagined?

Complexity Economics

Overview & buzzwords

- Out-of-equilibrium dynamics
- Chaos
- Boundedly rational agents
- Non-linear feedbacks
- Self-organization
- Emergence
- Swarm-intelligence (or -stupidity)

Perspective | Published: 29 January 2021

Foundations of complexity economics

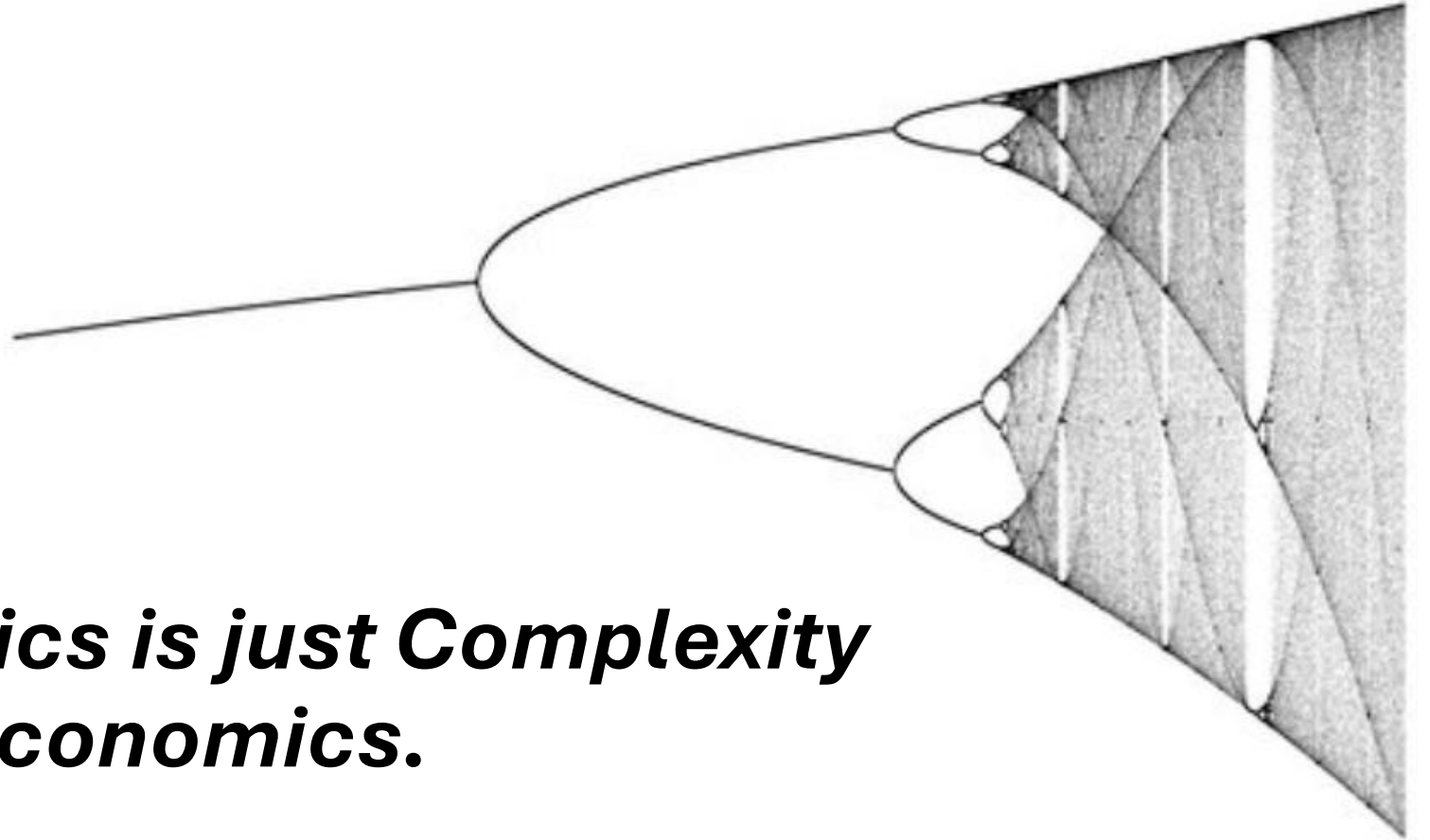
[W. Brian Arthur](#) 

[Nature Reviews Physics](#) 3, 136–145 (2021) | [Cite this article](#)

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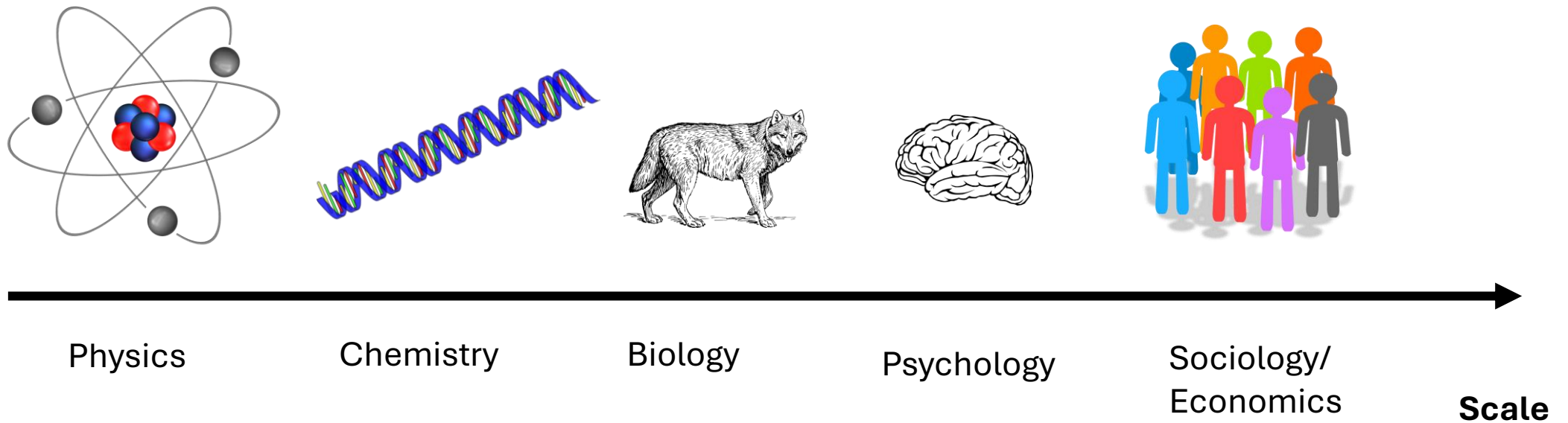
Abstract

Conventional, neoclassical economics assumes perfectly rational agents (firms, consumers, investors) who face well-defined problems and arrive at optimal behaviour consistent with –



***Complexity Economics is just Complexity
Science applied to economics.***

Complexity is a universal approach across the sciences



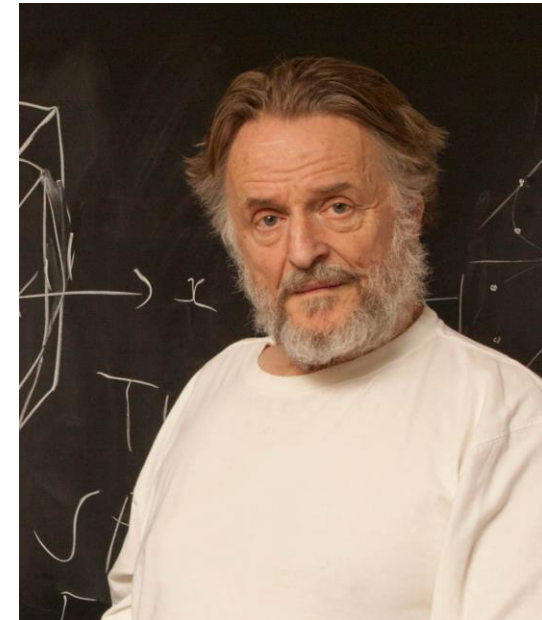
The biggest lesson of all of complexity science?

***EMERGENCE:
SIMPLICITY LEADS TO COMPLEXITY***

***From simple rules on a “local” level
to
complex structures emerge at a “global” level***

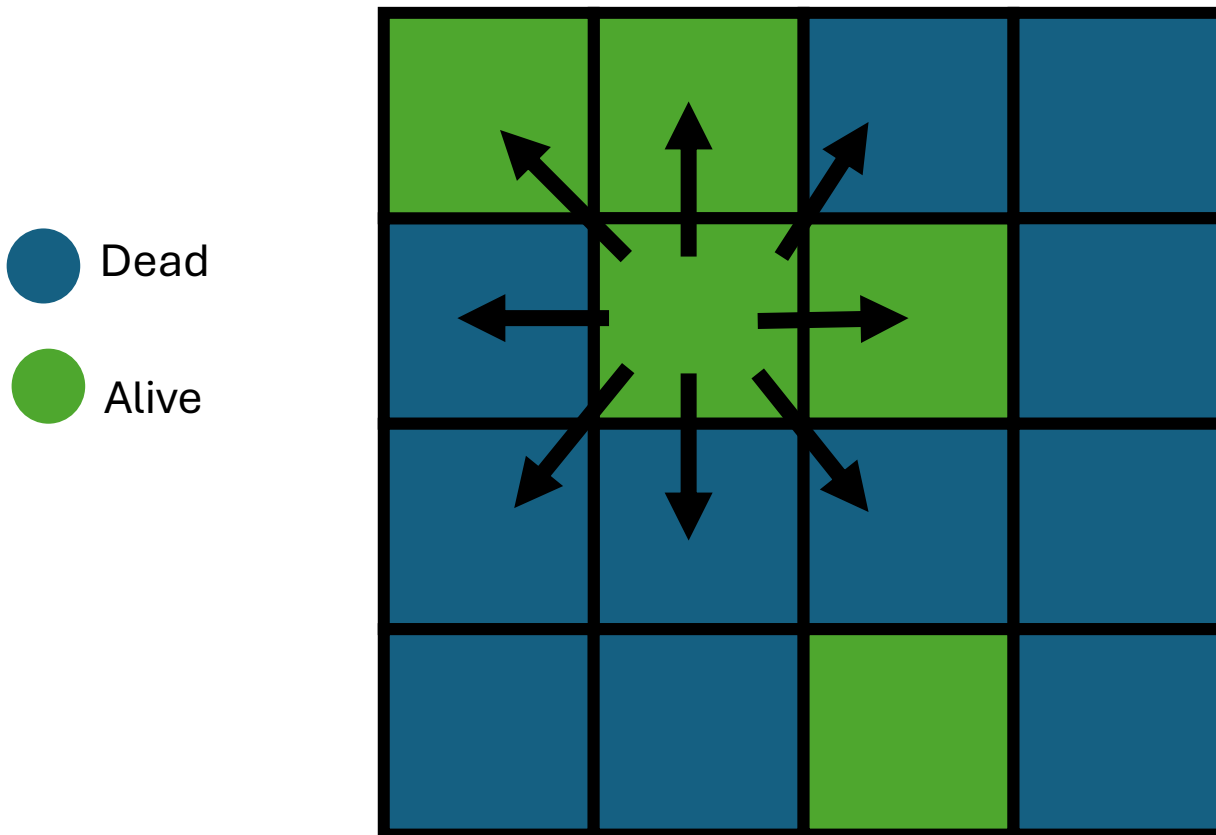
Conway's Game of Life (I)

- Perhaps most popular case of simplicity to complexity, which anyone can study
- **It is a cellular automaton**, so from computational theory.



John Conway
English mathematician at
Cambridge and Princeton
1937 - 2020

Conway's Game of Life (II)



Cell rules

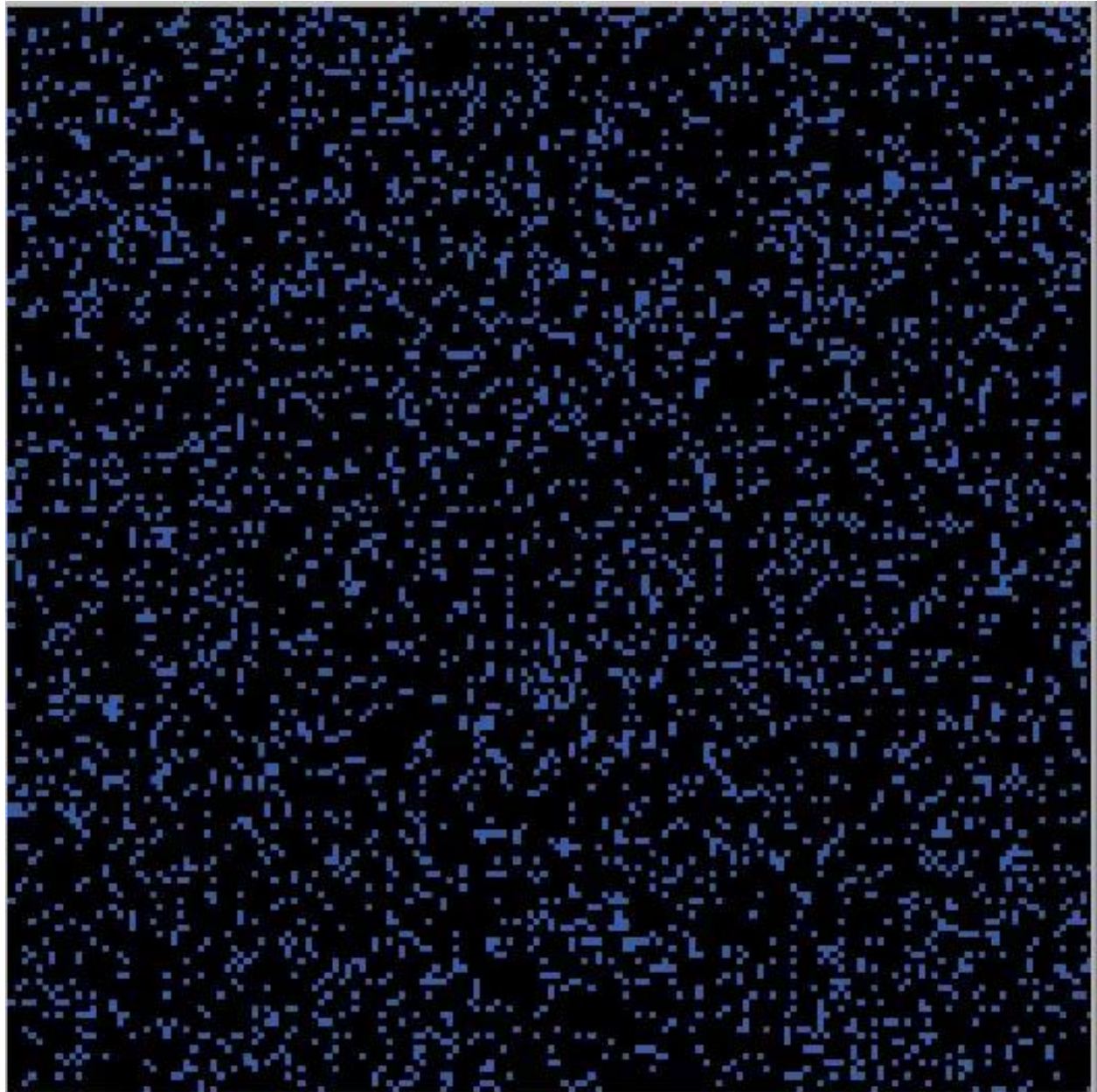
Live cell with < 2 neighbours $\rightarrow$ **dies** (underpopulation).

Live cell with **2–3** neighbours $\rightarrow$ **survives**.

Live cell with > 3 neighbours $\rightarrow$ **dies** (overcrowding)

Dead cell with **exactly 3** neighbours $\rightarrow$ **becomes live** (birth).

Life (III)



Why does this matter for economics?

Microeconomics assumes relatively sophisticated models

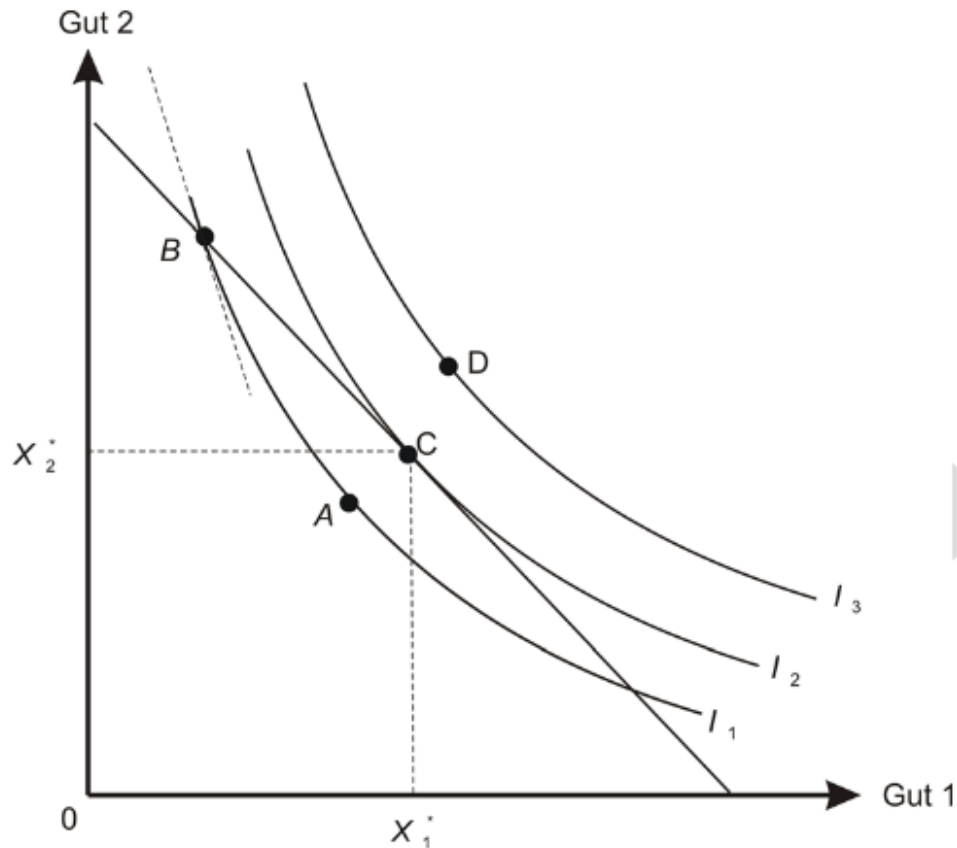


Abbildung (A 2.2-14): Die Auswahl des optimalen Güterbündels

Lagrange formalism

$$U = U(X_1, X_2, \dots, X_n) \text{ und} \\ B = P_1 X_1 + P_2 X_2 + \dots + P_n X_n.$$

$$\Lambda = U(X_1, X_2, \dots, X_n) + \lambda [B - P_1 X_1 - P_2 X_2 - \dots - P_n X_n].$$

$$\frac{\partial \Lambda}{\partial X_i} = U_i(X_1, X_2, \dots, X_n) - \lambda P_i = 0 \text{ für alle } i \in \{1, \dots, n\}.$$

$$\frac{\partial \Lambda}{\partial \lambda} = B - (P_1 X_1 + P_2 X_2 + \dots + P_n X_n) = 0.$$

***But simple rules can
sometimes explain a lot.***

The statistical mechanics of money paper (I)

Statistical mechanics of money

Adrian Drăgulescu and Victor M. Yakovenko*

Department of Physics, University of Maryland, College Park, MD 20742-4111, USA
(cond-mat/0001432, final version 4, August 4, 2000, to be published in Eur. Phys. J. B)

In a closed economic system, money is conserved. Thus, by analogy with energy, the equilibrium probability distribution of money must follow the exponential Boltzmann-Gibbs law characterized by an effective temperature equal to the average amount of money per economic agent. We derive



Journal of Economic Behavior & Organization

Volume 229, January 2025, 106820



Agent-based models of the United States wealth distribution with Ensemble Kalman Filter

Yannick Oswald ^a , Keiran Suchak ^b, Nick Malleson ^b

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The statistical mechanics of money paper (II)



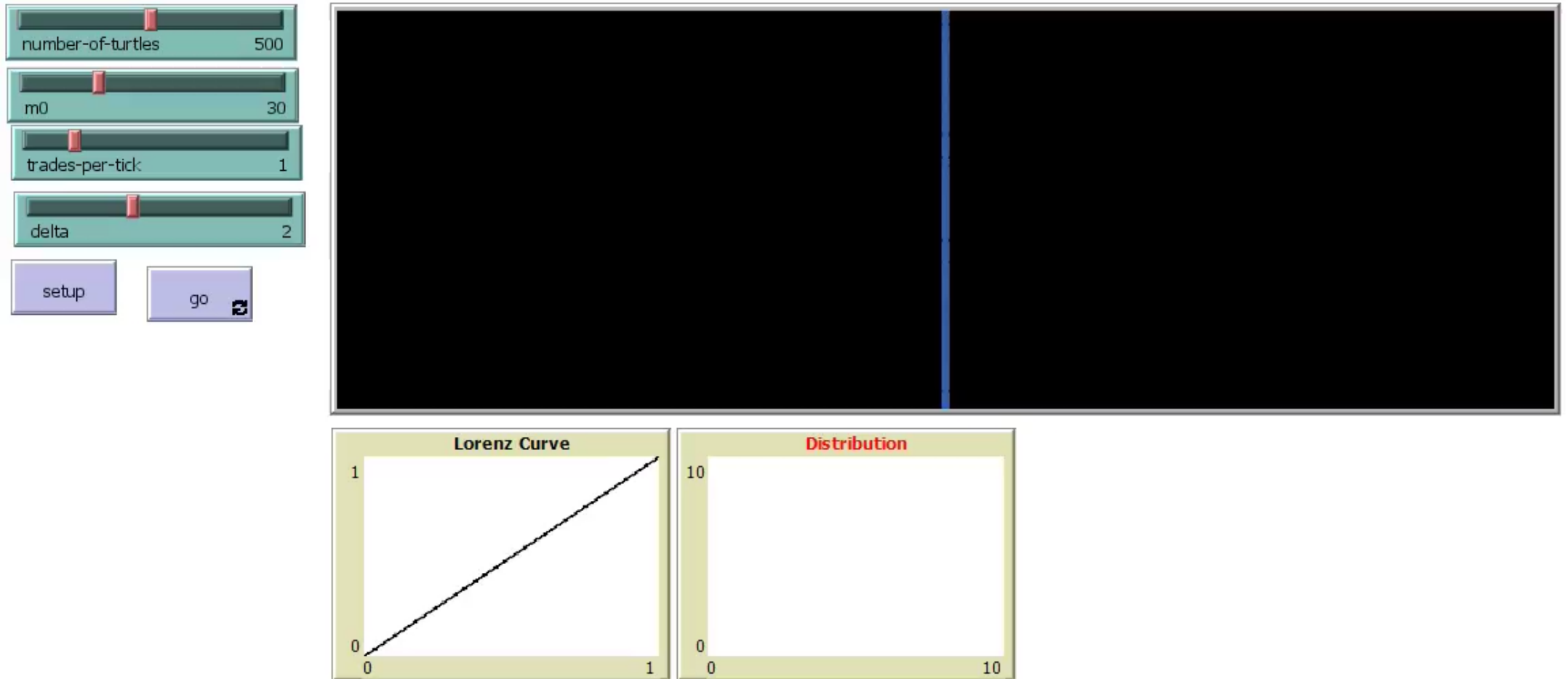
Pick distinct agents $i \neq j$ uniformly at random

choose the payer uniformly from $\{i, j\}$

$$m_i(t+1) = m_i(t) - \Delta$$

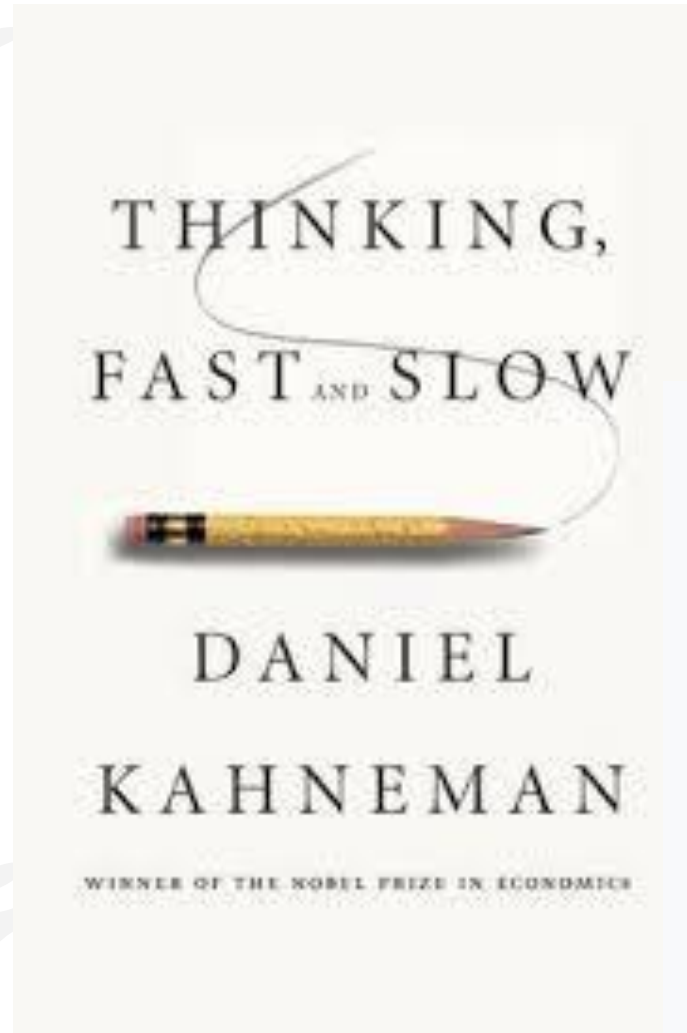
$$m_j(t+1) = m_j(t) + \Delta$$

The statistical mechanics of money paper (III)

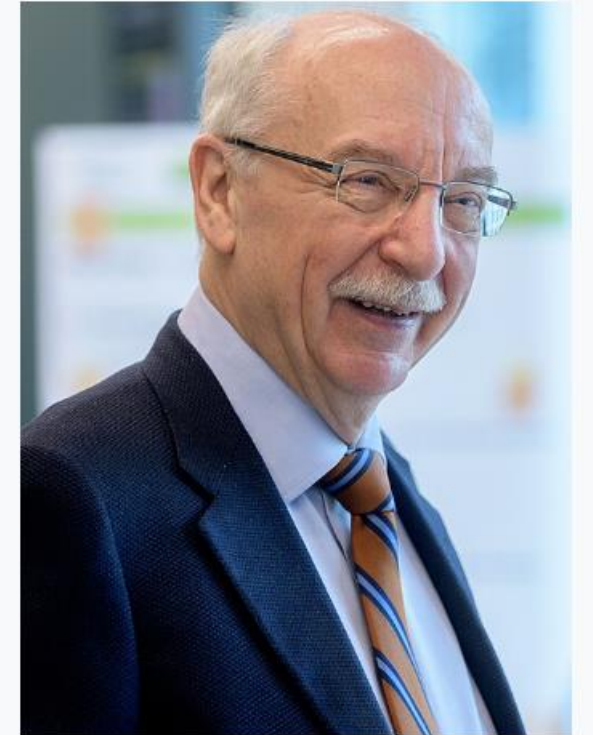


**Simple decision
rules may relate
well to behavioural
economics**

heuristics matter



Gerd Gigerenzer



A tool of choice – agent-based modelling (ABM)

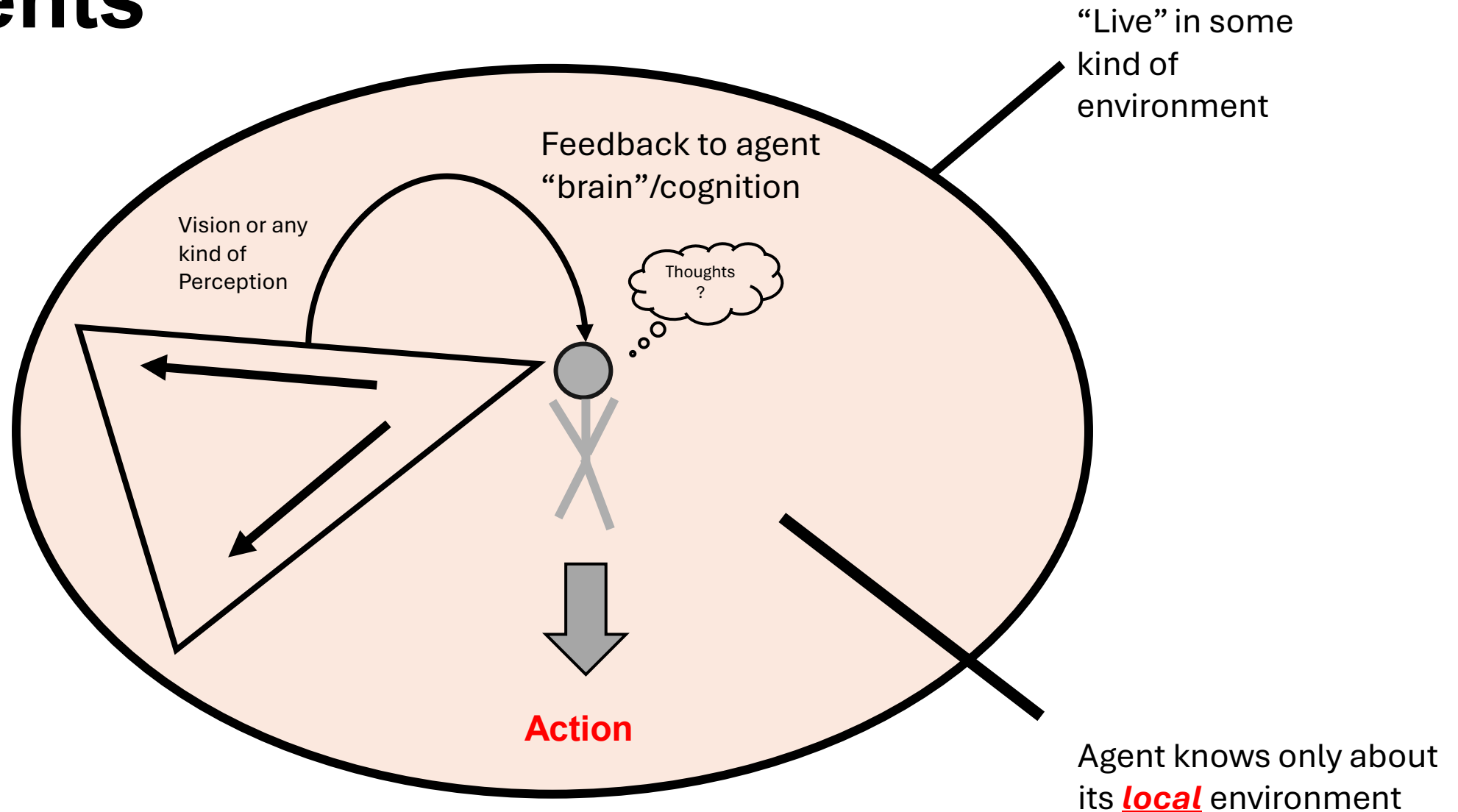
Agent-Based Modeling in Economics and Finance: Past, Present, and Future

Robert L. Axtell

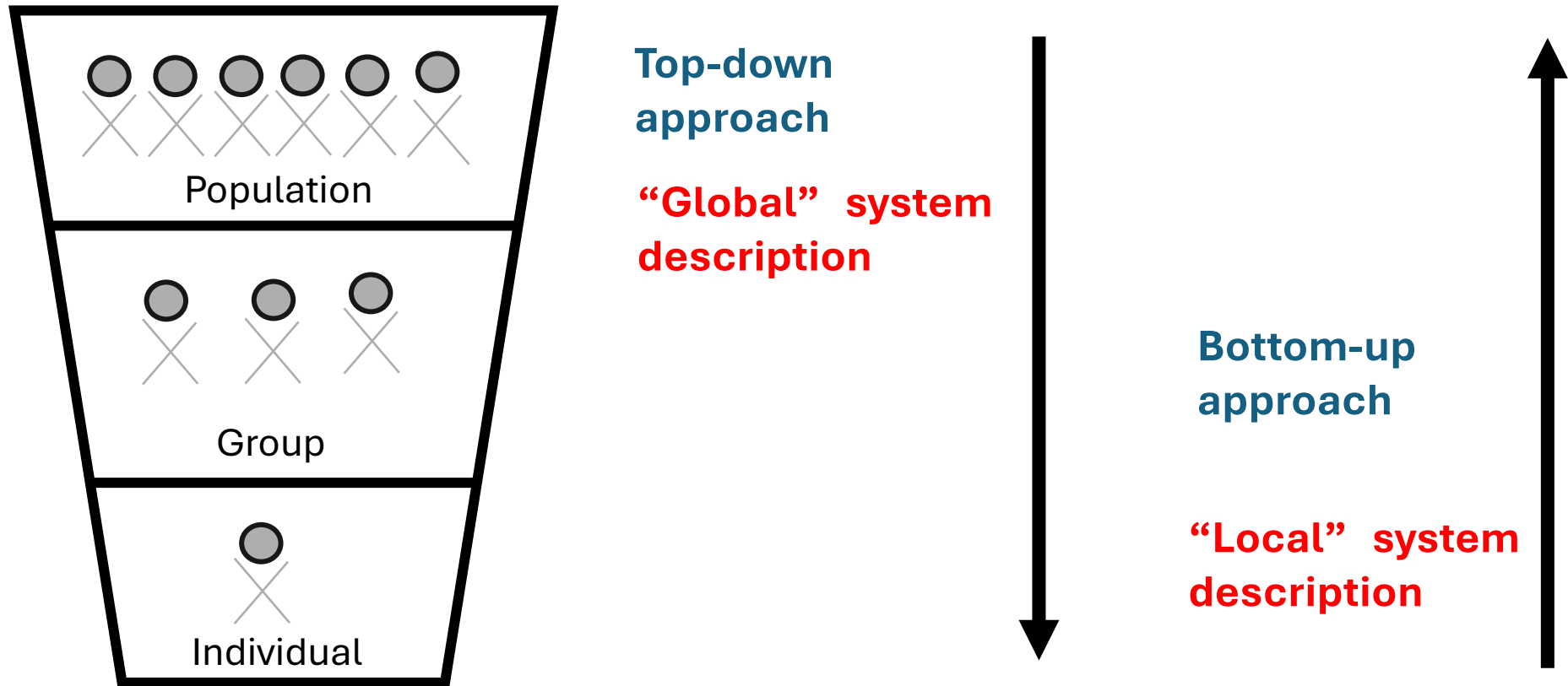
J. Doyne Farmer

JOURNAL OF ECONOMIC LITERATURE
VOL. 63, NO. 1, MARCH 2025
(pp. 197–287)

Agents



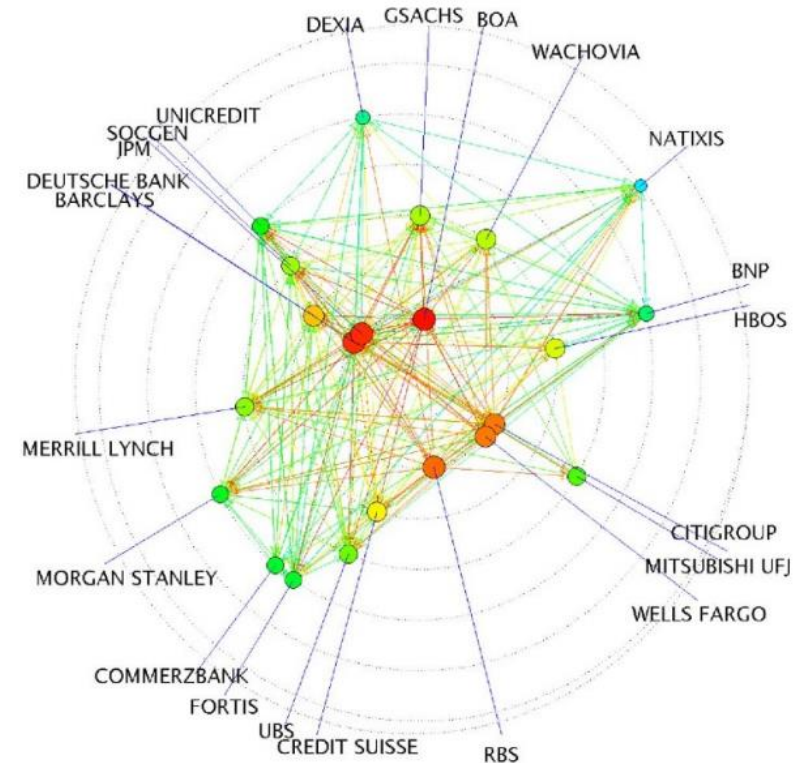
ABM is bottom-up modelling and can combine Macro and Micro



The other big idea – chaos

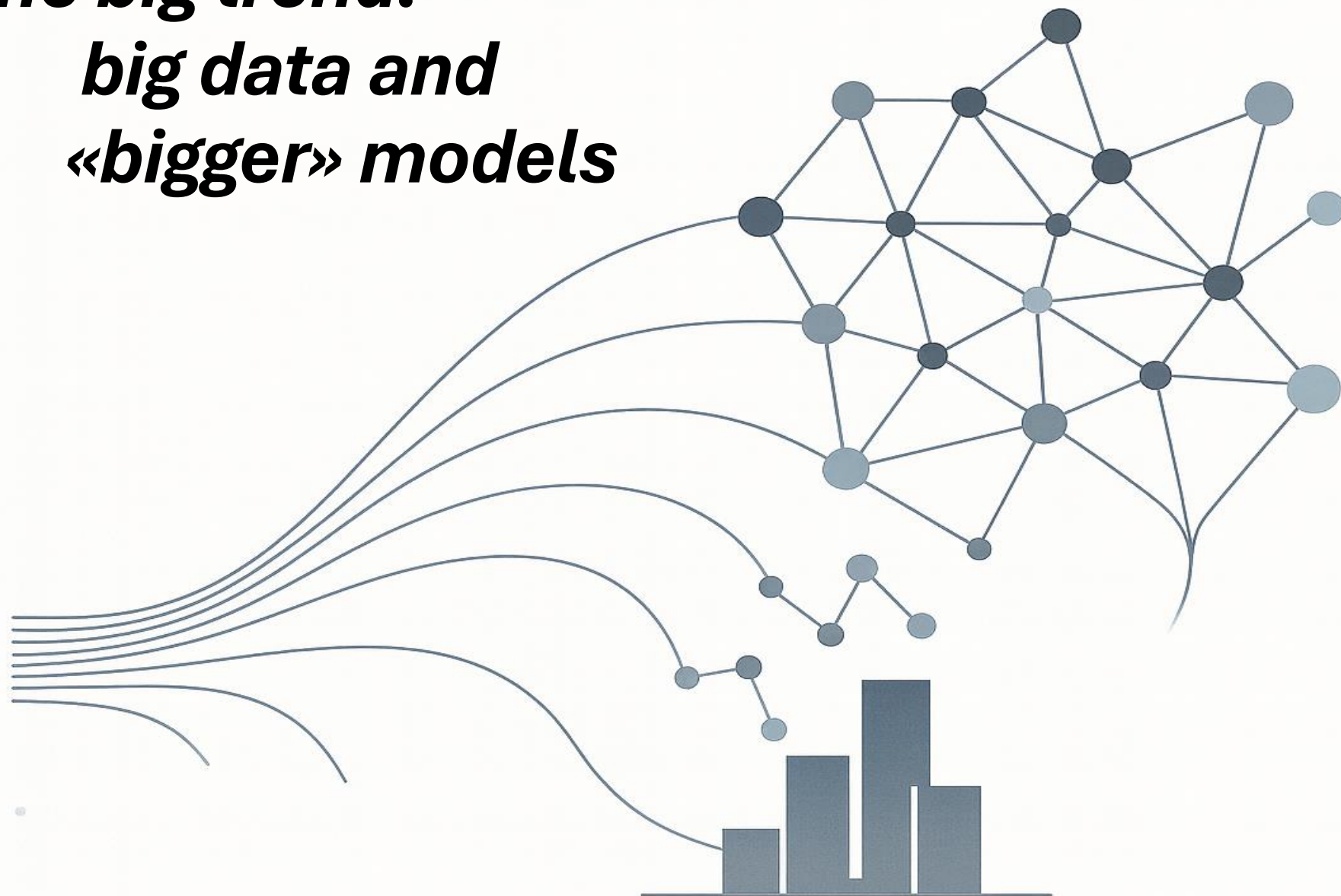


Butterfly effect
(A butterfly can cause a tornado)



From: Battiston, S., Puliga, M., Kaushik, R. *et al.* DebtRank: Too Central to Fail? Financial Networks, the FED and Systemic Risk. *Sci Rep* 2, 541 (2012). <https://doi.org/10.1038/srep00541>

The big trend: big data and «bigger» models



So what do we take from Complexity Economics Normatively?

- **Chaos →**

Interventions with caution, expect the unexpected

- **Simplicity & Emergent Complexity → ???**

Ecological Complexity Economics?

**Testing radical changes to society,
respecting planetary boundaries,
but with complexity methods**

Artificial Utopia

=

**Radically reimagine
but also radically rigorous**



Futures

Volume 174, December 2025, 103695



Artificial Utopia: Simulation and artificially intelligent agents for exploring Utopian and democratized futures

Yannick Oswald

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<https://doi.org/10.1016/j.futures.2025.103695>

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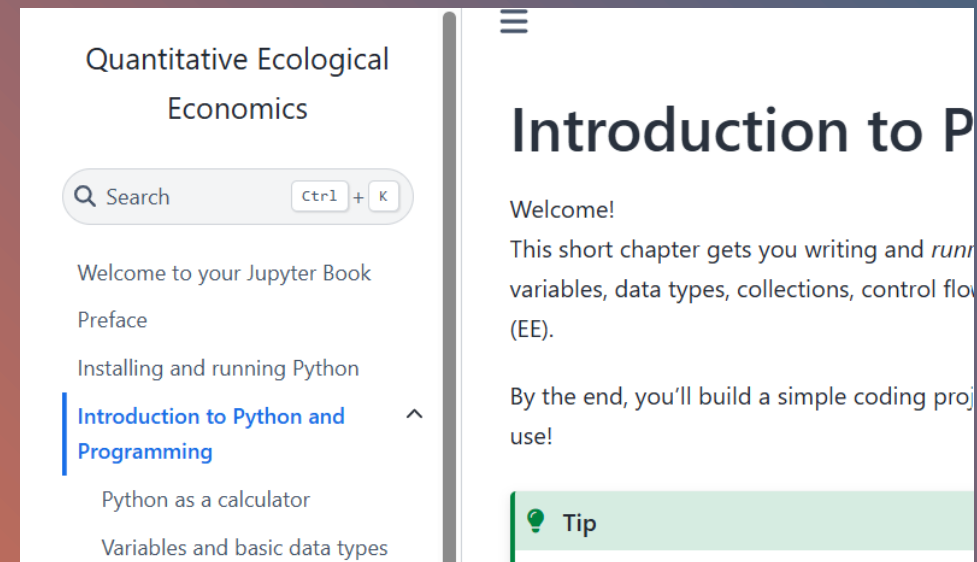
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Highlights

- Introduces Artificial Utopia to explore alternative democratic futures

– my own attempt at rethinking economics



<https://yannickoswald.github.io/ecoeconbook/intro.html>

Thank you!