Oxford
27 November 2008

Escaping the Last Malthusian Trap

A talk by
Eric Beinhocker
McKinsey Global Institute

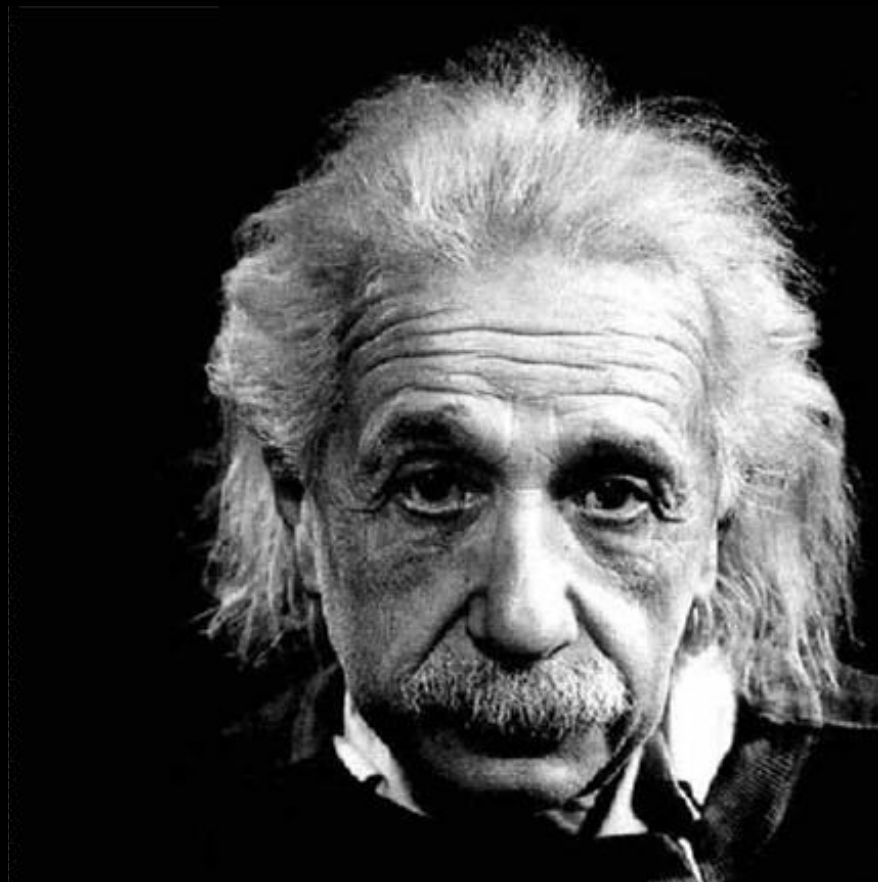
Complex systems, climate change and economic growth

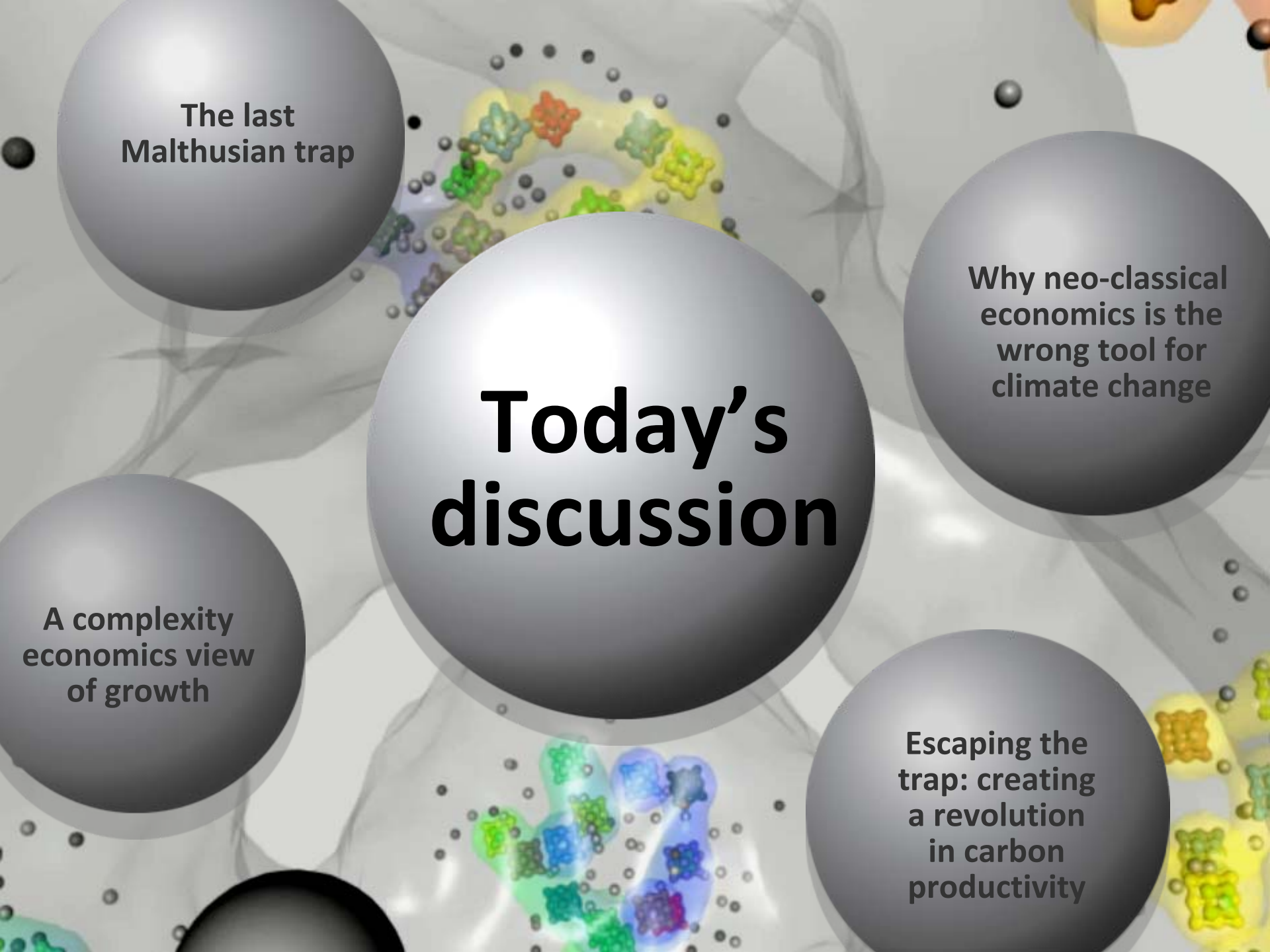
‘The ideas of economists and political philosophers, both when they are right and when they are wrong, are more powerful than is commonly understood. Indeed, the world is ruled by little else.’

JOHN MAYNARD KEYNES

‘We cannot solve problems by using the same kind of thinking we used when we created them.’

ALBERT EINSTEIN




The last Malthusian trap
Why neo-classical economics is the wrong tool for climate change
Today's discussion
A complexity economics view of growth
Escaping the trap: creating a revolution in carbon productivity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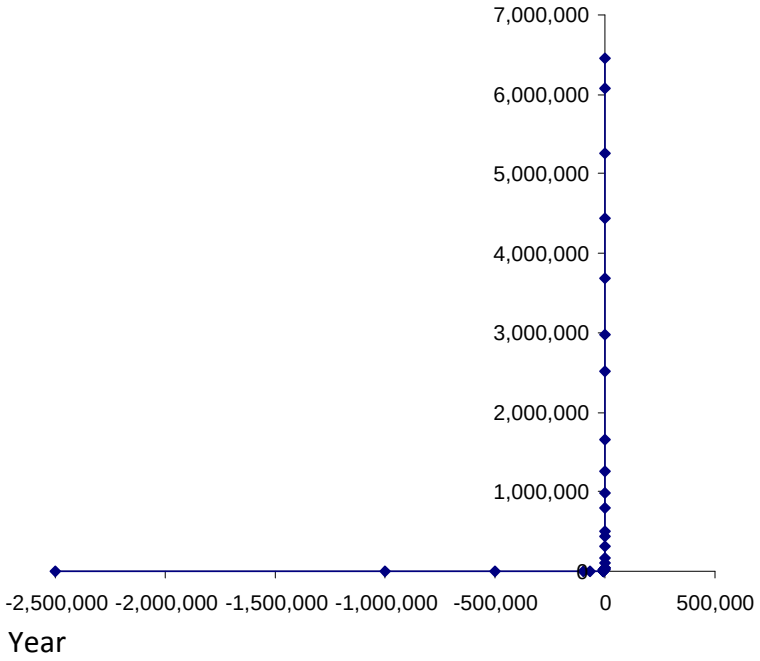
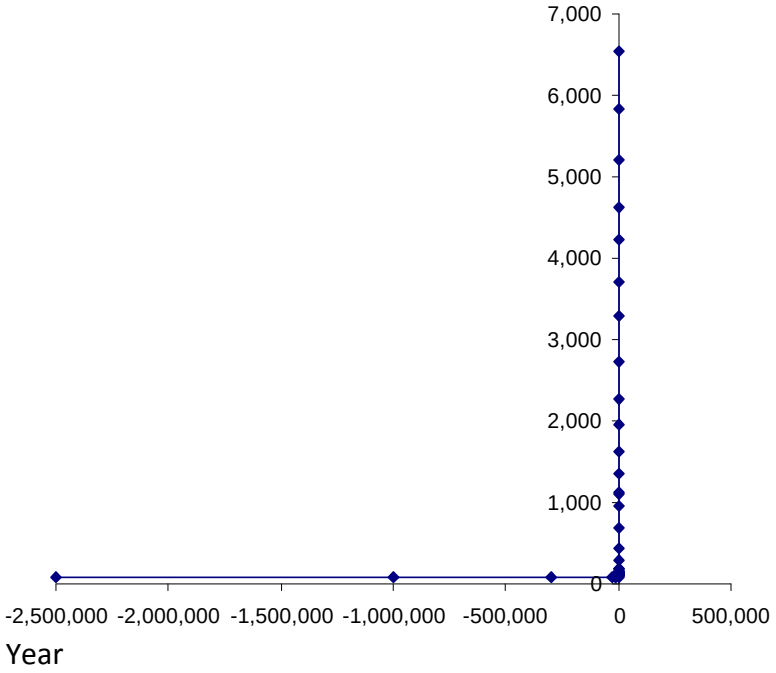
Some 2.5 million years of economic history (in brief)

World population
Thousands



Source: US Census Bureau Historical Estimates of World Population; Kremer (1993)

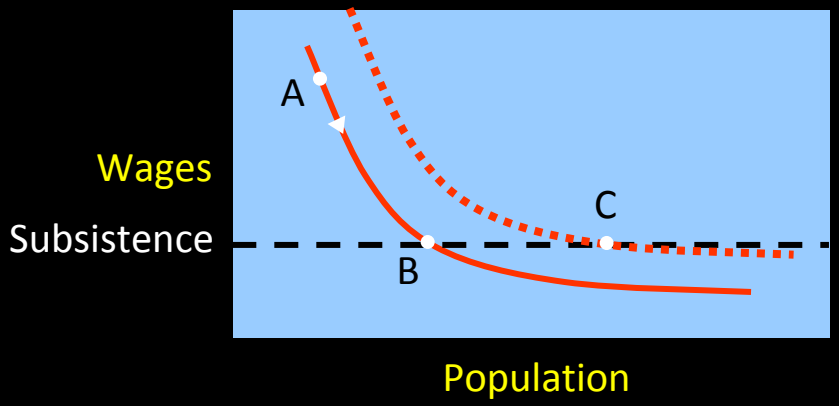
World GDP per capita
1990 international dollars



Source: DeLong (2005); data 2.5 million to 1 million B.C. extrapolated

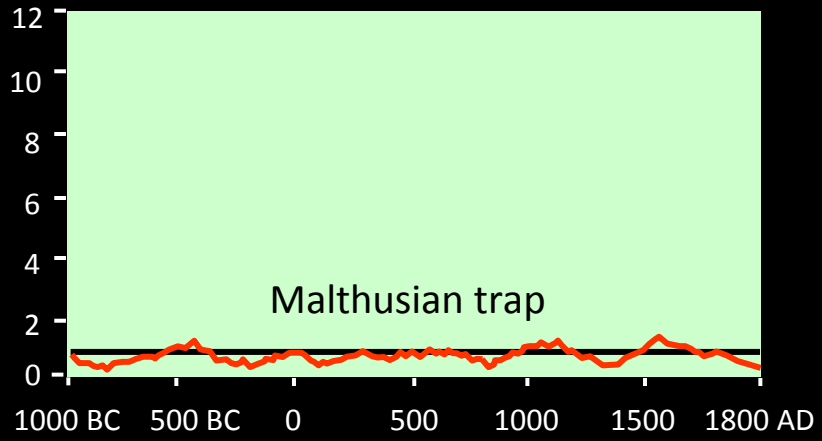
The Malthusian trap (circa 1000 BC to 1800 AD)

Malthus in a nutshell



Stagnant incomes

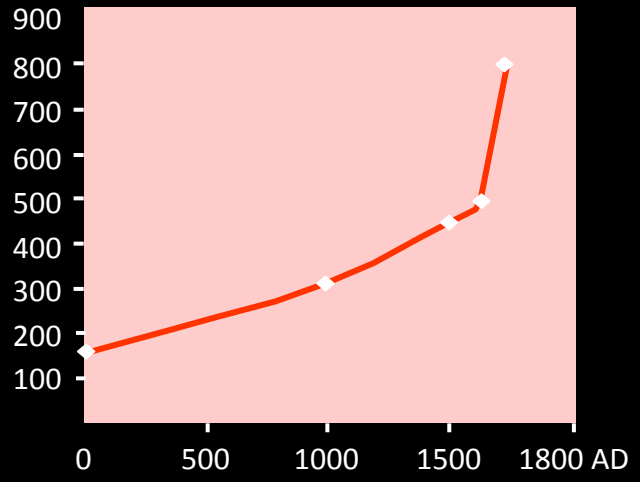
Global income per person (1800 AD = 1)



Source: Clark (2007)

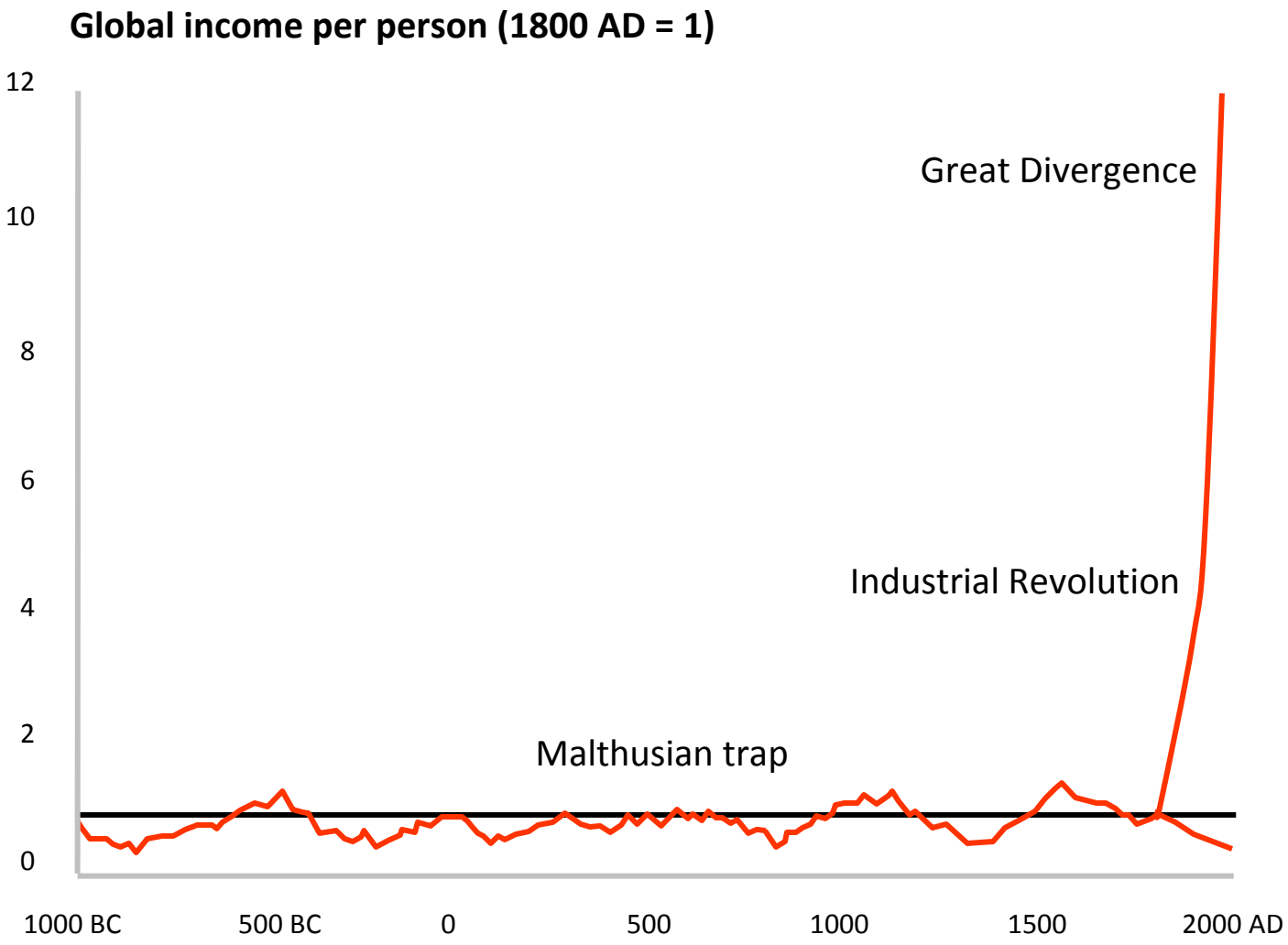
Rising population

Thousands



Source: US Census Bureau Historical Estimates of World Population; Kremer (1993)

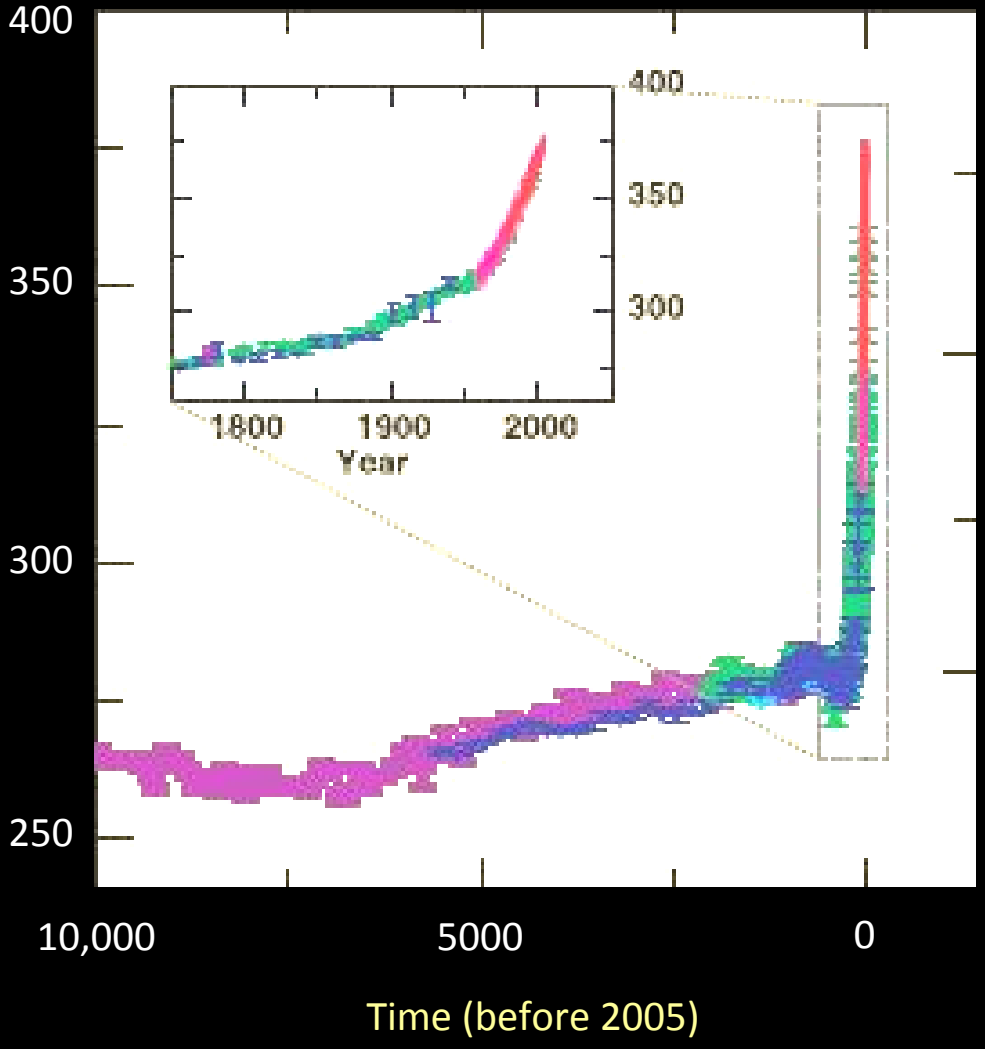
Then a third of the world escaped …



Source: Clark (2007)

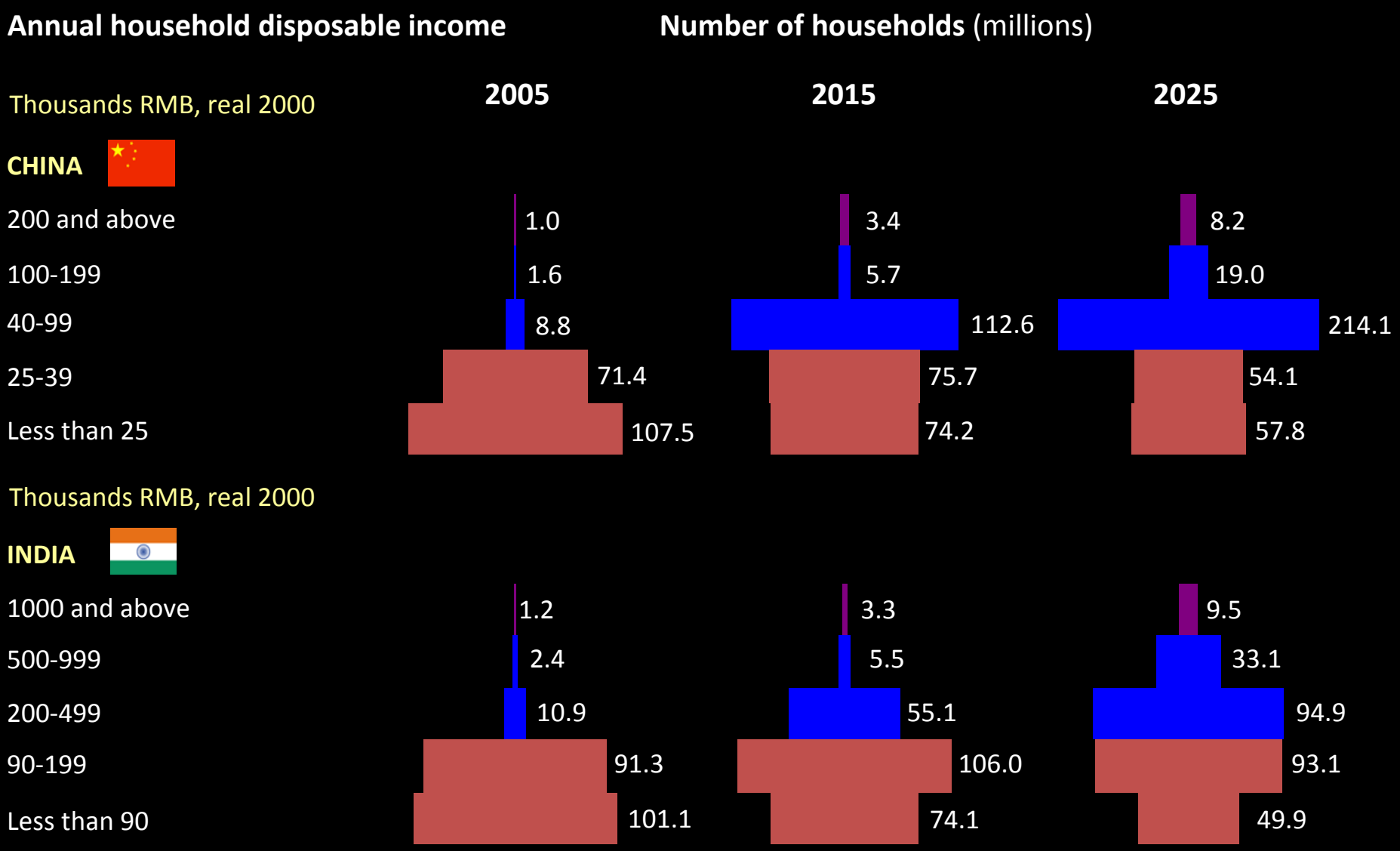
… but with an unsustainable growth model …

Changes in greenhouse gases from ice core and modern data



Source: IPCC AR4 WG1 (2007)

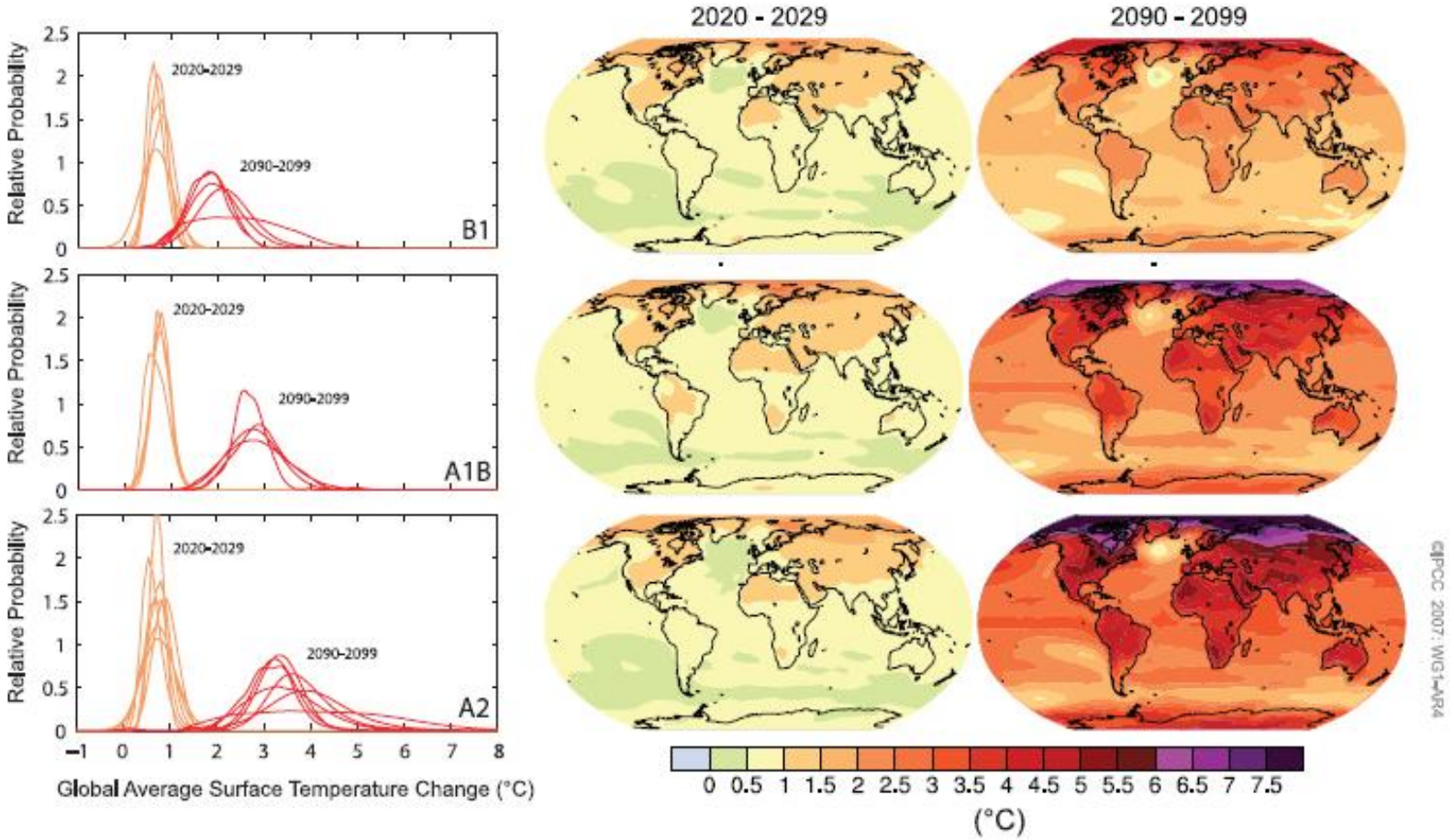
… and another third of the world are poised to escape



Source: McKinsey Global Institute

Humanity's next, and perhaps last, Malthusian trap

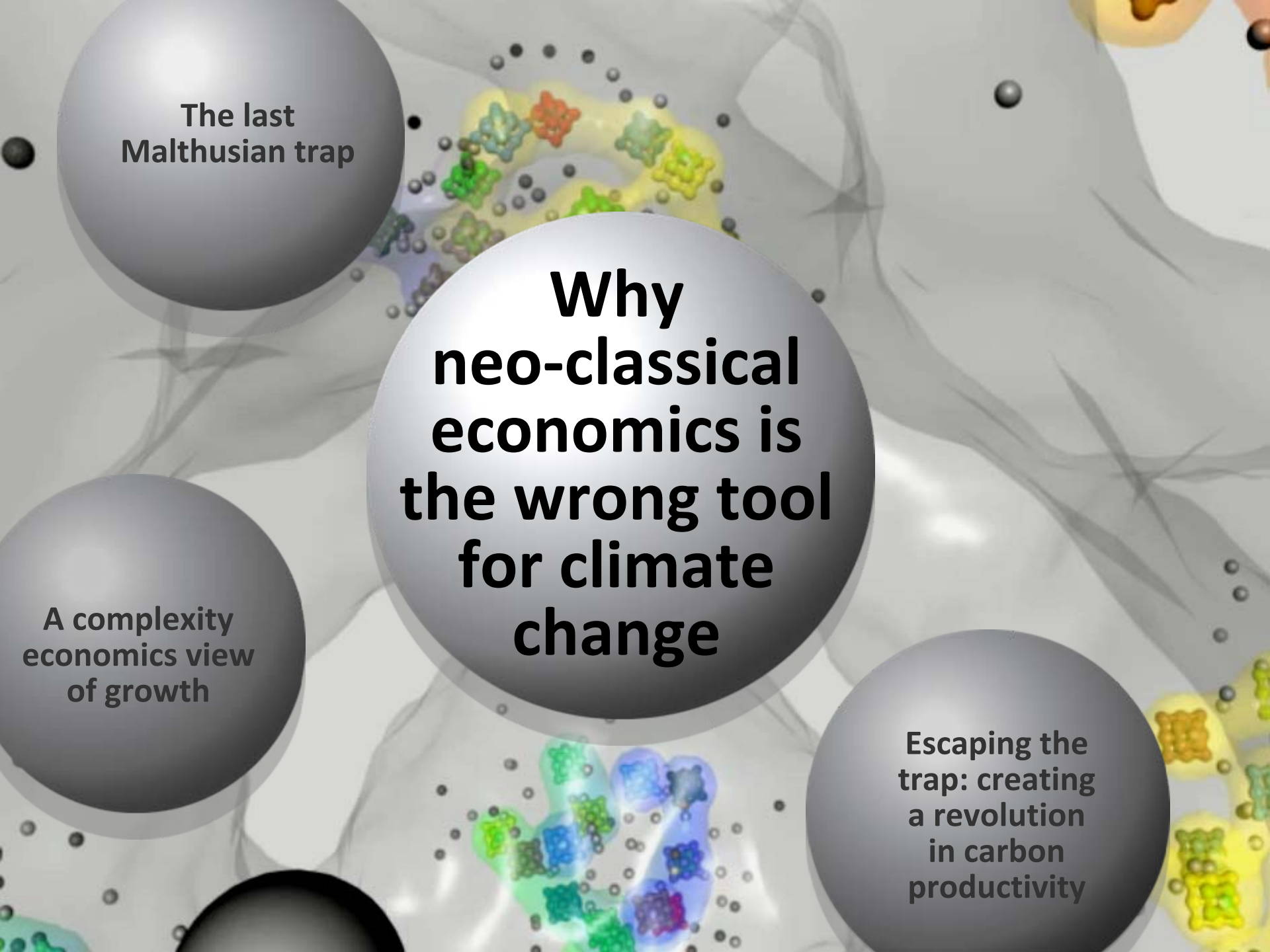
Projection of surface temperatures



Source: IPCC AR4 WG1 (2007)

What we need to do, and where economics can help

The world's to-do list	**Questions for economics**
Re-do the Industrial Revolution, creating a sustainable economic system	How did the first Industrial Revolution occur? How might we create a new one?
Transition to a low-carbon economy with minimal impact on welfare and growth, especially for the developing world	What are the interactions between welfare, growth and de-carbonisation? How do we assess the trade-offs?
Drive the above with policy – conduct global social engineering on an unprecedented scale	What are the leverage points? How do we avoid unintended consequences?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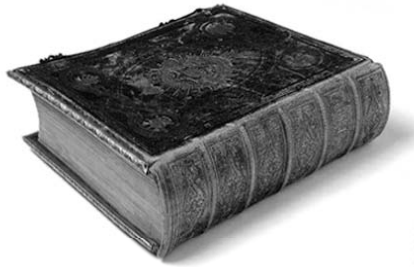
Neoclassical economics cannot explain key characteristics of the economy

The economy is viewed as an equilibrium system

The economy is viewed as an equilibrium system but such a system cannot grow explosively, create novelty, nor spontaneously self-organize

The accidental history of equilibrium in economics

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



LÉON WALRAS
(1834-1910)

THE ELEMENTS
OF STATIC
BY LOUIS POINSOT (1803)

WILLIAM STANLEY JEVONS
(1835–1882)

Neoclassical failure #1: Theory of growth

$$Y_{(t)} = F\,(K_{(t)}, A_{(t)} * L_{(t)})$$

Output — Capital — Knowledge — Labour

Cannot explain the Industrial Revolution

No connection with the physical world

Source: Bolow (1956), Romer (1996), Nelson (1996), Daly (1999)

Neoclassical failure #2: Cost-benefit analysis

Prof. William Nordhaus

‘Discount rate!’

Lord (Nicholas) Stern

Weitzman’s ‘Dismal Theorem’:

For any given ***n*** and ***k***, $\lim_{\lambda \to \infty} E[M/\lambda] = +\infty$

Uncertainty about climate has fat tails with power law scaling

Cost benefit analysis doesn’t work

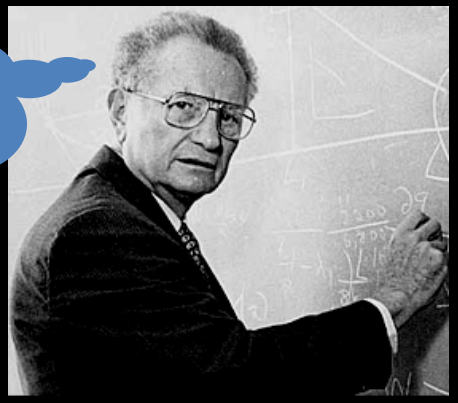
Would pay a lot to avoid catastrophe

Source: Stein (2006), Nordhaus (2007), Weitzman (2007), Barker (2008)

Neoclassical failure #3: Human behaviour

Theory doesn't match real world behaviour

Exponential discounting



Hyperbolic discounting

Example

Society spends $1 billion today to save 10 lives per year in perpetuity
Social cost of capital equals 5%

Exponential answer
Cost = $4.76 million per life saved

Hyperbolic answer
Cost = $1 million to $4 million per life saved

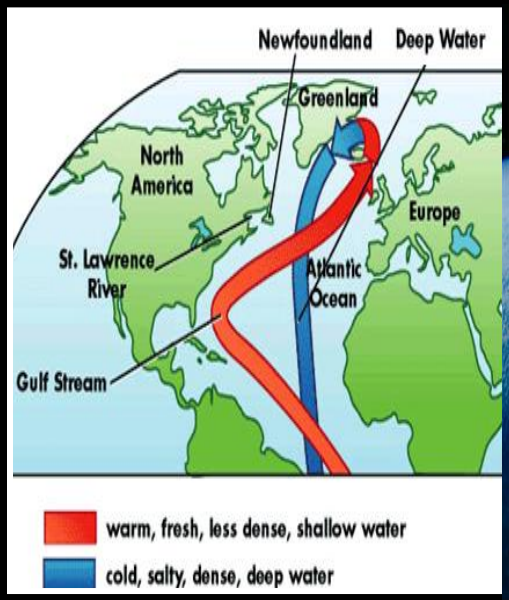
Source: Axtell and McRae (2006a), (2006b)

Neoclassical failure #4: Time symmetry

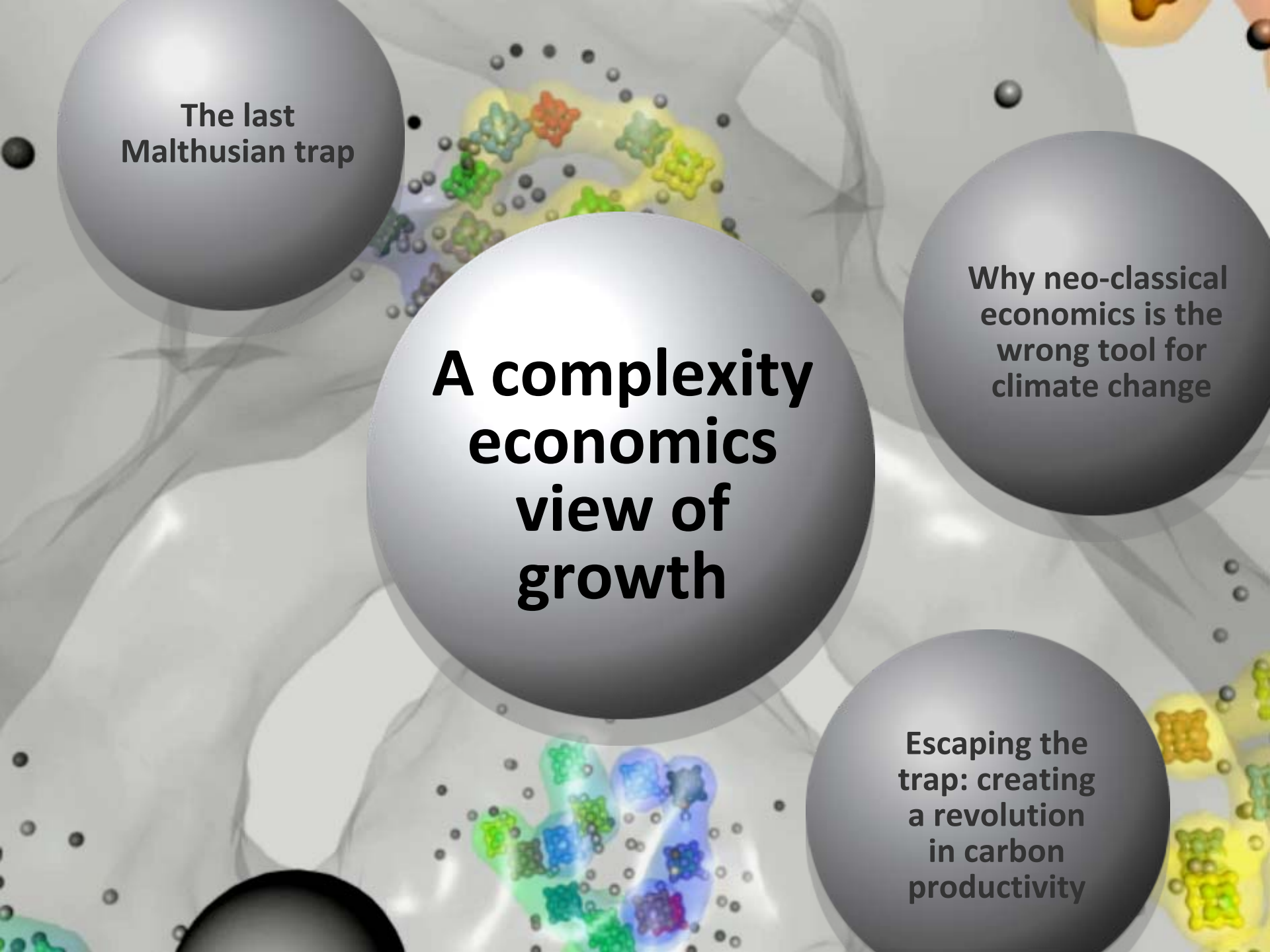
Cost-benefit analysis and discounting assume path independence and time symmetry

Samuelson : MRS (τ , τ ') independent of C τ ''

But climate effects are highly path dependent and largely irreversible on human time scales



Source: Arrow and Fischer (1974), Frederich, Lowenstein, Donohue (2002), Dietz (2007)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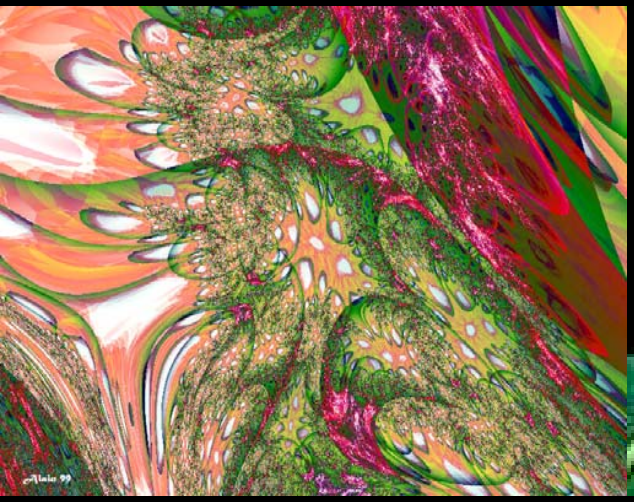
A different explanation – the economy is a ‘complex adaptive system’

Complex



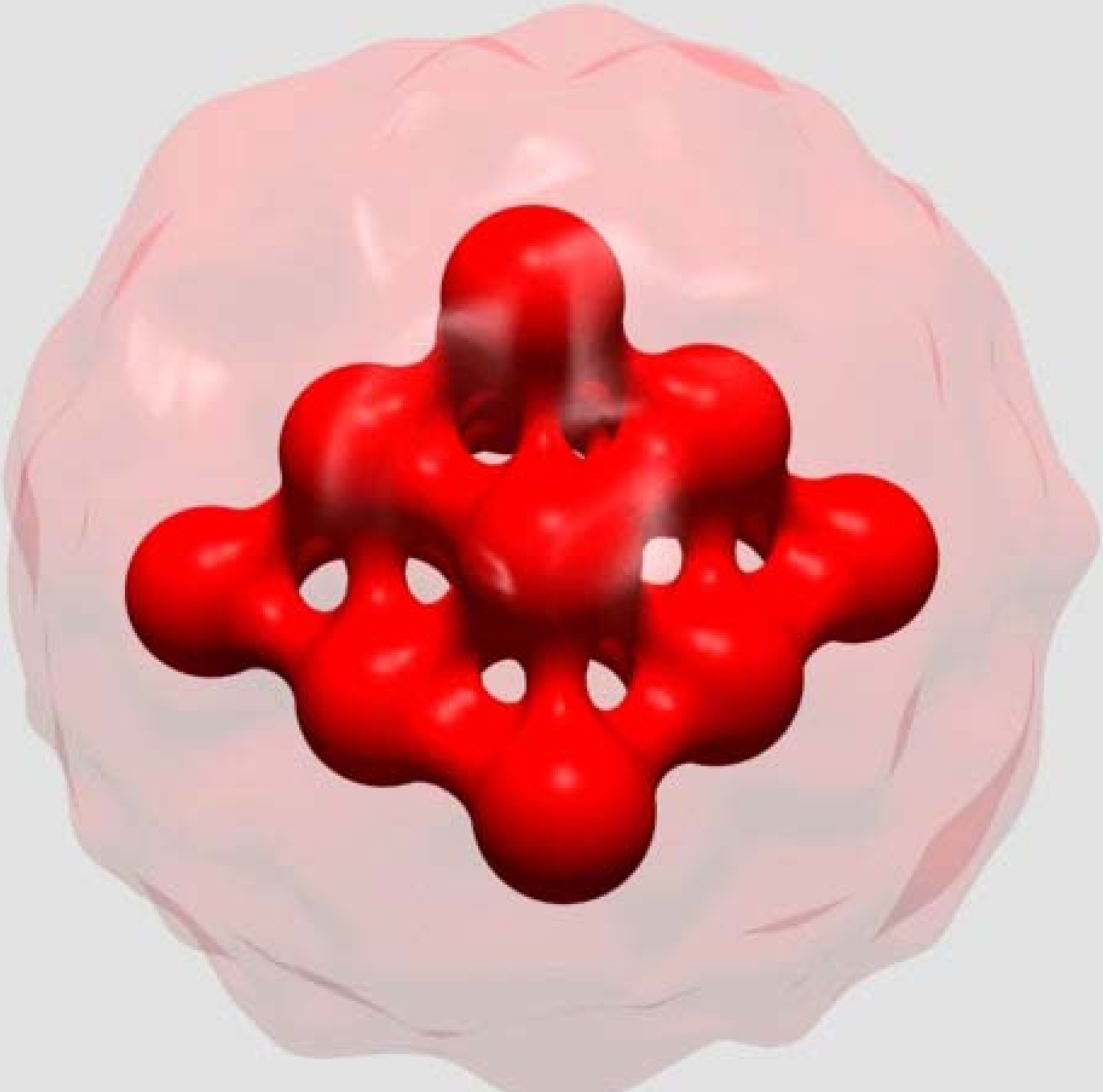
Many interacting agents and organizations of agents

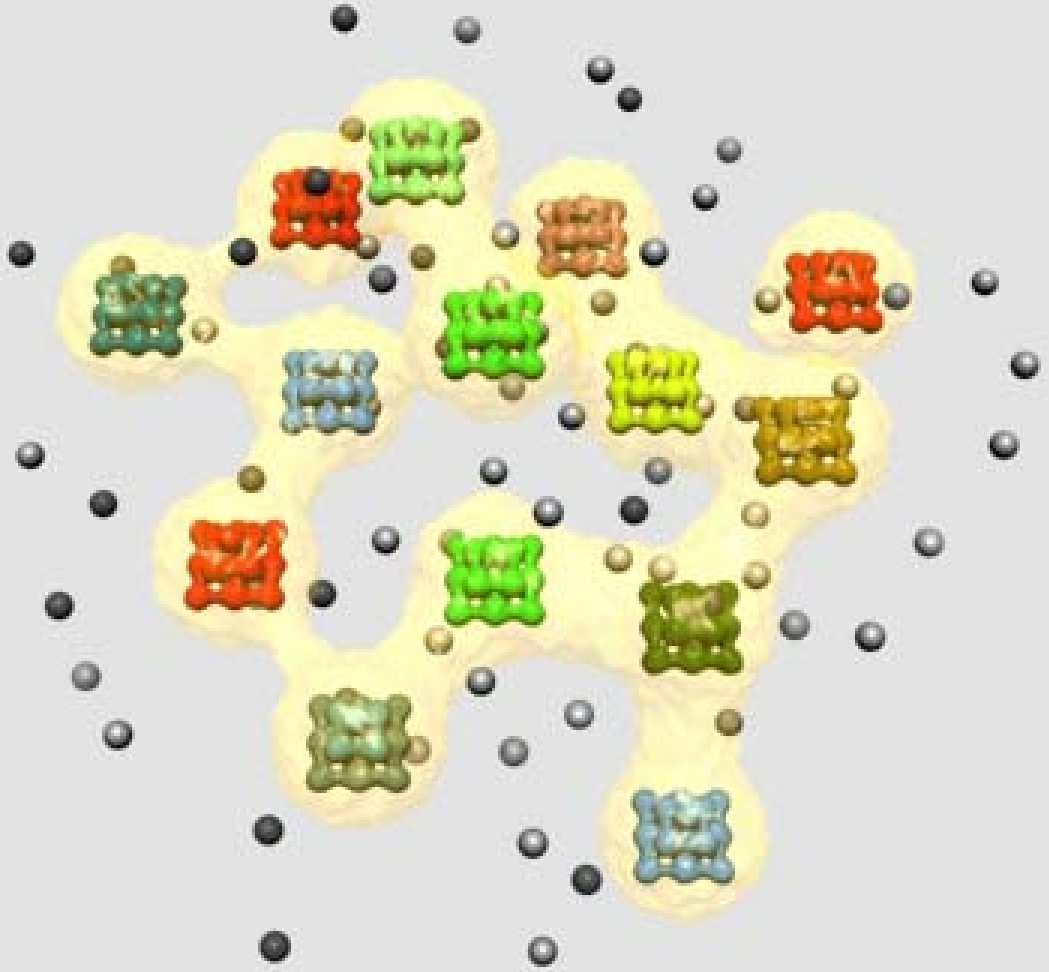
Adaptive

Designs and strategies evolve over time

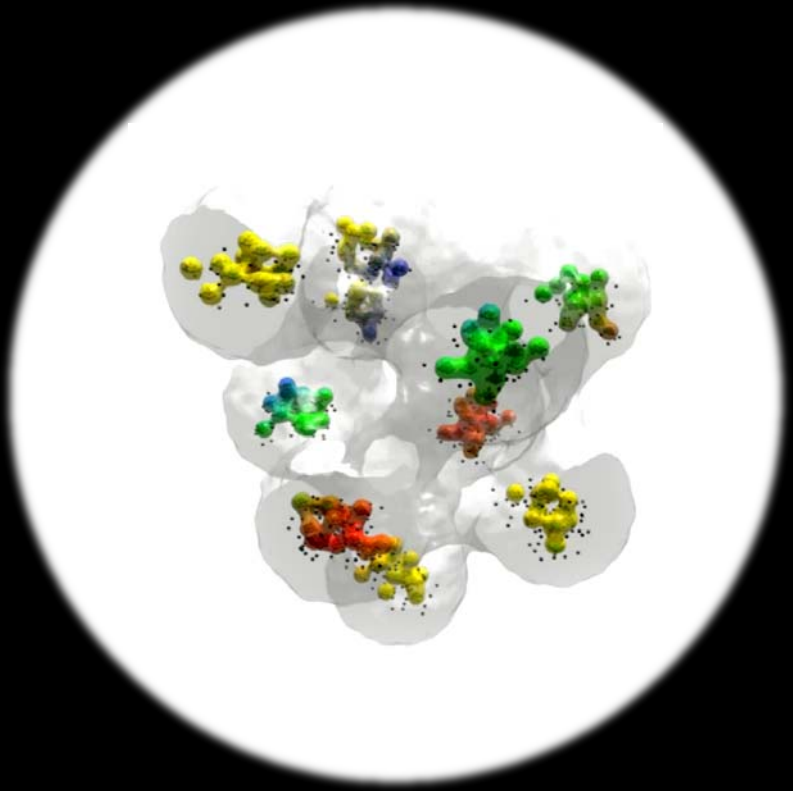
System

Macro patterns emerge from micro behavior





Traditional economics versus complexity economics



A paradigm shift

	TRADITIONAL ECONOMICS	COMPLEXITY ECONOMICS
Dynamics	Economies are closed, static, linear systems in equilibrium	Economies are open, dynamic, non-linear systems far from equilibrium
Agents	Homogeneous agents • Only use rational deduction • Make no mistakes, have no biases • No need to learn	Heterogeneous agents • Mix deductive/inductive decisions • Subject to errors and biases • Learn and adapt over time
Networks	Assume agents only interact indirectly through market mechanisms	Explicitly accounts for agent-to-agent interactions and relationships
Emergence	Treats micro and macroeconomics as separate disciplines	Macro patterns emerge from micro behaviors and interactions
Evolution	No endogenous mechanism for creating novelty or growth in order and complexity	Evolutionary process creates novelty and growing order and complexity over time

Source: Beinhocker (2006)

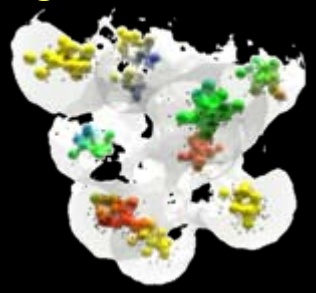
Complex economic systems use energy to decrease local entropy, create ‘fit order’

Energy inputs

Fossil fuels

Calories

Agents interacting

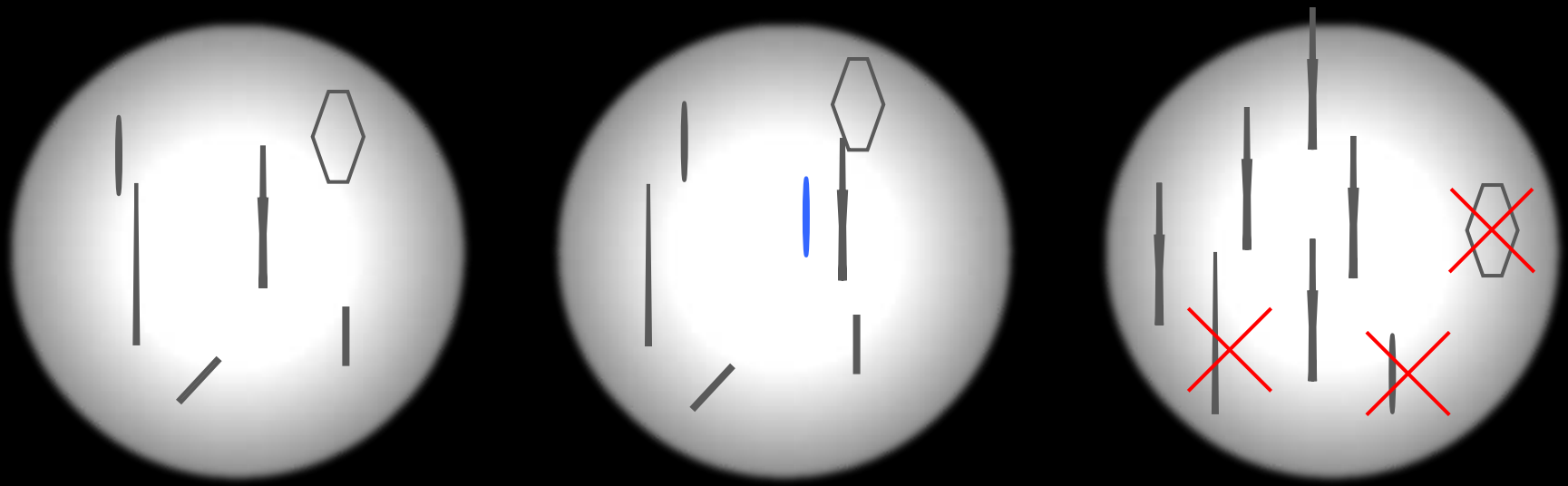


Disordered outputs:
Waste products, heat, gases
(entropy universally increased)

Ordered outputs:
Goods and services
(entropy locally decreased)

“Economic activity is fundamentally an order creating process” *(Georgescu-Roegen)*

Evolution is a search algorithm for ‘fit order’



VARIATION

Create a variety of experiments

SELECTION

Select designs that are ‘fit’

AMPLIFICATION

Amplify fit designs,
de-amplify unfit designs

REPEAT

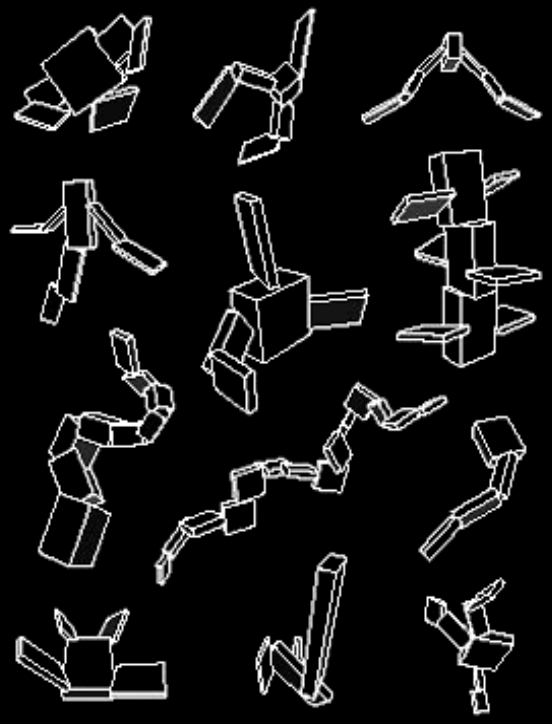
Long history of evolution in economics (and *vice versa*)

Problems

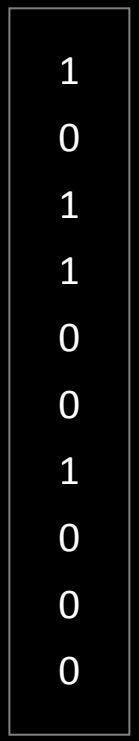
- Driven by a biological metaphor for the economy
- Not built on a general computational view of evolution

A general computational model of evolution

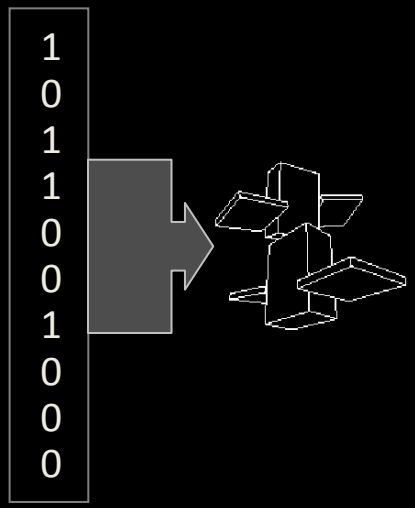
Design space



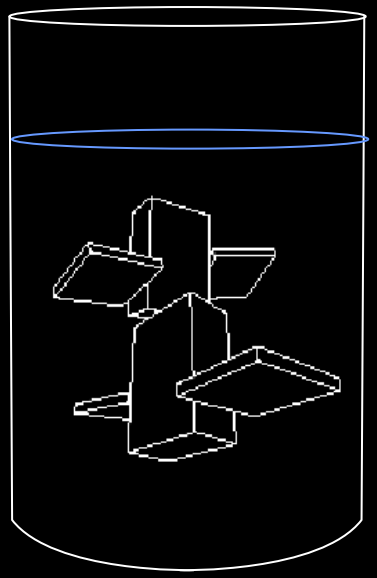
Schema



Schema reader-builder



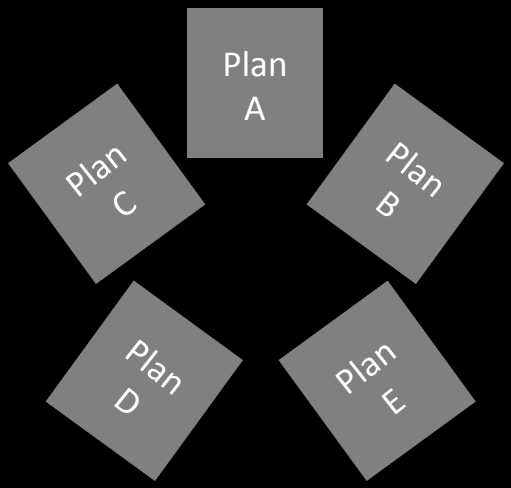
Environment



Source: E.g. Holland (1975), Mitchell (1996), etc.

A computational model of economic evolution

Design space



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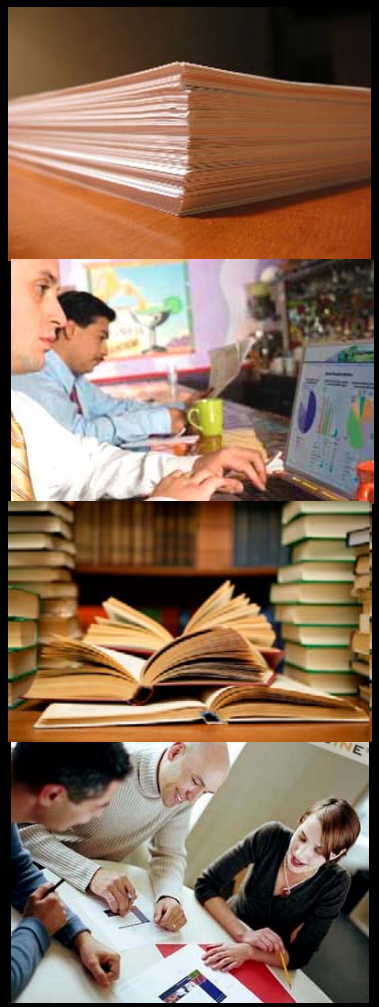
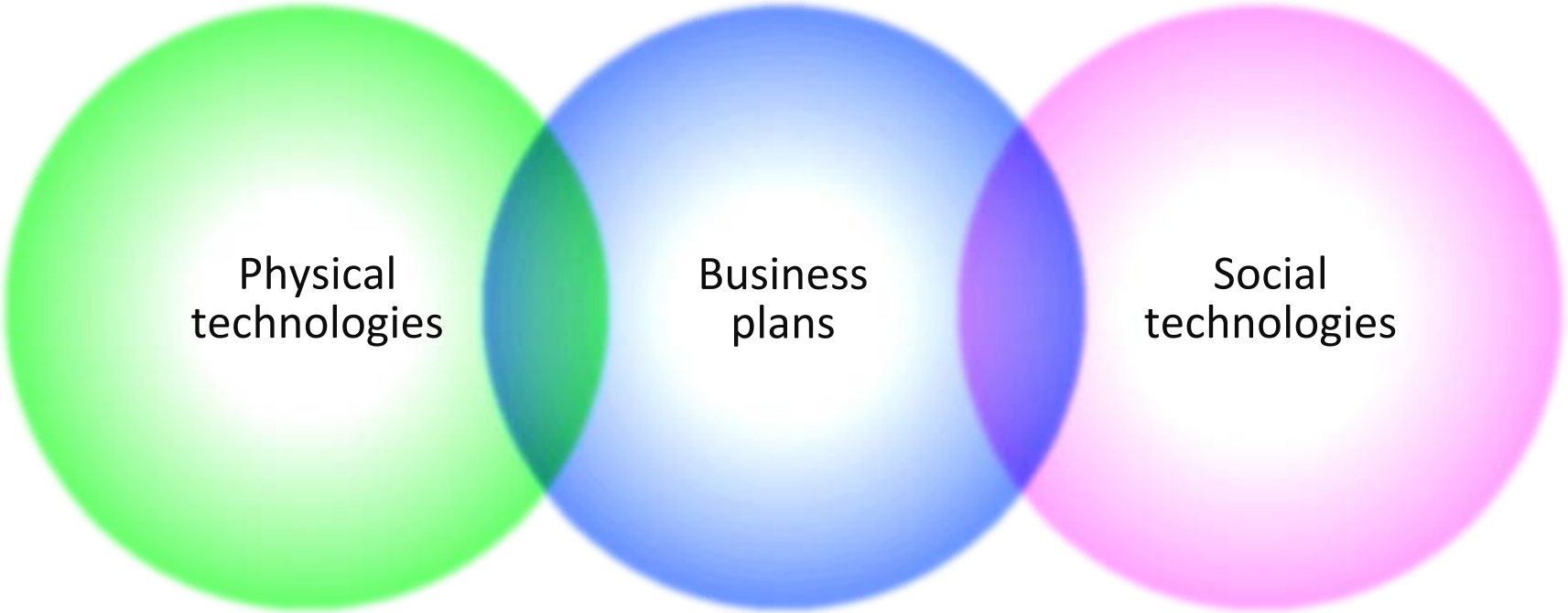


Schema reader-builder

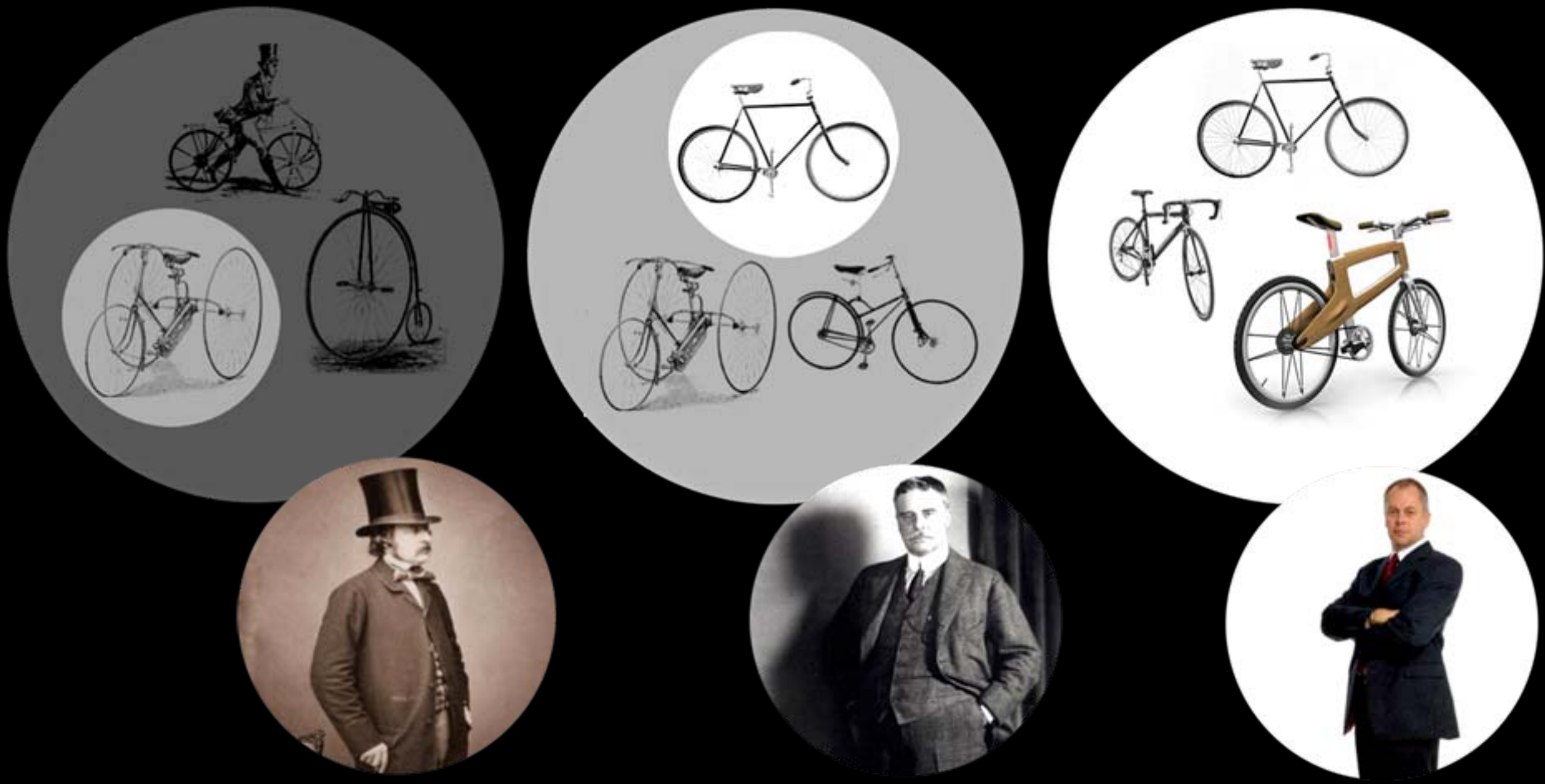
Source: Beinhocker (2006)

Economic evolution occurs in three ‘design spaces’



Source: Beinhocker (2006)

Evolutionary search through ‘deductive-tinkering’



Source: Beinhocker (2006)

Technologies evolve









Business plans are a form of ‘design’ too

BORDERS®

Strategy
Large selection book superstore
Suburban malls, urban centres
Enjoyable browsing experience

Social technologies
Organized by brand/geography
Values
Logistic systems

Physical technologies
Store design
Computers
Warehousing

intel®

Strategy
High-end microprocessors
Integrated chip sets
Chips/components

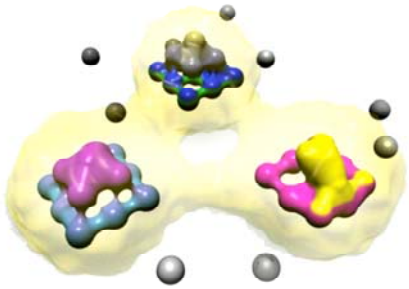
Social technologies
Innovation processes
Direct sales
Competitive culture

Physical technologies
Semiconductor design
Testing
Fabrication

Source: Beinhocker (2006)

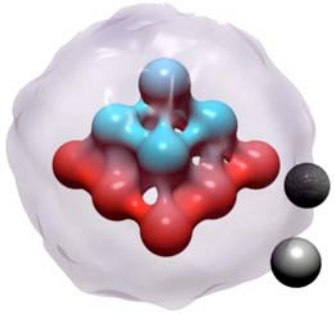
Business plan evolution works on three levels

Markets



- Business A
- Business B ???
- ~~Business C~~
- Business D ???

Organizations



- ~~Option A~~
- Option B
- ~~Option C~~
- ~~Option D~~

Individuals

- ~~Option A~~
- Option B ???
- Option C
- ~~Option D~~

Source: Beinhocker (2006)

What would economic evolution look like?

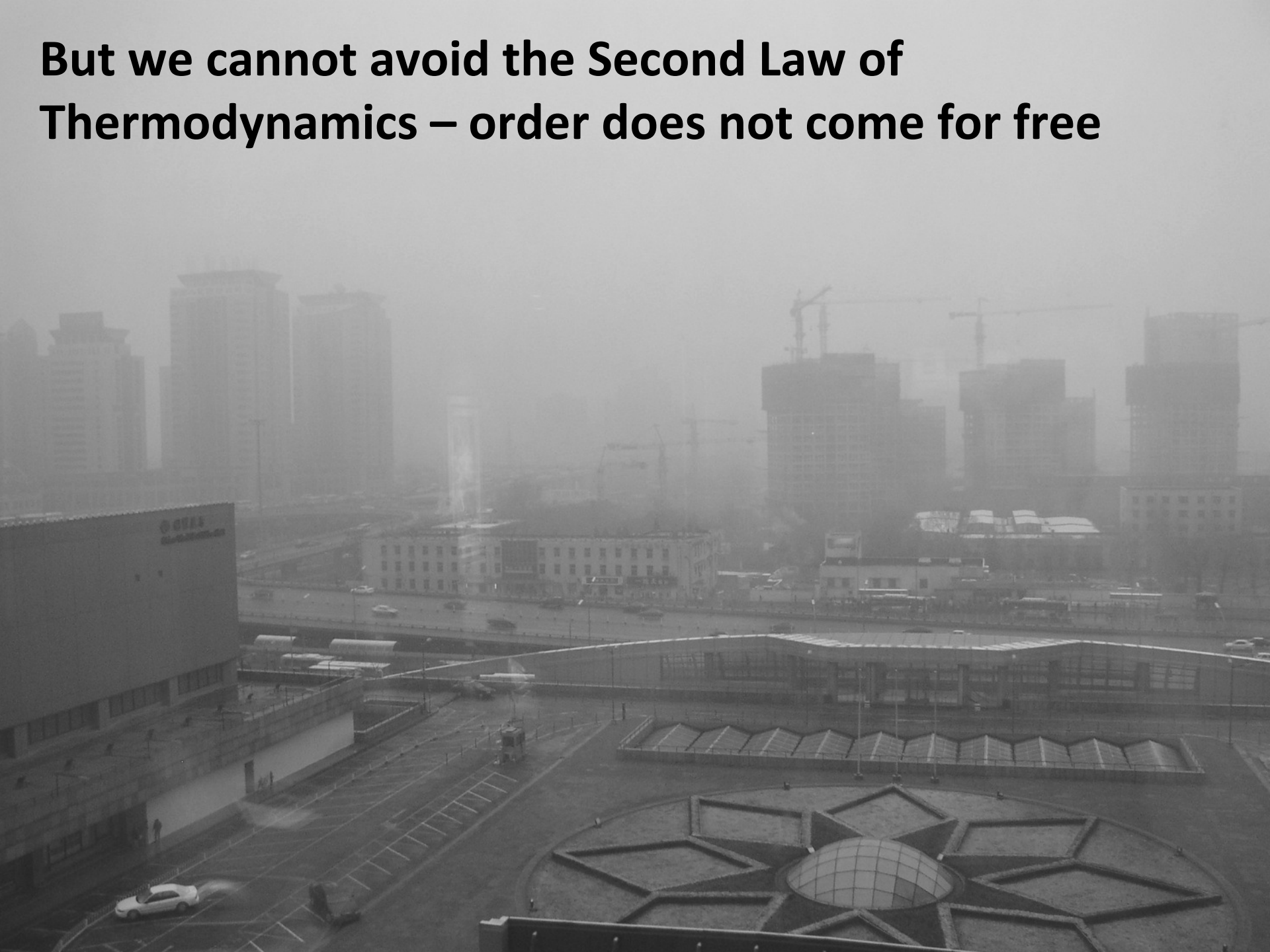
Non-linear wealth creation

Increasing variety and complexity

Spontaneous self-organization

Source: Beinhocker (2006)

But we cannot avoid the Second Law of Thermodynamics – order does not come for free

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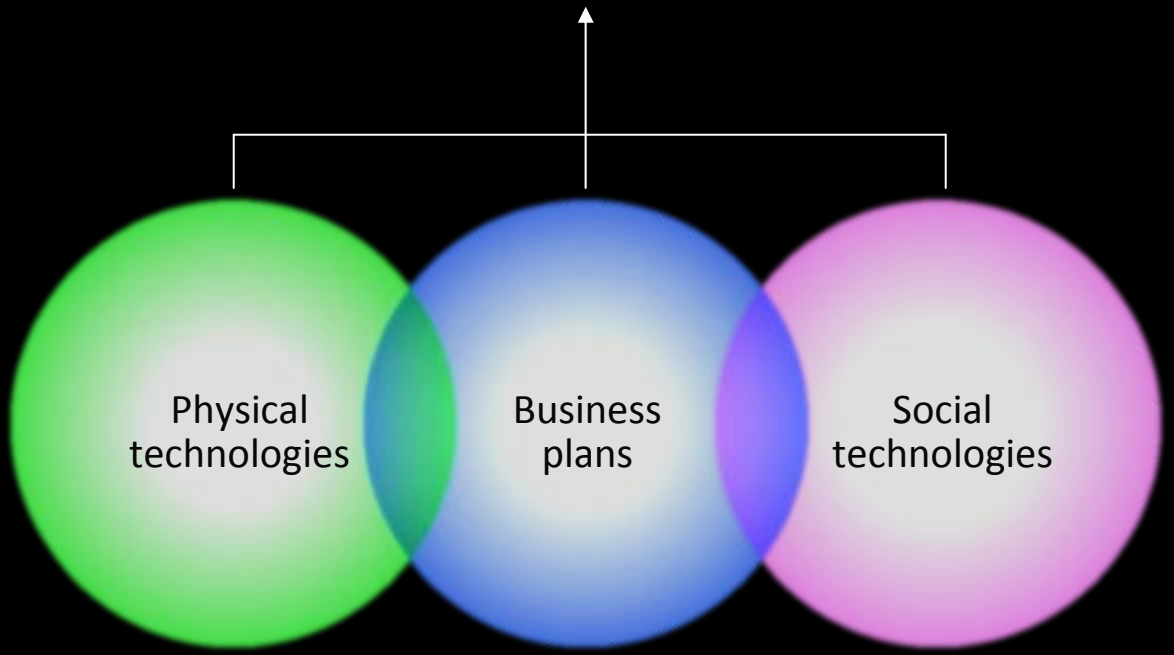
Solow wasn't wrong – just incomplete

$$Y_{(t)} = F\left(K_{(t)}, A_{(t)} * L_{(t)}\right)$$

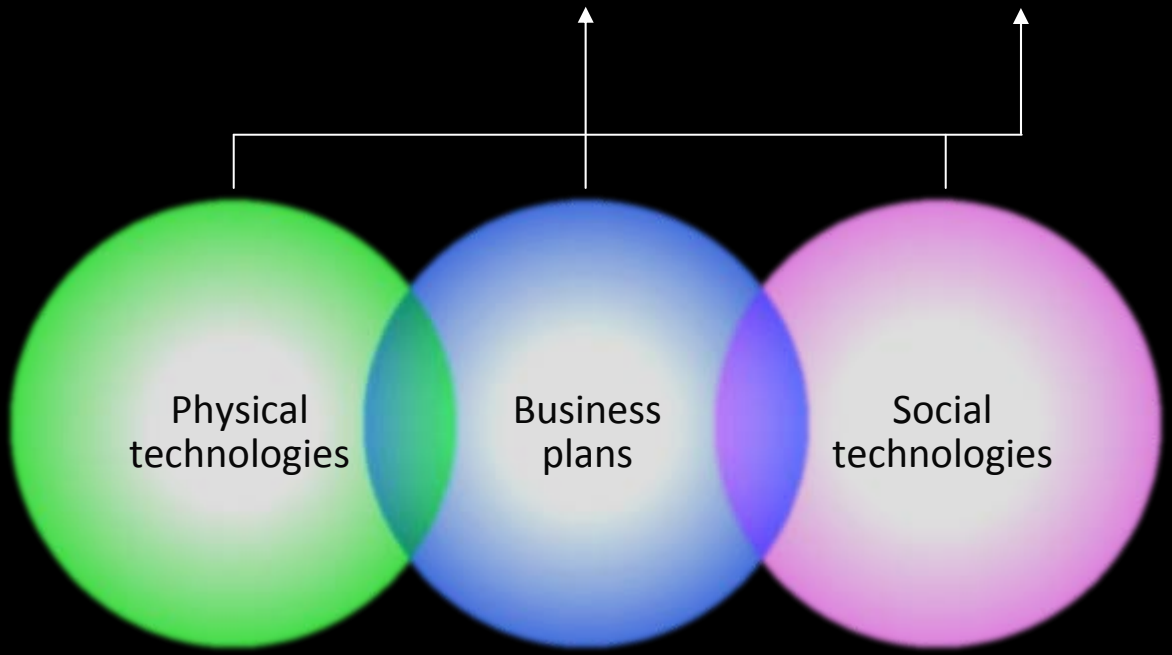
Output — Capital — Knowledge — Labour



Solow wasn't wrong – just incomplete

$$Y_{(t)} = F\,(K_{(t)},\ A_{(t)} * L_{(t)},\ A_{(t)} * R_{(t)})$$

Output — Capital — Knowledge — Labour — Knowledge — Resources



How do we evolve ‘carbon productivity’?

Kaya identity

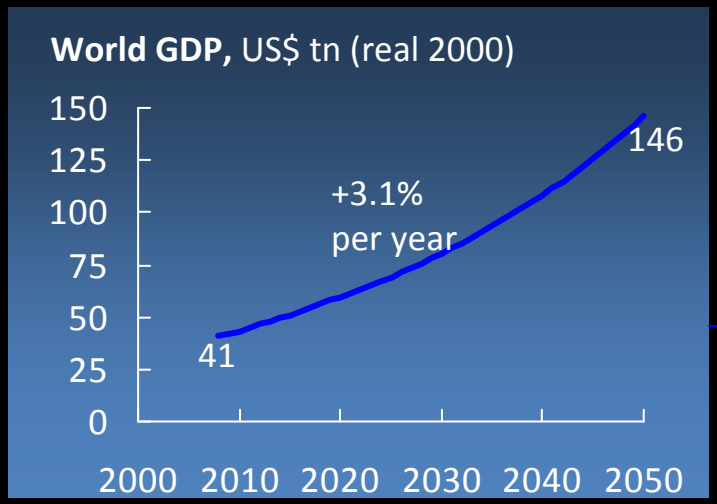
$$F = p * g * e * f$$

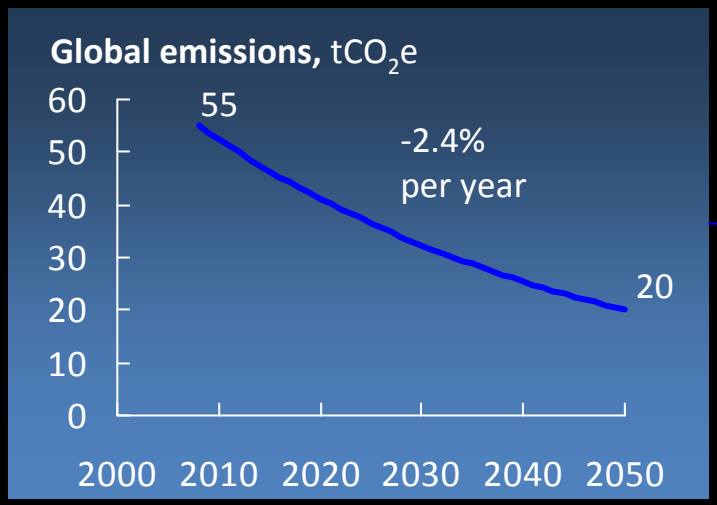
F	p	g	e	f
Anthropogenic (CO_2 emissions)	Population	GDP per capita	Energy intensity of GDP	Carbon intensity of energy

$$\text{Carbon productivity} \cong \frac{1}{e * f} + \text{Non-energy emissions and emissions from other GHGs} \approx \frac{\$GDP}{CO_2e}$$

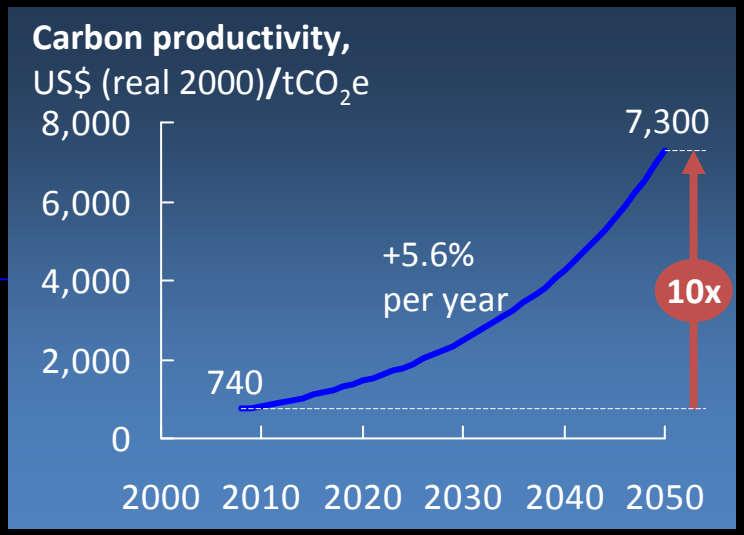
Source: Beinhocker, et. al. (2008)

To grow the economy *and* reduce emissions, carbon productivity must rise 10x to $7,300 per tonne by 2050





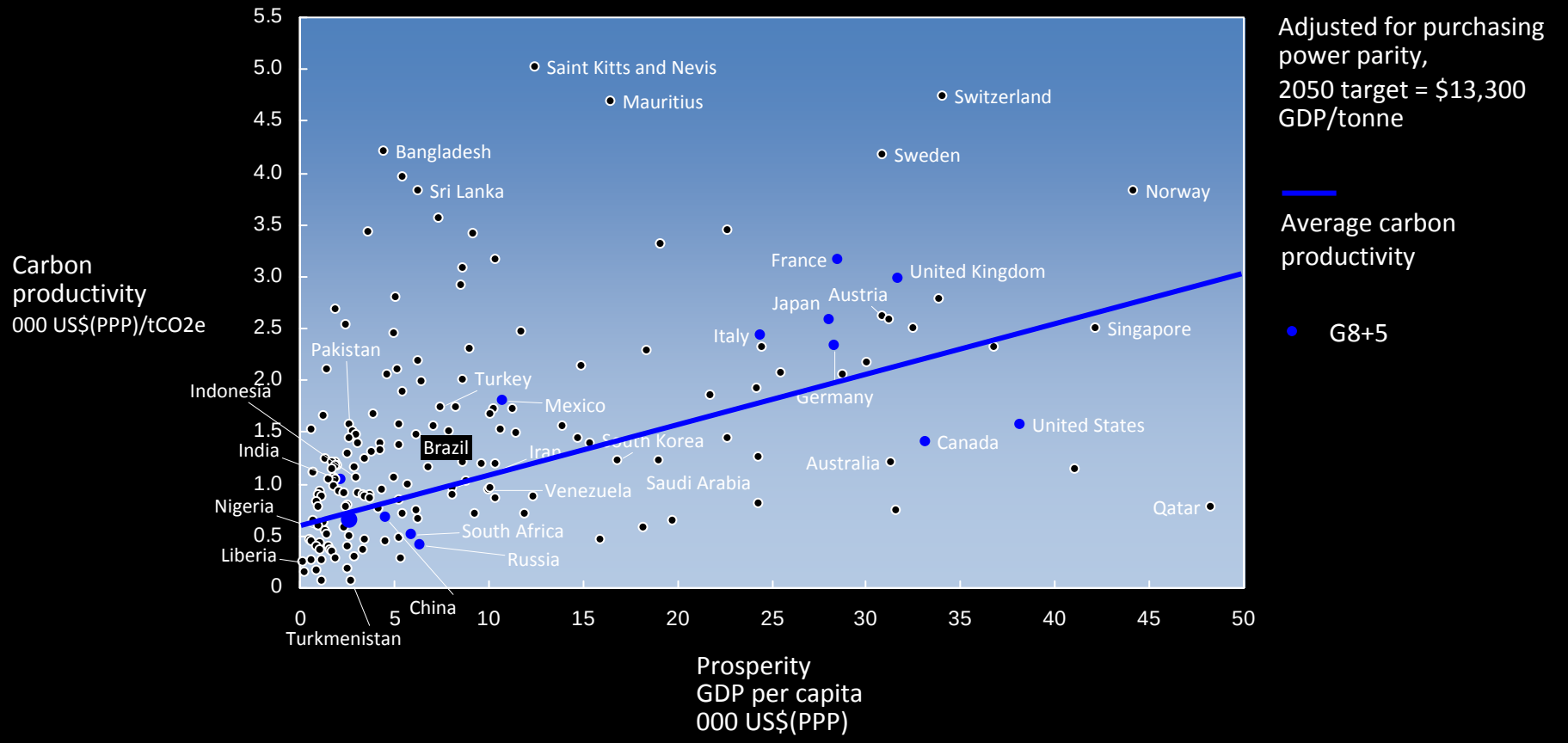
Carbon productivity = GDP / Emissions



Source: Beinhocker, et. al. (2008)

Varied relationship between carbon productivity and prosperity; no-one is close to target carbon productivity

Carbon productivity 2007, 177 countries, all GHGs excluding LULUCF

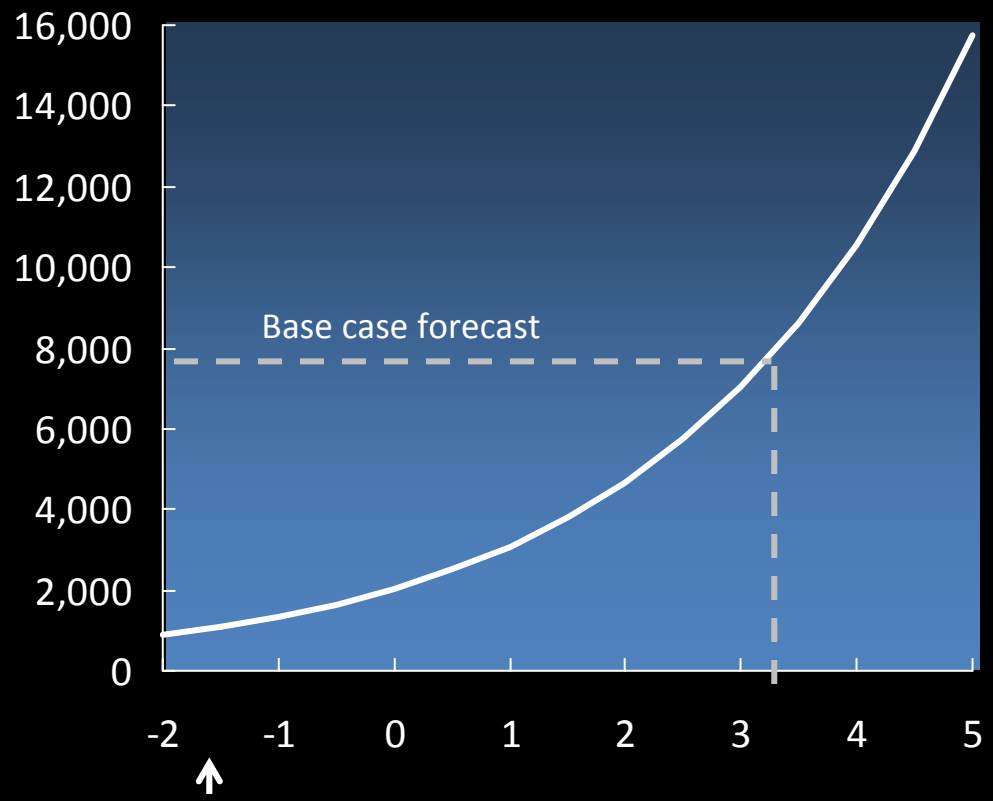


Source: McKinsey Global Institute

If emissions are capped, higher economic growth requires higher carbon productivity

Carbon productivity required to reach 20 Gt CO_2e by 2050

US$ (real 2000)/tCO_2e

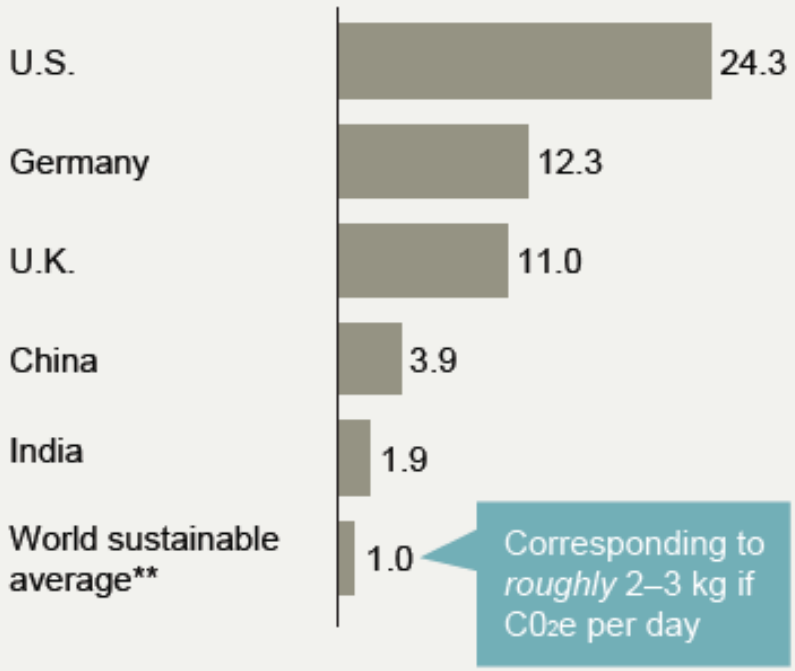


Annual real growth, %	Carbon productivity required
-2	870
-1	1,300
0	2,000
1	3,100
2	4,700
3	7,000
4	10,500
5	15,800

Source: McKinsey Global Institute

If we capped emissions and lived at today's carbon productivity, there is not much we could 'afford'

Per capita emissions 2000*
t CO_2e



'Emission budget' for a day (Alternatives)

Travel — 10–20 km car ride

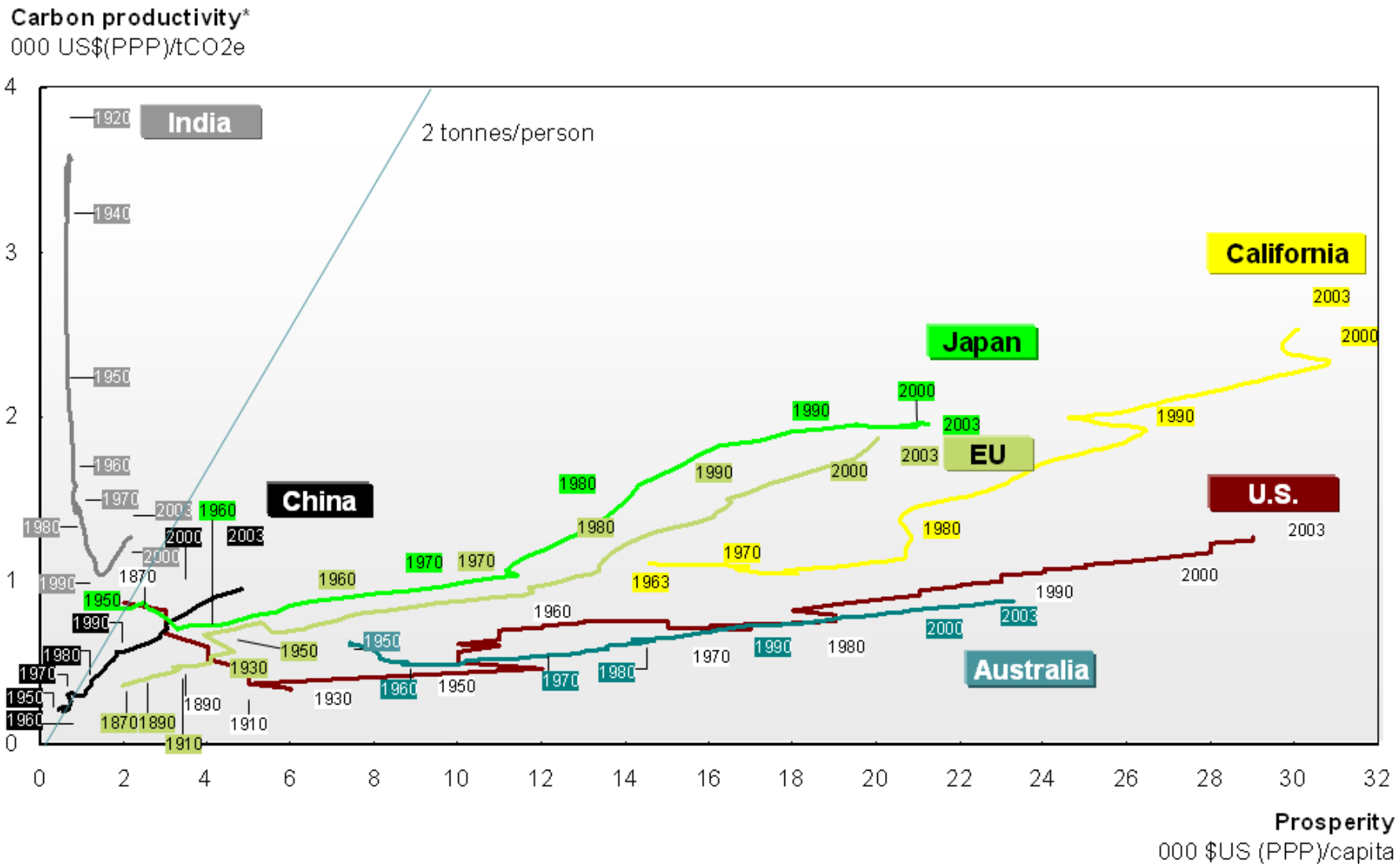
Stay home — 5-10 hours air conditioning

Shop — 1 new t-shirt (3 kg of CO_2, so don't drive to the shop)

Eat — 1 meal a day (3kg CO_2): 300 g meat, 200 g fries, tap water

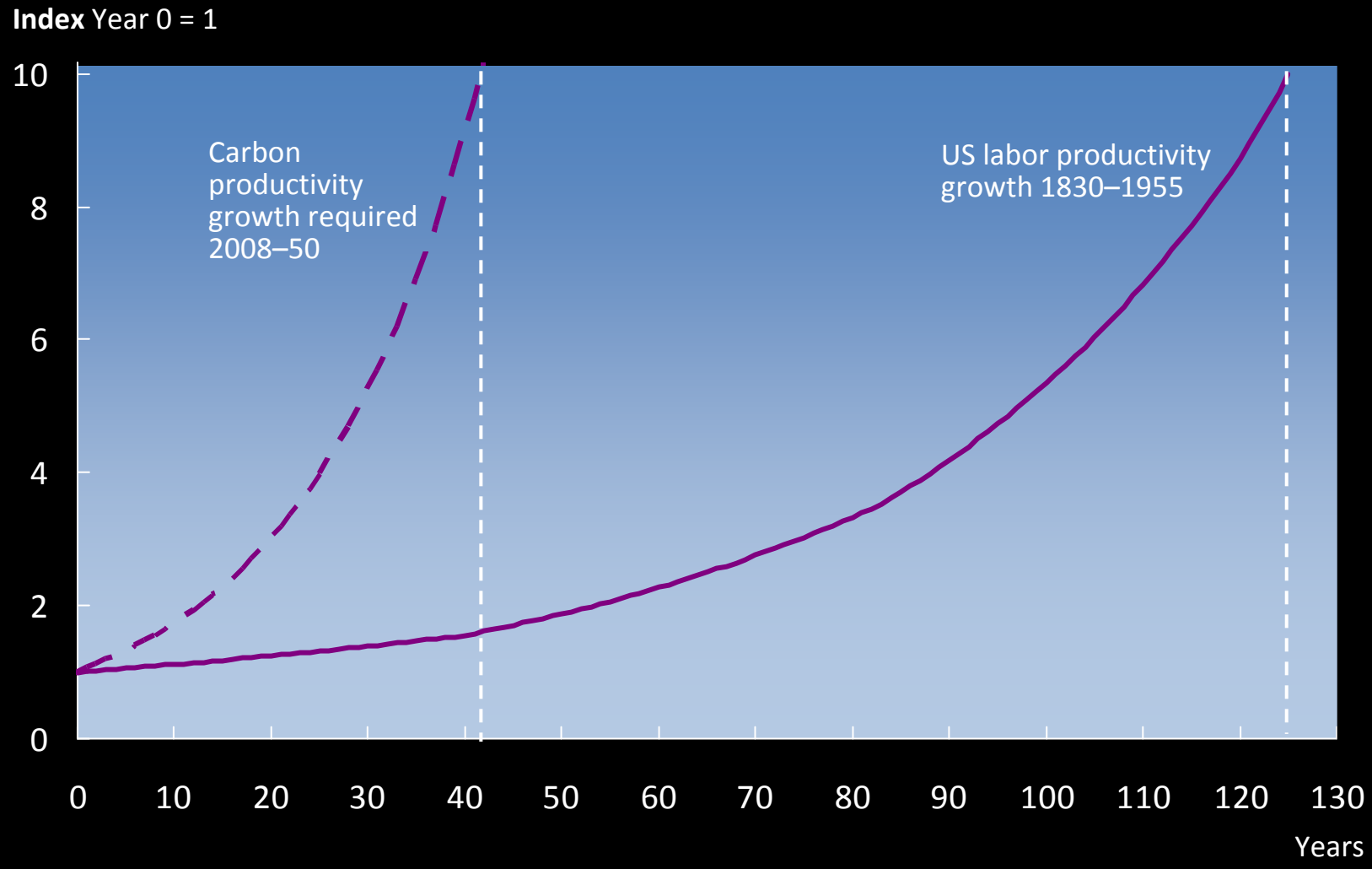
* Emissions from land use change not included
** Based on 10Gt/year sustainable emissions and future population of 10 billion people
Source: McKinsey Climate Change Special Initiative

Carbon productivity has gradually increased over time



* 5-year running average. Emissions data includes CO_2 from fossil fuels and cement, with projections for CO_2 from land use changes and five non-CO_2 gases (CH4, N2O, HFCs, PFCs, and SF6)
Source: McKinsey Global Institute

But a carbon productivity revolution is required three times faster than the industrial revolution



Source: Beinhocker, et. al. (2008)

Some questions and some hypotheses

How do we create a carbon productivity revolution on par with Industrial Revolution – at three times the speed?

How do we activate the evolutionary processes of the economy to do so?
- Physical technologies?
- Social technologies?
- Business plans?

Can we use policy to change the evolutionary fitness function of the economy to include carbon?

A carbon price is necessary but far from sufficient
- Industrial revolution did not happen because labour was expensive
- Need mutual reinforcement between price signals and other selection pressures (e.g., policy, social norms, competition)

Innovation in social technologies will be critical
- New regulatory frameworks
- New market structures
- New business forms
- New international institutions

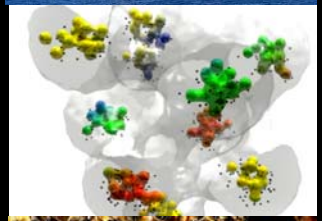
We need to think more broadly than current policy debates, e.g.
- Female education in developing countries
- Green technology innovation clusters
- Catalysing infrastructure investments
- Changing cultural norms

Summary: *Escaping the Last Malthusian Trap*

Industrial Revolution enabled a third of the population to escape the Malthusian trap of poverty, hardship and disease

But it created our next, and possibly last, Malthusian trap – climate change

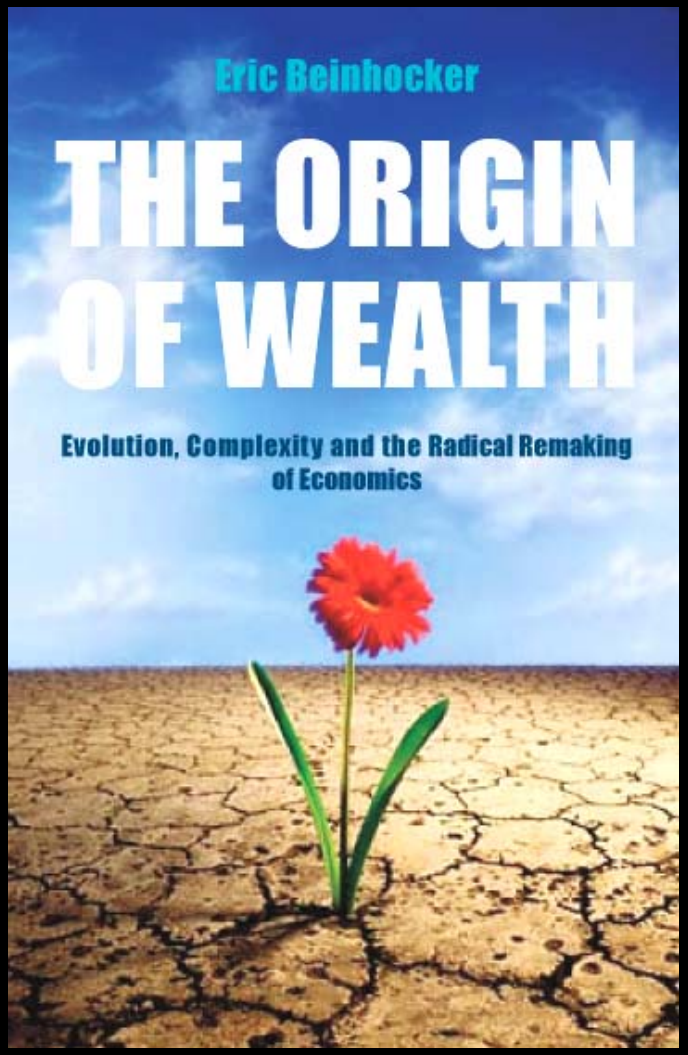
Escaping that trap will require a low-carbon revolution on the scale of the Industrial Revolution, but at three times the speed



Economic revolutions are profoundly disequilibrium phenomena – not explained well by neoclassical theory

A complex systems view helps us understand the evolutionary processes that drive discontinuous innovation and growth

Climate policies should activate and leverage economic evolutionary processes – policymakers need new ideas, there is much work to do!


Eric Beinhocker
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