Frameworks and prospects for Integrated Assessment Modelling of Global Change (IAM-GC)

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Workshop on Coupled Climate-Economics Modelling and Data Analysis
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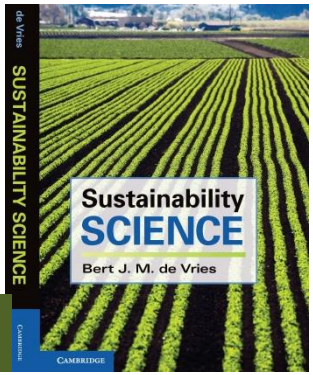
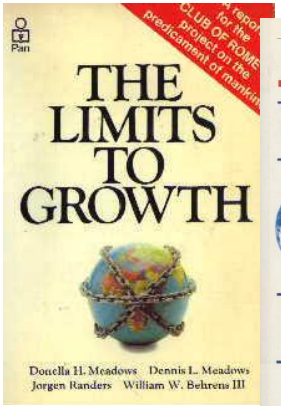
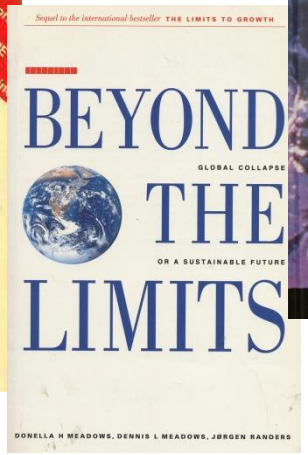
Planbureau voor de Leefomgeving

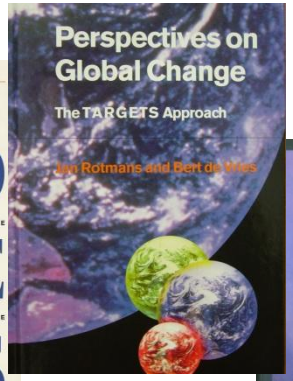
1. Introduction: entering a period of tensions
2. Three gaps to be bridged
3. Some research projects and directions
    a) Use and availability of (ground)water
    b) Competition vs. cooperation in climate policy
    c) The financial system

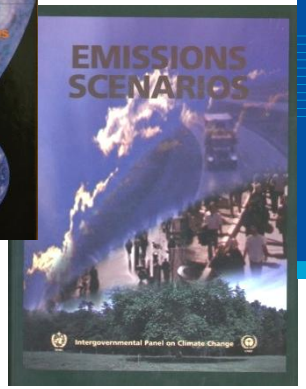


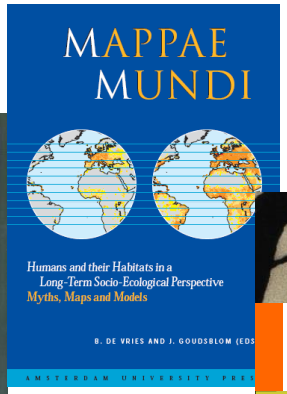
More communicator than scientist…





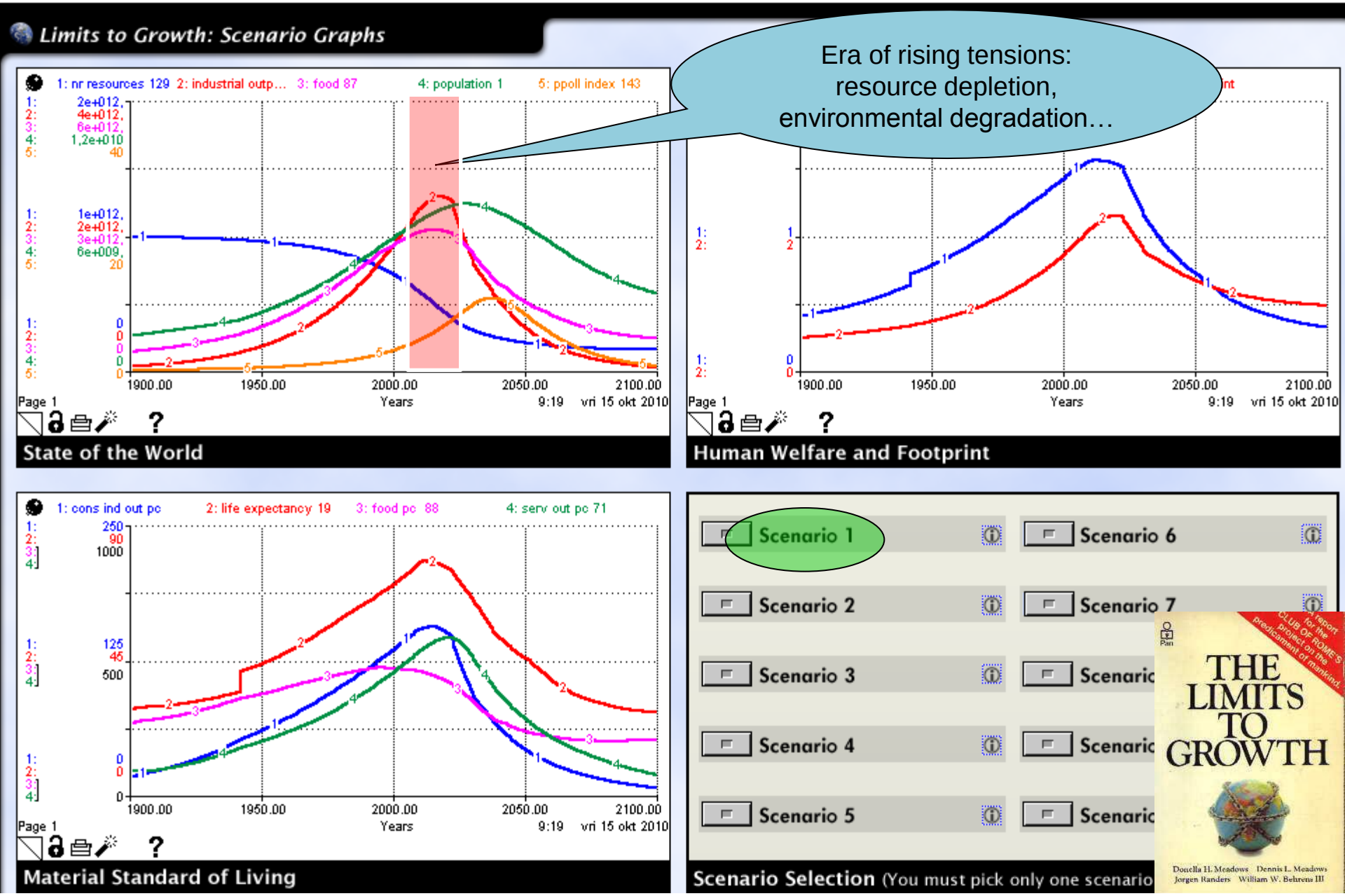






GSD
Global System Dynamics & Policies

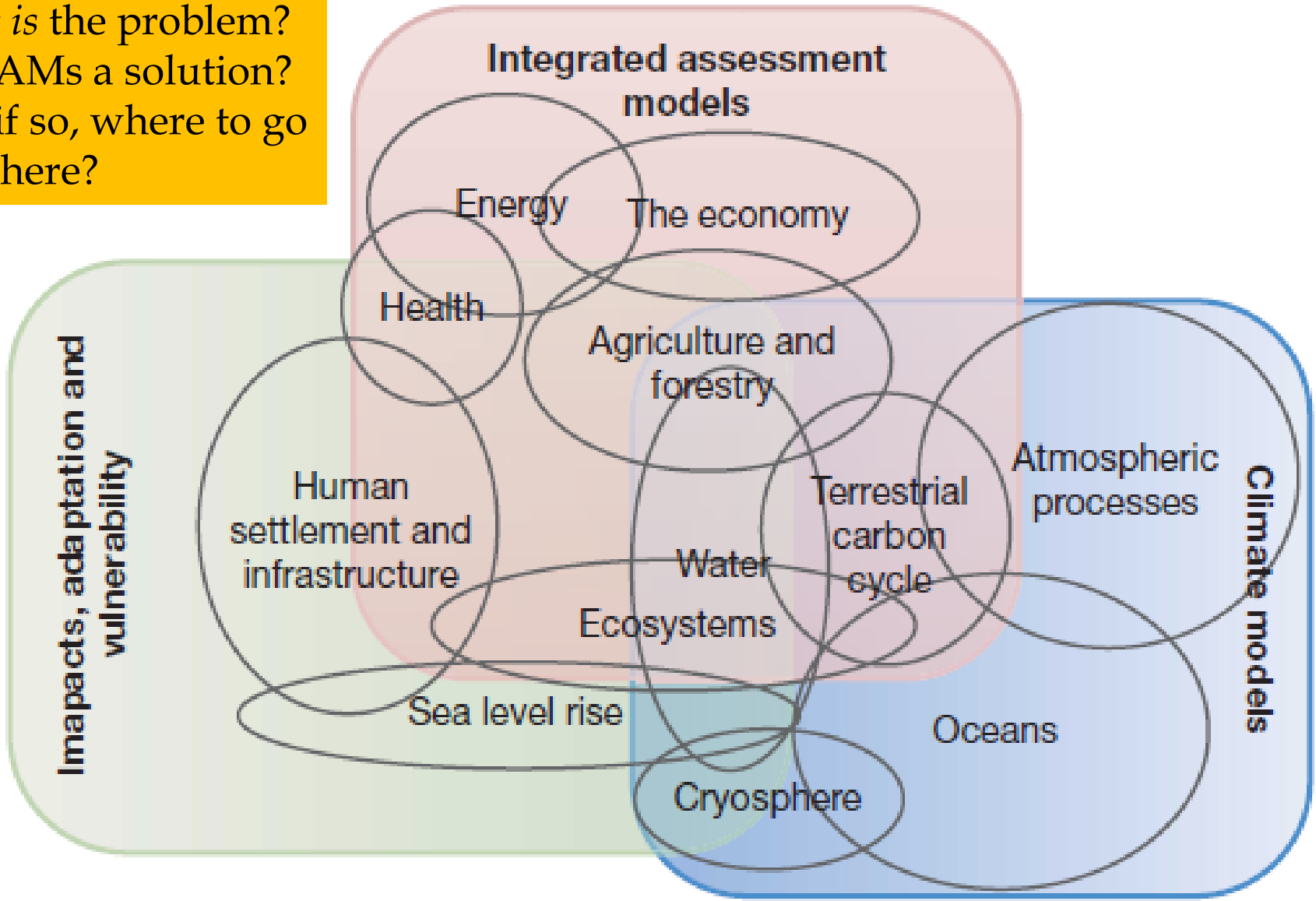
Scenario #1 Business-as-Usual – A Reference point



Published with the book Limits to Growth – the 30-year Update, by Meadows et al. (2005). Courtesy: D. Meadows.

Integration: IA Models on climate-society

What *is* the problem? Are IAMs a solution? And if so, where to go from here?



Moss et al. Nature 463(2010)747756

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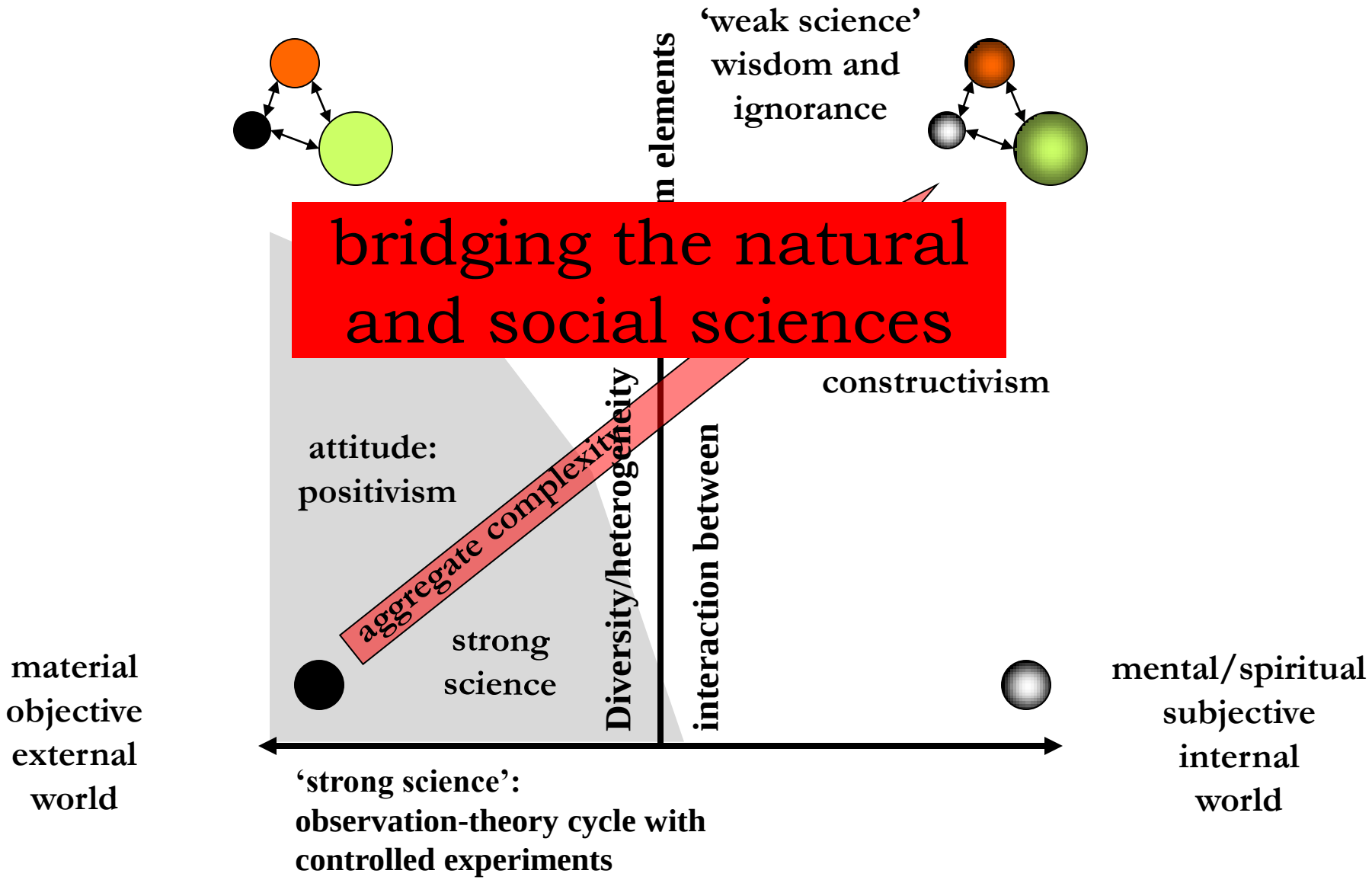
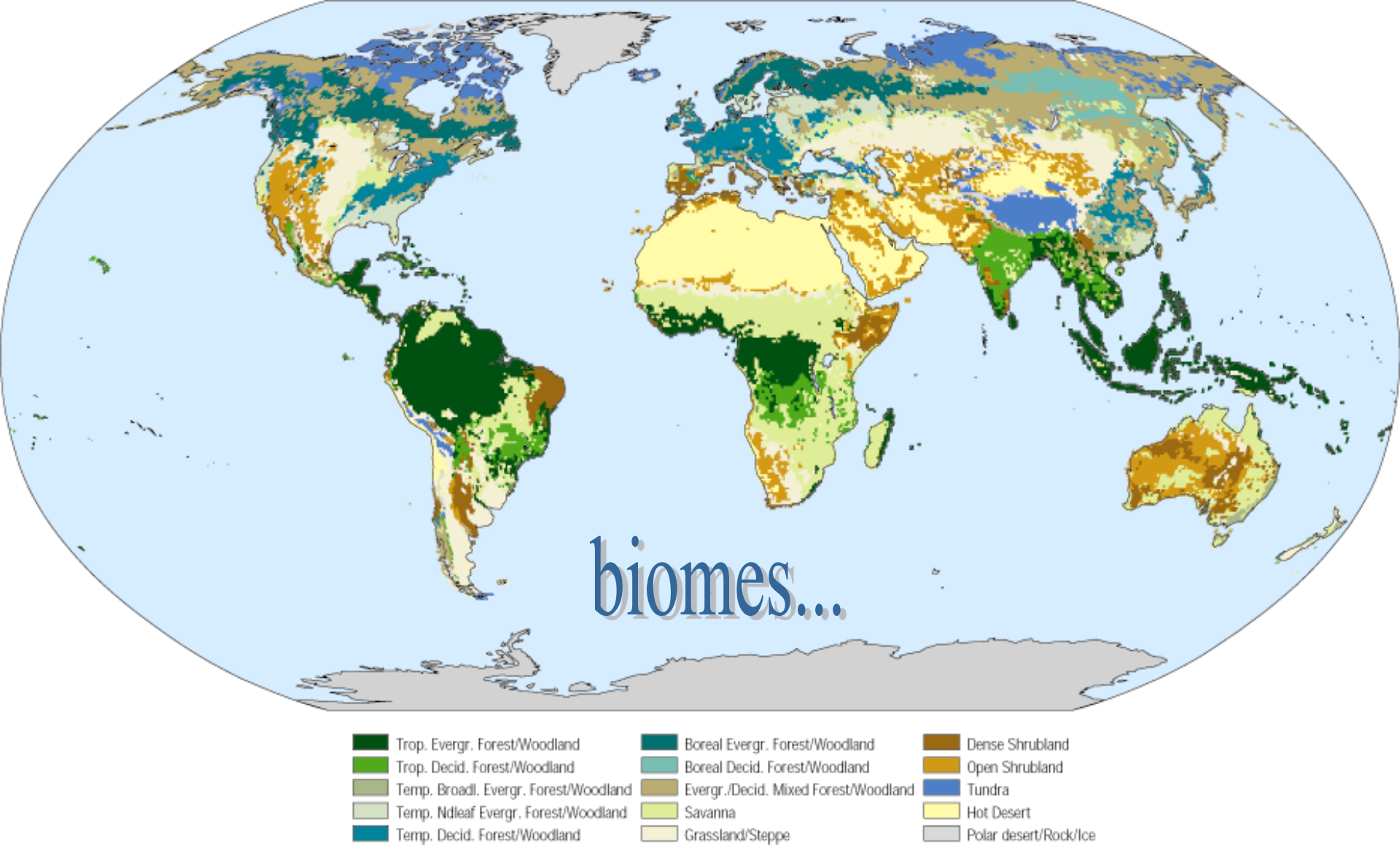
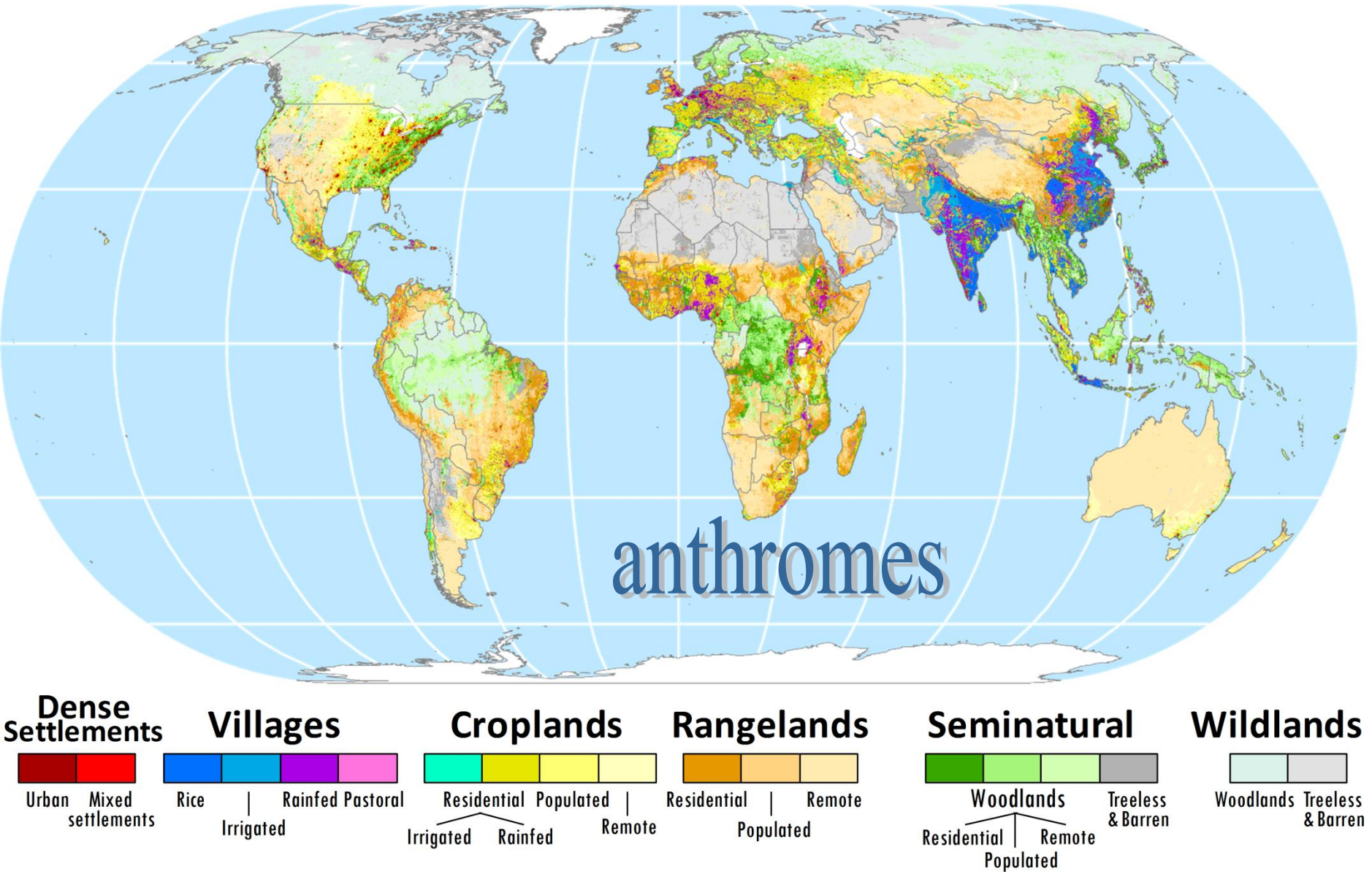
i. Natural science – social science
ii. Science – policy
iii. Micro - macro

Global Change Modelling:
an increasing need to deal with complexity and uncertainty



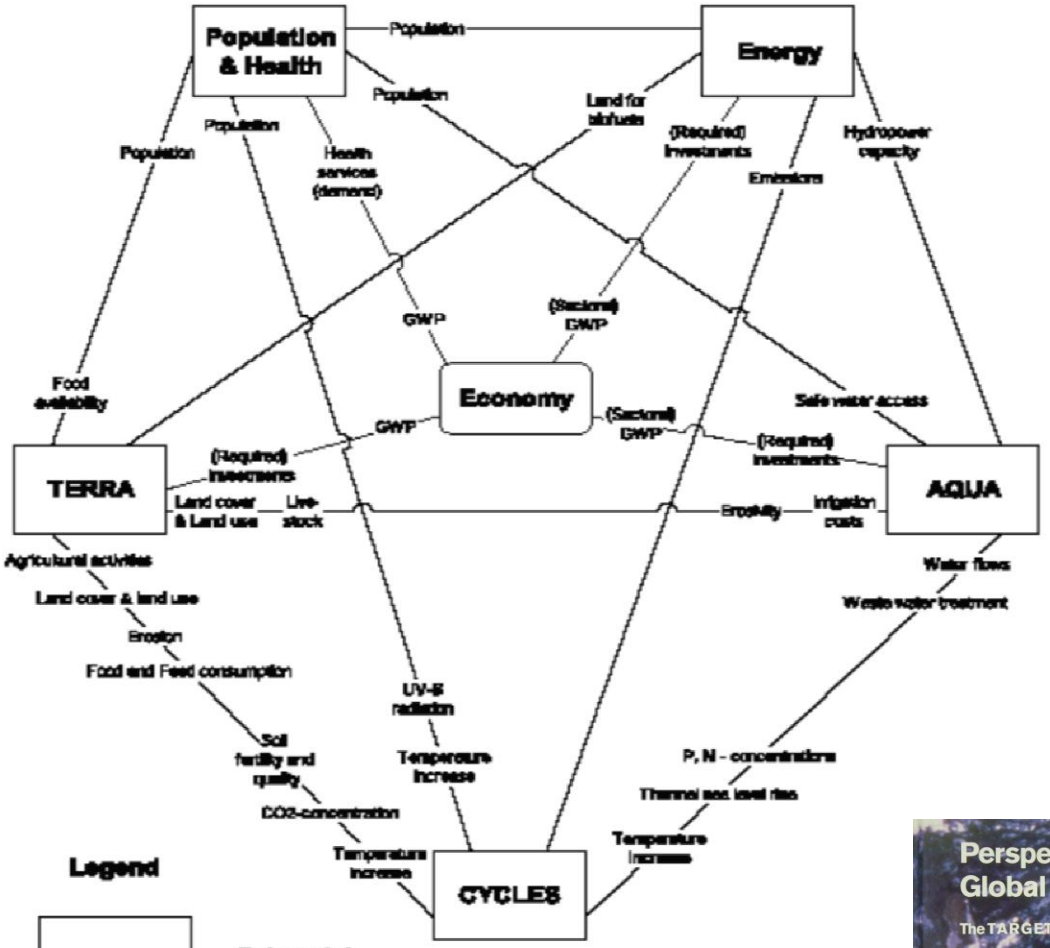


Potential land cover map (Ramankutty and Foley 1999)



Actual land cover map (Ellis, Klein Goldewijk et al. 2008)

Uncertainty and worldviews…



TARGETS1.0 model:

- use of 'stylized facts'
- explicit use of value orientations

people

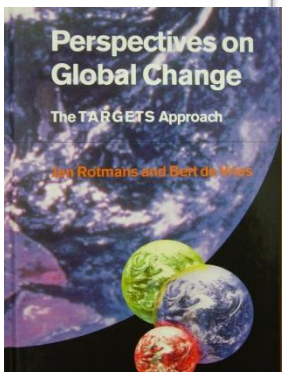
goods&services [money]

food

energy

water

element stocks &flows



(Rotmans and De Vries 1997)

Worldview: how does the world ‘work’?

Individualist Hierarchist Egalitarian

Management style: according to whose interpretation the world is ‘managed’?

Egalitarian Hierarchist Individualist

Hierarchist crisis

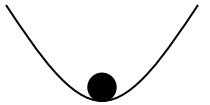
Egalitarian nightmare

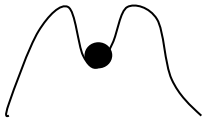
Too much bureaucracy

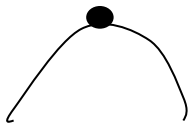
Too little, too late bureaucracy

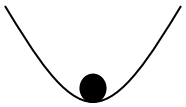
World of ‘missed opportunities’

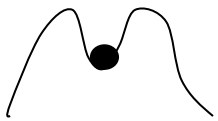
World of ‘anarchist threat’

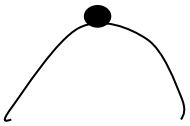




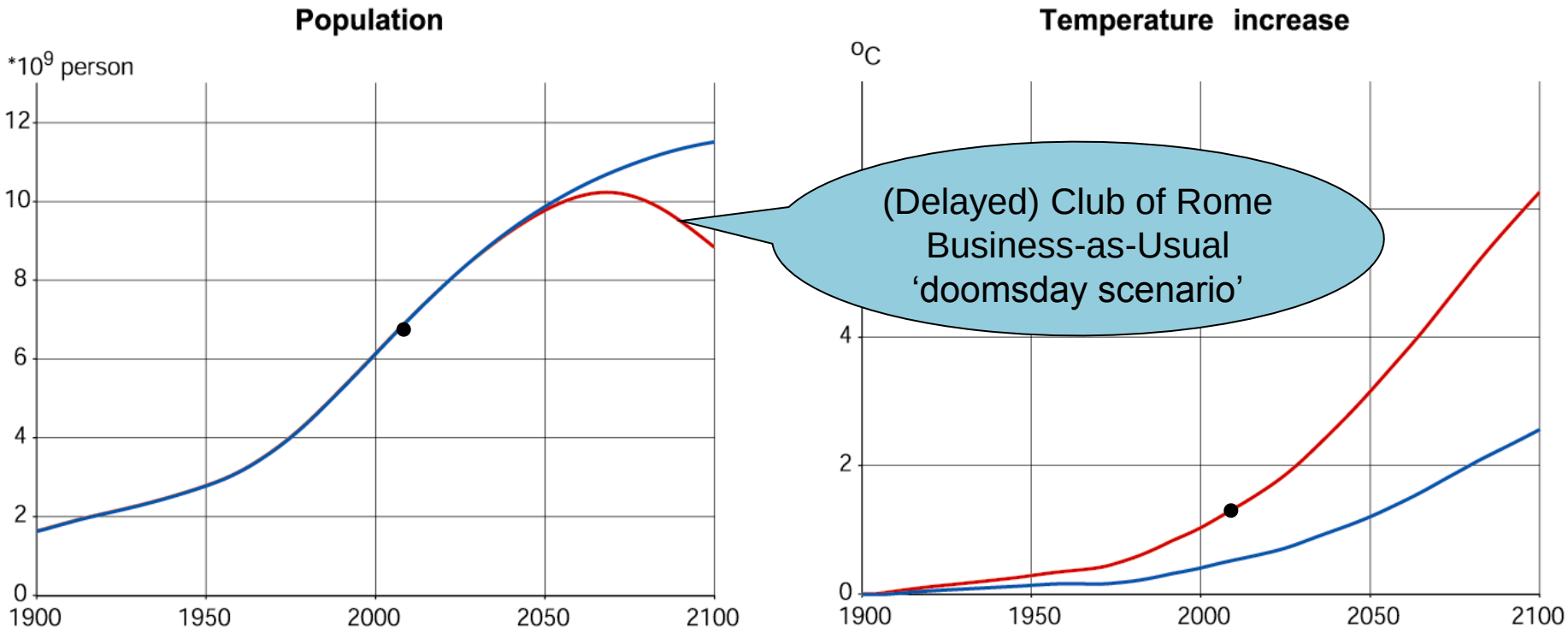








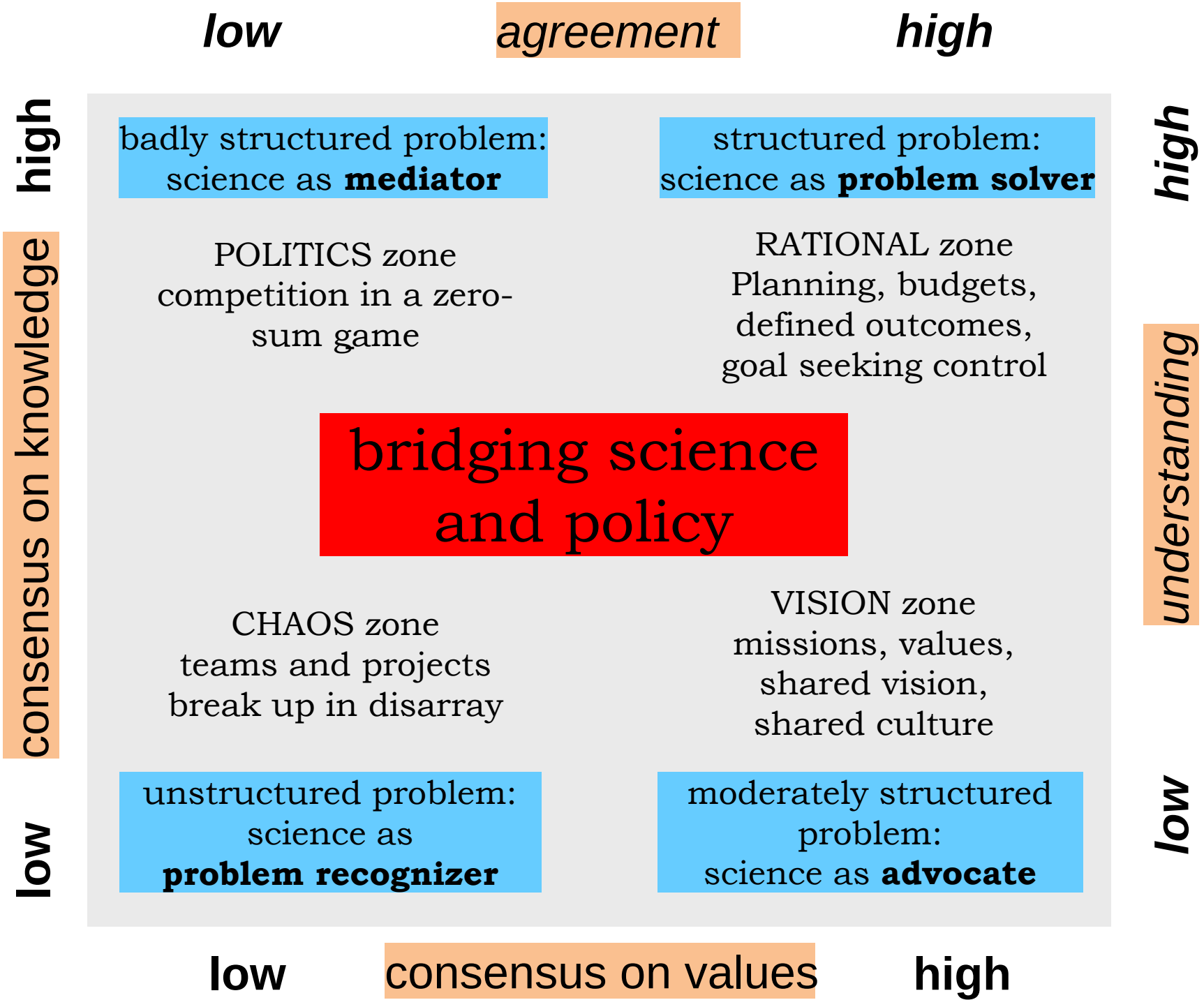
Individualist Hierarchist Egalitarian

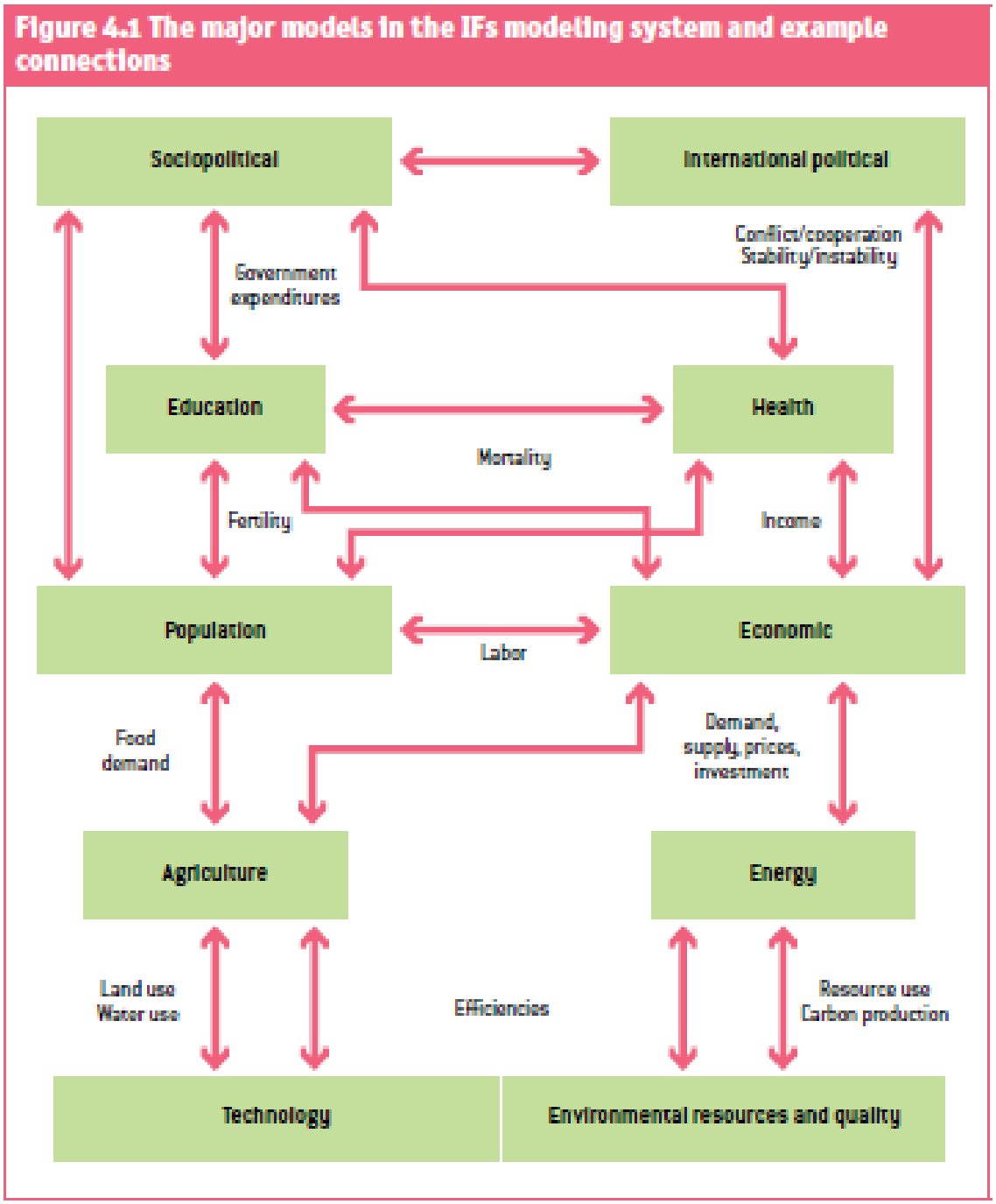


A dystopian future - the egalitarian nightmare:

population decline due to the integrated feedback from greenhousegas emissions->climate change->declining food availability

Fig. 18.2a Rotmans and De Vries 1997


low
agreement
high
high
consensus on knowledge
low
badly structured problem:
science as **mediator**
structured problem:
science as **problem solver**
POLITICS zone
competition in a zero-sum game
RATIONAL zone
Planning, budgets, defined outcomes, goal seeking control
bridging science and policy
CHAOS zone
teams and projects break up in disarray
VISION zone
missions, values, shared vision, shared culture
unstructured problem:
science as
problem recognizer
moderately structured problem:
science as **advocate**
high
understanding
low
low
consensus on values
high



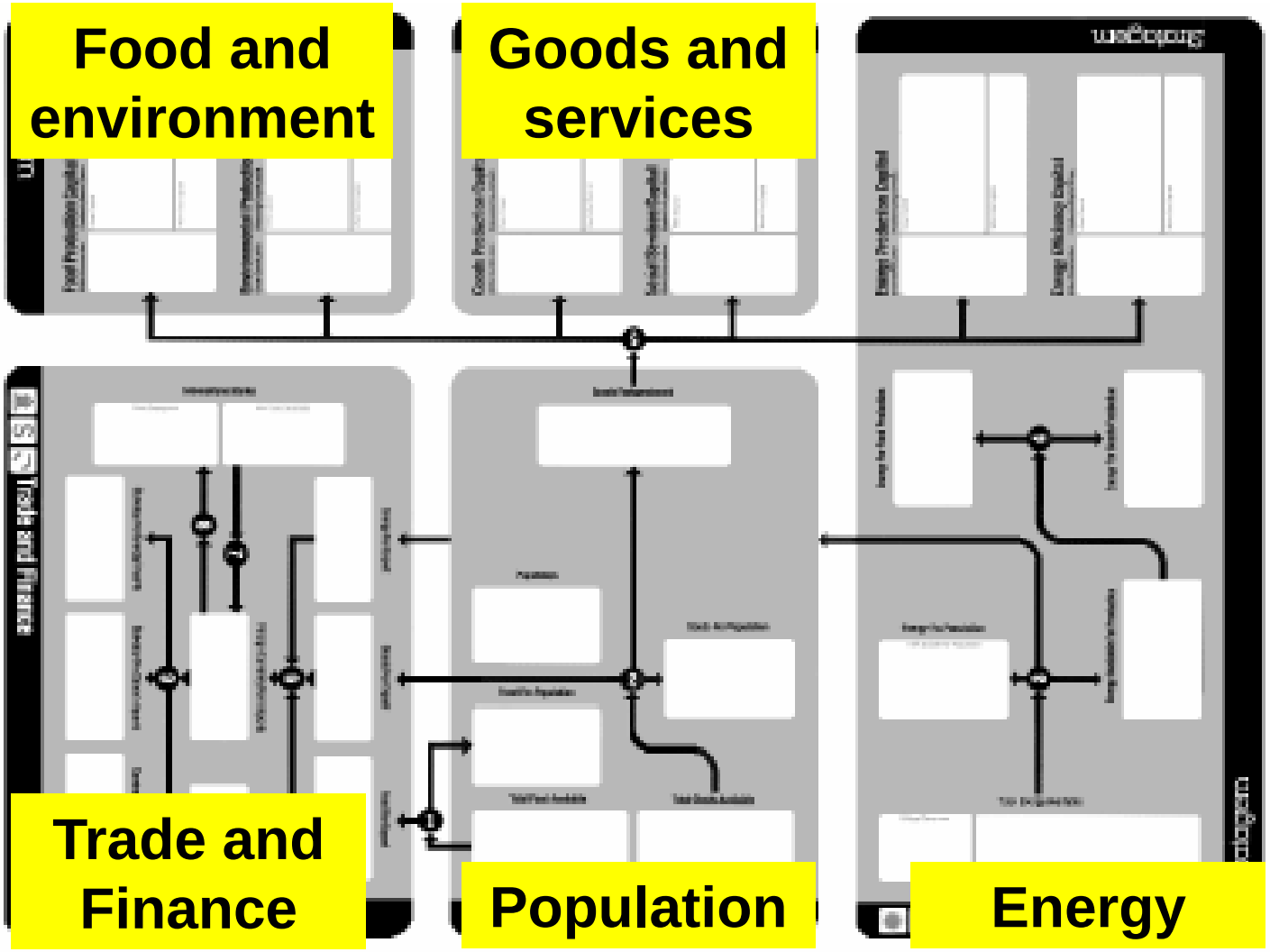
IFs model to simulate local/global development (www.ifs.du.edu)

IFs submodel set-up:

- transparant
- interactive
- generic

(cf. GISMO, Hilderink, Lucas et al. 2009, www.pbl.nl)

Stratagem: World3 made into country model as part of simulation game



Games
Metamodels
Toy models
…

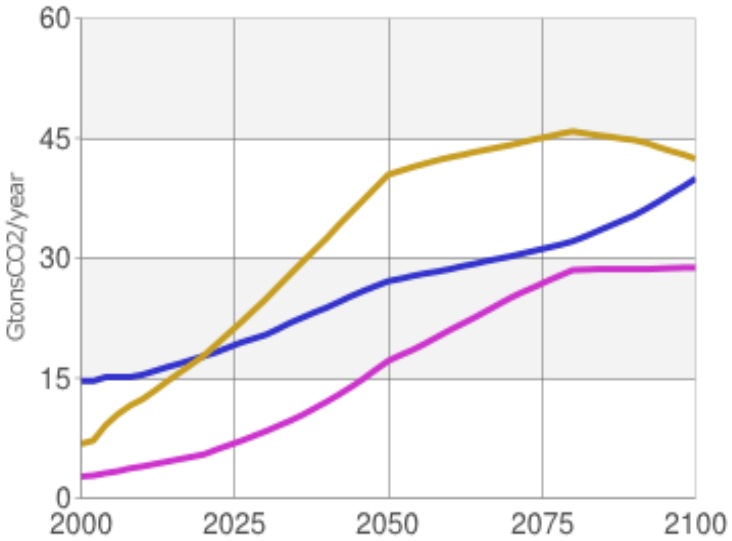
Game board: Five roles

C-LEARN CLIMATE SIMULATION

HOME | ABOUT | FOSSIL FUEL EMISSIONS | OTHER EMISSIONS | CO2 & CO2EQ | TEMPERATURE | SEA LEVEL RISE | DATA

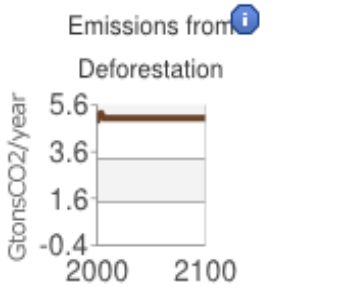
Main Control Panel

Change the values and click "Run Simulation". See the graphical representations of your decisions below, and explore climate impacts in the graphs to the right and using the menu options above.

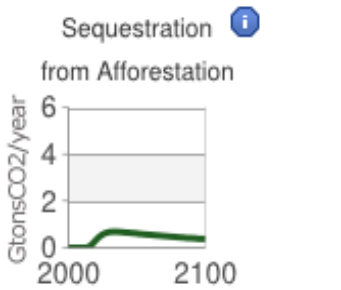


	Stop Growth year	Reduction Start Year	% Annual Reduction
Developed	2100	2012	0.0
Developing A	2100	2012	0.0
Developing B	2100	2012	0.0

Click for Info on Baseline Scenarios



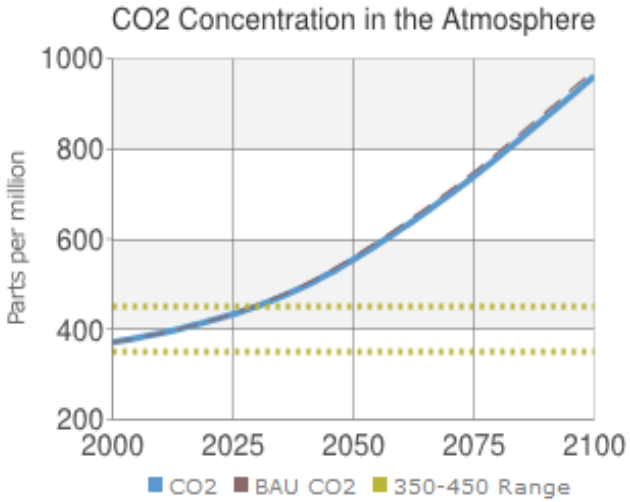
(0-1 index for low to high values) 1.0



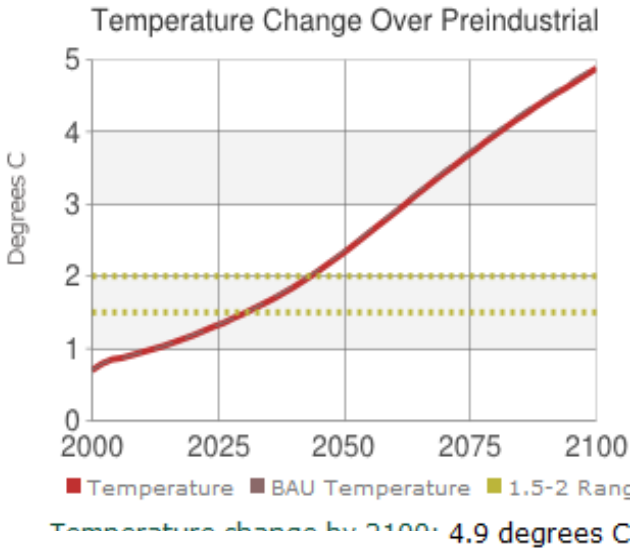
(0-1 index for low to high values) 0.5

Change scenario name(s) | Run Simulation | Reset Inputs | Clear Runs

Impacts



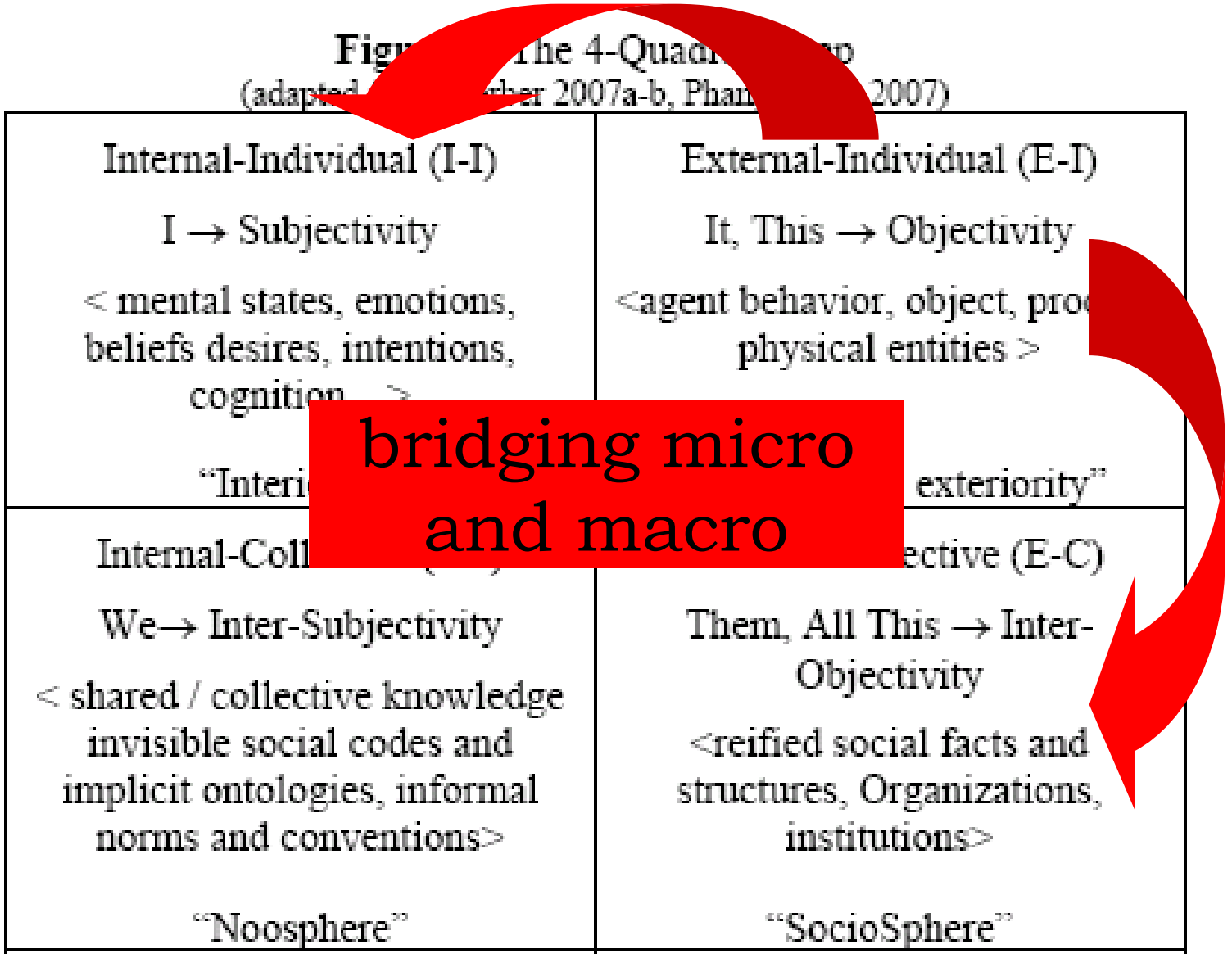
CO2 in 2100: 961 ppm



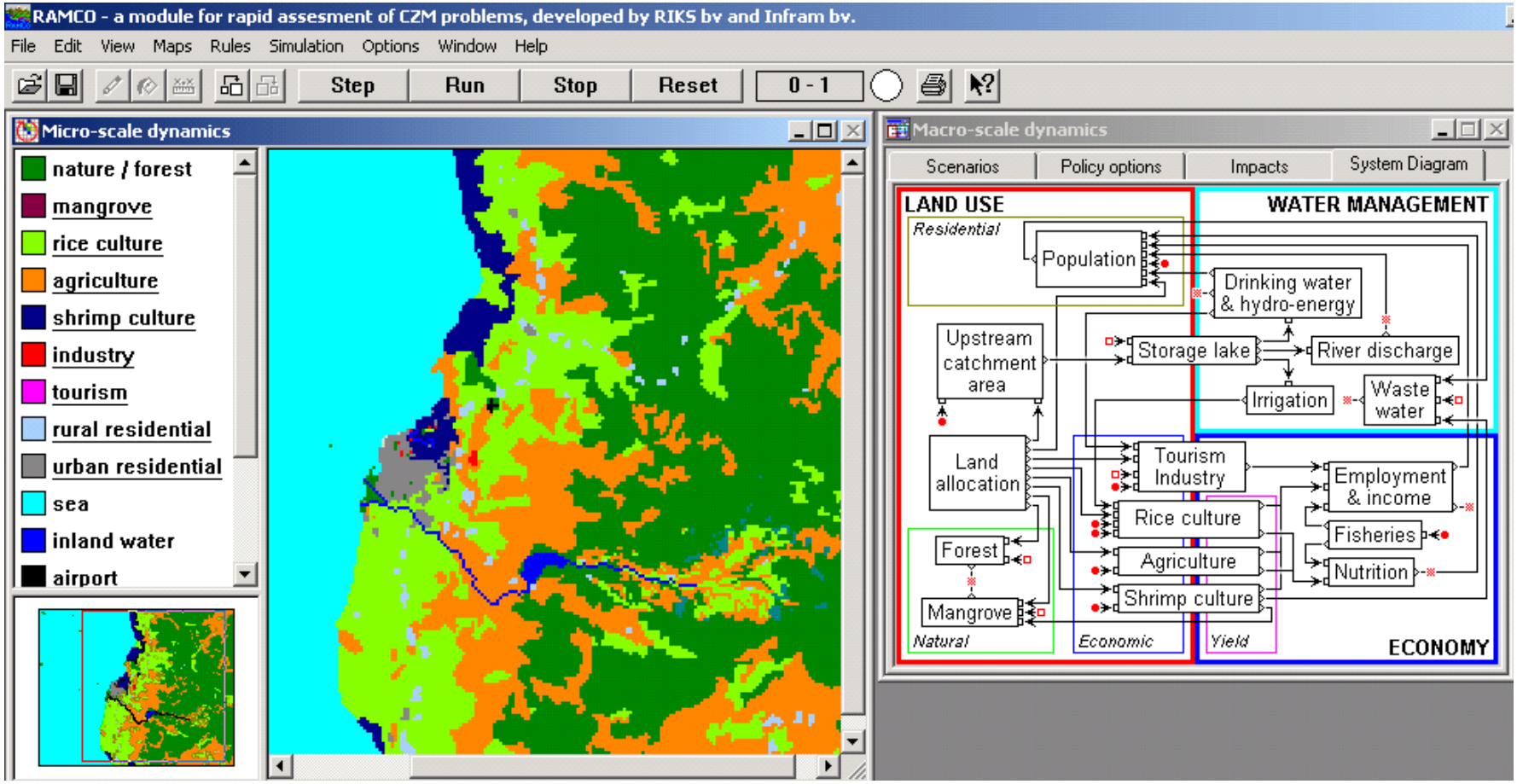
Temperature change by 2100: 4.9 degrees C

http://www.climateinteractive.org/simulations/world-climate/overview

From inner to outer, from individual to collective



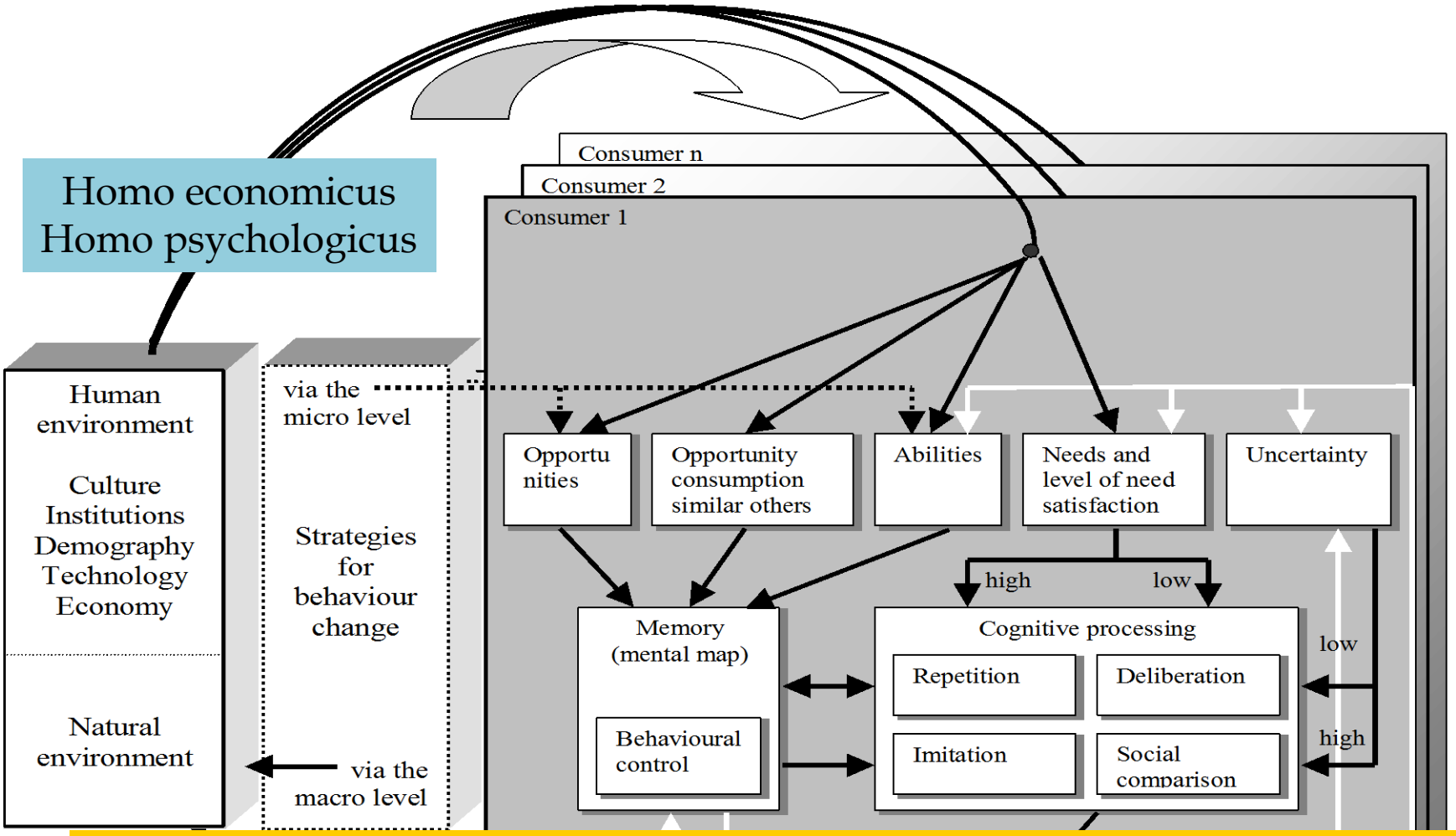
(Dessalles et al. 2007, Wilber 2000)



Application of the Geonamica software to explore sustainable development in western Sulawesi (Indonesia). The right side shows the high-level dynamic simulation model; the left side shows the underlying base maps. The CA-mechanisms relate both. (Courtesy: Guy Engelen).

Geography leading in discrete spatial modelling
e.g. Geonamica (Engelen et al.), Cormas-CompanionModelling…

Agents in Lakeland: the consumat multi-agent simulation approach



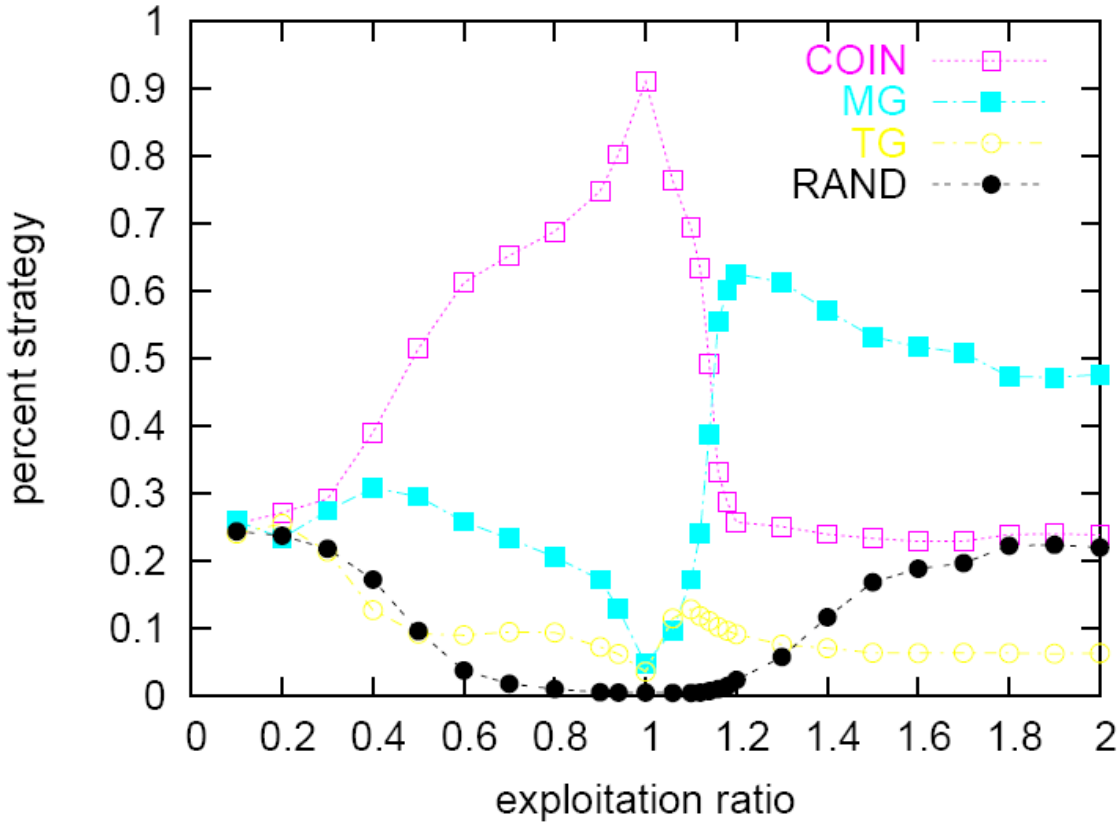
COMSUMAT MODEL (Jager et al. 2000)

- rational deliberation only one of possible behaviours
- also: imitation, repetition en social comparison
- dynamics depend on degree of satisfaction and of (un)certainty
- ambiguous role of technology: more productive → faster overexploitation

00)

Fishing strategies: An ABM

Dependence on the exploitation ratio $r = \frac{NC_{\max}}{\sum_i Z_i}$

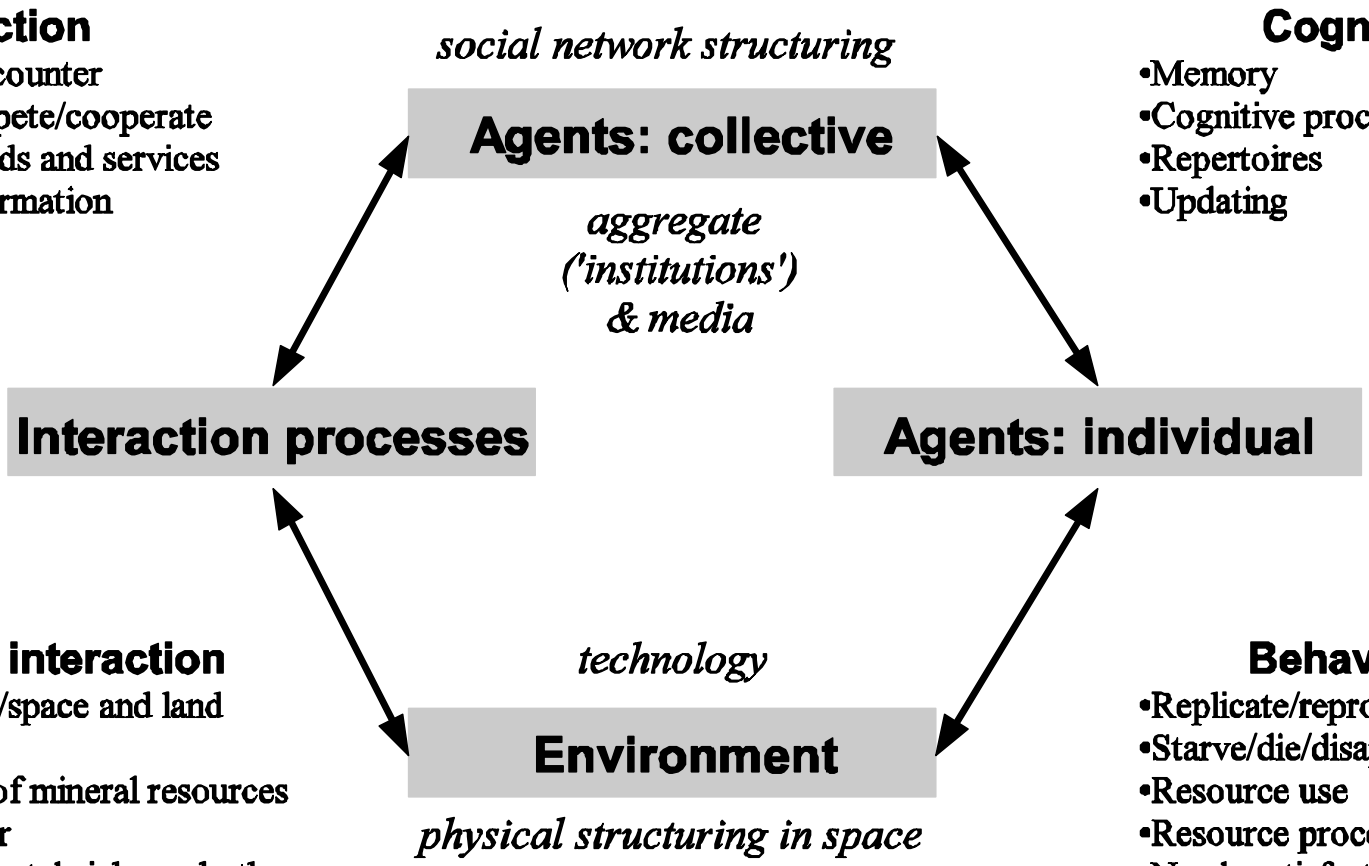


COIN COllecitive INtelligence
MG Minority Game
TG Team Game
RAND Random

putting in humans...

under-exploited ← → over-exploited

- Far above tipping point: uncoordinated and community-based strategies
- Around tipping point: cycles short- and long term planning
- Below tipping point: “Communism” of team games


Social interaction
•Reproductive encounter
•Fight/flight, compete/cooperate
•Exchange of goods and services
•Exchange of information
social network structuring
Agents: collective
aggregate
('institutions')
& media
Cognition
•Memory
•Cognitive processing
•Repertoires
•Updating
Interaction processes
Agents: individual
Environment interaction
•Use of landscape/space and land resources
•Extraction / use of mineral resources and (ground)water
•Use of environmental sinks and other ecosystem services
technology
Environment
physical structuring in space
Behaviour
•Replicate/reproduce
•Starve/die/disappear
•Resource use
•Resource processing
•Needs satisfaction

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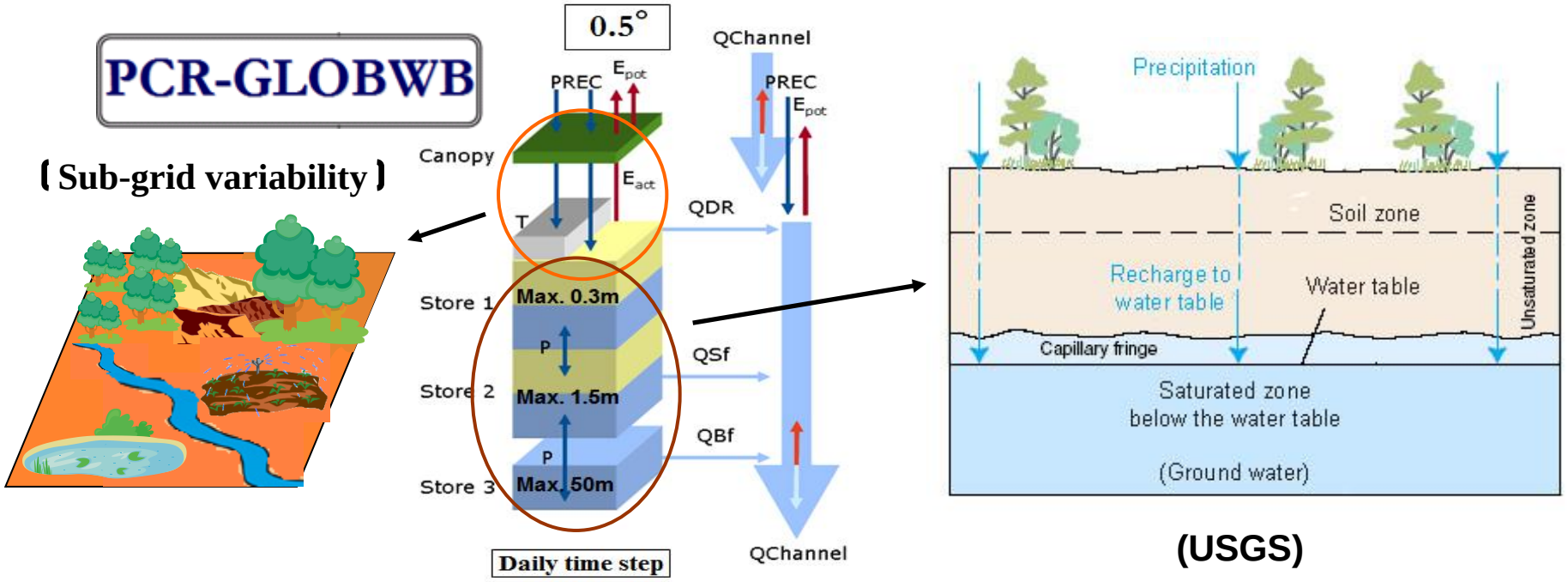
a) Use and availability of (ground)water
    as part of joint effort in IAM-GC between PBL and UU
b) Competition vs. cooperation in climate policy
    paper by Brede & De Vries: a social dilemma with a focus on coupling energy –transition & climate change
c) The financial system
    analysis of role of financial system in realizing climate change policy targets (within Sustainable Finance Lab)

water

PCR-GLOBWB and related models:

- Simulation of hydrological cycle (vegetation-climate)
- Assessment of (ground)water availability (depletion)
- Simulation of N- and P-stock and flows (eutrophication)



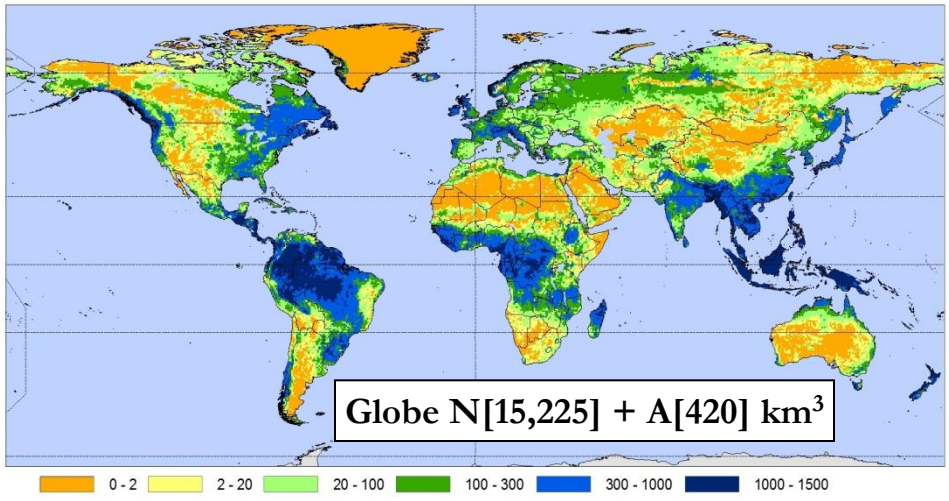
Wada, Van Beek and Bierkens, *AGU Fall Meeting 2011*

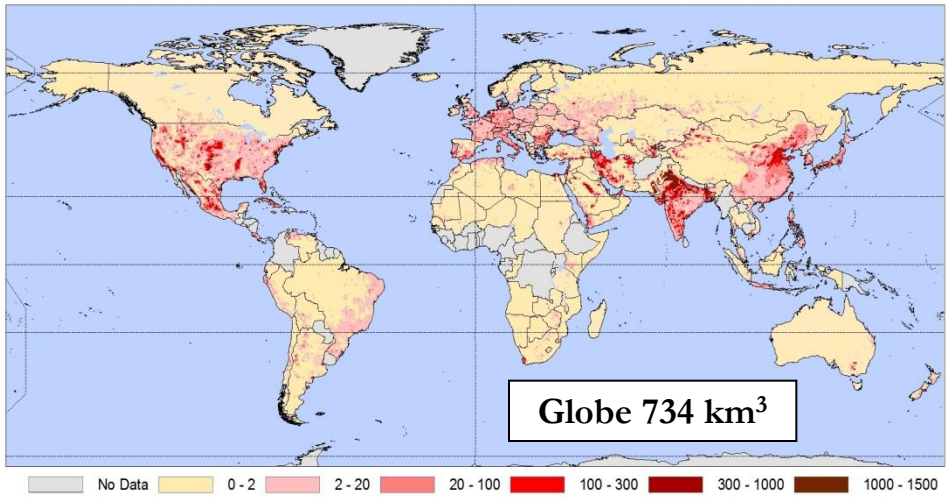
Processes modelled:

- vegetation and evaporation
- vertical flow
- surface water routing
- floodplain inundation

Output fields PCR-GLOBWB

- Soil moisture (two reservoirs)
- Active groundwater storage
- Surface water storage (including lakes, reservoirs, floodplains)
- snow cover
- Interception storage
- Runoff (melt water, surface, interflow, groundwater)
- Discharge (daily, monthly, average)
- River stages
- Levels of lakes and reservoirs
- Groundwater recharge
- Evaporation (soil, canopy, open water), transpiration, reference potential





Water scarcity

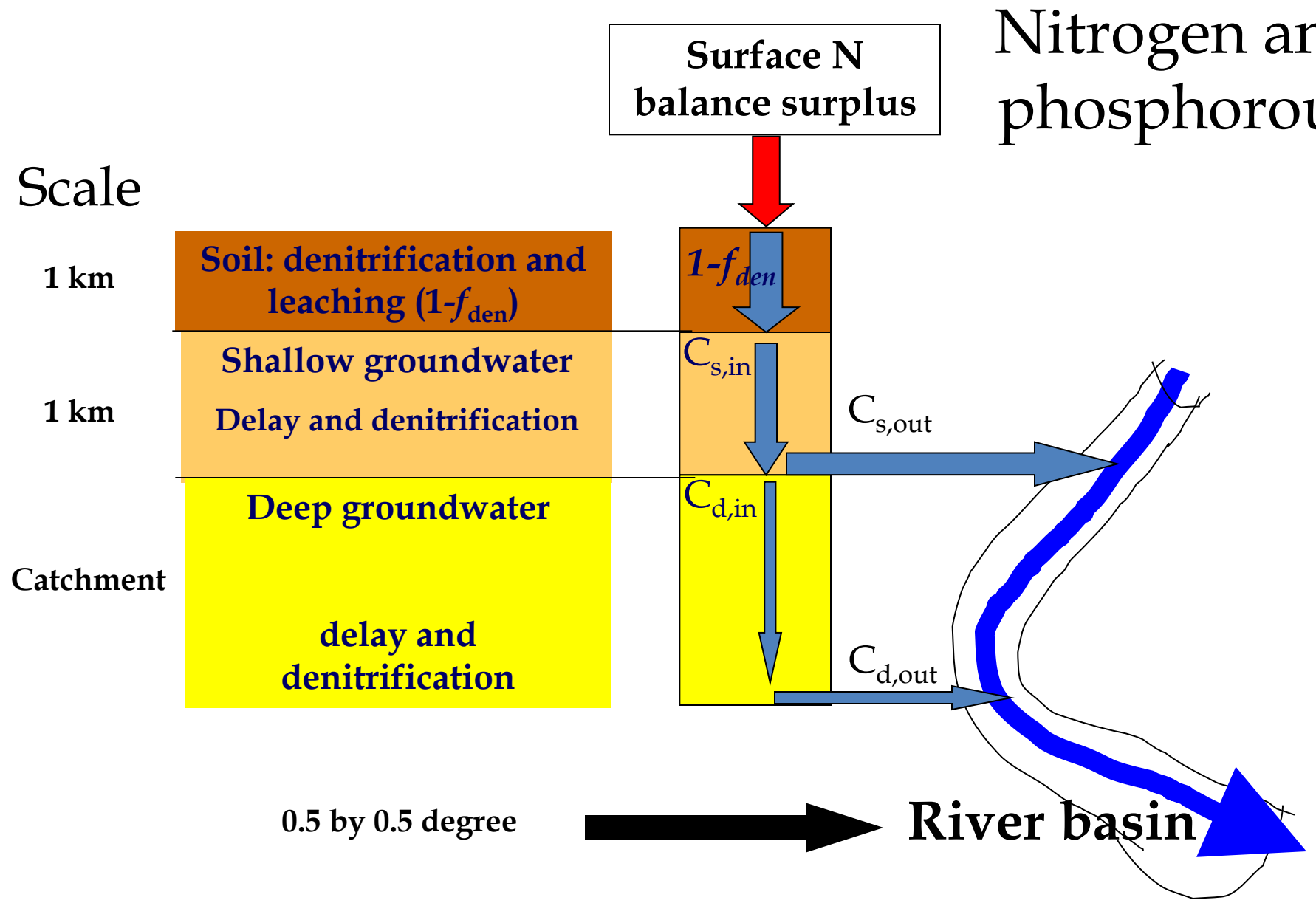
India	71 km³
Pakistan	37 km³
USA	32 km³
Iran	27 km³
China	22 km³
Saudi Arabia	15 km³
Mexico	11 km³
Globe	256 km³

Groundwater abstraction – Groundwater recharge

All in million m³/year 2000

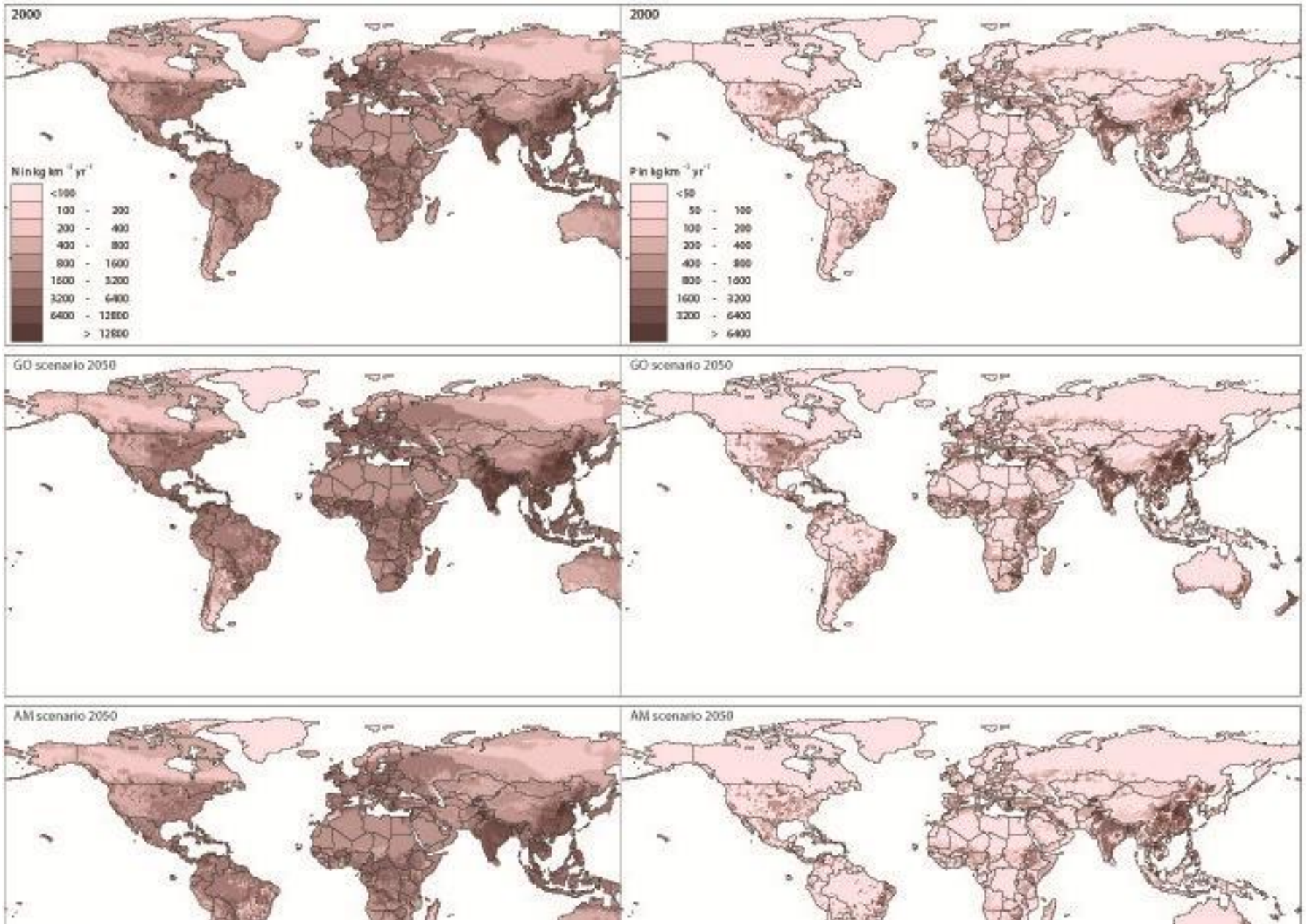
No Data | 0 - 2 | 2 - 20 | 20 - 100 | 100 - 300 | 300 - 1000 | 1000 - 1500

Nitrogen and phosphorous

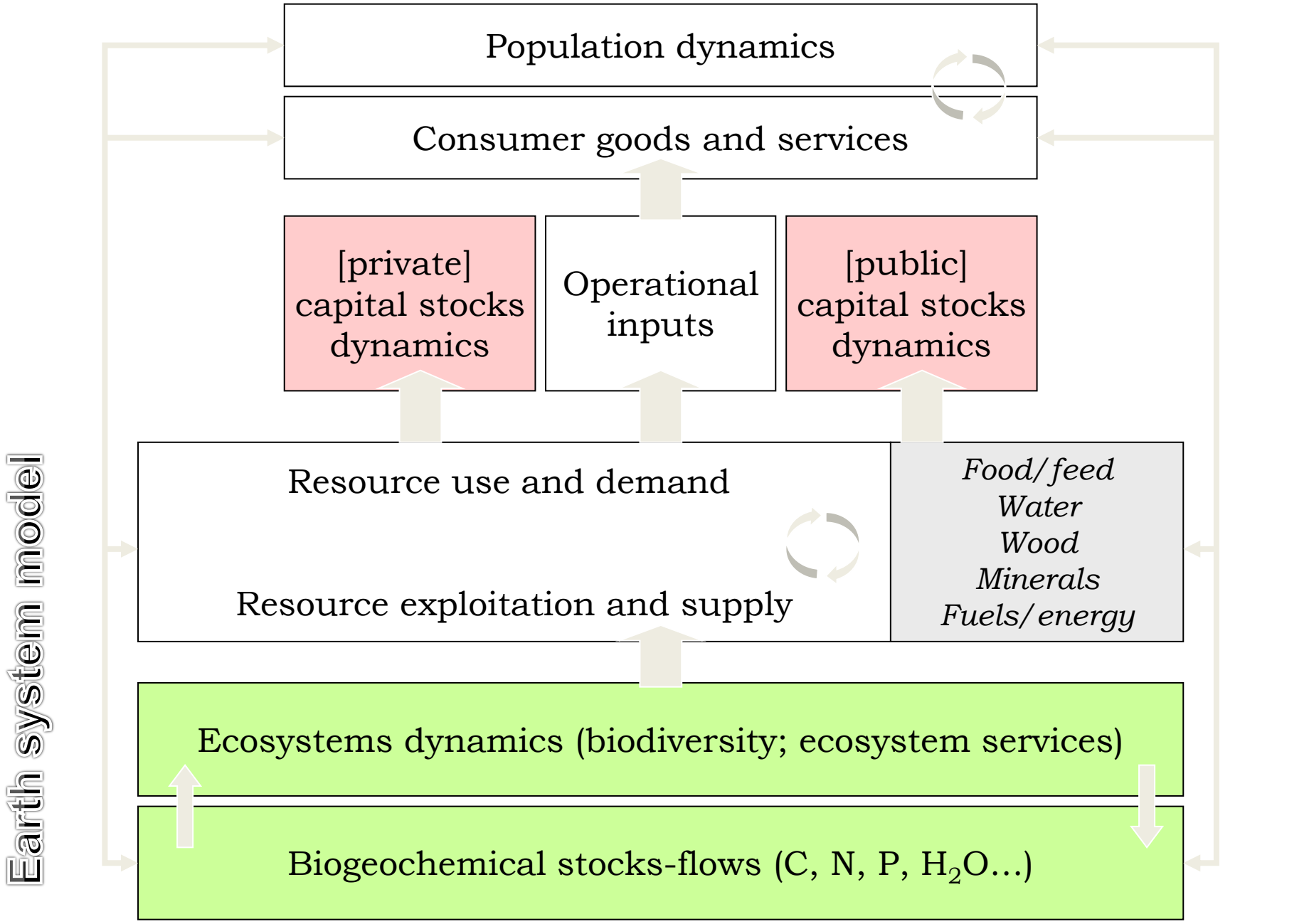


Van Drecht et al. GBC (2003),
Bouwman et al. *GBC* (2005)

Compartment modelling N&P
*Rooted in natural science principles, **initially** data-poor*



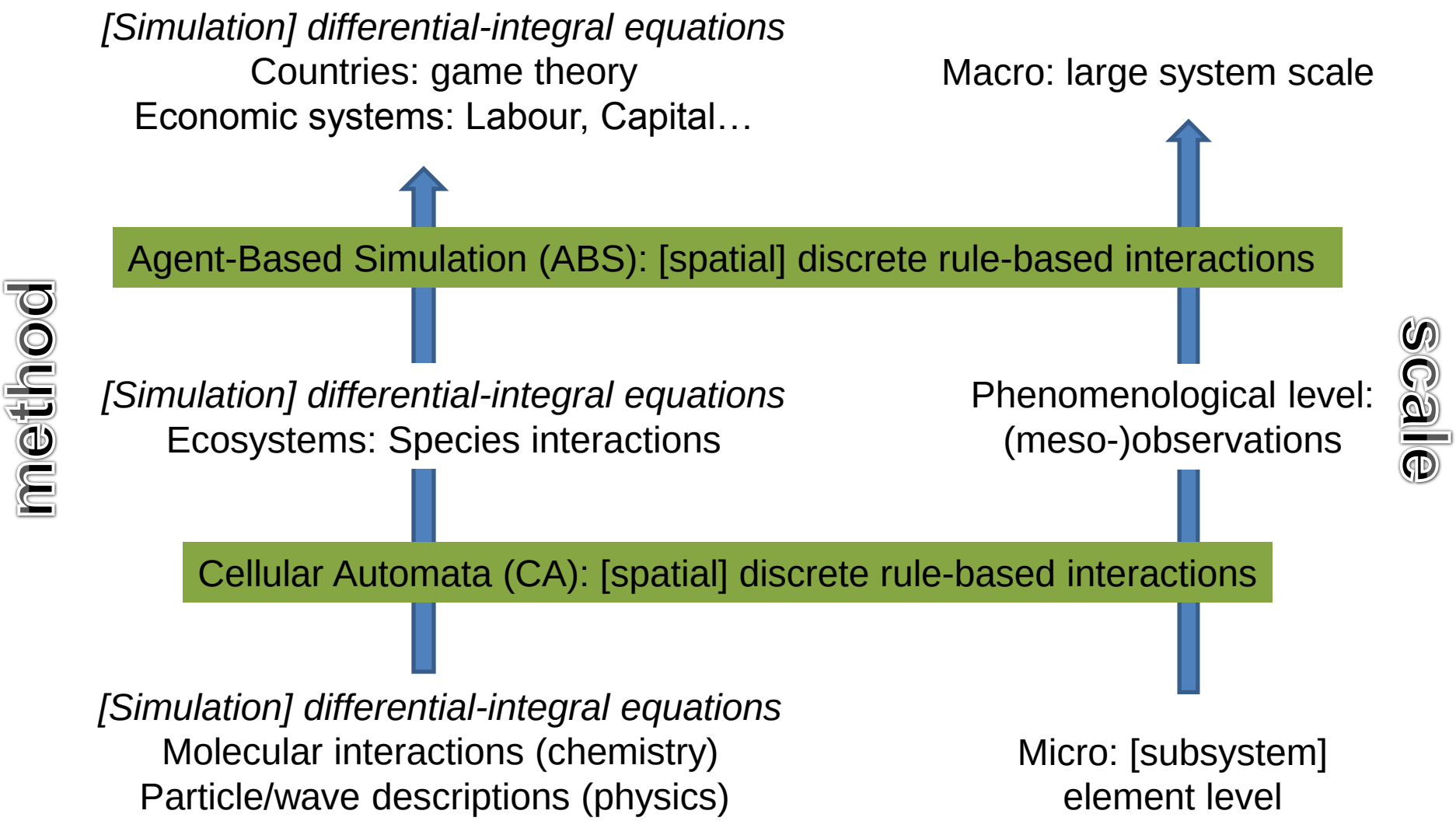
Total net flows of N (left) and P (right) in 2000 and for two scenarios in 2050 (Bouwman et al. 2009)



A possible metamodel

(De Vries 2011)

Integration: the role of scale and method



climate

Real world?

(i) agents optimize a *regional utility* function Ui = U(Ci, Pi), where the index i specifies the consumption and population in region i. It is based on regional planning in a competitively managed world.

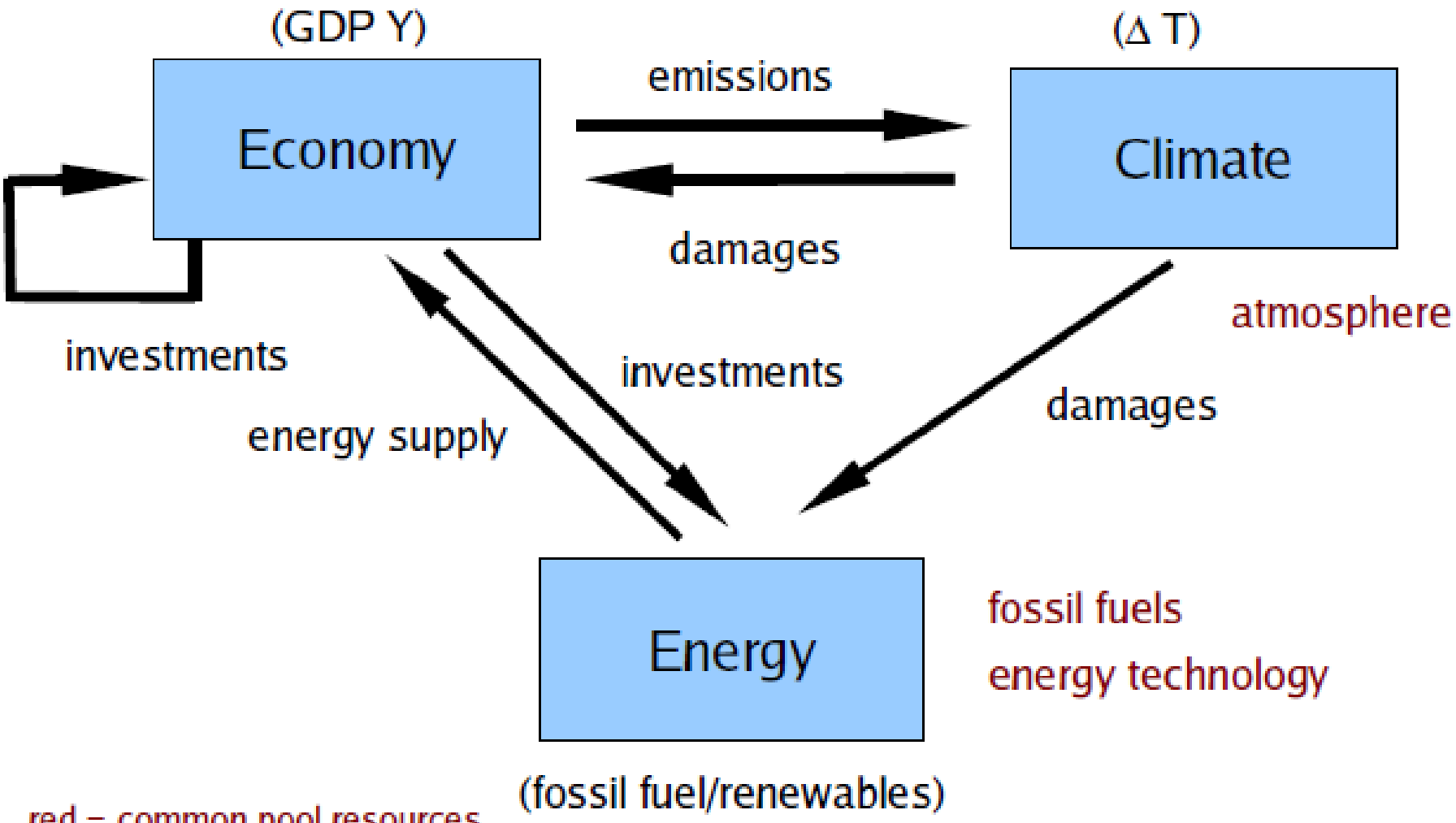
(ii) agents strife to optimize the *world utility* function U = U(Pi Ci,Pi Pi). The latter is based on global planning in a cooperatively managed world

Simulated world in IAMs for climate policy

What matters is coordination,
Not optimizing and efficiency…

(Brede and De Vries 2012)

Economy-Energy-Climate Model



Managing the economy as an optimal control problem

- Given economy-energy-climate system: What is the decision vector $D=(\sigma_Y(t),\sigma_F(t), \sigma_R(t),\sigma_C(t))$ that maximizes U (respecting that $1= \sigma_Y(t)+\sigma_F(t)+\sigma_R(t)+\sigma_C(t)$) ?
- Scenarios:
  - collaborative: maximize "world utility" $U(\sum_i C_i, \sum_i P_i)$
  - competitive: maximize individual utility $U(C_i, P_i)$

Most models: global optizer. Only few models explore regional optimization e.g. WITCH-FEEM

(Brede and De Vries 2012)

Economy

essence:
invest in K
to maximize U(C)

- Goods production Y (=GDP)

$$Y = Y_0 K^{\gamma} L^{1-\gamma} D(\Delta T) f_{energy}$$

K ... goods producing capital stock — $dK/dt = \sigma_Y Y - \delta_Y K$

L ... labour force — $L = .25\,P$

γ ... capital labour elasticity — $\gamma = 1/2$

D ... damage fraction — $D(\Delta T) = 1 - \alpha \Delta T$

α ... damage constant

f_{energy} ... energy supply factor

P ... population — $dP/dt = P \times (const.\ c)^{-.6}$

c ... per caput income — $c = \sigma_C Y / P$

essence:
optimal transition
fossil → renewable

Energy sector

- Fossil fuel based vs. renewable energy techs

K_F ... capital stock energy fossil fuels

K_R ... capital stock energy renewables

S ... energy supply

$p_{R,F}$ ... productivities of $K_{R,F}$

E ... emissions

f_{energy} ... energy supply factor

D ... energy demand

$$dK_F/dt = \sigma_F Y - \delta_F K_F$$

$$dK_F/dt = \sigma_R Y - \delta_R K_R$$

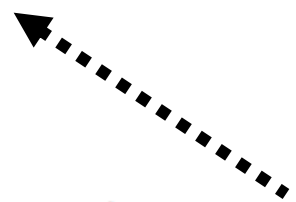
$$S = p_F K_F + p_R K_R$$

$$p_{R,F} = f(\int K_{R,F})$$

$$E = \epsilon K_F$$

$$f_{energy} = max(1, S/D)$$

$$D = \eta Y$$

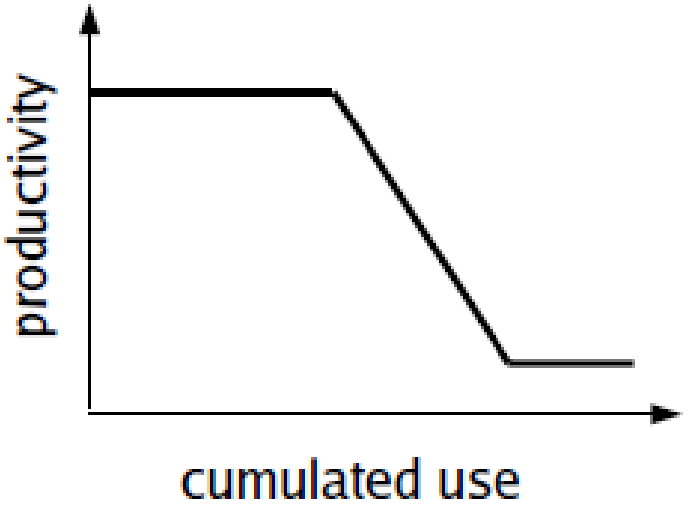


essence:
optimal transition
fossil → renewable

Energy sector

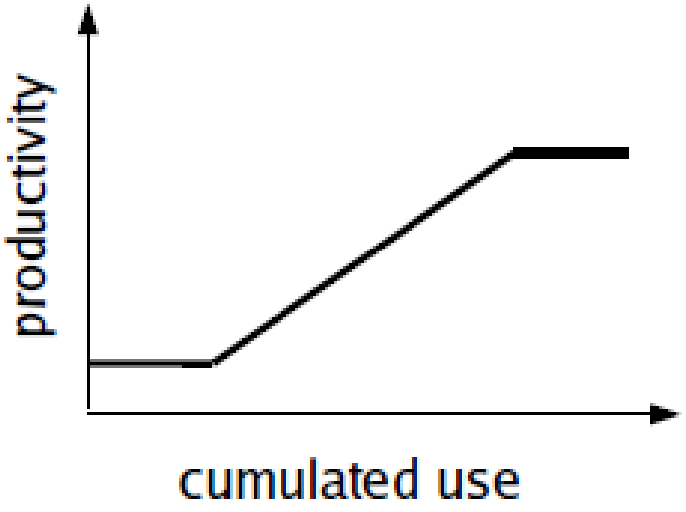
- Evolution of renewables and fossil fuel productivities

Fossil fuels



resource depletion

Renewable energy sources



"learning by doing"

essence:
least damage over time

Climate

- Extremely simplified model, "fit" to a suite of climate models

$$\rho_{Co2} \ldots atmospheric\ Co_2\ concentration$$

$$\rho_{CO_2} = \rho_{CO_2}(0) + \int_{t_0}^{t} E(\tau) \sum_i \exp(a_i(\tau - t_i)) d\tau$$

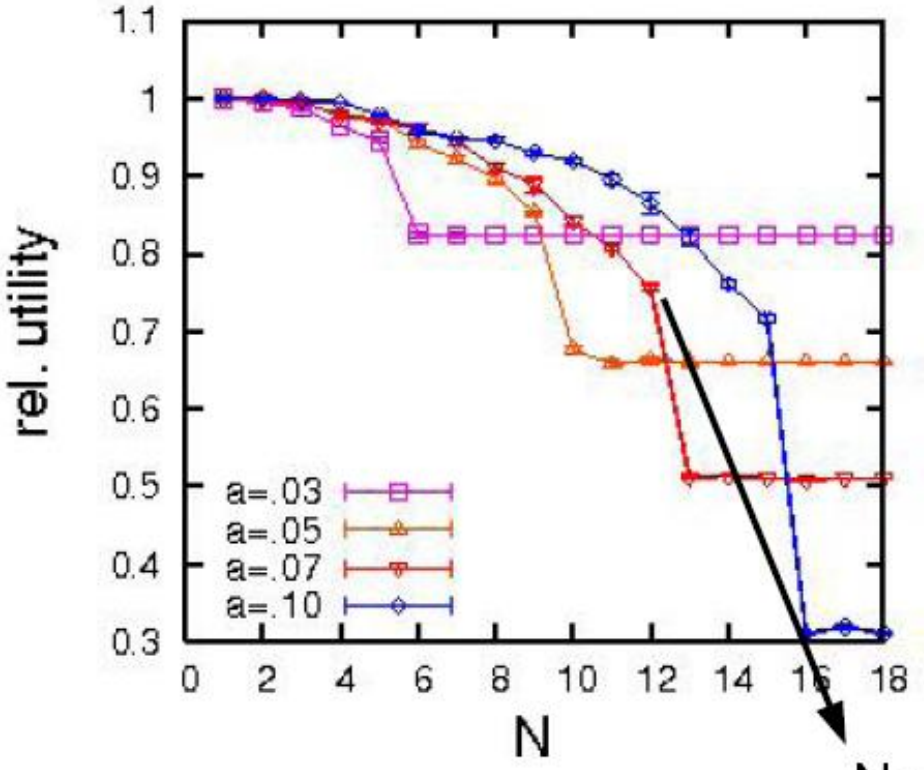
$$\Delta T_p \ldots equilibrium\ change\ of\ land\ surface\ temperature$$

$$\Delta T_p(t) = const. \times \ln(\rho_{CO_2}(t) / \rho_{CO_2}(0))$$

$$\Delta T \ldots actual\ temperature\ increase$$

$$d\Delta T / dt = \beta(\Delta T_p - \Delta T)$$

Competitive management of the atmosphere

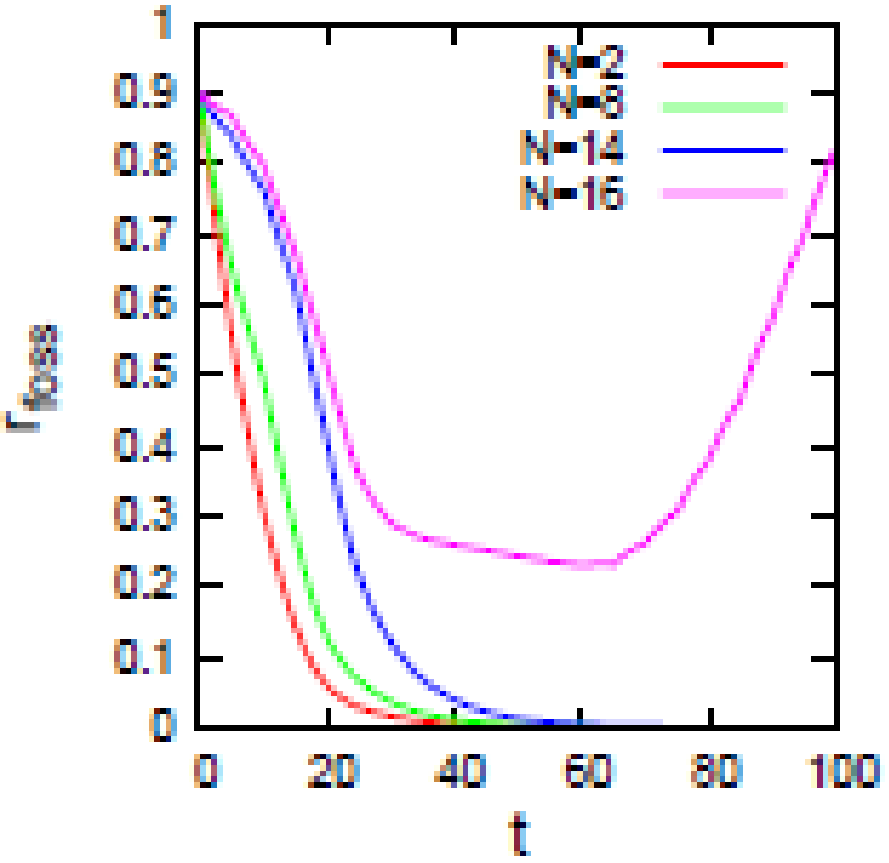


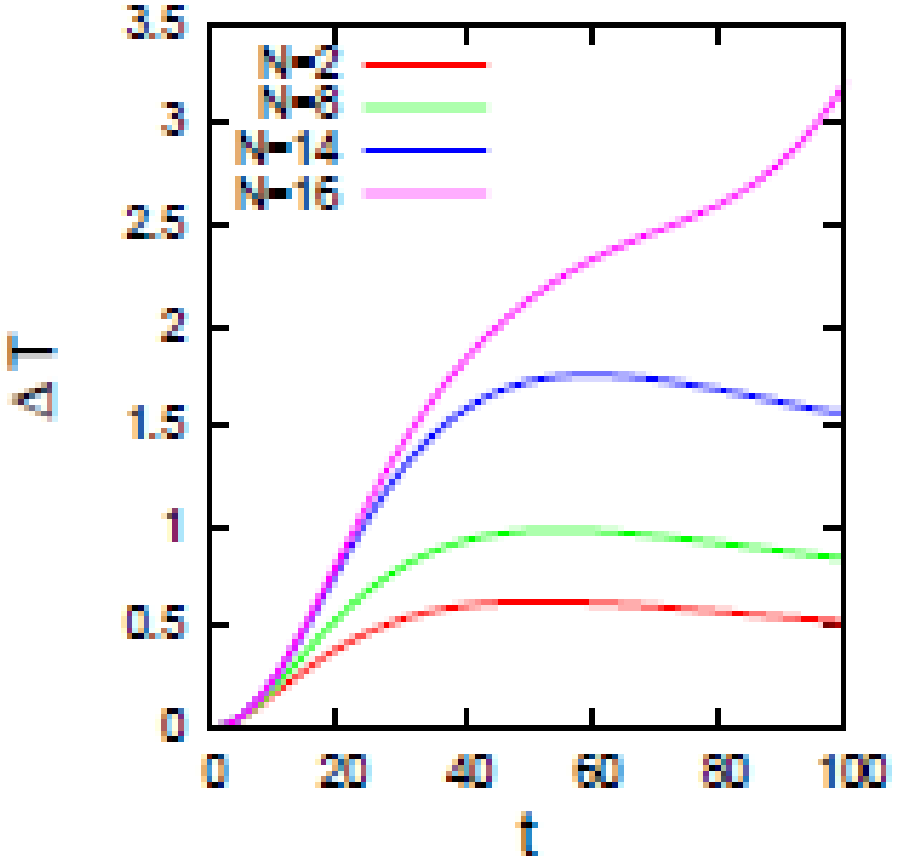
- Identical countries
- Developed economies
- Atmosphere CPR
- Fossil fuels individual
- Knowledge individual

$N<N_c$ energy transition

$N>N_c$ no energy transition

(Brede and De Vries 2012)

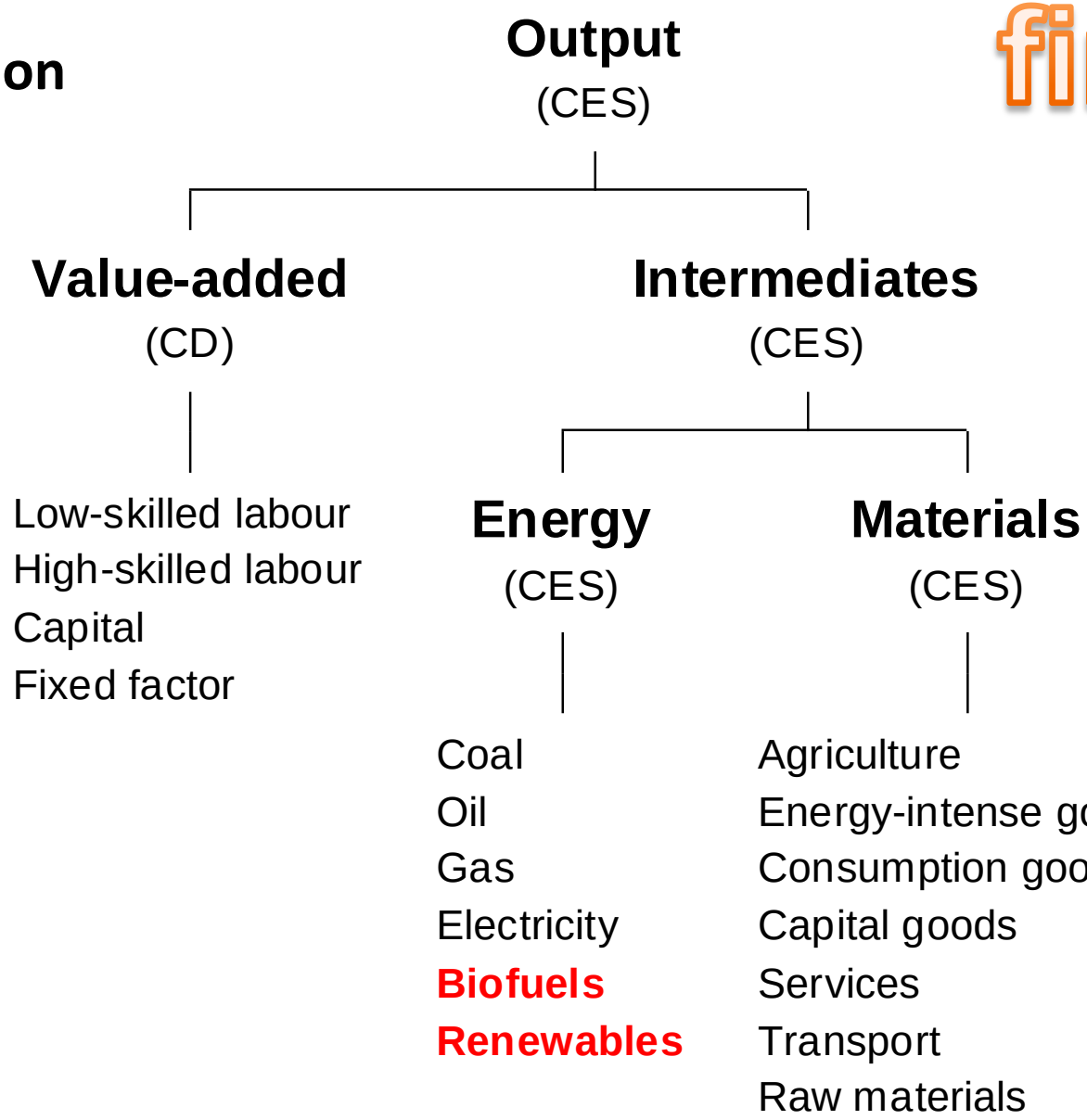




Objective 3: staying below 2°C

(Brede and De Vries 2012)

Production



finance

(nesting)

WorldScan model

No finance submodel…

Nonequilibrium

In real/world economic systems are many causes of disequiibria and associated fluctuations, mostly from delays in and anticipation of information, perceptions and actions

- Labour marker rigidities create oscillations (Philips curve)
- Investors make decisions on the basis of trend forecasting
- Consumers determine spending on basis of income expectations
- Technological innovations
- ….

…new economics…

Money creation

The financial system plays an important role, according to recent views (Post/Keynesian school):

- Private banks create money, when they give loans to investers, consumers and governments
- The constraints on loans is set by a minimum amount of reserves (i.e. cash and accounts). This can be expressed with the leverage ratio, defined as the ratio of assets and own capital (equity, net worth)
- The profit incentive induces private banks to give out as many loans as possible (within the official rules and inasfar as on the balance sheet)

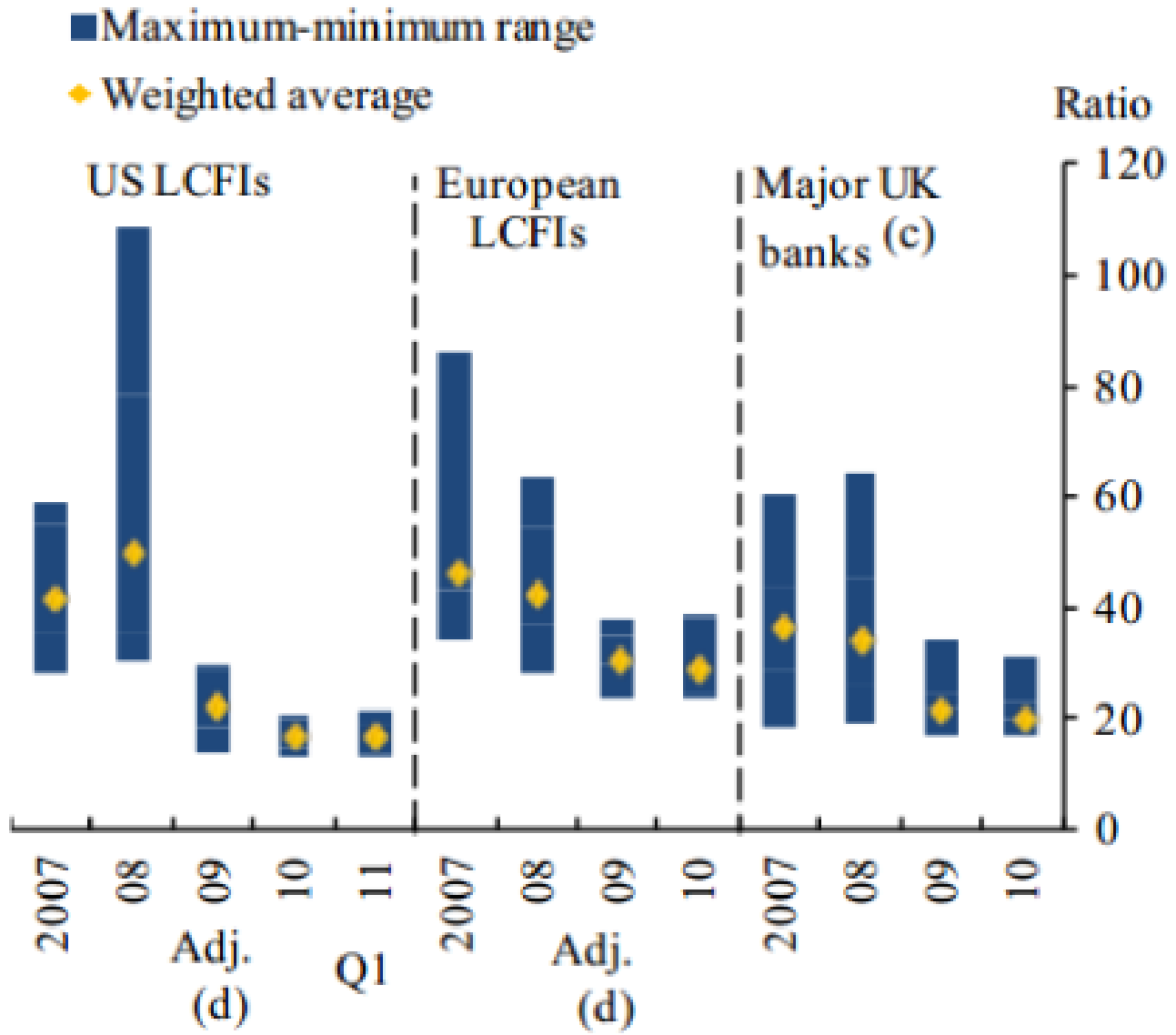


Figure 58. Leverage Ratios of Major US, EU, and UK Banks from 2007-2011 (Haldane, 2011).

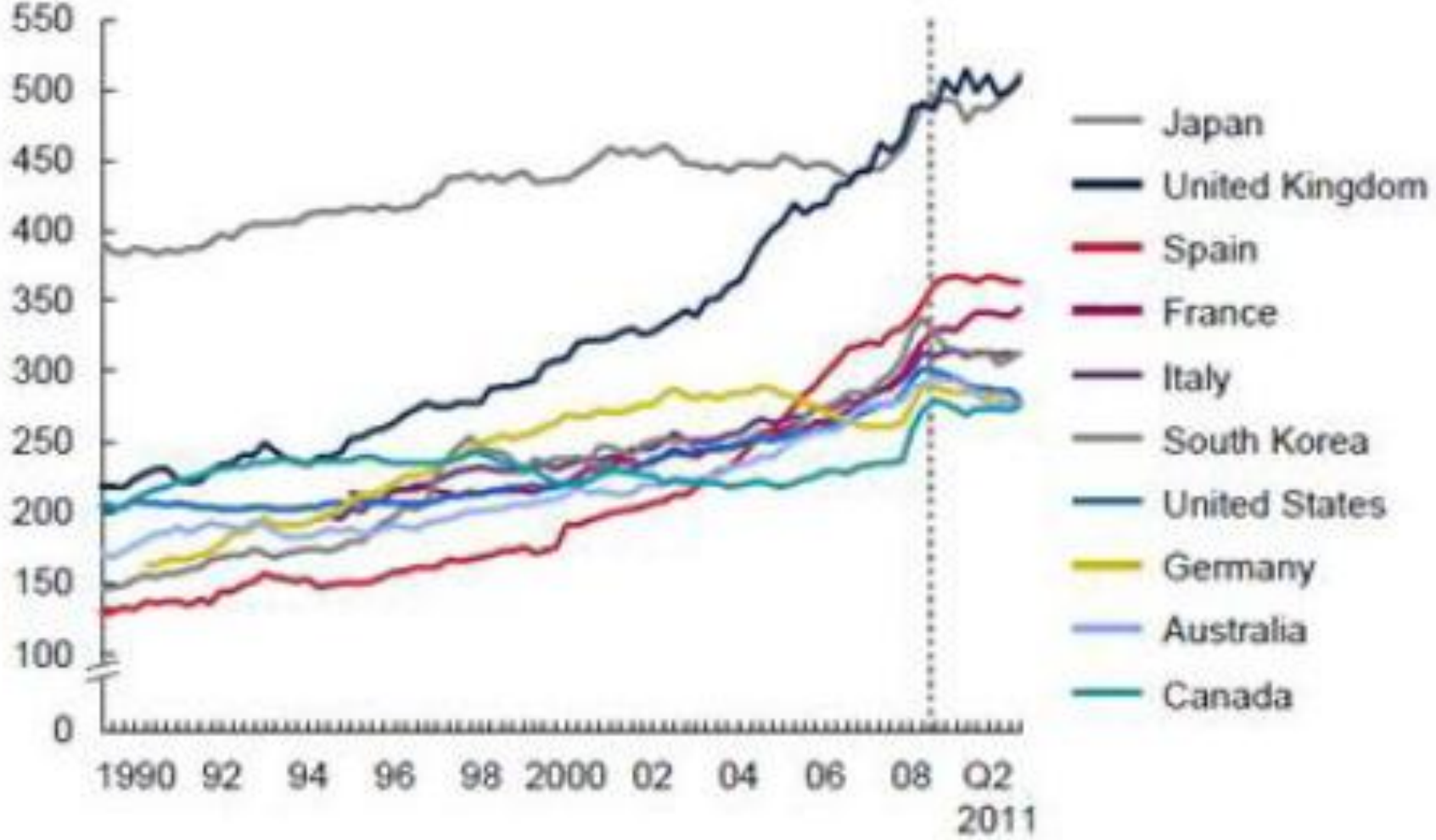
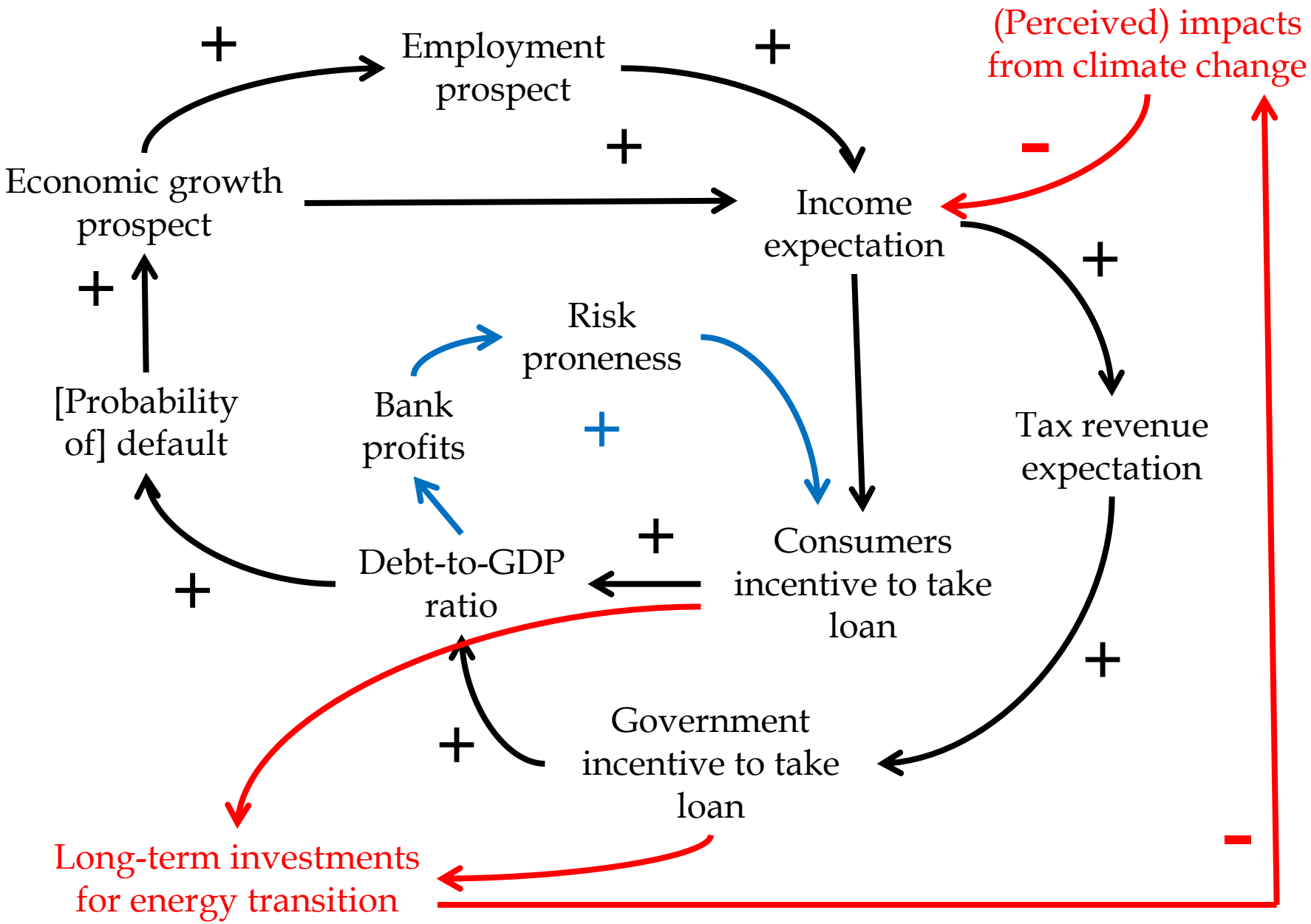


Figure 37. Total Debt-to-GDP Ratio in Ten Developed Economies (Roxburgh et al., 2012).

What is the relevance in climate-society (or climate-economics) models?



Built-in disequilibria: planned actions as the driver of more (less) loans in times of high (low) expectations

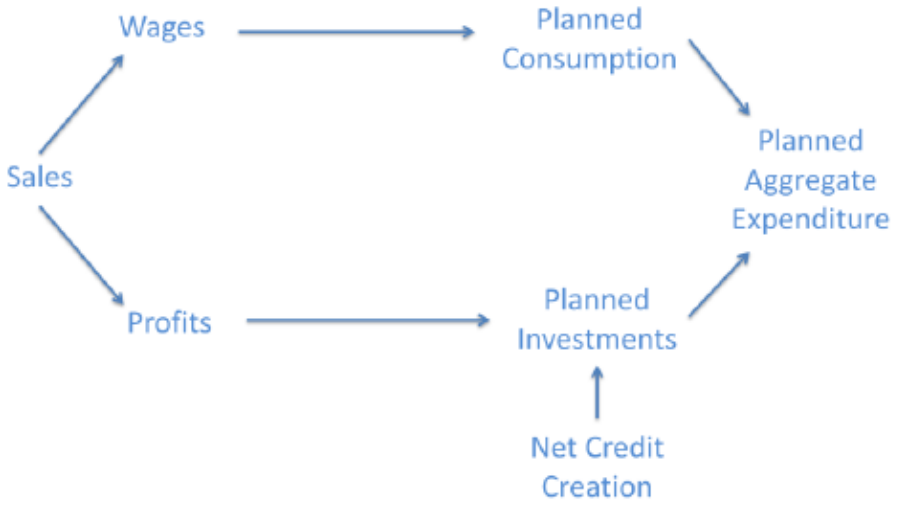


Figure 70. Income Becomes Planned Aggregate Expenditure via Debt (Credit) (Campiglio and Bernardo, 2012).

"aggregate demand equals income plus the change in debt, and aggregate supply equals output plus new purchases of financial assets" (Keen, 2012b)

$$AD = AS + \Delta D = Y + \Delta D$$

$$E = Y + \Delta D_I + \Delta D_S + \Delta D_G$$

AD Aggregate Demand AS Aggregate Supply D Debt

(Keen 2012; Van Dixhoorn 2012)

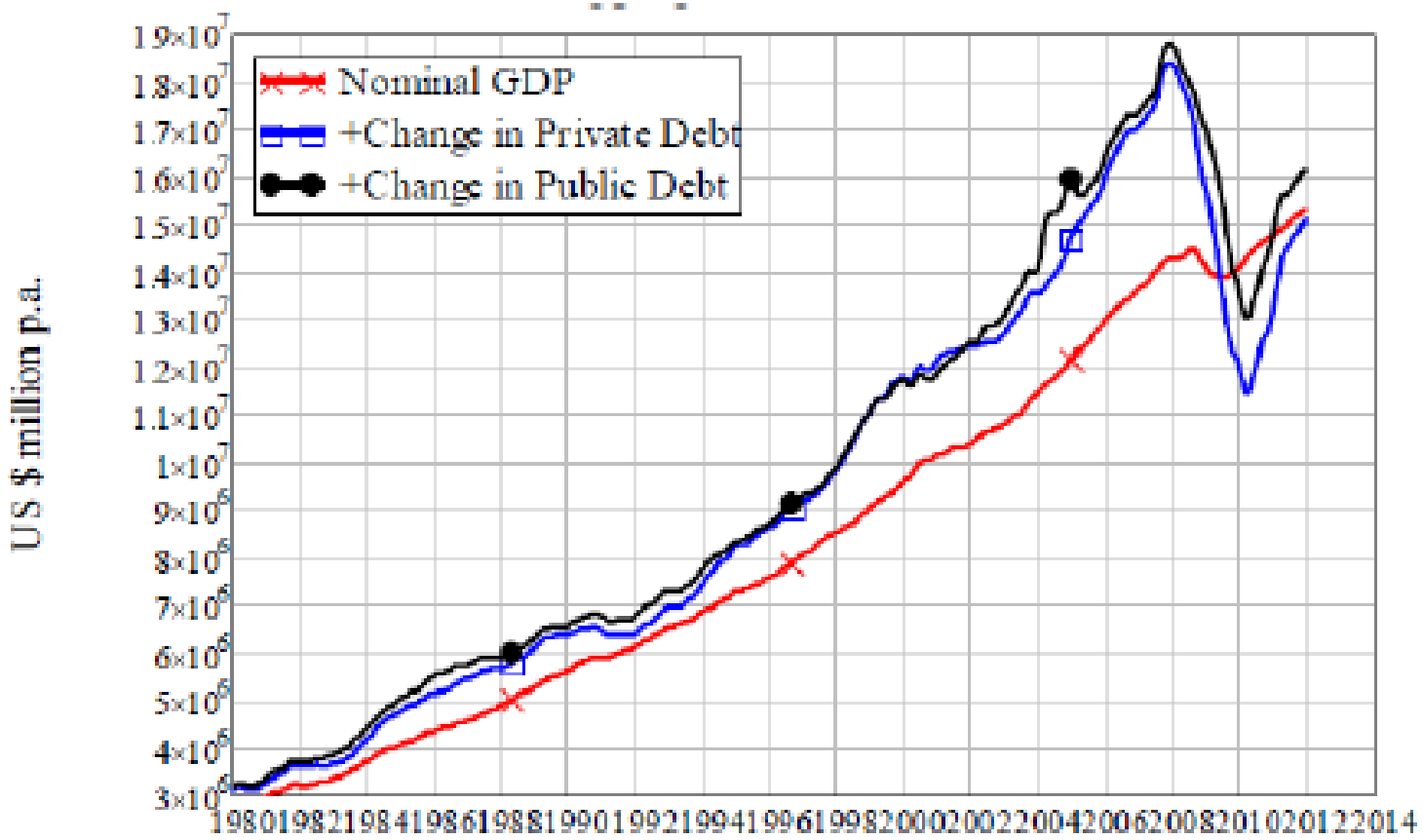


Figure 71. US Aggregate Demand (Including Change in Debts) and Income (GDP) 1980-2012 (Keen, 2012a).

In this way, the (unregulated) financial system can intensify already existing fluctuations

Do I believe GCM is useful, and if so, why?

There are serious obstacles to advance Integrated Assessment Modelling (IAM) of Global Change (GC) at UU:

- Modest interest and commitment from disciplinary scientists, for various reasons (publication score/status, own disciplinary background/concepts /methods and specialist network…)
- Scientific enterprise tends to become inherently fragmented and application oriented → no time/money for more fundamental (holistic) system approaches
- ‘Great stories’ have become discredited → ‘models of everything’ are impossible and dictatorial
- ‘Earth system’ is too complex → (meta)models à la World3 are bound to fail

Do I believe GCM is useful, and if so, why?

Yet, I believe we have to continue and advance IAM-GC, because:

- The world is inherently complex with nested dynamics across scales and domains, that demands integrated simulation models to understand uncertainties, non-linearities and associated risks, and side-effects of (more) interventions
- Every local [model-based] investigation into more sustainable pathways is bound to happen in two-way interaction with the rest of the world system
- A (meta)model à la World3 can serve as framework for research agenda and cooperation among researchers

Do I believe GCM is useful, and if so, why?

Yet, I believe we have to continue and advance IAM-GC, because:

- Science should find ways to connect to the ‘world problématique’ (Sustainable Development, Millennium Development Goals, Biodiversity Convention…) – for this, we need small-scale local and large-scale global models
- The science-policy interface must be strengthened: prevailing attitudes and behaviour, media influences and policy interventions can and will happen on the basis of manipulation and vested interests unless science contributes to (better) understanding as part of a new ‘great story’

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