Agent-Based Modeling
of Environmental Conflict and Cooperation

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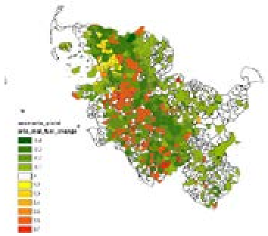
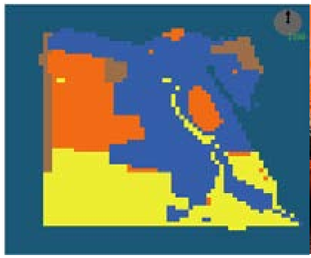
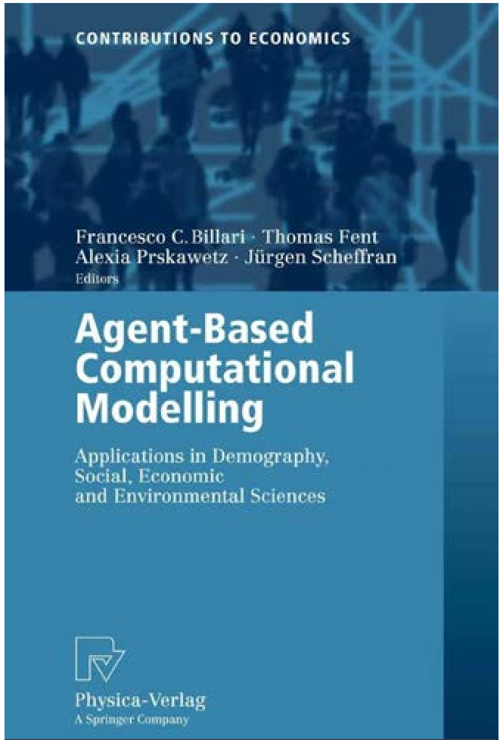
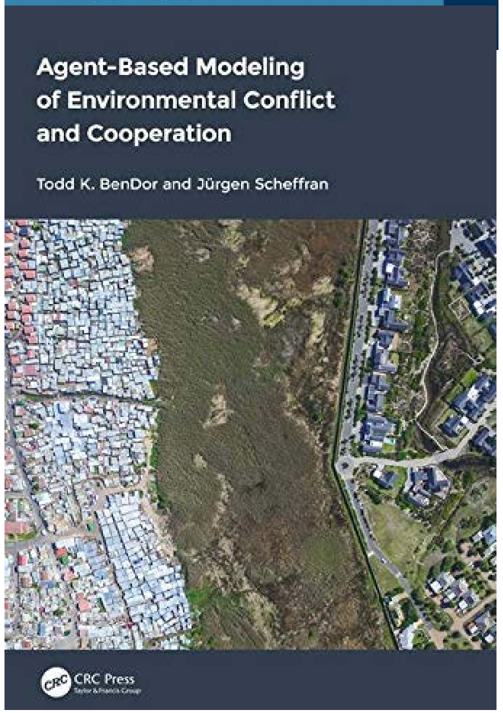
"Artificial societies and information technology"

International online-seminar (Moscow), April 16, 2021



Agent-based modeling (ABM)

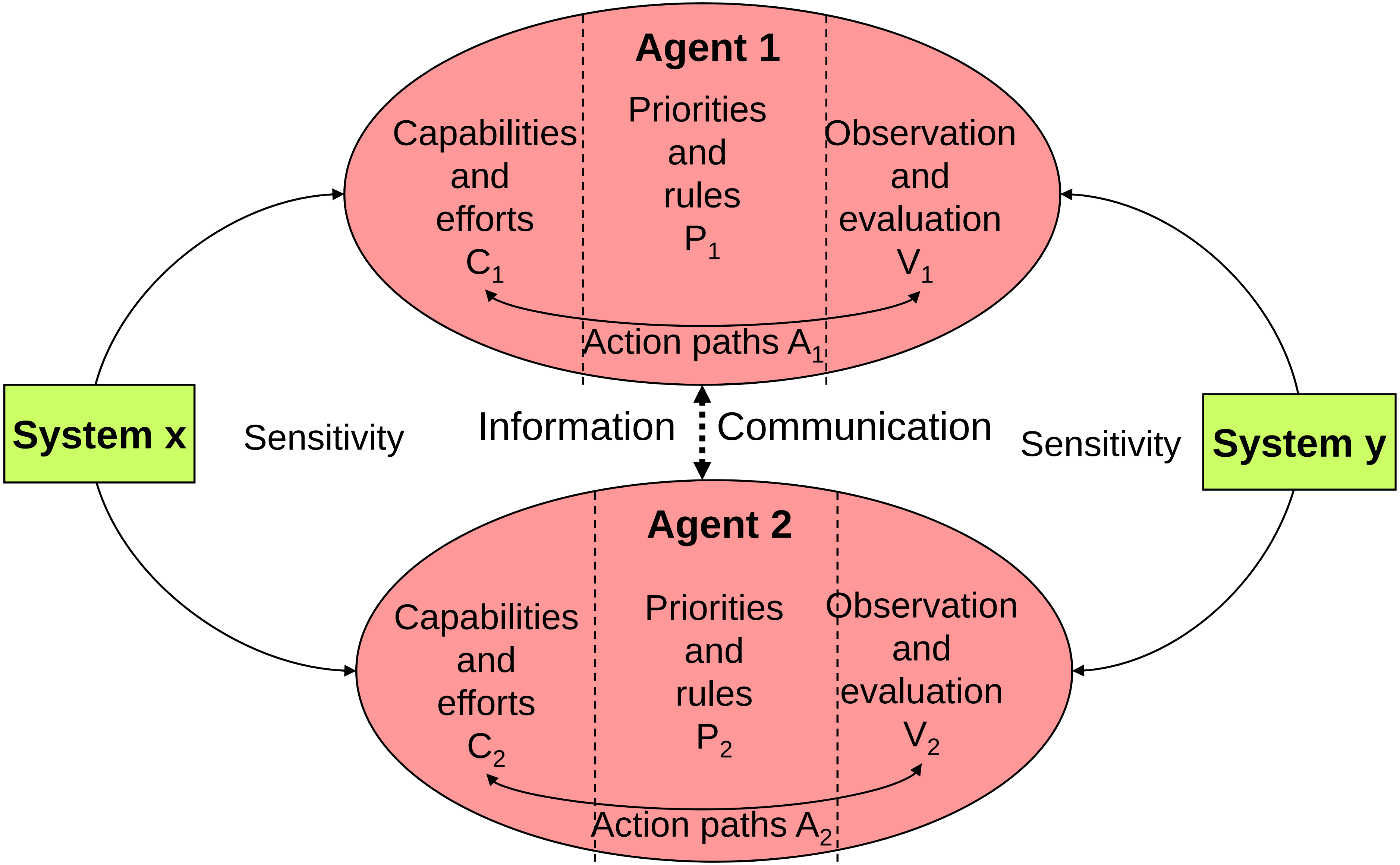
Bottom-up study of **agent interaction** in virtual landscapes and artificial societies, based on rules of behavior.

Cognitive capabilities: "perceive signals, react, act, making decisions, etc. according to a set of rules" (Conte 1995):

- ***beliefs*****:** what agents think to know about the world (experience, perception)
- ***goals***: desired states agents want to achieve
- ***priorities****:* action selection to achieve desires.
- ***reactive and adaptive:*** observe & respond to environment
- ***rule-based:*** follow defined decision rules.

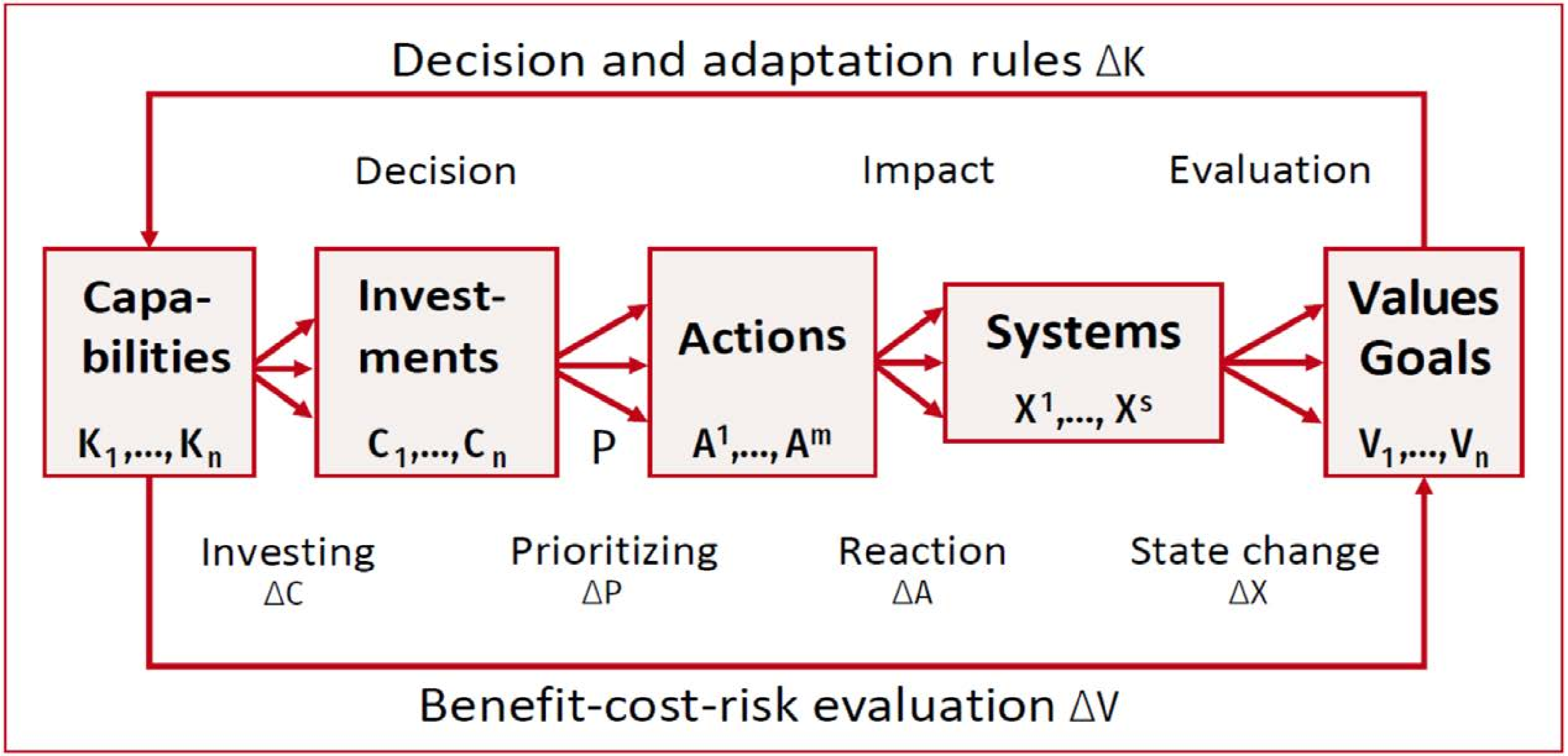
→ABM should represent essential aspects of human behavior and social interaction
→Agents have motivation and capability to act on their natural and social environment
→Agents follow adaptive decision rules of selecting action and observe the outcome of actions and reactions
→ Agents learn to balance what they want, what they can and how they act

Two-agent interaction



Multi-agent adaptive cycles in the VIABLE model

*V*alues and *I*nvestments in *A*gent-*B*ased interaction and *L*earning for *E*nvironmental Systems



$\Delta V_i = \Sigma f_{ij} \Delta C_j = \Delta V_i^*$ Value goal

$$f_{ij} = \sum^{m} \frac{v_{ij}^k}{c_j^k} p_j^k$$ Mutual impact

$$\Delta p_{i,k} = a_i \times p_{i,k} \, v_{i,k}$$ Adaptive decision rule for priority pik of agent i for action k

$v_{i,k}$: (marginal) value driver of action k for agent i

Stability of interaction matrix determines tipping between conflict and cooperation

Capability

V= F C = V*

$C_1 \quad C_i \quad C_n$

$$F(p) = \begin{pmatrix} f_{11} & \cdots & f_{1i} & \cdots & f_{1n} \\ f_{21} & \cdots & f_{2i} & \cdots & f_{2n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ f_{n1} & \cdots & f_{ni} & \cdots & f_{nn} \end{pmatrix} \begin{matrix} \rightarrow V_1 - V_1^* \\ \rightarrow V_2 - V_2^* \\ \\ \rightarrow V_n - V_n^* \end{matrix}$$

Value

-Equilibria, stability and complexity depend on mutual impacts $f_{ij}(p)$ and thus can be controlled by changing **action priority** p.

-Stability depends on **eigenvalues** of interaction (Jacobi) matrix F(p)

-**Two agent stability** for $f_{ii} > 0$, $f_{ij} < 0$ and **det F = $f_{11} f_{22} - f_{12} f_{21} > 0$**

→ Instability leads to tipping point between conflict and cooperation

End of Cold War: Tipping from nuclear arms race to disarmament

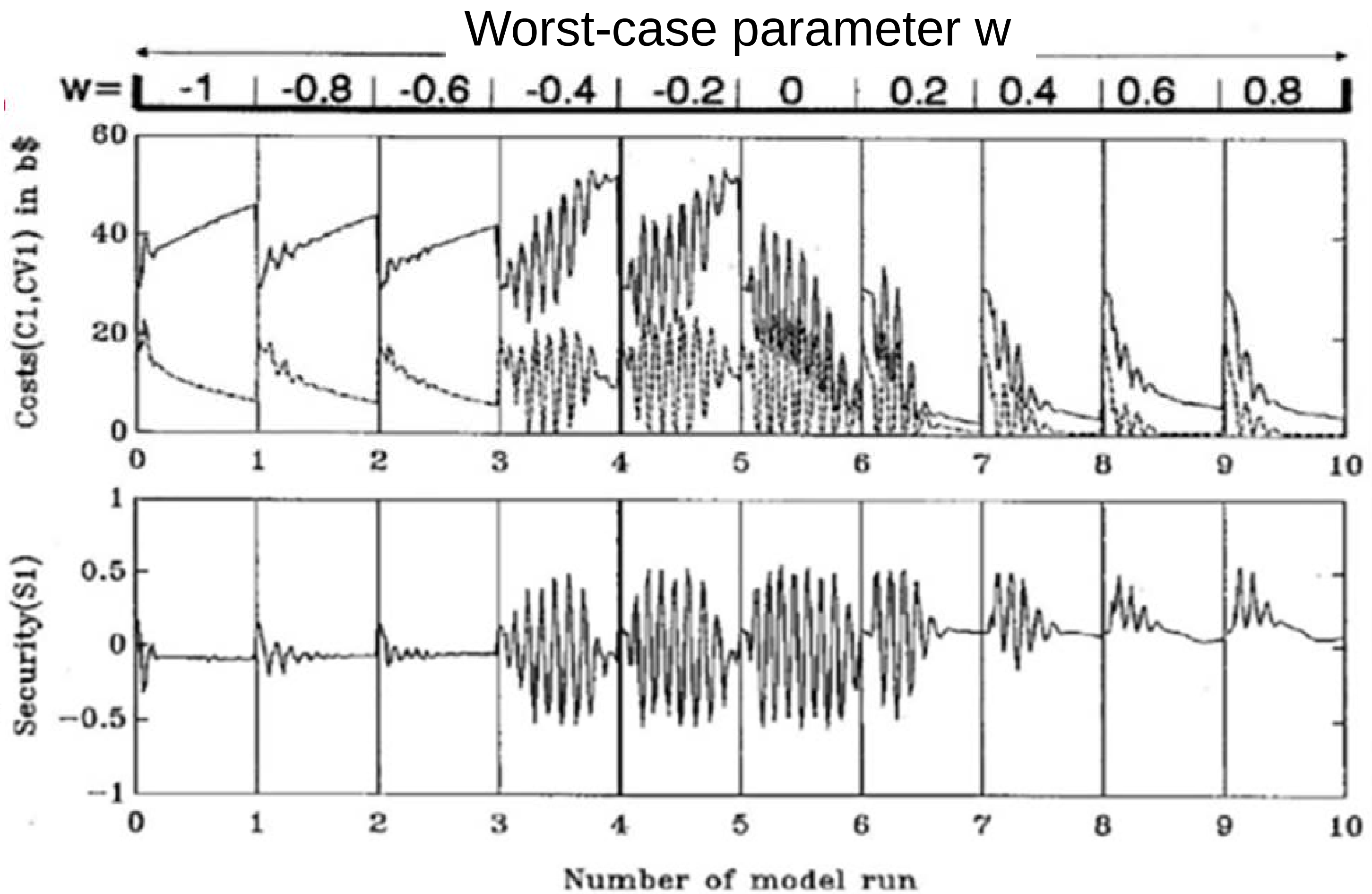

Jürgen Scheffran

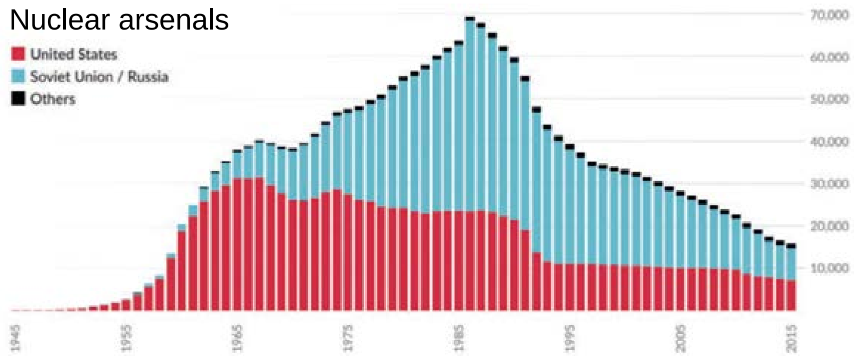
Strategic Defense, Disarmament, and Stability

Modelling Arms Race Phenomena with Security and Costs under Political and Technical Uncertainties

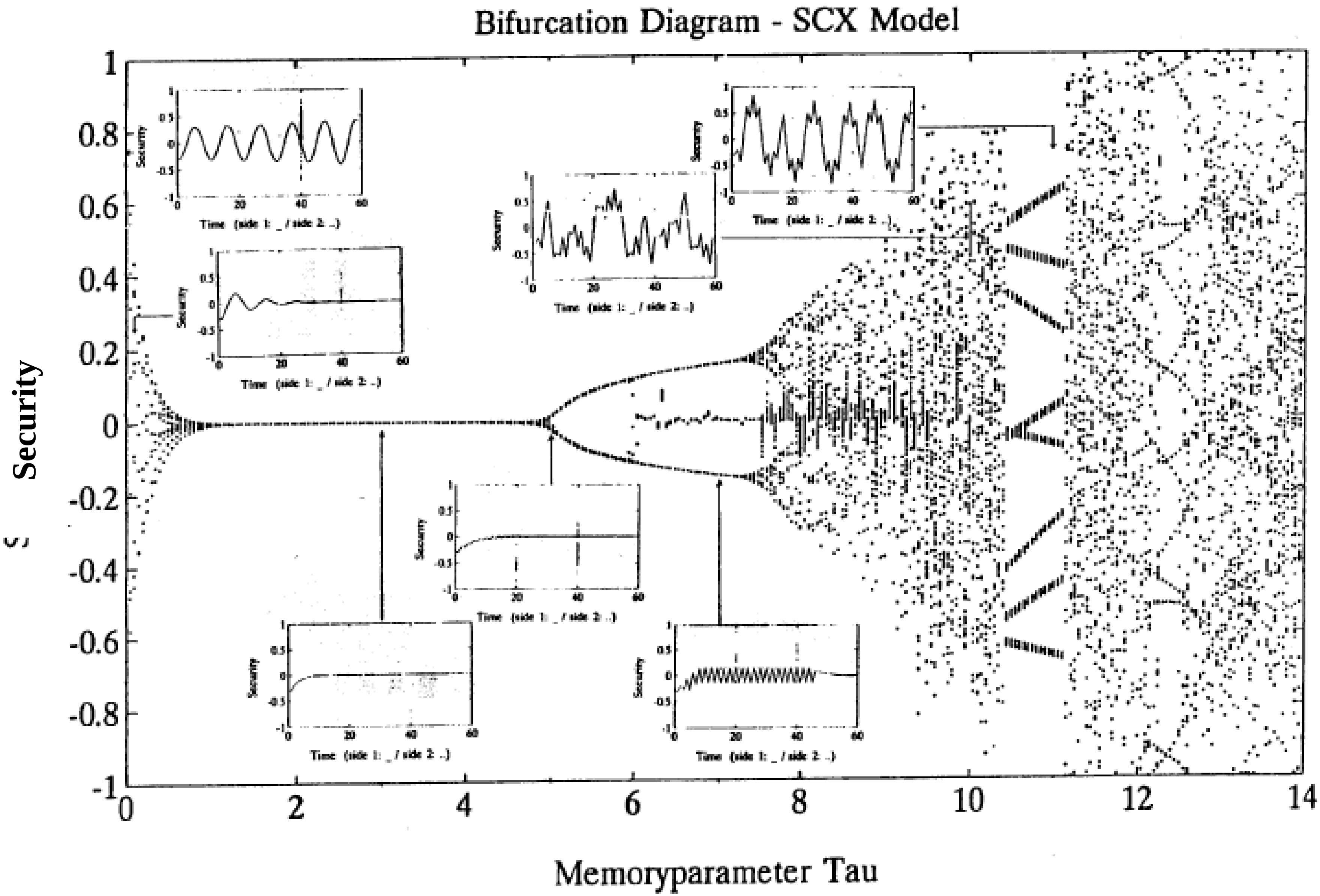
Department of Physics, Unversity of Marburg, October 1989

Schriftenreihe
des Arbeitskreises Marburger Wissenschaftler für Friedens-und Abrüstungsforschung und der Interdisziplinären Arbeitsgruppe Friedens- und Abrüstungsforschung an der Universität Marburg (IAFA)
Nr. 9



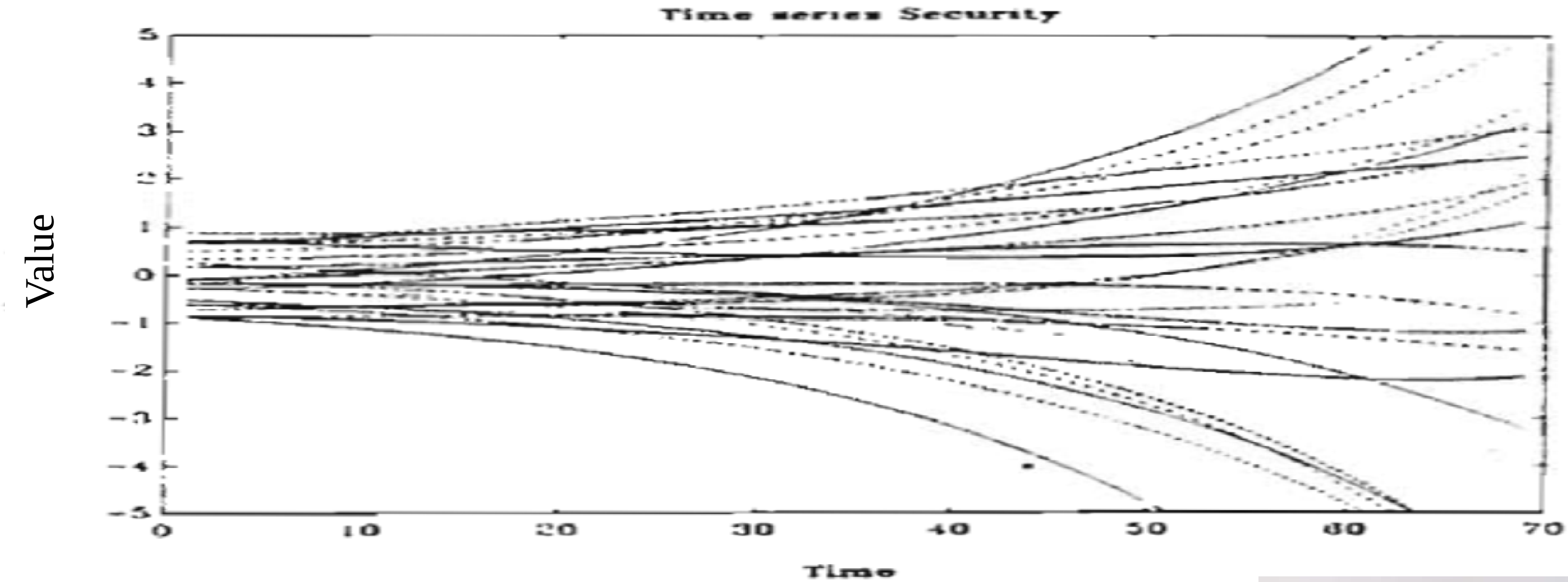


Post-Cold-War: Security bifurcation cascade in the VIABLE model



Source: Jathe/Scheffran (1993) Complexity and Stability of International Security: A Dynamic Approach

Post-Cold-War: Winners and loosers in multi-agent world



Complexity and Stability of International Security
A Dynamic Approach
1993
Markus Jathe Jürgen Scheffran

From Complex Conflicts to Stable Cooperation

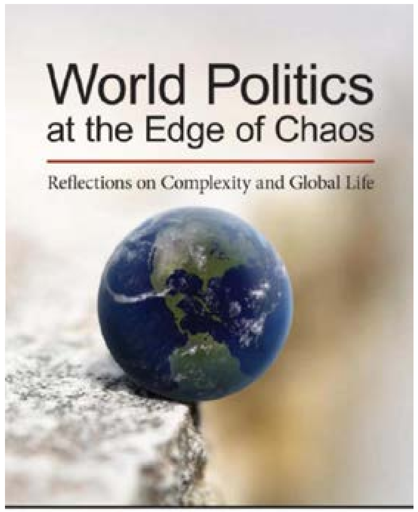
Cases in Environment and Security
Complexity 2007

JÜRGEN SCHEFFRAN[1] AND BRUCE HANNON[2]

Complexity and Stability in Human-Environment Interaction
Scheffran (2015), in: Kavalski
The Transformation from Climate Risk Cascades to Viable Adaptive Networks

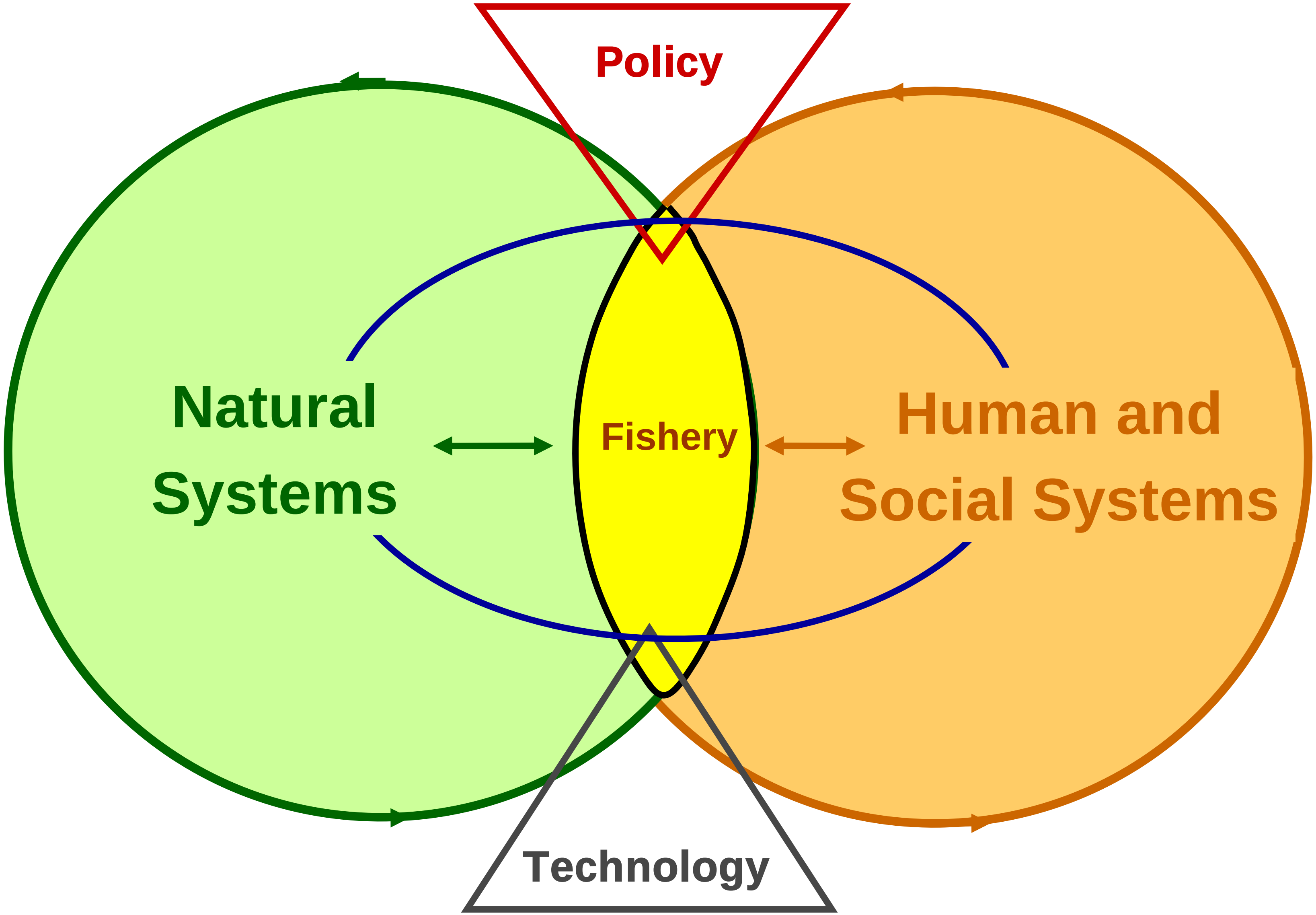
The Complexity of Security

Jürgen Scheffran (2008), Complexity



Edited by Emilian Kavalski

Fishery management in human-environment interaction



Overexploitation of marine resources and fishery conflicts

70% of fish stocks worldwide heavily overexploited

Some of them collapsed or to be collapsed, e.g. Northwest Atlantic or North Sea cod

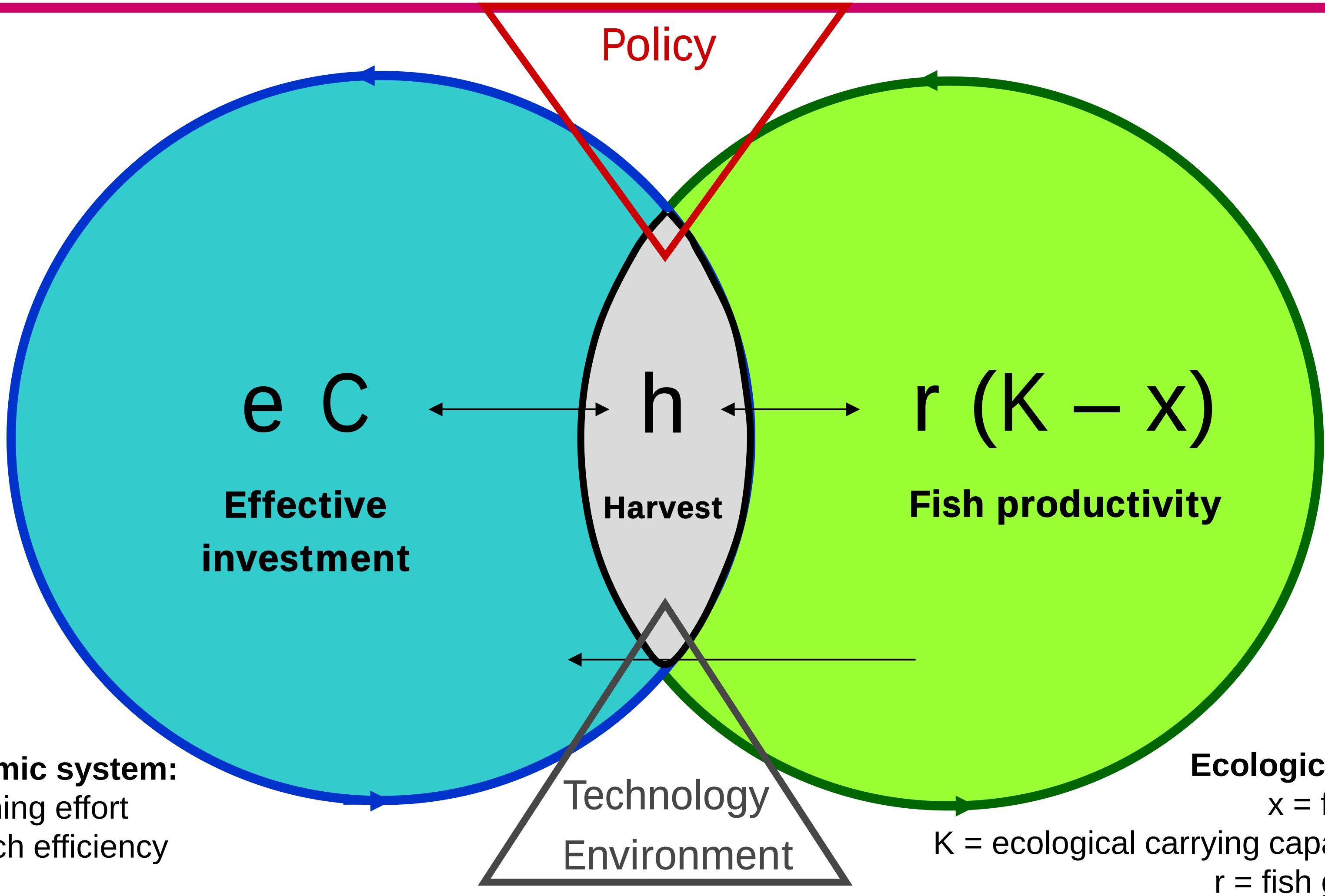
Low quality of management strategies

High levels of subsidies

Collective-action problem in common pool resource (Tragedy of the commons)

Conflicts on scarce fish stocks

Interaction and balance of ecological and economic dynamics in fishery

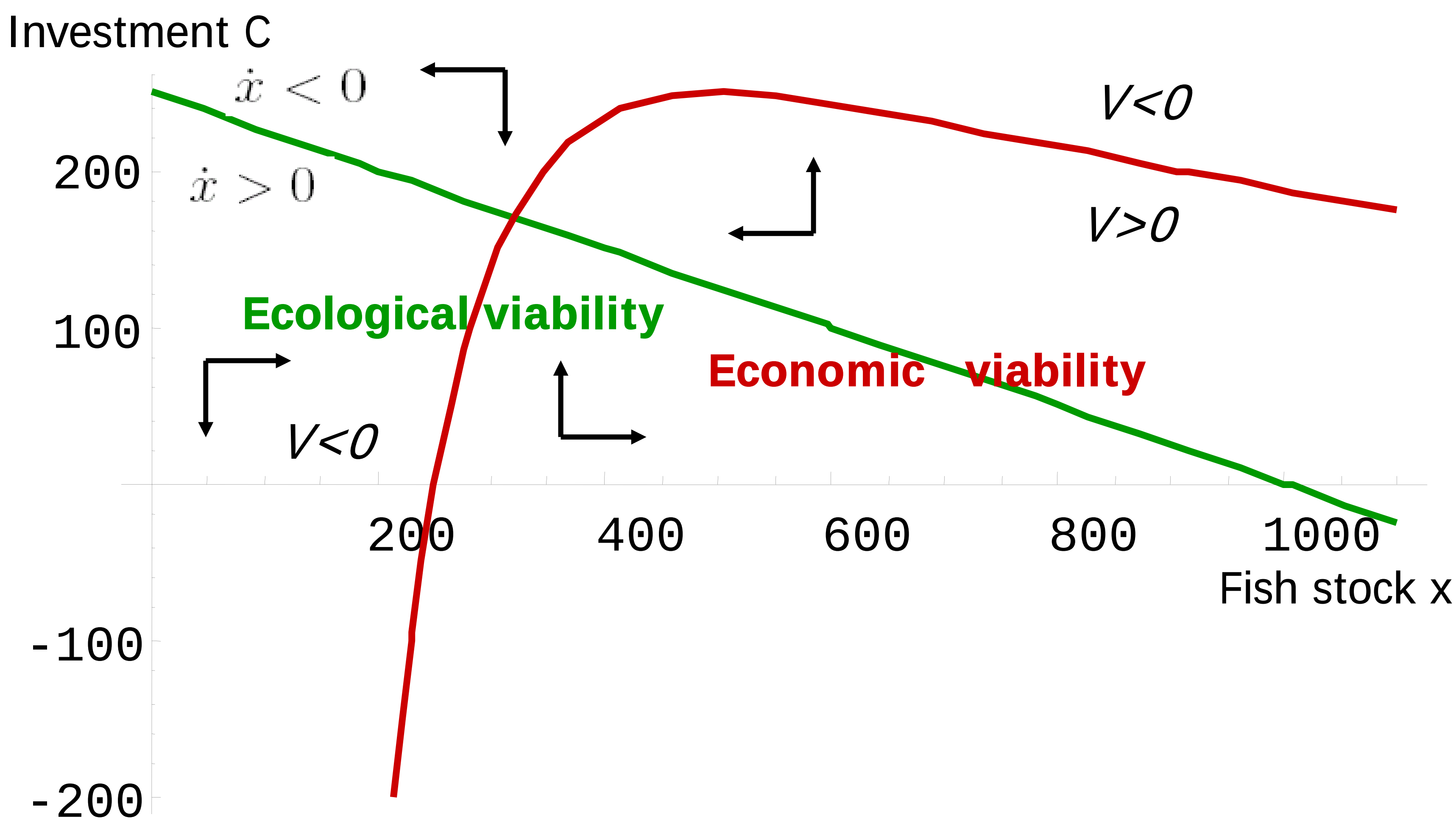


Economic system:
C = fishing effort
e = catch efficiency

Ecological system:
x = fish density
K = ecological carrying capacity of fish
r = fish growth rate

Viability conditions:
--Ecological: How much investment C in harvesting h to not exceed fish productivity?
--Economic: How much investment C to avoid negative profit on fishery market?

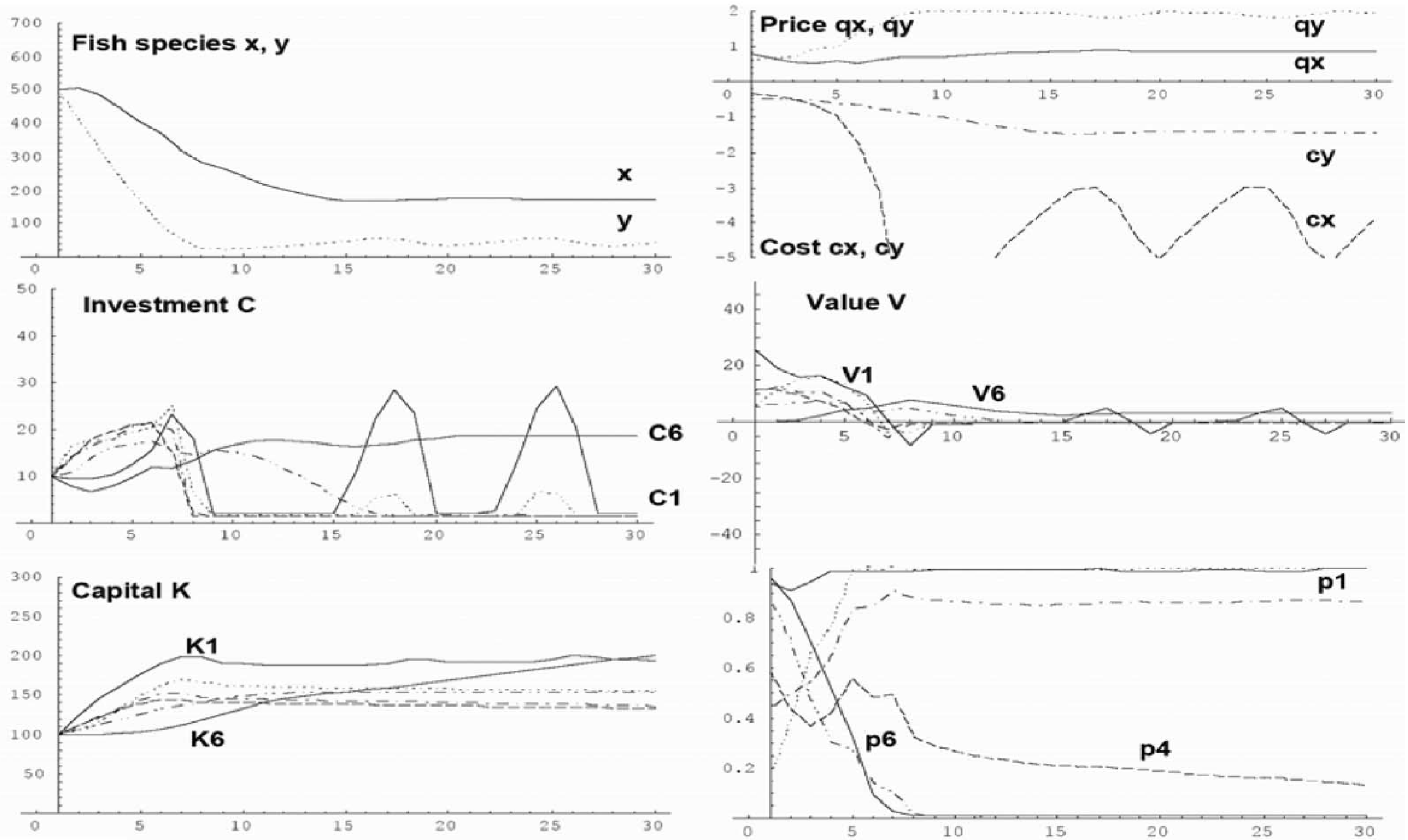
Compatibility of economic and ecological viability



Source: Bendor/Scheffran 2009

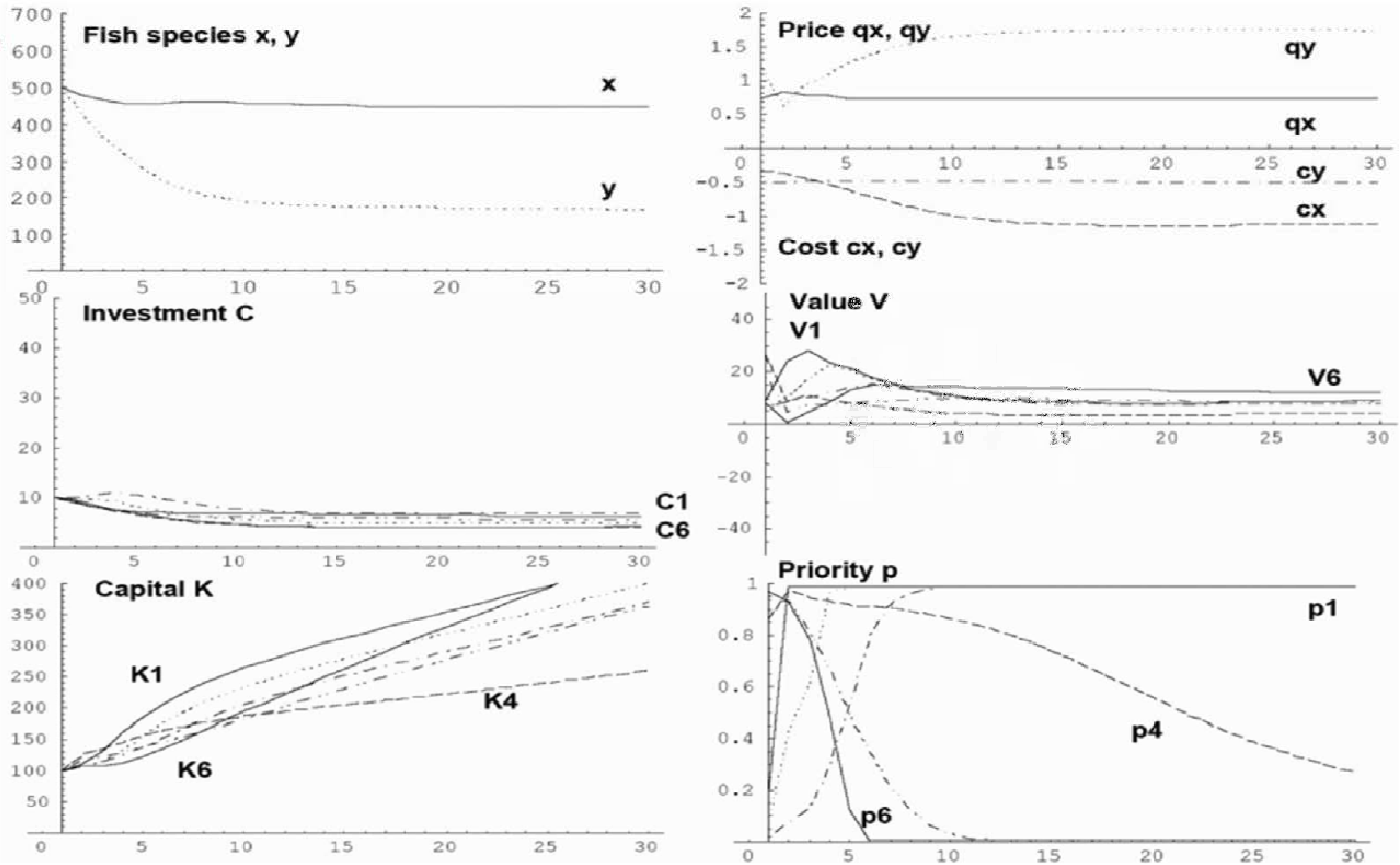
Competitive fishery case

6 fishing companies, 2 fish species



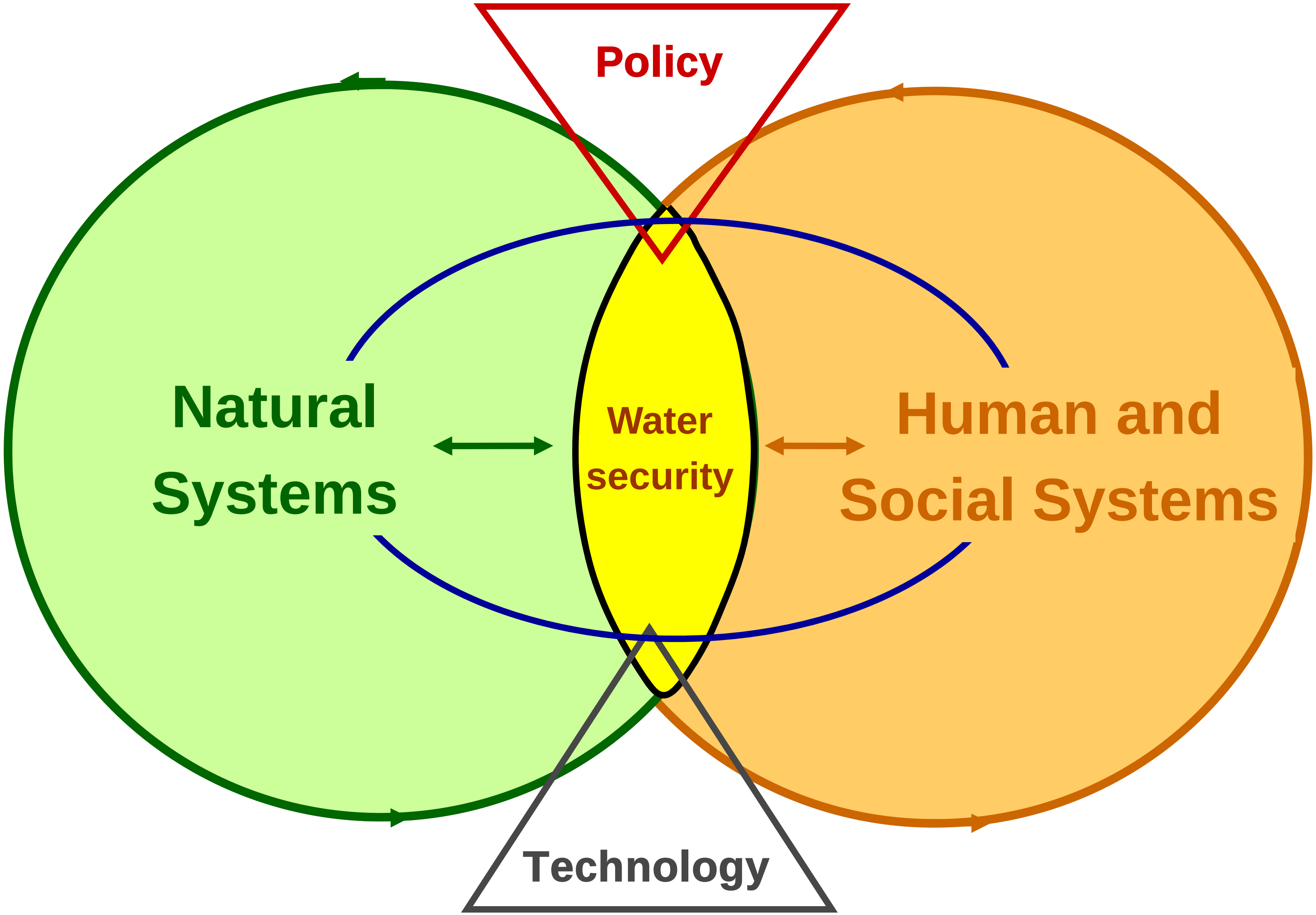
Scheffran, J. (2000) The Dynamic Interaction Between Economy and Ecology: Cooperation, Stability and Sustainability for a Dynamic-Game Model of Resource Conflicts. *Mathematics & Computers in Simulation* 53: 371–380.

Cooperative sustainable fishery case



Scheffran, J. (2000) The Dynamic Interaction Between Economy and Ecology: Cooperation, Stability and Sustainability for a Dynamic-Game Model of Resource Conflicts. *Mathematics & Computers in Simulation* 53: 371–380.

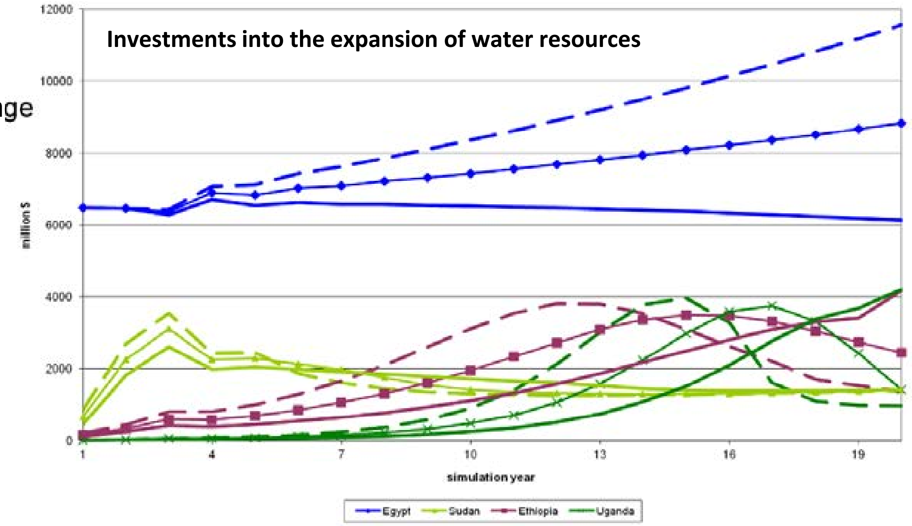
Water management
in human-environment interaction

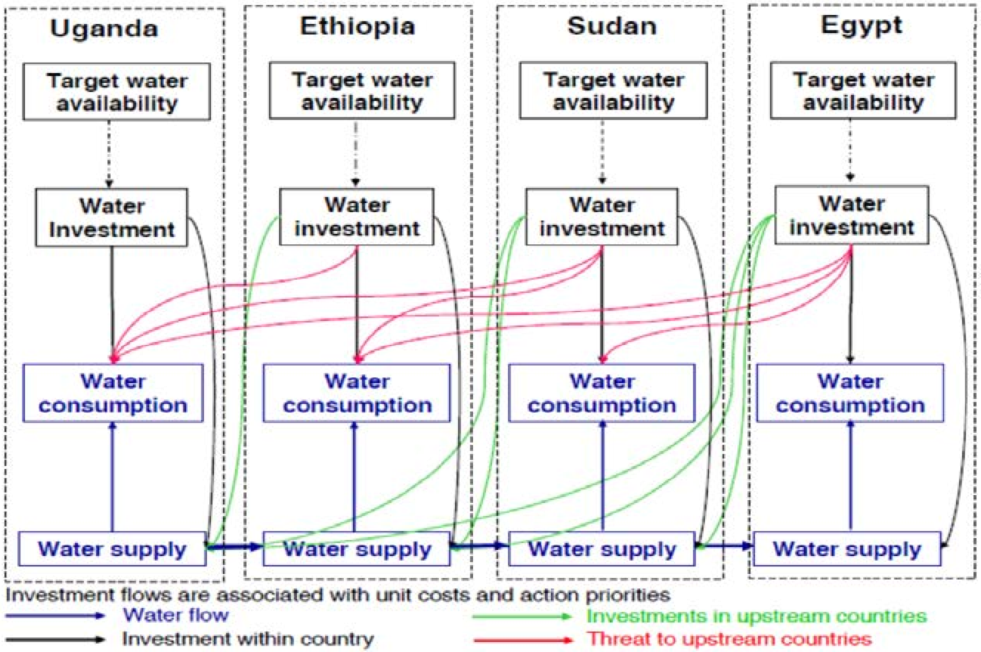


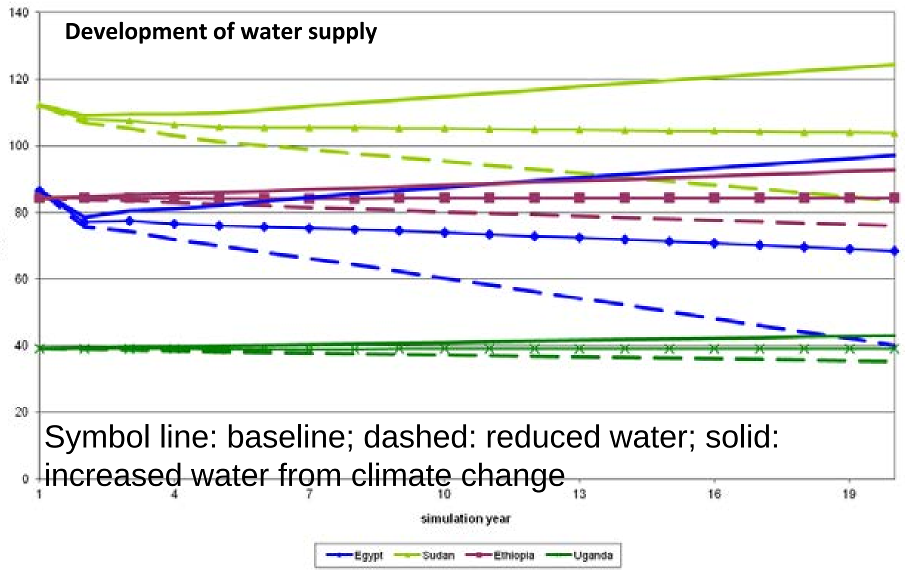
Agent-based social network model of country interactions in Nile river basin

Scenarios of climate change (20 year period):

1. Baseline scenario without climate change
2. Reduced water availability by 20%
3. Increased water availability by 20%



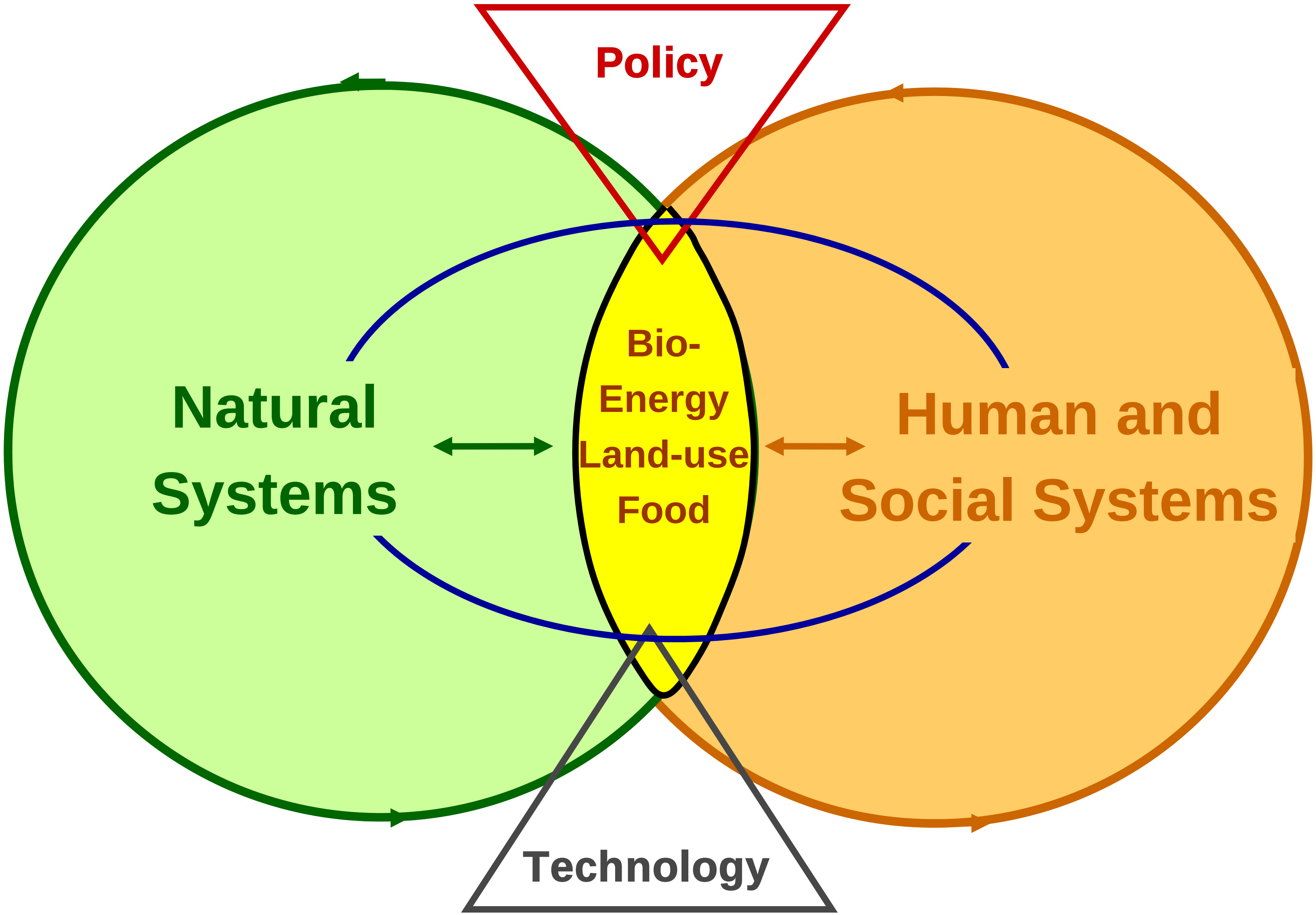




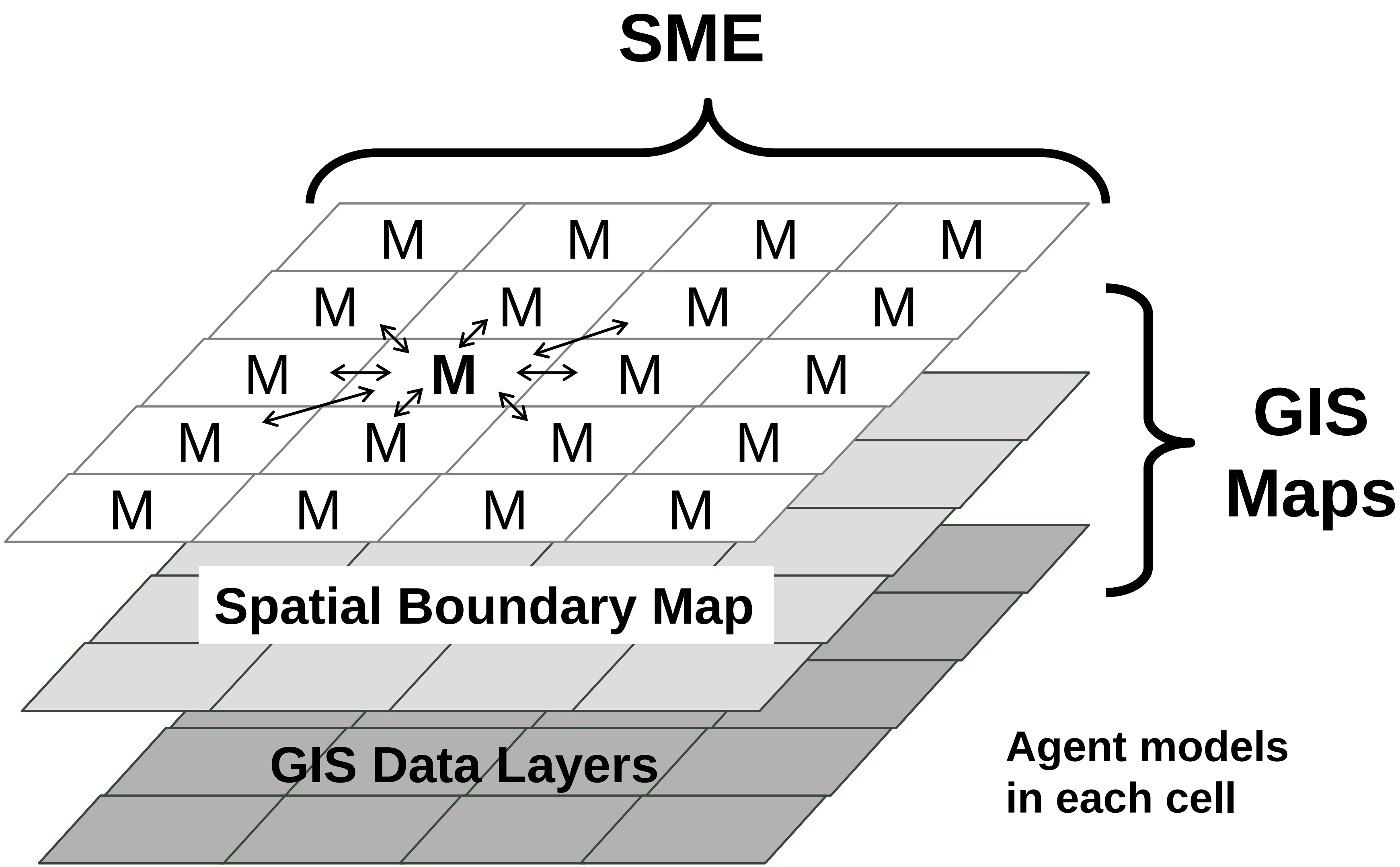
Symbol line: baseline; dashed: reduced water; solid: increased water from climate change

Source: Scheffran, Link, and Schilling (2012)

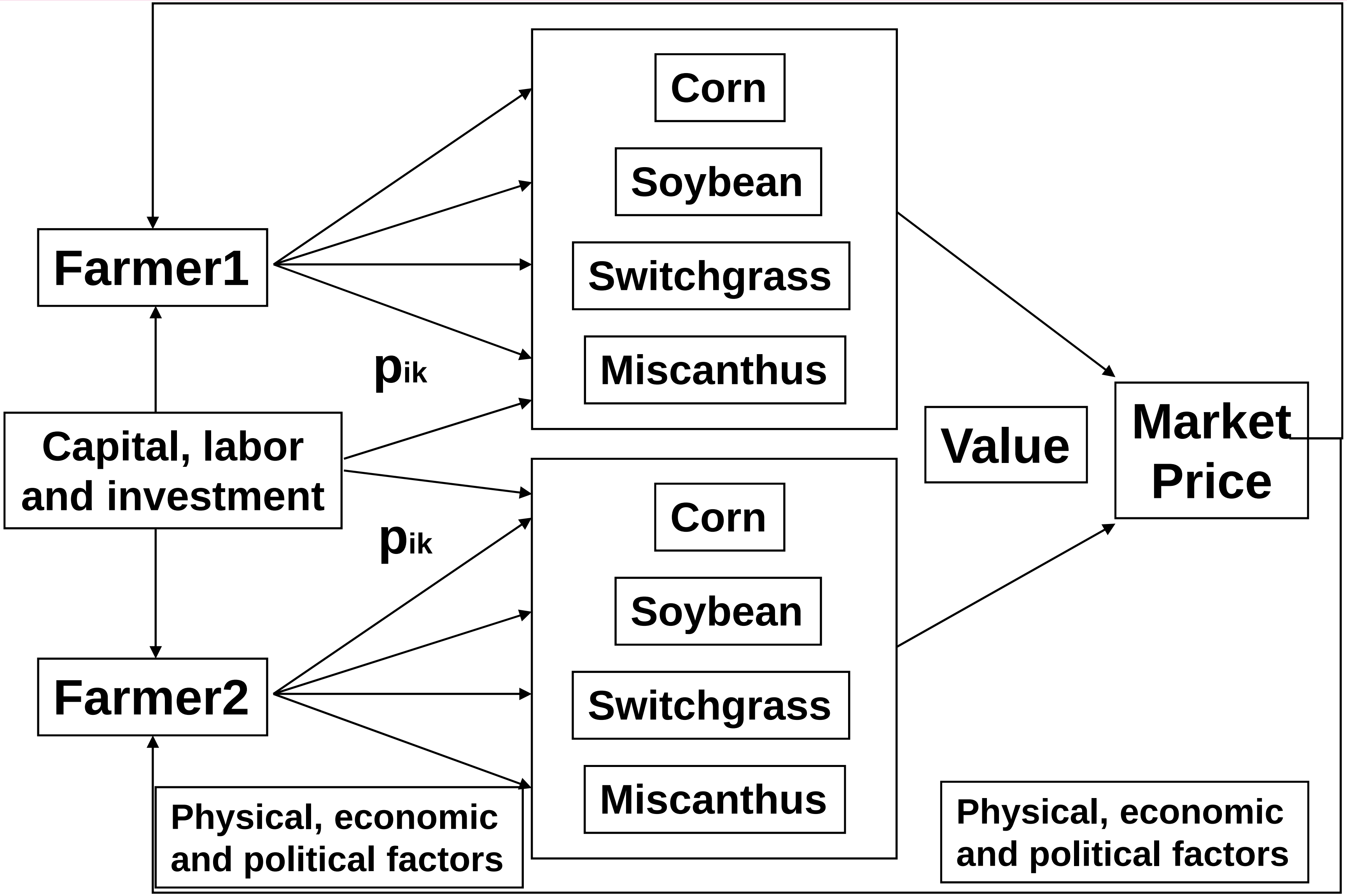
Bioenergy and food in human-environment interaction



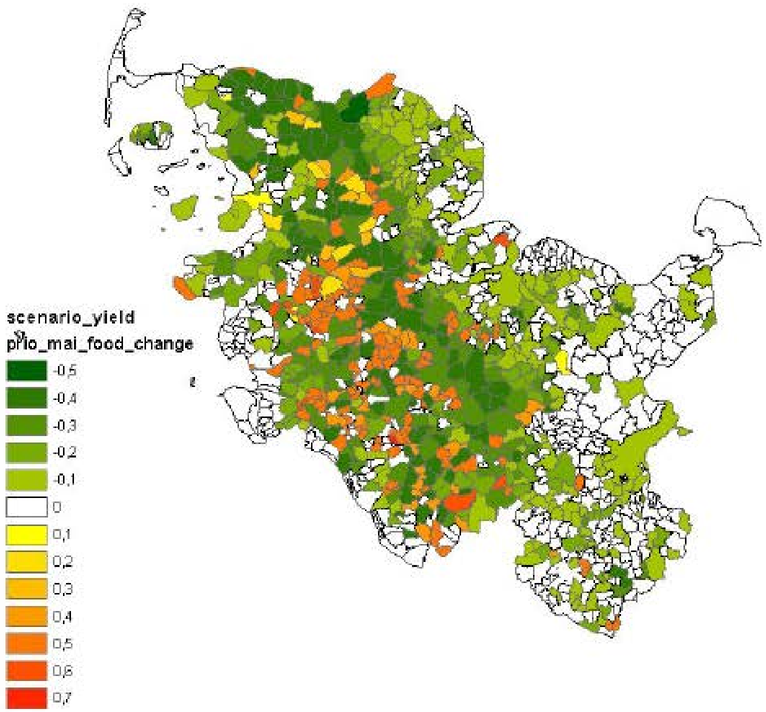
Agent networks in spatial modeling environment

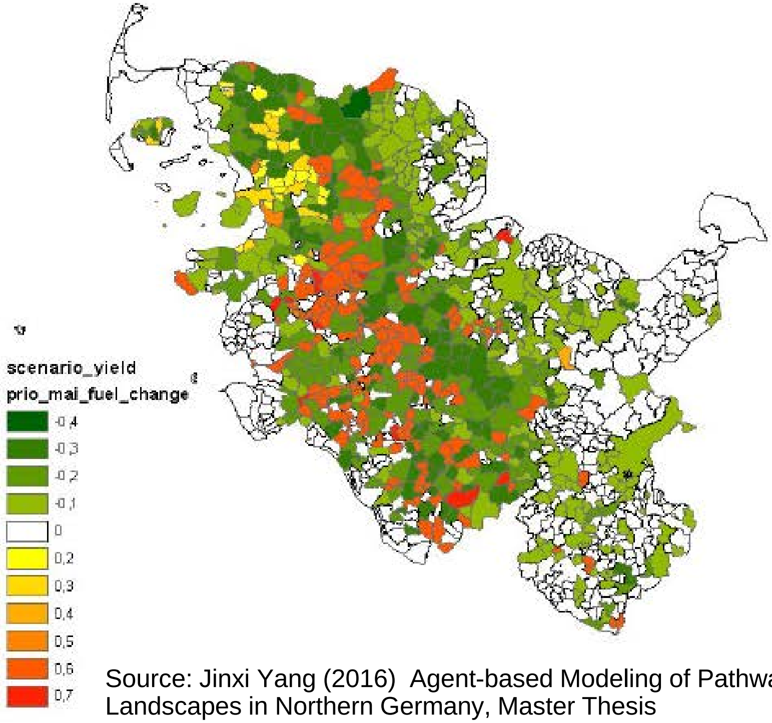


Multi-crop multi-agent model for Illinois

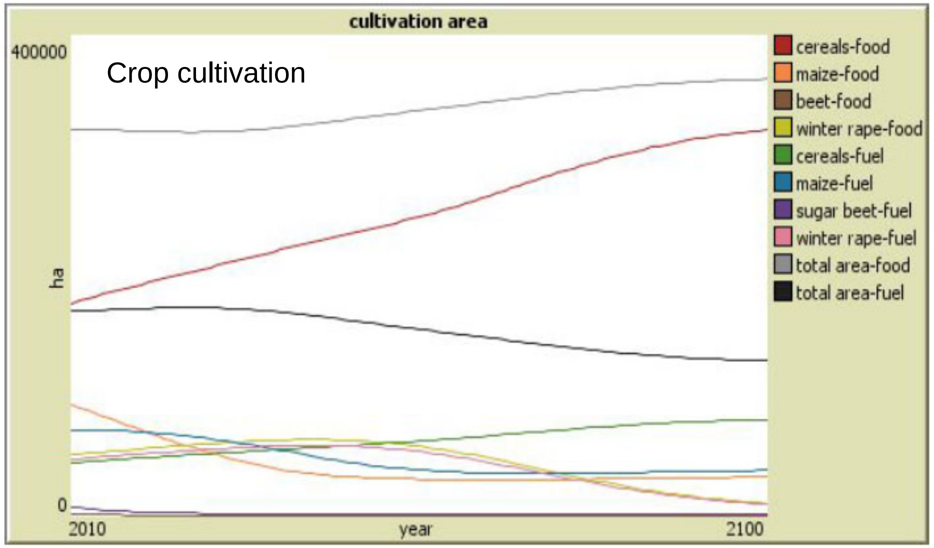


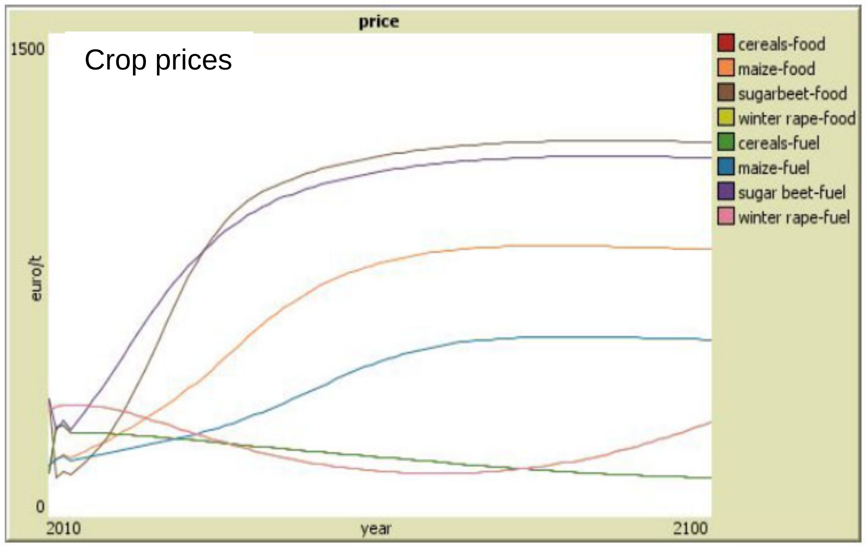
Spatial agent model of bioenergy landscapes in North Germany





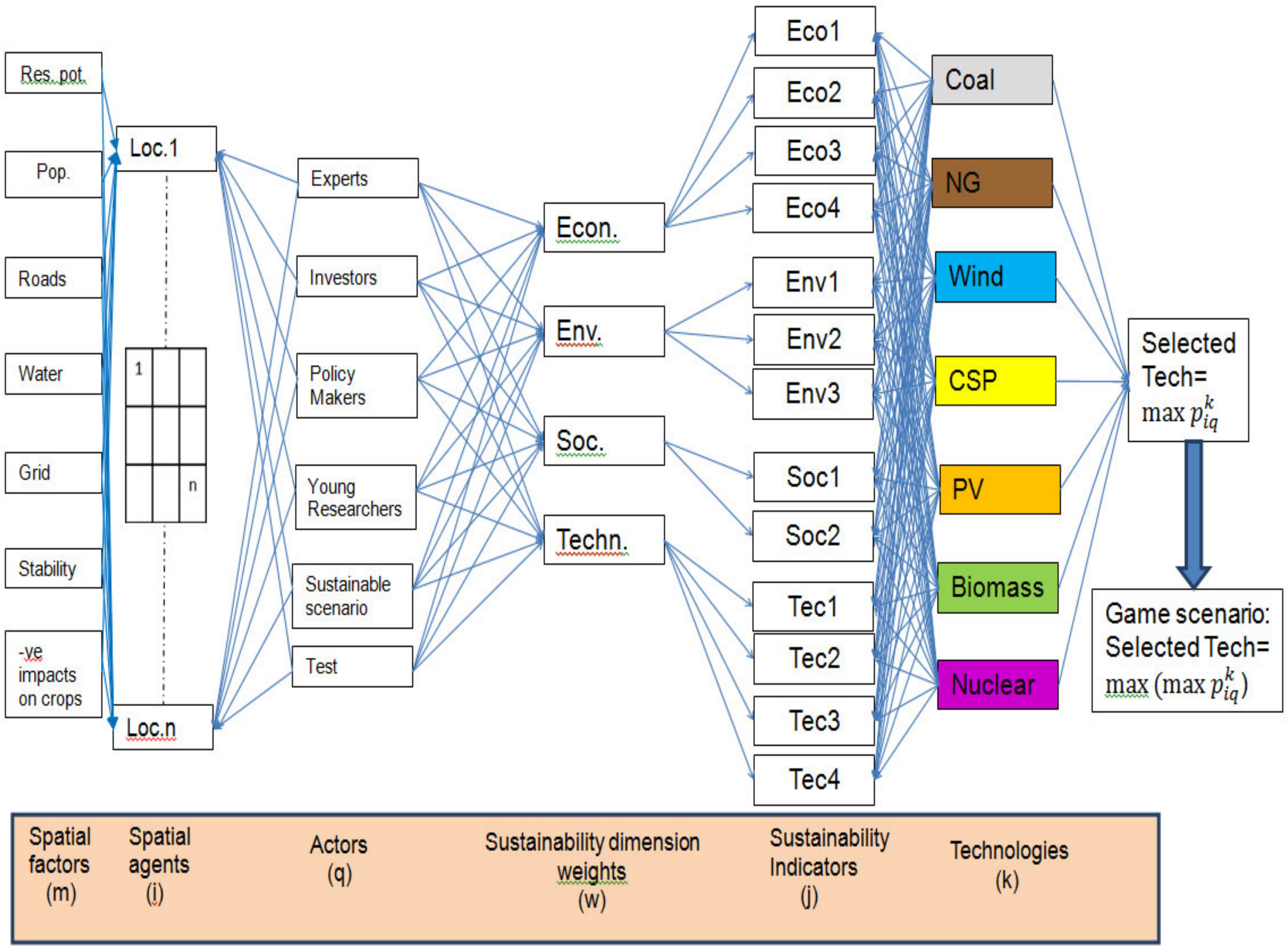
Source: Jinxi Yang (2016) Agent-based Modeling of Pathways of Energy Landscapes in Northern Germany, Master Thesis



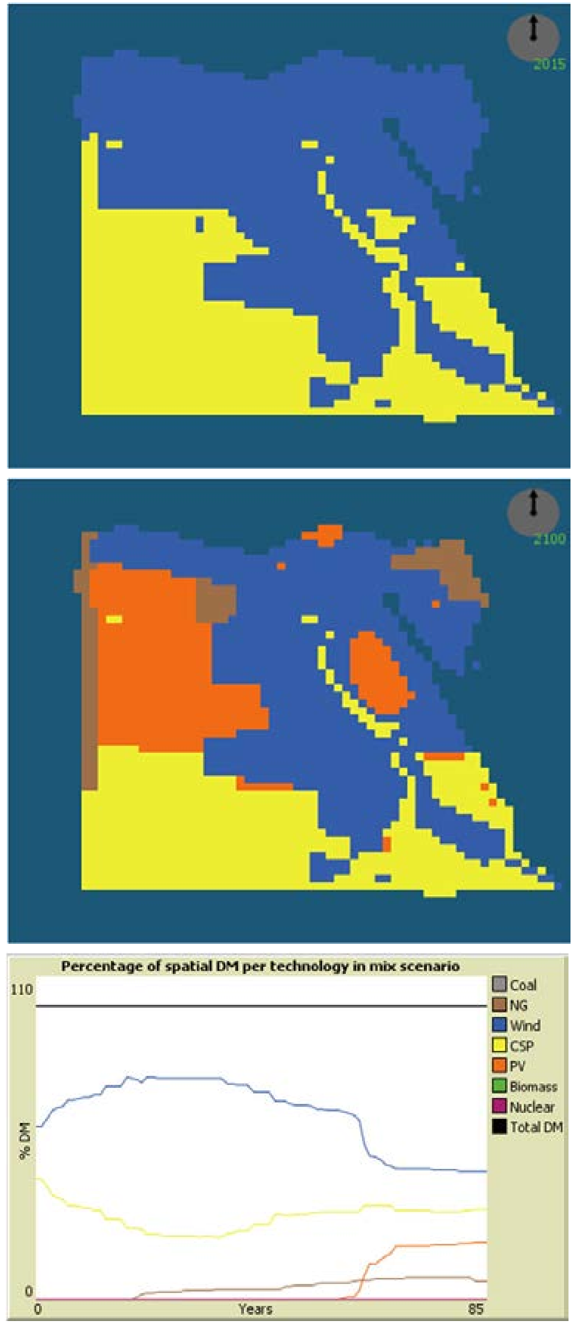


A Dynamic Sustainability Analysis of Energy Landscapes in Egypt: A Spatial Agent-Based Model Combined with Multi-Criteria Decision Analysis

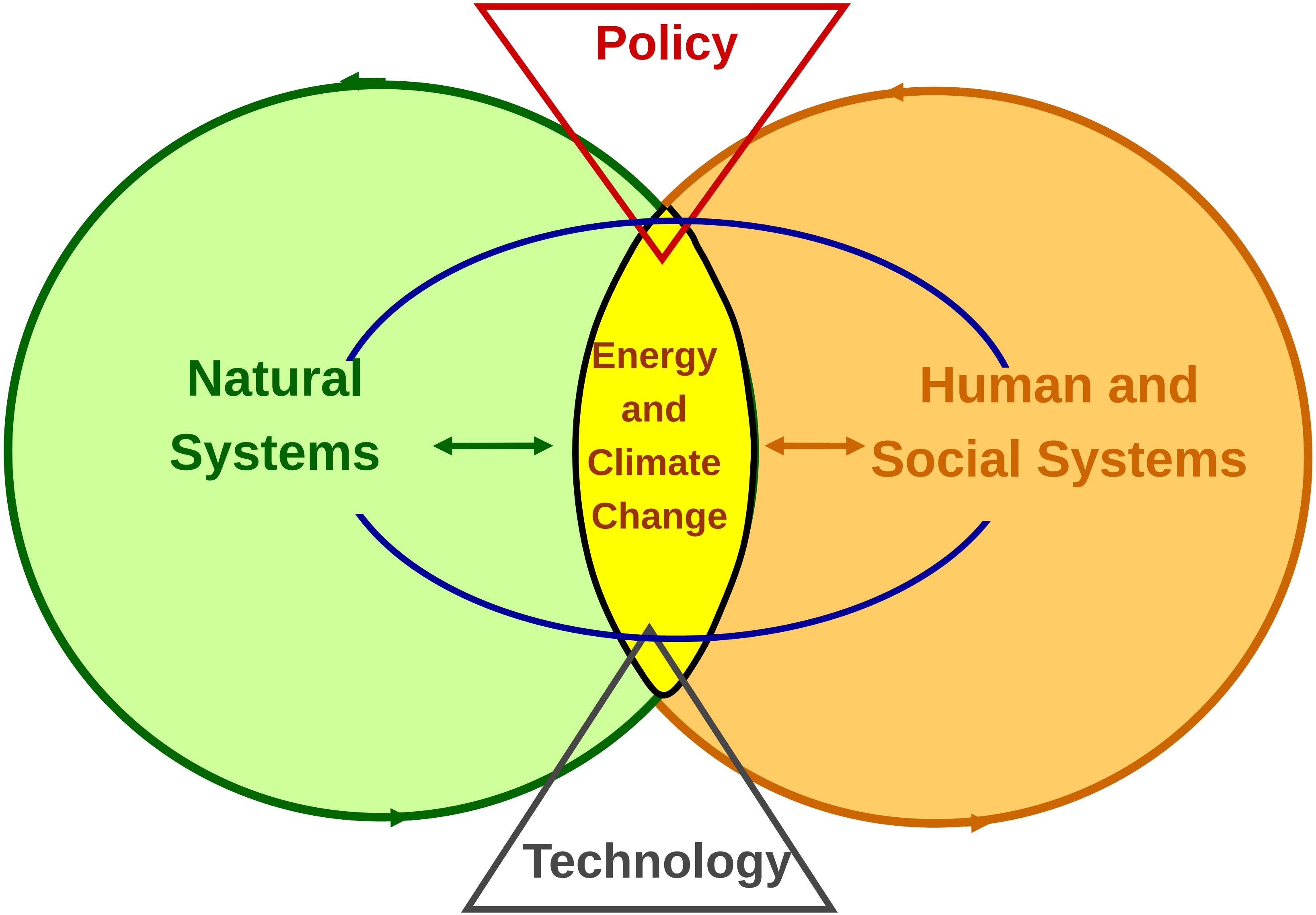
Mostafa Shaaban[1], Jürgen Scheffran[1,2], Jürgen Böhner[2], Mohamed S. Elsobki[3]



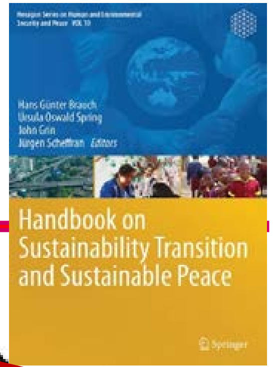
Policy-makers

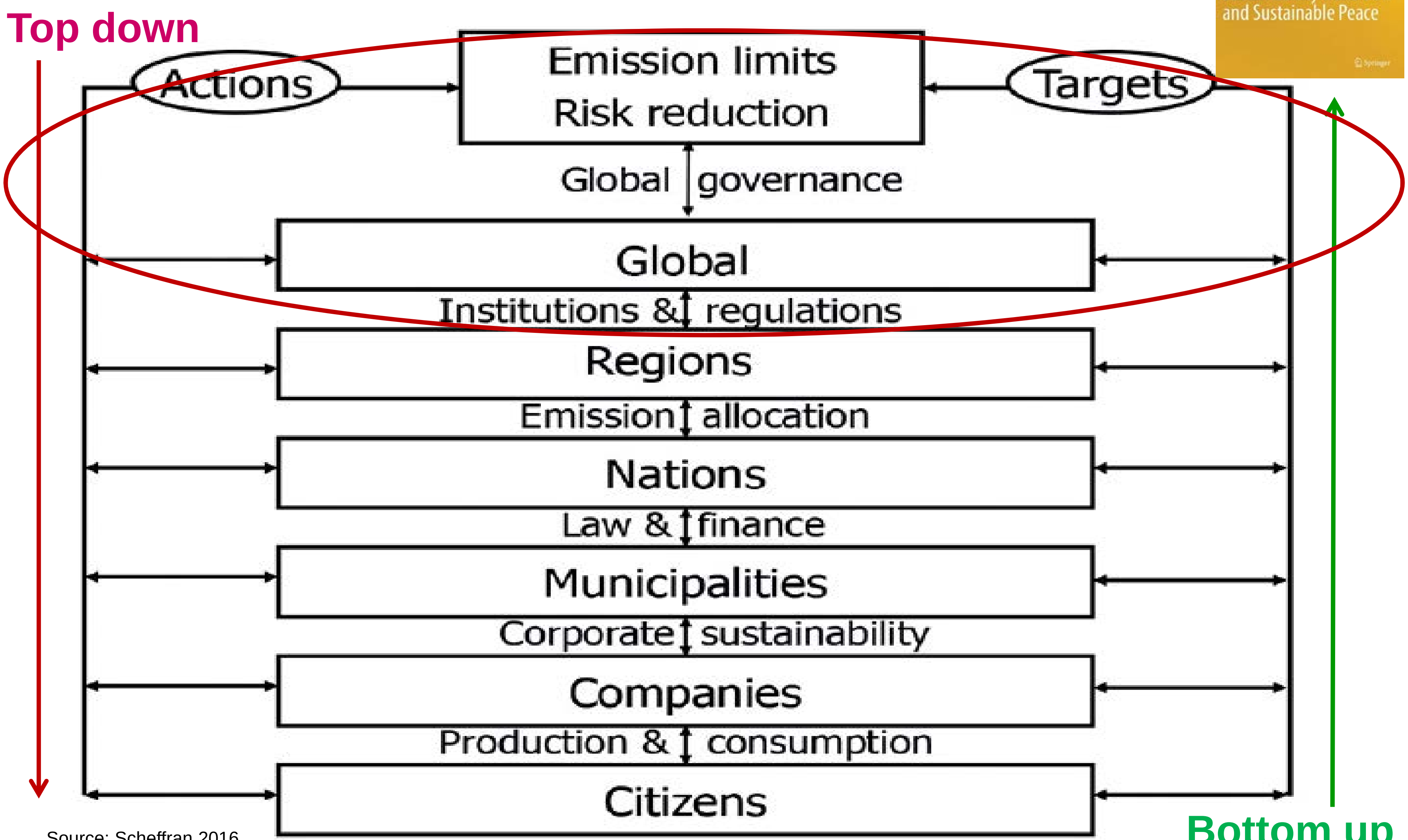


Energy and climate change in human-environment interaction



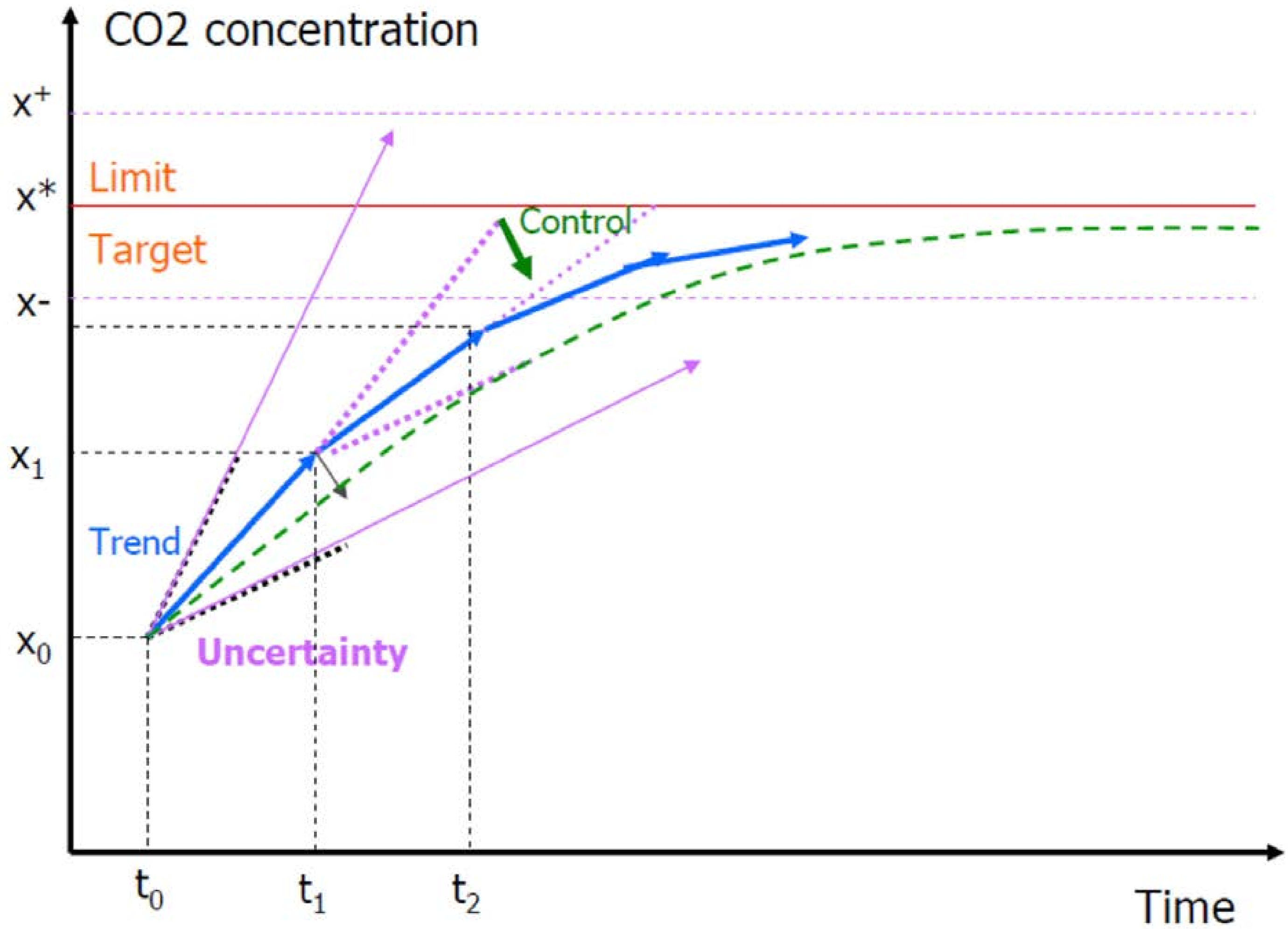
Multi-level transitions in climate governance at macro level





Source: Scheffran 2016

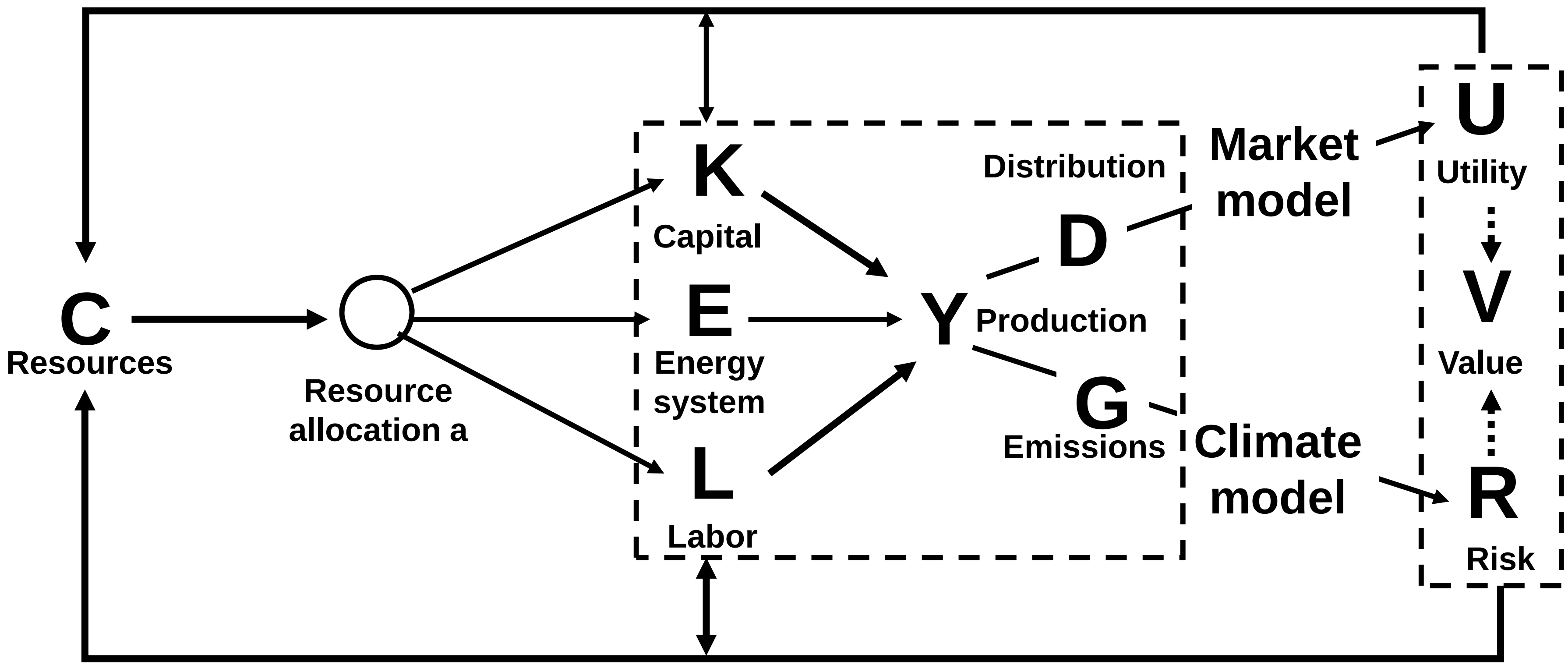
Adaptive emission control under uncertainty



Adaptive decision rules: $\Delta x(t) = w(x,t)\, D(x,t)$

Speed control $\Delta x(t) \leqq w\,(x^*(t) - x(t))$

Integrated energy-climate system modeling



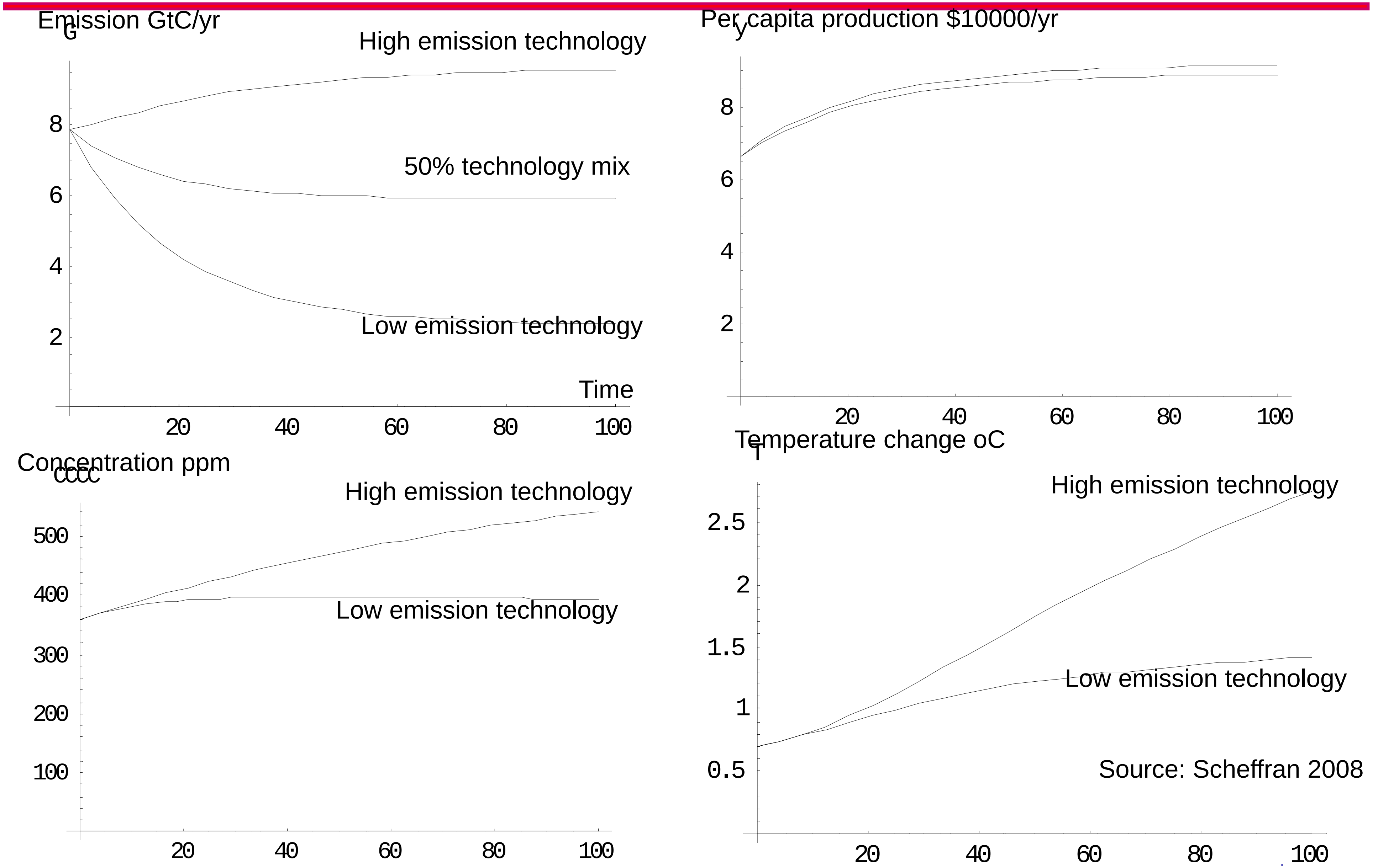
CMS (2008) 5:259–286
DOI 10.1007/s10287-007-0044-1

ORIGINAL PAPER

Adaptive management of energy transitions in long-term climate change

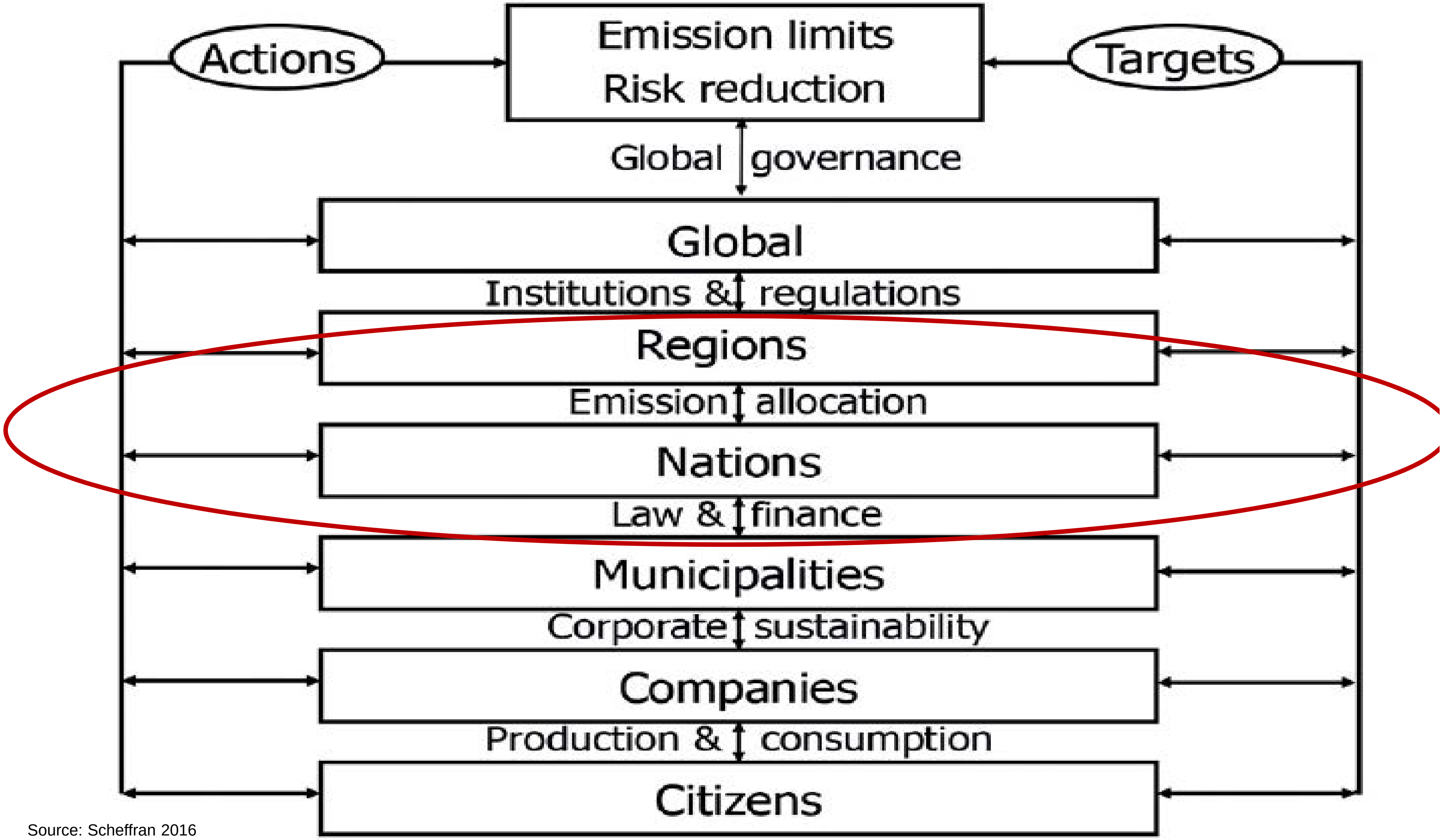
Jürgen Scheffran

Comparison of technology paths



Source: Scheffran 2008

Energy and climate change in transformation at meso level



Source: Scheffran 2016

Global emission reduction: a multi-agent collective action problem

$$G(t) = \sum_i G_i(t)(1 - r_i(t)) < G^*(t)$$

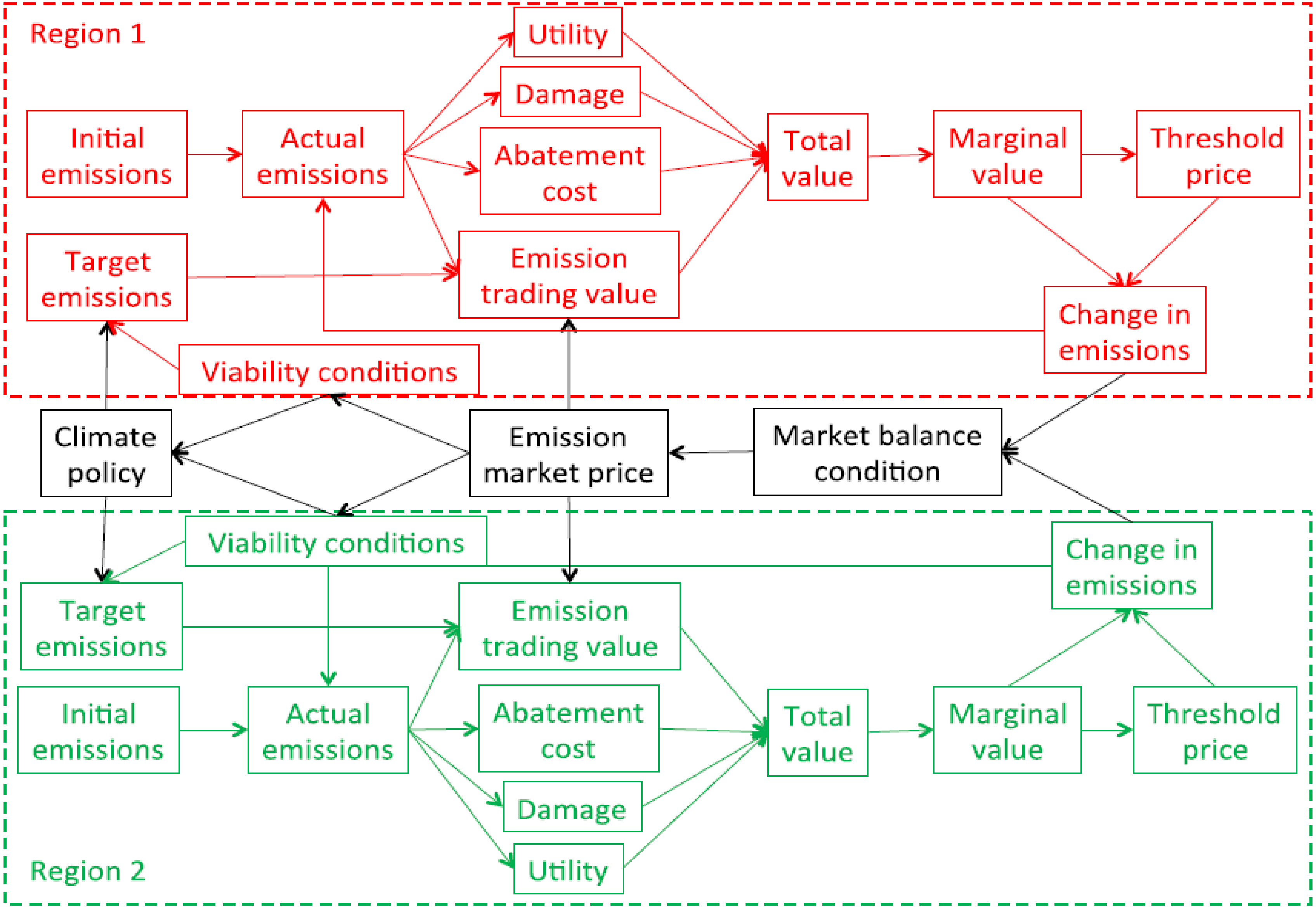
$G(t)$: Global emissions at time *t*

$G^*(t)$: Global emission target at time *t*

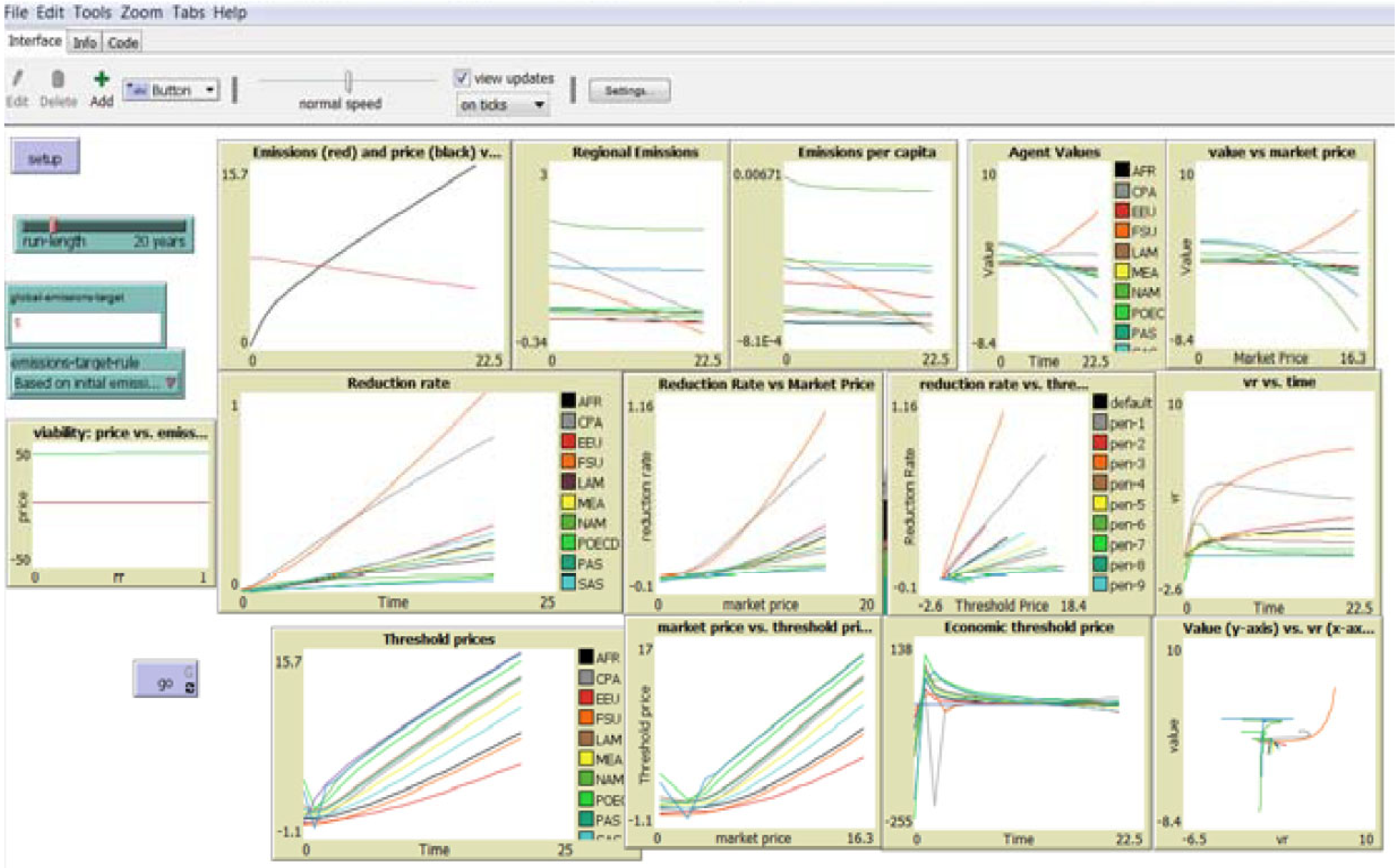
$G_i(t)$: Baseline emissions path of actor *i*

$r_i(t)$: Emission reduction of *i* from baseline

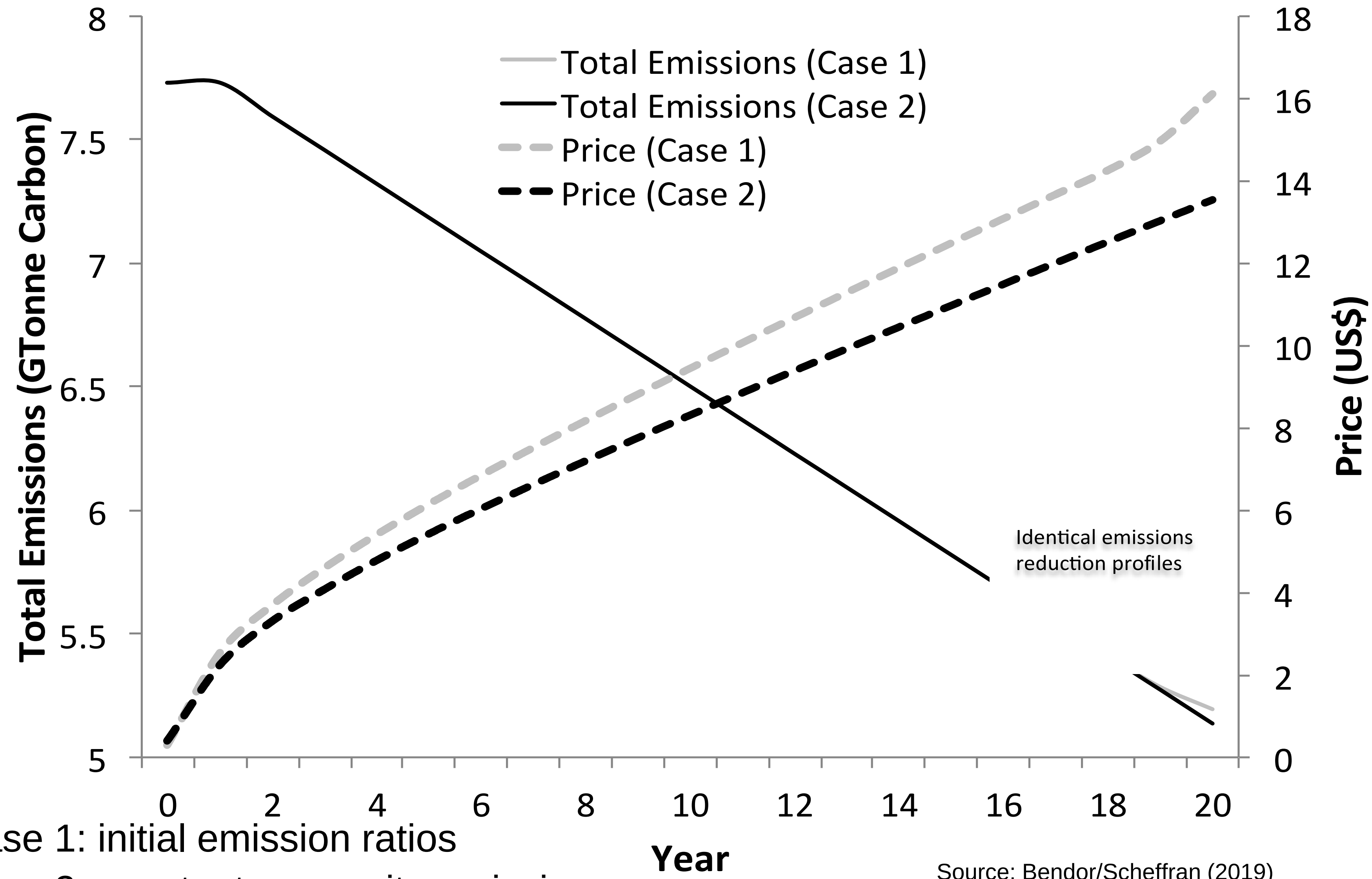
Agent-based model of emissions trading in the VIABLE framework



Emission trading in Netlogo



Baseline simulations for global emission target 5 Gt for two cases of allocation

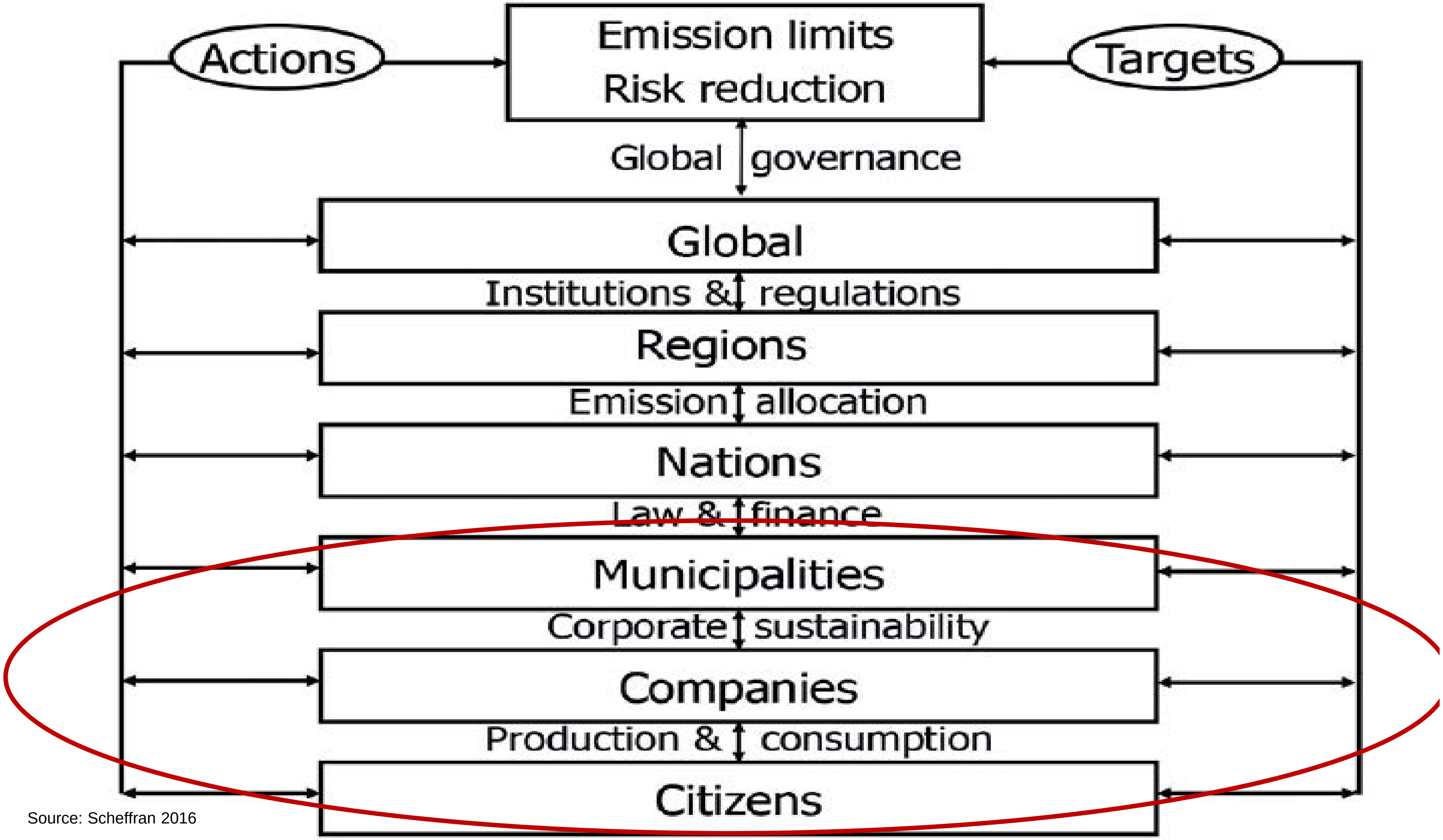


Case 1: initial emission ratios

Case 2: constant per capita emissions

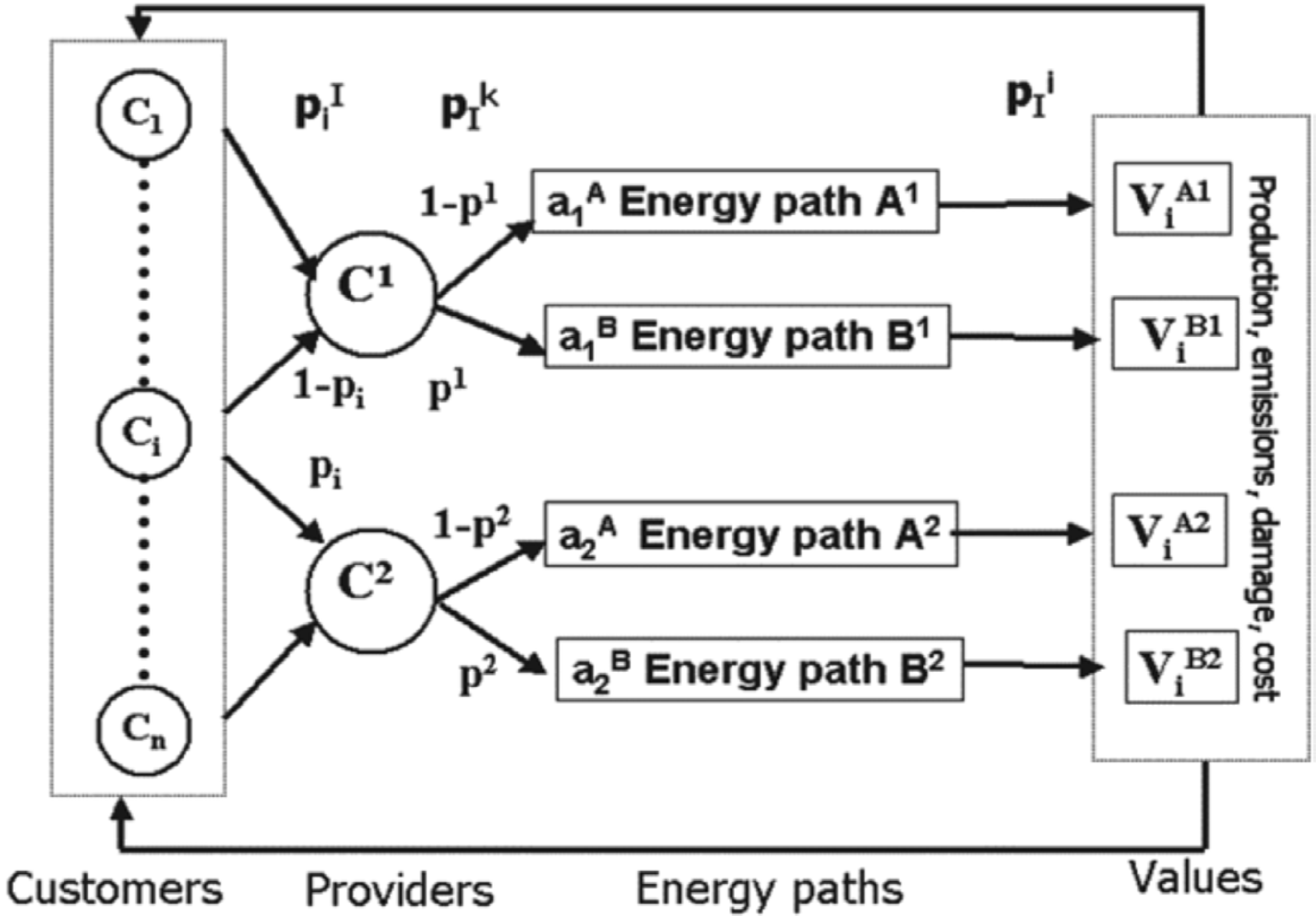
Source: Bendor/Scheffran (2019)

Energy and climate change in transformation at micro level



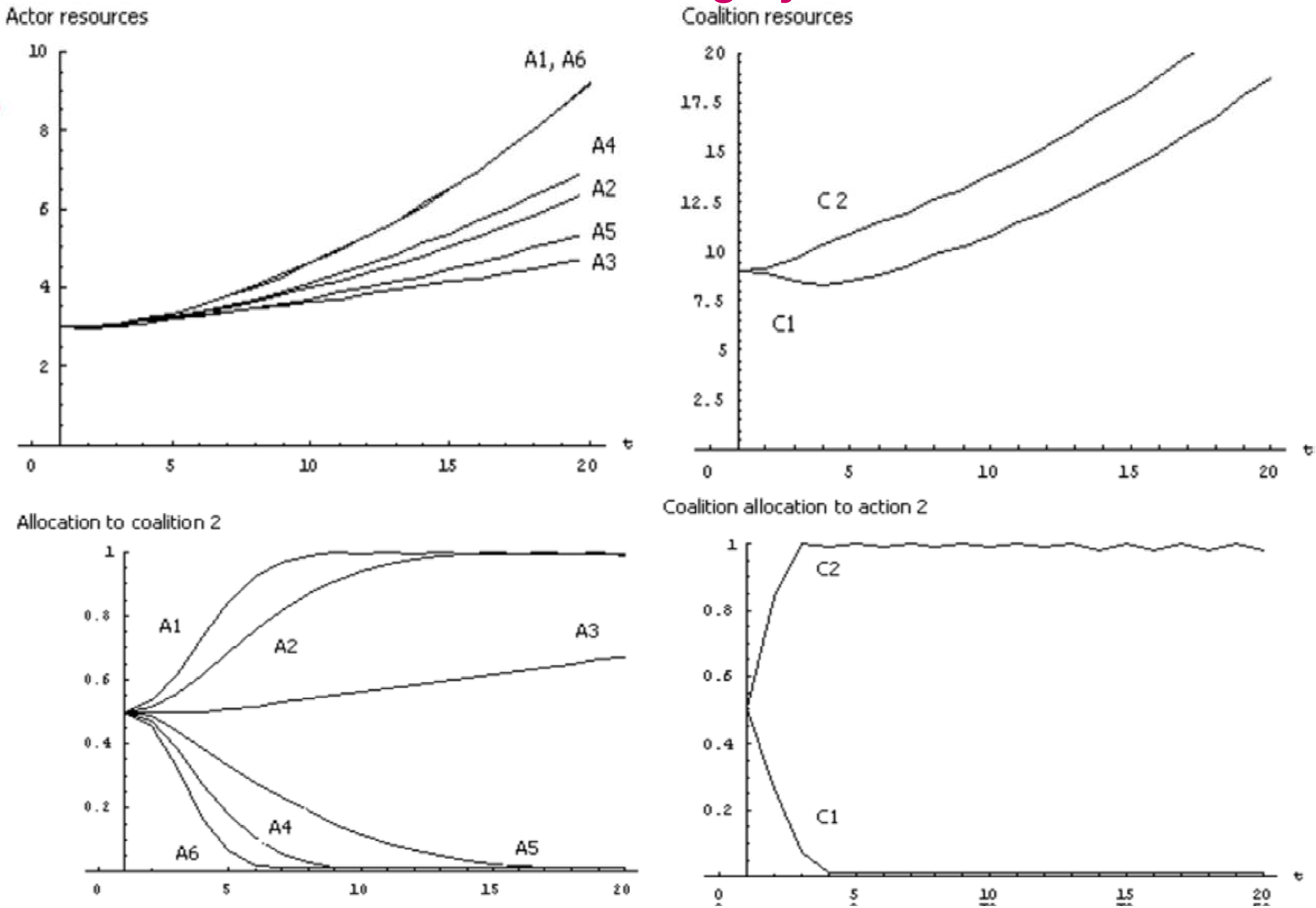
Source: Scheffran 2016

Adaptive coalition formation between energy providers and customers for high-and low-carbon energy paths



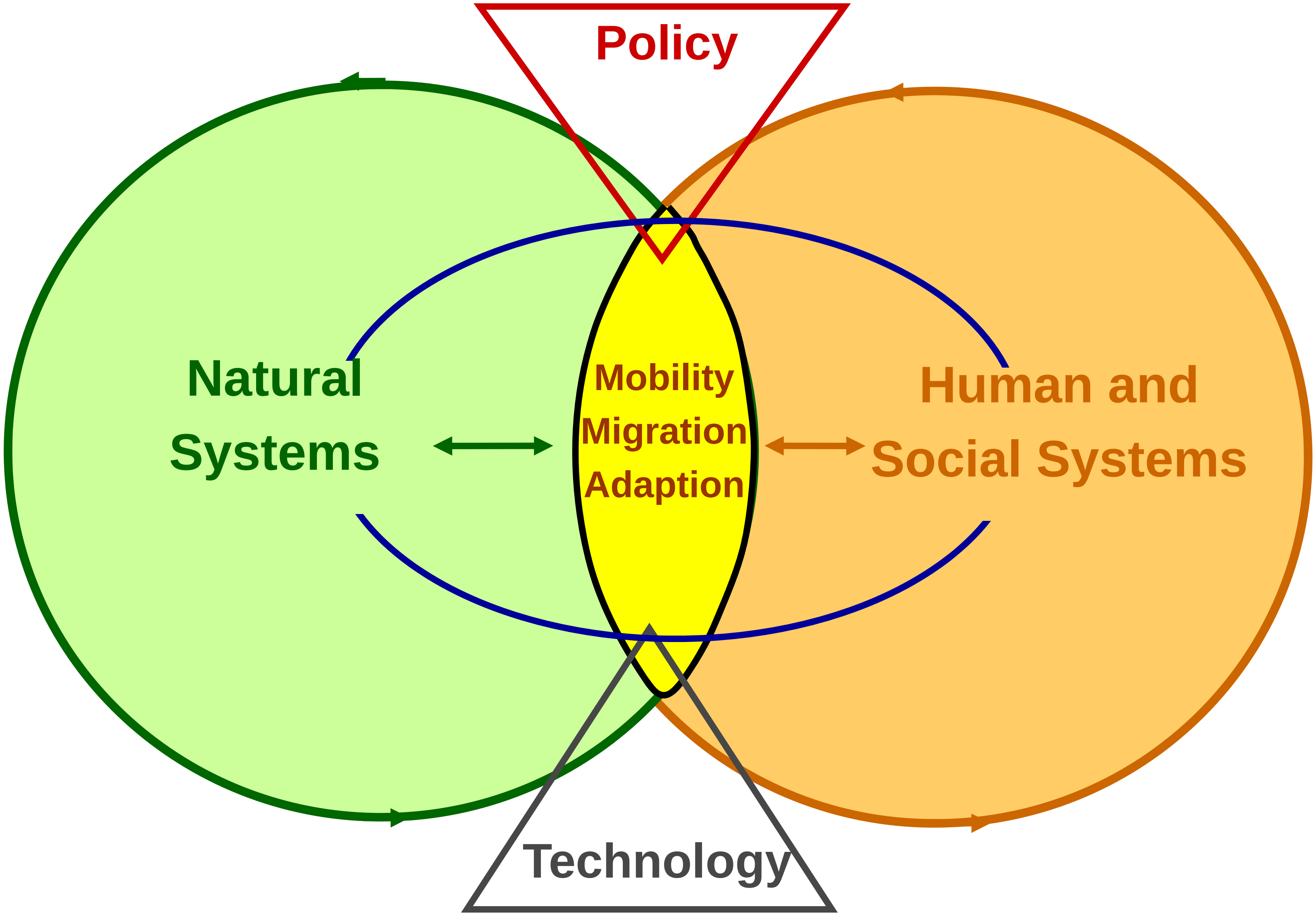
Scheffran (2006) The Formation of Adaptive Coalitions. In: Haurie et al (eds.) Advances in Dynamic Games

Coalition building dynamics

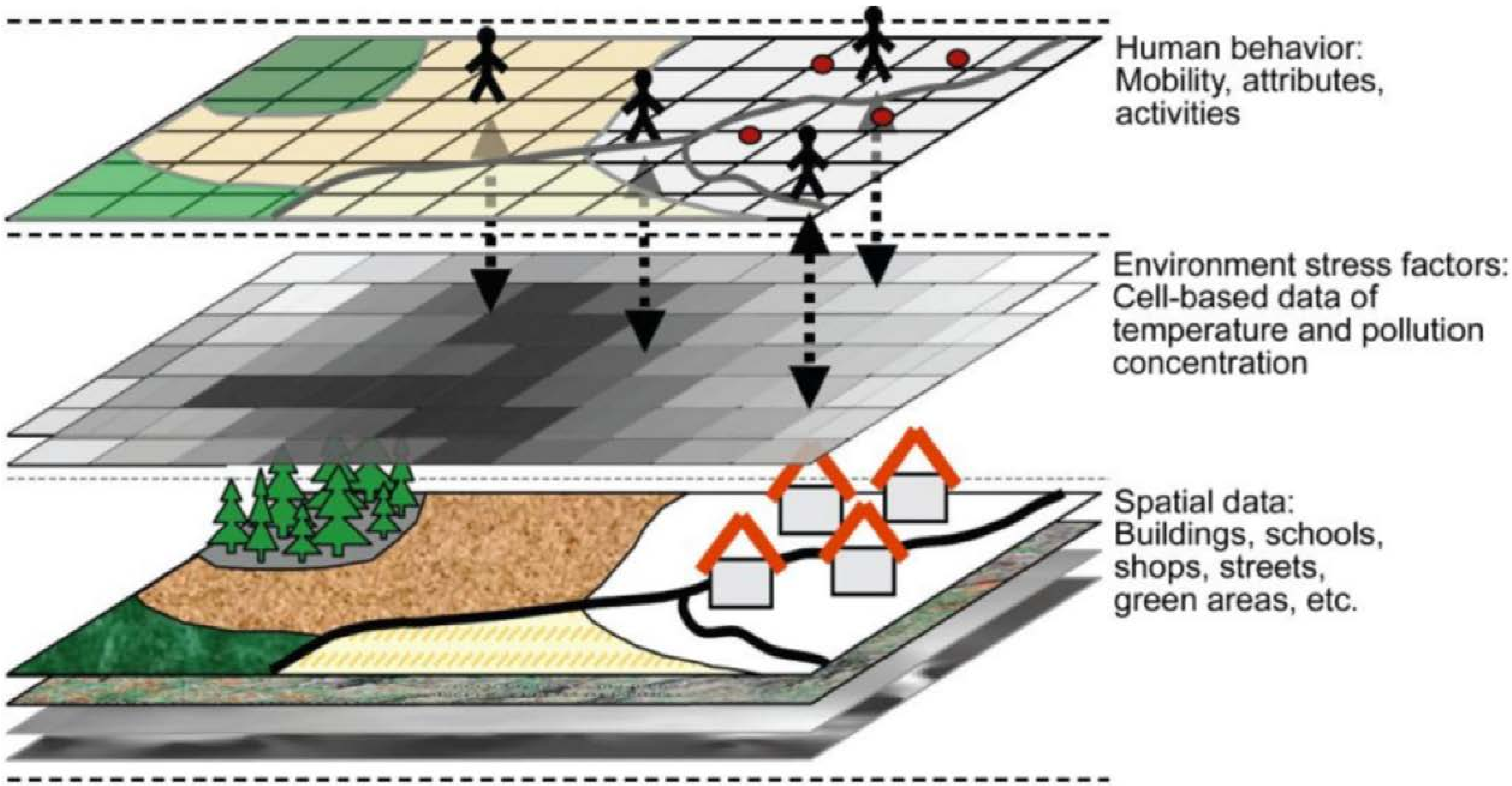


Scheffran (2006) The Formation of Adaptive Coalitions. In: Haurie et al (eds.) Advances in Dynamic Games

Mobility, migration and adaptation in human-environment interaction



Agent-based modeling of GIS-based human-environment interaction

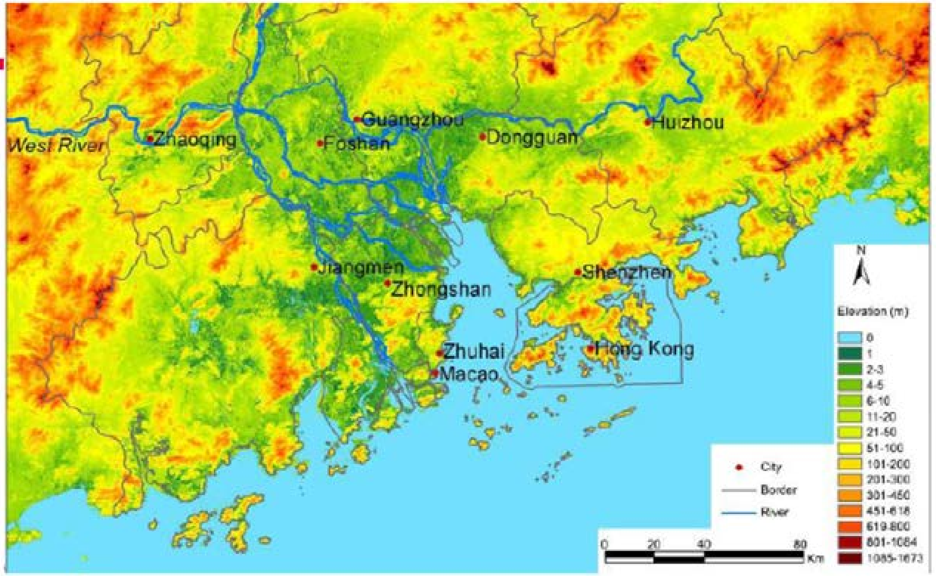


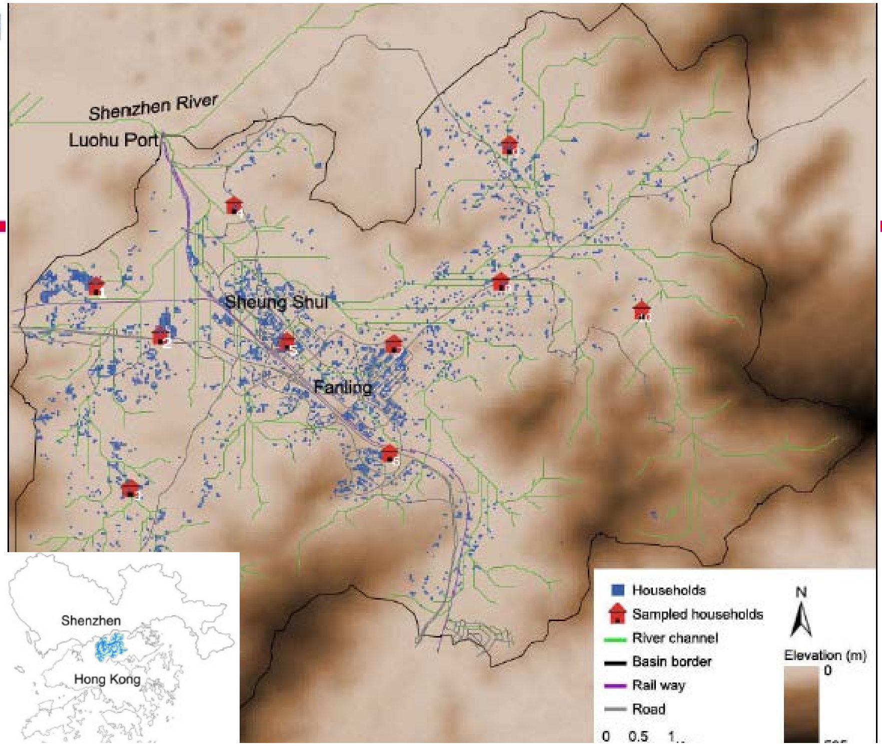
Source: Yang/Hoffmann/Scheffran/Rühe/Fischereit/Gasser 2018, adapted and reedited from Leyk et al.

Assessment of Flood Losses with Household Responses: Agent-Based Simulation in an Urban Catchment Area

Environmental Modeling & Assessment (2018) 23:369–388

Liang Emlyn Yang[1,2] · Jürgen Scheffran[1] · Diana Süsser[3,4] · Richard Dawson[5] · Yongqin David Chen[6]





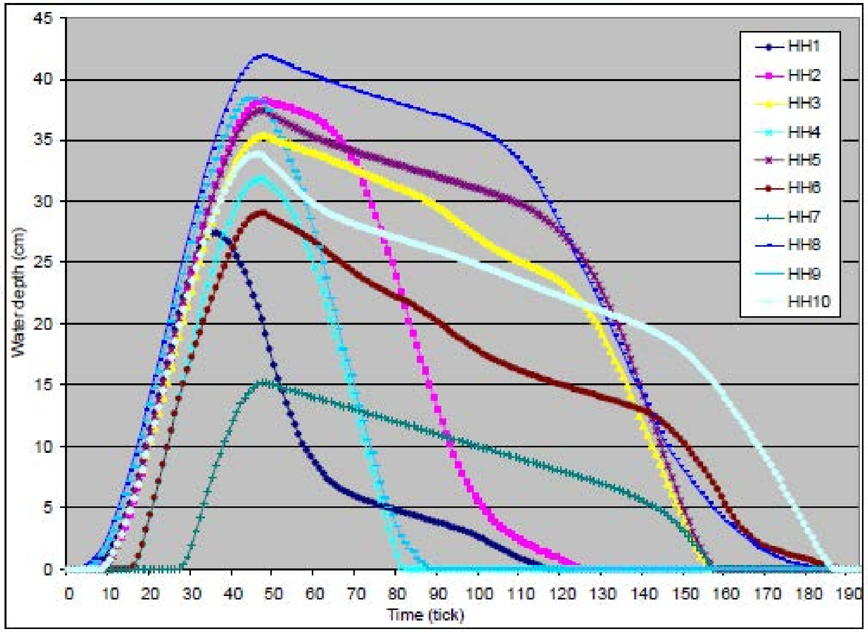
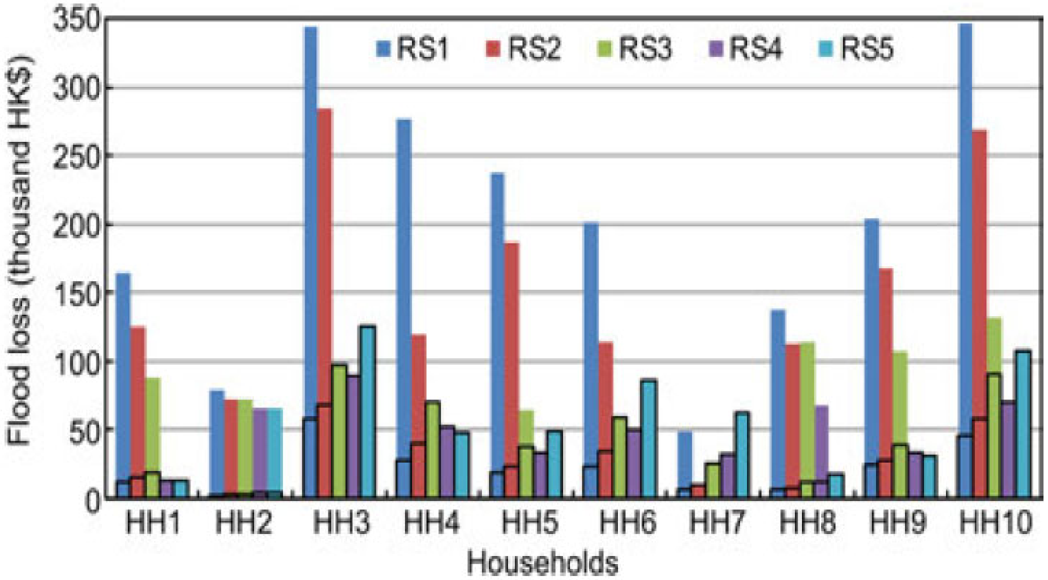


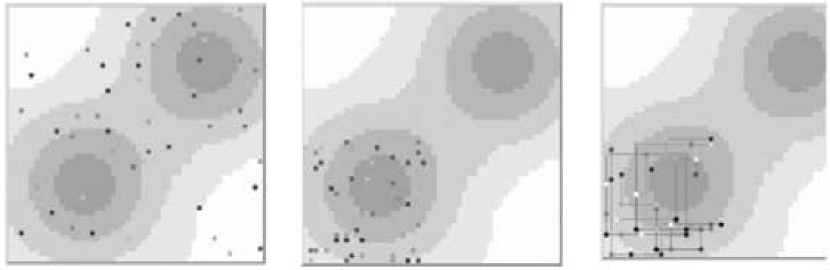
Figure 5-6 Inundation processes of the 10 selected cells of the model in action, in rainfall scenario 3.



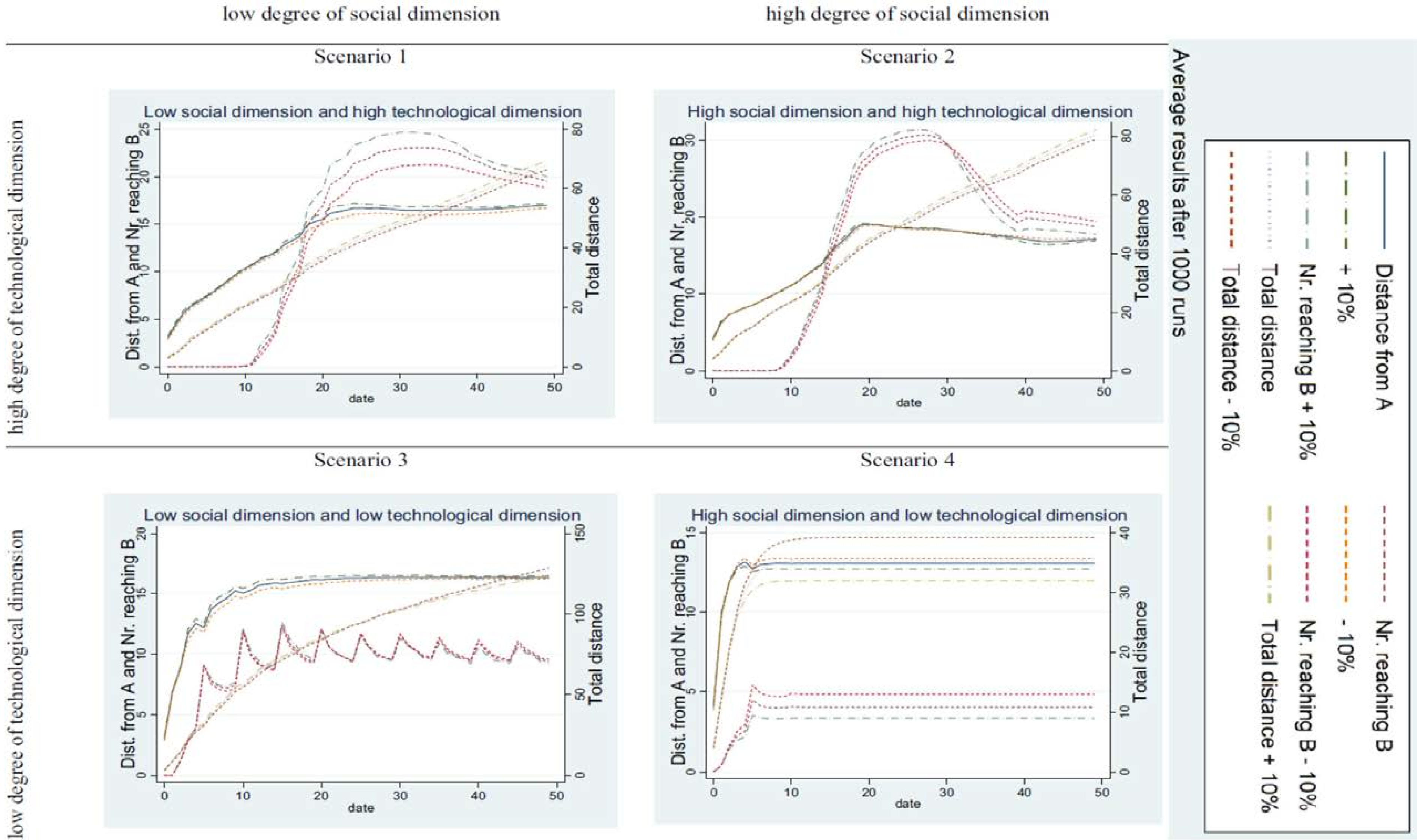
Flood loss of households for different rainfall scenarios and same warning information (lead time 12 h, interval 3 h); black boxes indicate response costs

Technological and social networks of a pastoralist artificial society: agent-based modeling of mobility patterns

Juan Miguel Rodriguez-Lopez[1] · Meike Schickhoff[2] · Shubhankar Sengupta
Jürgen Scheffran[1] ***Journal of Computational Social Science*** **(2021)**



(a) Original model (b) Model with accumulation (c) Graphic with networks



Urban ABM for Hamburg

Different commuting routes between home and work for selected area in Hamburg

urban science

MDPI

Article

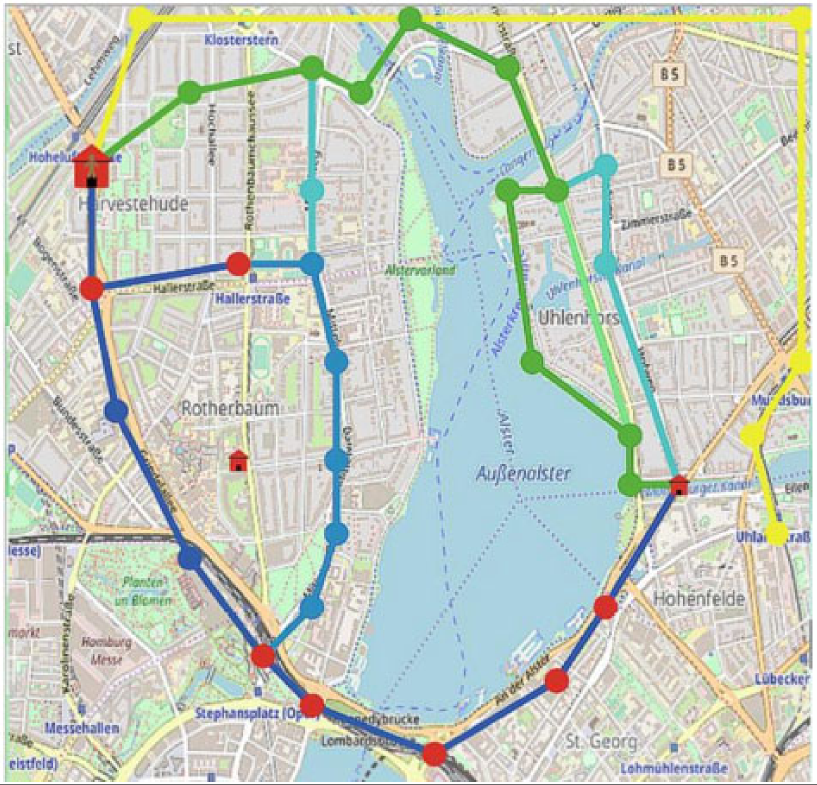
An Agent-Based Modeling Framework for Simulating Human Exposure to Environmental Stresses in Urban Areas

Liang Emlyn Yang [1,2,*], Peter Hoffmann [2], Jürgen Scheffran [3], Sven Rühe [3], Jana Fischereit [4] and Ingenuin Gasser [2]

Hamburg-based "agents" in the service of climate research

Agent-based modeling allows researchers to simulate human behavior.

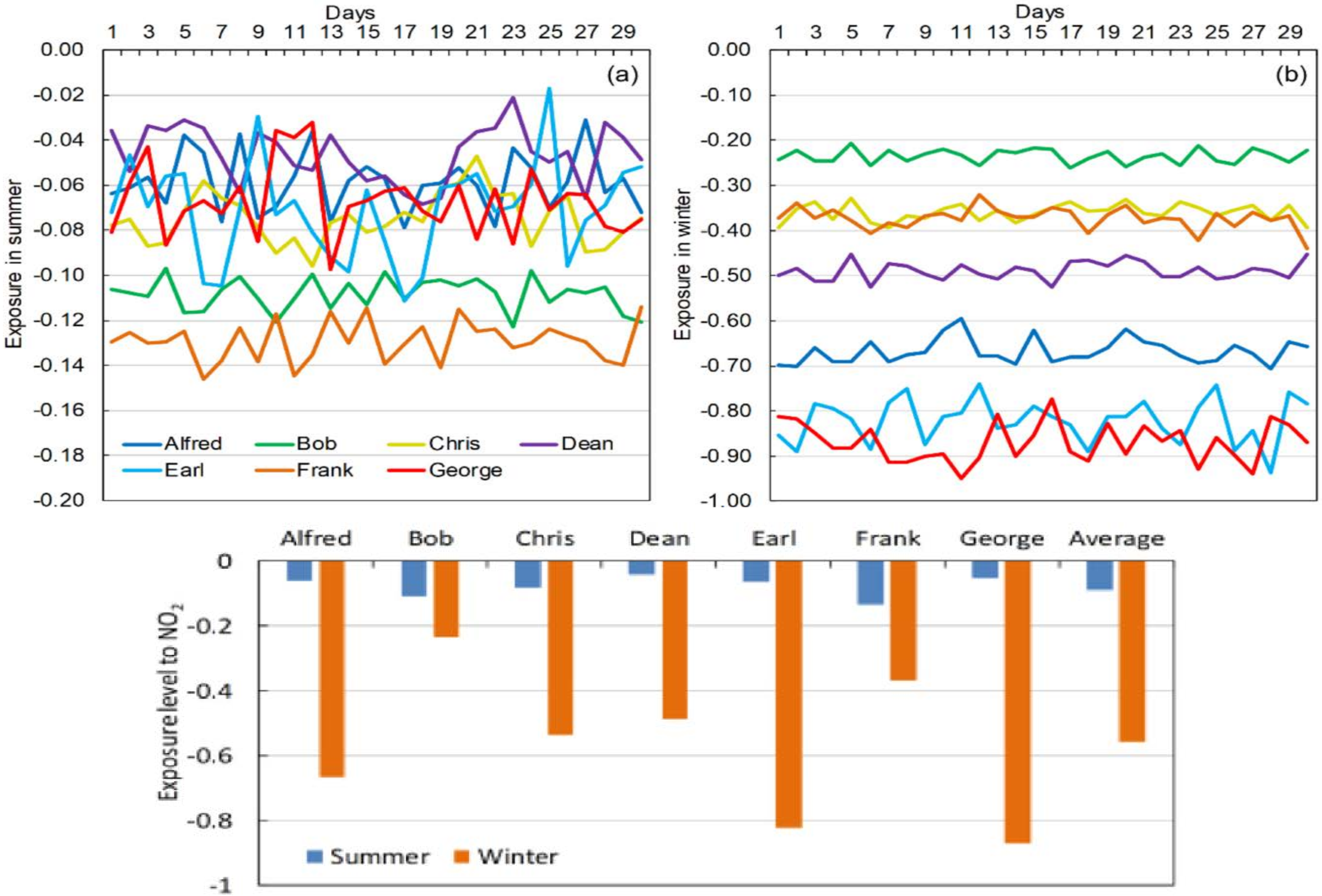
27 June 2018, by Prof. Dr. Jürgen Scheffran, CEN



	Car1	Car2	Car3	Car4	Car5	Bike	Public
Time [min]	10	16	17	15	13	19	18
Length [km]	5.1	5.3	6.8	7.1	6.6	5.0	6.3
Costs [€]	1.53	1.59	2.04	2.13	1.98	0.4	1.07

Source: https://www.cen.uni-hamburg.de/en/about-cen/news/1-news-2018/2018-06-18-abendblatt-scheffran.html

Urban ABM for Hamburg: Exposure to environmental stressors



Source: Yang/Hoffmann/Scheffran/Rühe/Fischereit/Gasser 2018

Integrative framework of rural-urban interaction under climate change