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Climate change from the perspective of complexity economics

Berlin | 28 October 2021

Michael Roos

- What is complexity economics?
- Climate change and complexity
- What do we learn?

What is complexity economics?

Complexity

- ***Complexity*** *arises in any system in which many agents interact and adapt to one another and their environments. These interactions and adaptations result in evolutionary processes and often surprising „emerging“ behaviors at the macro level.* (Santa Fé Institute)
- ***Complex adaptive systems*** *are systems that have a large number of components, often called agents, that interact and adapt or learn.* (John Holland 2006)
- ***Emergence***

  The arising of novel and coherent structures, patterns and properties during the process of self-organization in complex systems.
  - Properties that do not exists for the parts
  - Families vs. cities -> degree of segregation
  - Individuals vs. population -> income distribution

Complexity sciences

- Complexity sciences attempt to understand fundamental properties of complex adaptive systems.
- Multi-disciplinary approach
  - Physics, mathematics, computer science, biology, sociology ...
- Origins in the 1940s and 1950s, e.g. systems theory and cybernetics
- **Restricted interpretation** (reductionist complexity science, simple complexity)
  - Based on mathematics, physics and computer science
  - Focused on creation of computational research tools (agent-based modeling, system dynamics, network modeling)
- **General interpretation** (complexity thinking, complex complexity)
  - Calls for epistemological turn
  - Challenges reductionism, determinism, simplification, causality and linearity of traditional science

Complexity economics

- Application of general ideas from complexity science to economics
- W. Brian Arthur: “A different framework for economic thought“
- “*Complexity economics builds on the proposition that the economy is **not necessarily in equilibrium**: economic agents (firms, consumers, investors) constantly change their actions and strategies in response to the outcome they mutually create. This further changes the outcome, which requires them to adjust afresh. Agents thus live in a world where their beliefs and strategies are constantly being “tested“ for survival within an outcome or “ecology“ these beliefs and strategies together create.*“

Complexity economics

- *“Economics has largely avoided this nonequilibrium view in the past, but if we allow it, we see patterns or phenomena not visible to equilibrium analysis. These emerge probabilistically, last for some time and dissipate, and act at the “meso-level“ of the economy (between the micro- and macro-levels).*
- *We also see the economy not as something given and existing but forming from a constantly developing set of technological innovations, institutions, and arrangements. Complexity economics thus sees the* ***economy as in motion****, perpetually “computing“ itself – perpetually constructing itself anew. Where equilibrium economics emphasizes order, determinacy, deduction, and stasis, complexity economics emphasizes contingency, indeterminacy, sense-making, and openness to change“*

- **Verb-based** instead of noun-based science, algorithmic
- **Formation and change of structure and patterns**

Economics for the 21st century

- Is complexity economics new?
  - Yes and no
  - Many ideas quite old → classical economists
  - New methods of analysis → computer simulations and nonlinear math
- Equilibrium economics is based on 19th century physics
  - Walras and other neoclassicals in 1870s
  - Physicists, mathematicians and engineers from 1920s (optimization)
- Complexity economics much more modern

https://news.mit.edu/2013/new-kind-of-microscope-uses-neutrons-1004

Important complexity concepts

- Fundamental uncertainty
  - No optimization
  - Bounded rationality
- Interaction, feedback and nonlinearity
  - Complex dynamics
  - Unpredictability
- Learning, adaptation and sensemaking
  - Contingency
  - Subjectivity
- Emergence and self-organization
  - Distinction of different levels
  - Limited controllability
- Holism and irreducibility
  - Systems view

Relation to other economic schools of thought

- Complexity economics has a lot of overlap with other schools of thought.
- Main premise: Economy is a complex adaptive system
- For Arthur neoclassical economics is a special case of complexity economics
- This might also be said for other schools of thought which focus on specific issues that also play role in complexity economics.

Post-Keynesian	Evolutionary	Austrian	Institutional	Political Economy
• Fundamental uncertainty • Instability	• Structural change • Knowledge • Learning	• Self-organization • Subjectivity	• Institutions	• Embeddedness • Power

Climate change and complexity

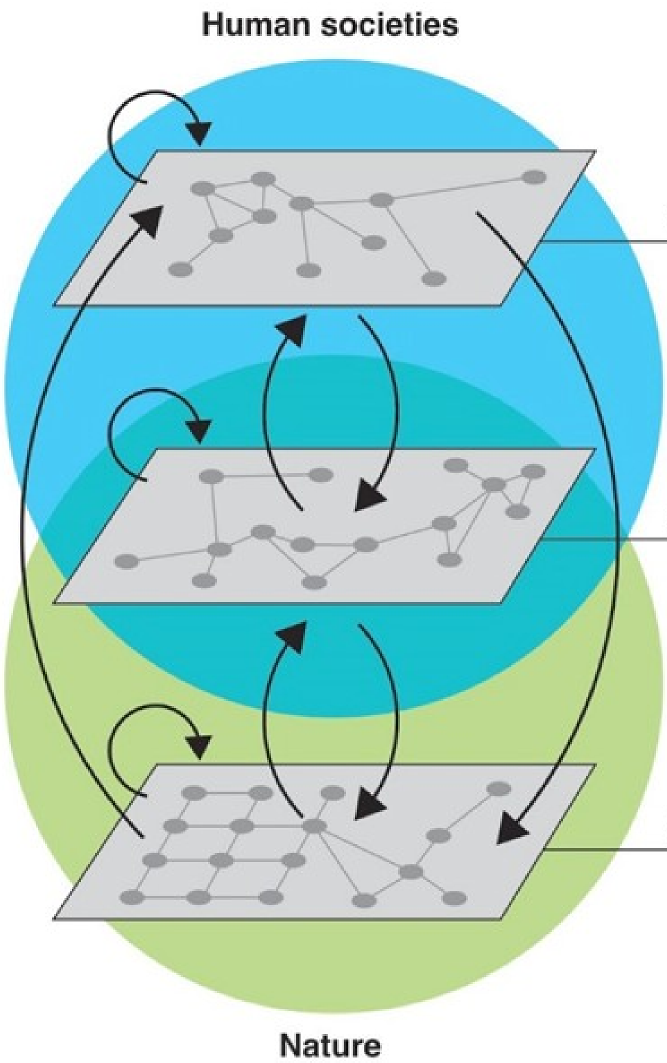
Why is a complexity perspective important?

- Climate system and all other natural systems are complex systems
- Systemic view crucial
  - Natural systems interact
  - Many sustainability problems interrelated, e.g. climate change, diversity loss, acidification of oceans
- Complex dynamics
  - Tipping elements
  - Critical transitions
  - Collapse of systems
- Illusion of controllability and optimal climate policy
- Better understanding, but also better policy recommendations?

World-Earth system

- Planetary-scale system with various subsystems (Donges et al. 2018)
- **Earth**: “natural”, ecological, environmental systems, including climate
  - Goverened by laws of physics, chemistry or ecology
- **World**: subsystem of human societies, their cultures and artefacts
  - Economy
  - Technosphere
- Donges et al. (2018) argue that quantitative World-Earth models which integrate biophysical, socio-cultural and socio-metabolic processes are needed to understand climate change and its impact on human societies
- They are not available yet
  - Only beginnings

World-Earth system



Socio-cultural taxon (CUL)

Models of behaviour and interactions of human minds and their immaterial legacies
(e.g., behavioural change, decision making, opinion formation, social network dynamics, policies, values)

Socio-metabolic taxon (MET)

Models of human-environment interactions for social reproduction, maintenance and growth
(e.g., infrastructure, demographics and agriculture)

Biophysical taxon (ENV)

Models of natural Earth system processes
(e.g., atmosphere and ocean dynamics, biogeochemistry, ecology)

Neoclassical climate economics

William D. Nordhaus

Facts

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William D. Nordhaus
The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 2018

Born: 31 May 1941, Albuquerque, NM, USA

Affiliation at the time of the award: Yale University, New Haven, CT, USA

Prize motivation: "for integrating climate change into long-run macroeconomic analysis."

Prize share: 1/2

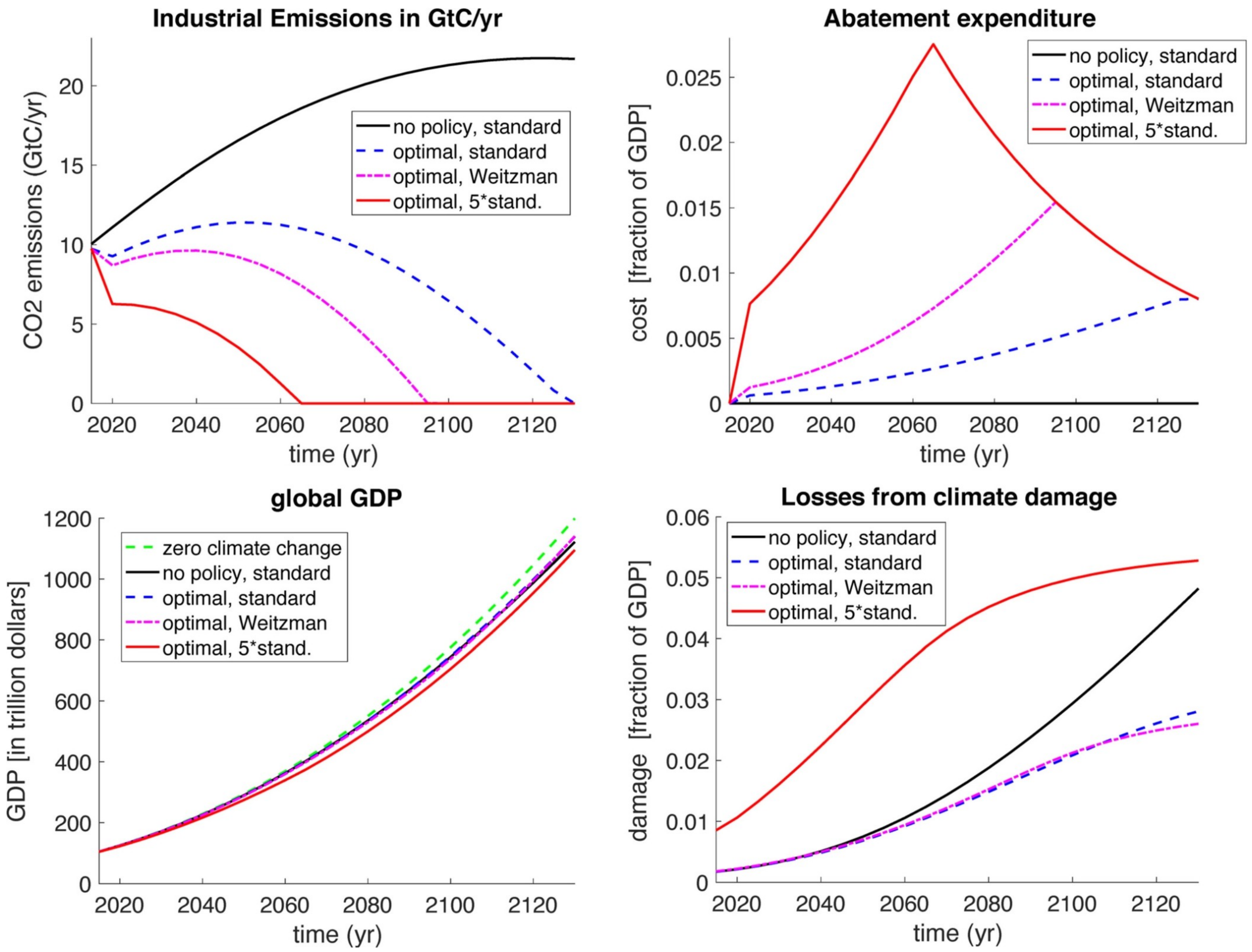
[redacted]rk

At its heart, economics deals with the management of scarce resources. Nature dictates the main constraints on economic growth and our knowledge determines how well we deal with these constraints. William Nordhaus' findings deal with interactions between society, the economy and climate change. In the mid-1990s, he created a quantitative model that describes the global interplay between the economy and the climate. Nordhaus' model is used to examine the consequences of climate policy interventions, for example carbon taxes.

Neoclassical climate economics

- Integrated assessment models
- Often extension of the neoclassical Ramsey-Cass-Koopmans growth model
- Optimal CO2 price (social cost of carbon)
- Collapse of ecological systems (and of economy) typically not included
- Theoretical foundation of economic climate policies

DICE model (Grubb et al. 2021)



Complex World-Earth model

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Environmental Research Letters

LETTER

Sustainability, collapse and oscillations in a simple World-Earth model

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Keywords: World-Earth modeling, anthropocene, global carbon cycle, energy transformation, coevolutionary dynamics, bifurcation analysis

Complex World-Earth model

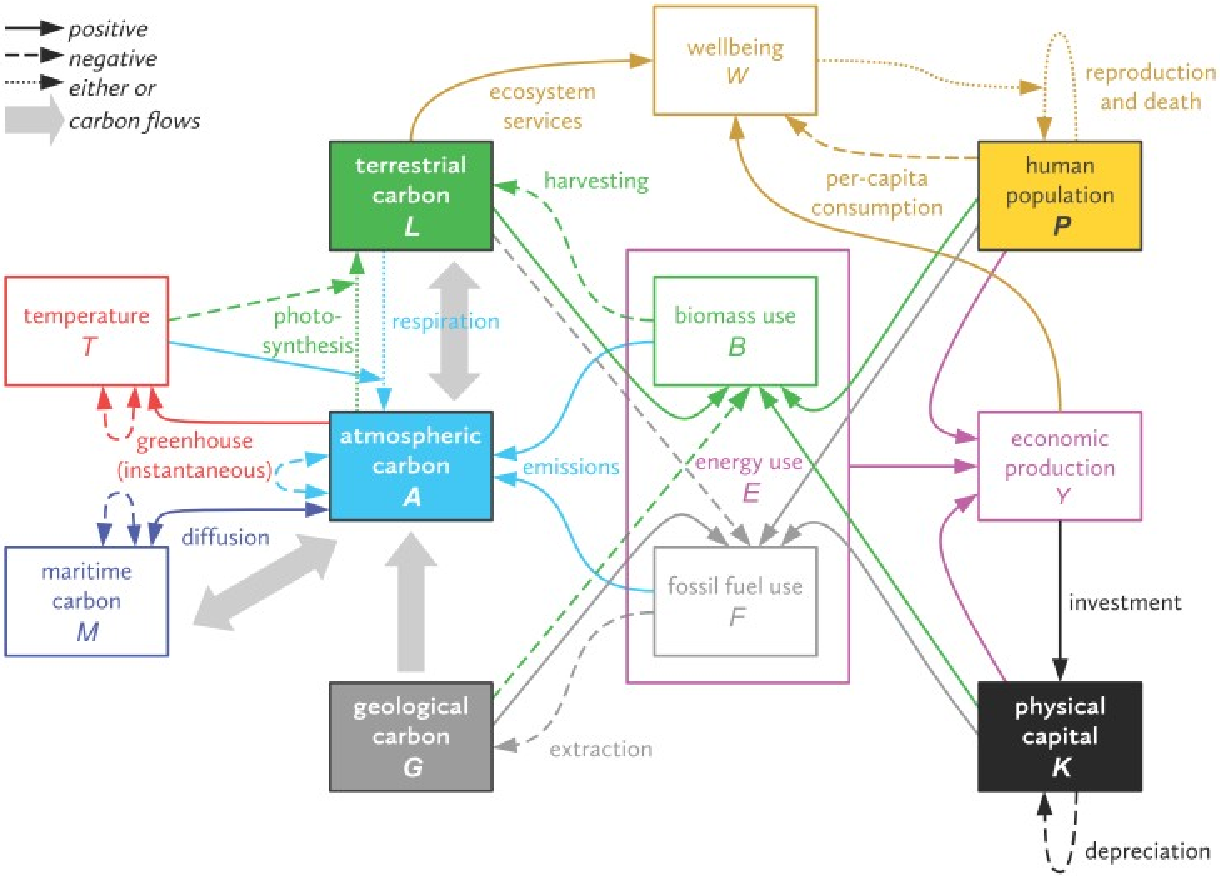
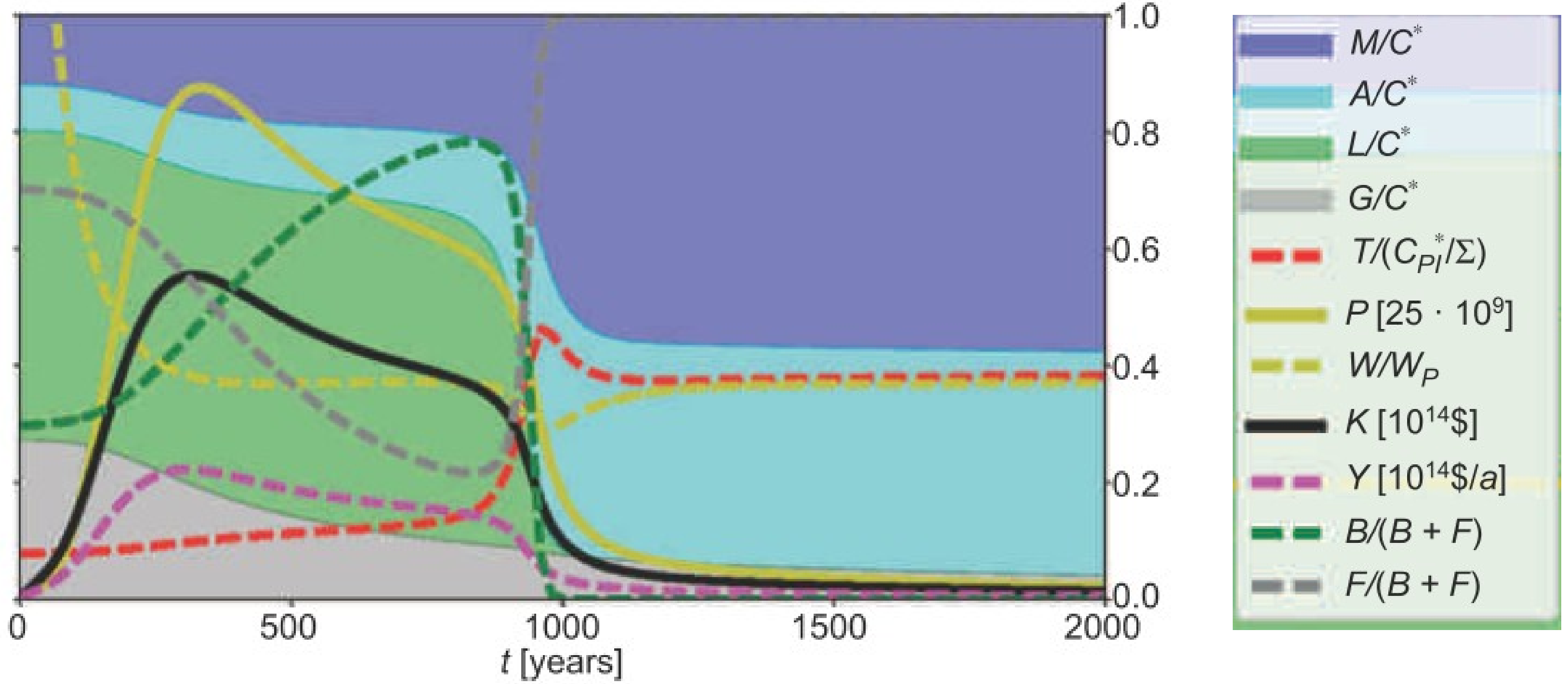


Figure 1. Overview of the model structure with five state variables (colored boxes) and several derived variables (white boxes). Arrows represent coupling processes between the variables. The left part represents the natural subsystem of the Earth (Ecosphere) via the global carbon cycle, while the right part represents socio-economic entities related to human activities in the World (Anthroposphere).

Complex World-Earth model



Cultural processes

- Most existing climate models ignore cultural and political processes (socio-cultural taxon).
  - Behavior change
  - Opinion and attitude formation
  - Value change
  - Political decision making
- Neoclassical models describe optimal climate policies
- Policy is not exogenous, but endogenous!!

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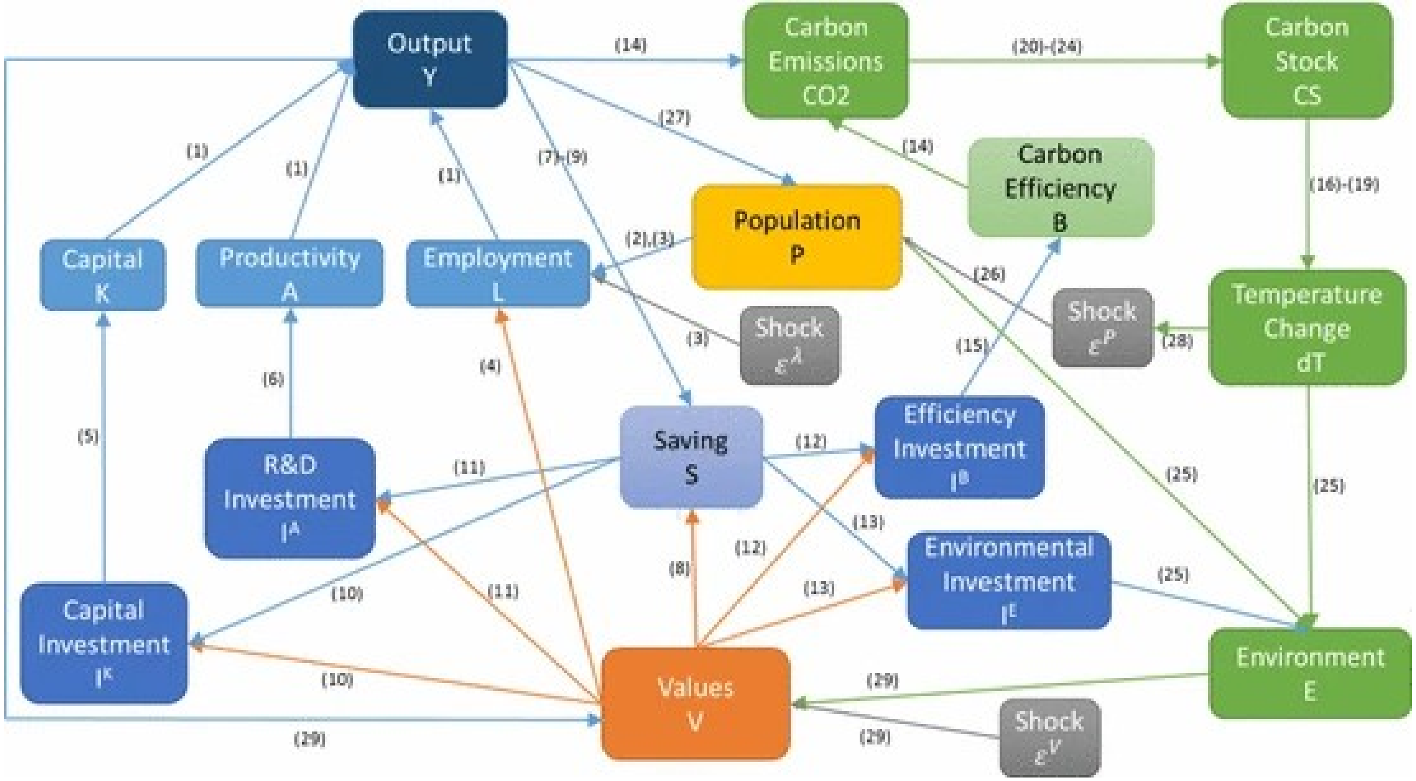
Endogenous Economic Growth, Climate Change and Societal Values: A Conceptual Model

Michael W. M. Roos

Computational Economics **52**, 995–1028 (2018) | Cite this article



Complexity concepts for the CUL taxon

- Emergence of institutions and downward causation
  - Formal institutions: formal rules, laws, governance
  - Informal institutions: social norms, worldviews, customs, lifestyles
- Upward causation
  - Institutions arise bottom-up
- Downward causation
  - Institutions constrain individual behavior top-down

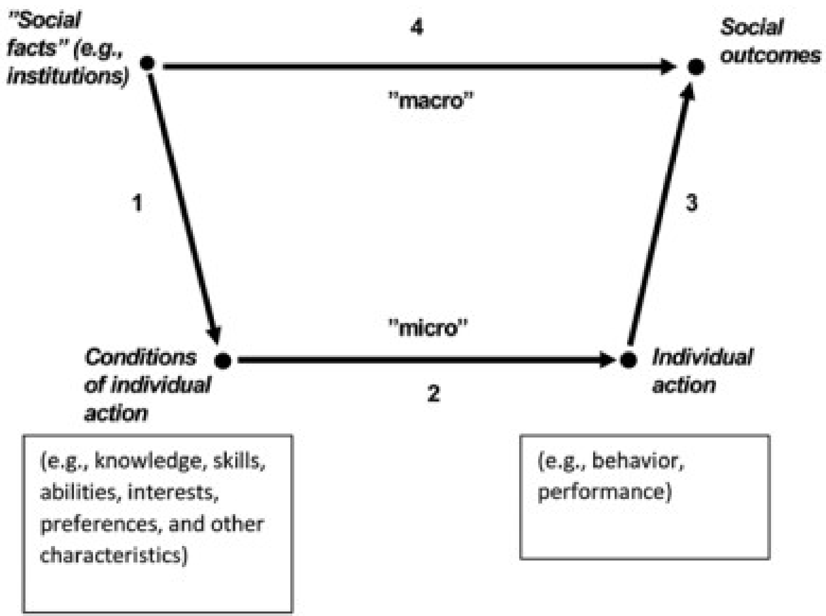


Fig. 1. A General Model of Social Science Explanation.

Belief systems

- Social reality is a construction.
- People act upon their beliefs of the world, not upon “reality”.
- Belief systems
  - Mental models → How does the world work?
  - Values → How should the world be?
- Examples:
  - Does climate change exist?
  - Is it caused by human activity?
  - Is it bad?
  - Who is responsible to fight it?
  - What are consequences of (not) fighting climate change?
  - How do we assess these consequences?
- Loss vs. collapse

What do we learn?

Understanding climate change

- World-Earth system overwhelmingly complex.
- Analytical approach tries to reduce complexity by looking at subsystems in isolation
  - Climate system, oceans, biosphere
  - Economy, political system, social system ...
- We even have difficulties understanding all these isolated subsystems.
- However, all subsystems interact, e.g.
  - Climate change and loss of biodiversity
  - Soil degration
  - Marine circulation
  - Health, e.g. pandemics
- We focus on some issues (climate change) and ignore others like biodiversity loss.
  - There will be “side effects” of everything we do.

Understanding climate change

- Climate change will be accompanied by pervasive social change
    - Food production
    - Mass migration
    - Conflict
    - Trade patterns
    - Social life in all countries
    - Governance
- We need models and theories that incorporate these changes.
- Scope of change not recognized yet!
- Change by design or by disaster?
    - Mitigation vs. adaptation
    - Voluntary reforms of economic and political systems are rare
    - Currently we are not very good at designing better systems
    - Too slow!!

Policy conclusions

- The complexity perspective offers rather sobering policy conclusions
  - There is no optimal climate policy.
  - We do not know what the consequences of policy instruments will be.
  - There will be “side effects”.
  - Misbelief that the right carbon price will fix the problem.
- Socio-cultural change is a condition of political change
  - Change of beliefs, worldviews, values, ...
  - We cannot change these factors by design.
  - Slow, evolutionary change.
- Positive messages?
  - Increase resilience
  - Build institutions that foster collaboration
  - Reduce inequality
  - In general: institutional design more important than direct interventions