The Multi-Actor Dynamic Integrated Assessment Model System (MADIAMS)

Klaus Hasselmann,

European Climate Forum and
Max Planck Institute of Meteorology, Hamburg

Utrecht, 22 January 2010

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* ECF: founded to promote communication between climate scientists, economists, business, CSOs, other stakeholders, public and policy-makers –

- A GSD goal: overcome deficiencies of IPCC WGs2-3

MADIAMS modelling approach

- keep it simple and understandable

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- develop models as a hierarchy

Tree structure of a conceivable dynamic, multi-actor, macroeconomic model hierarchy

root model 1.0

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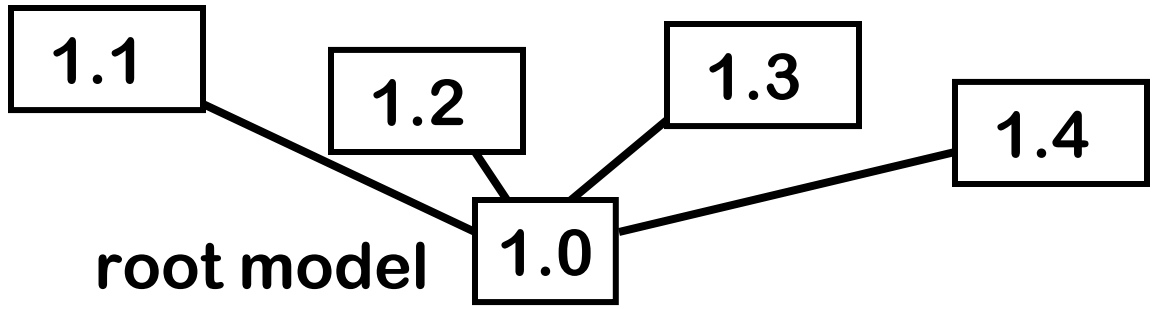

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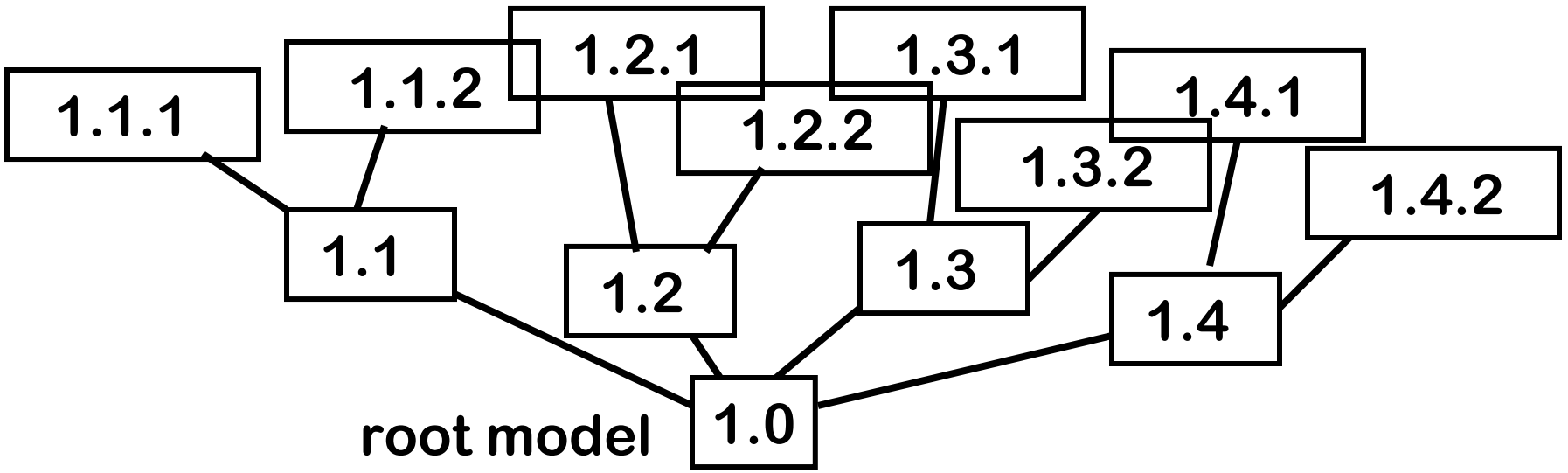

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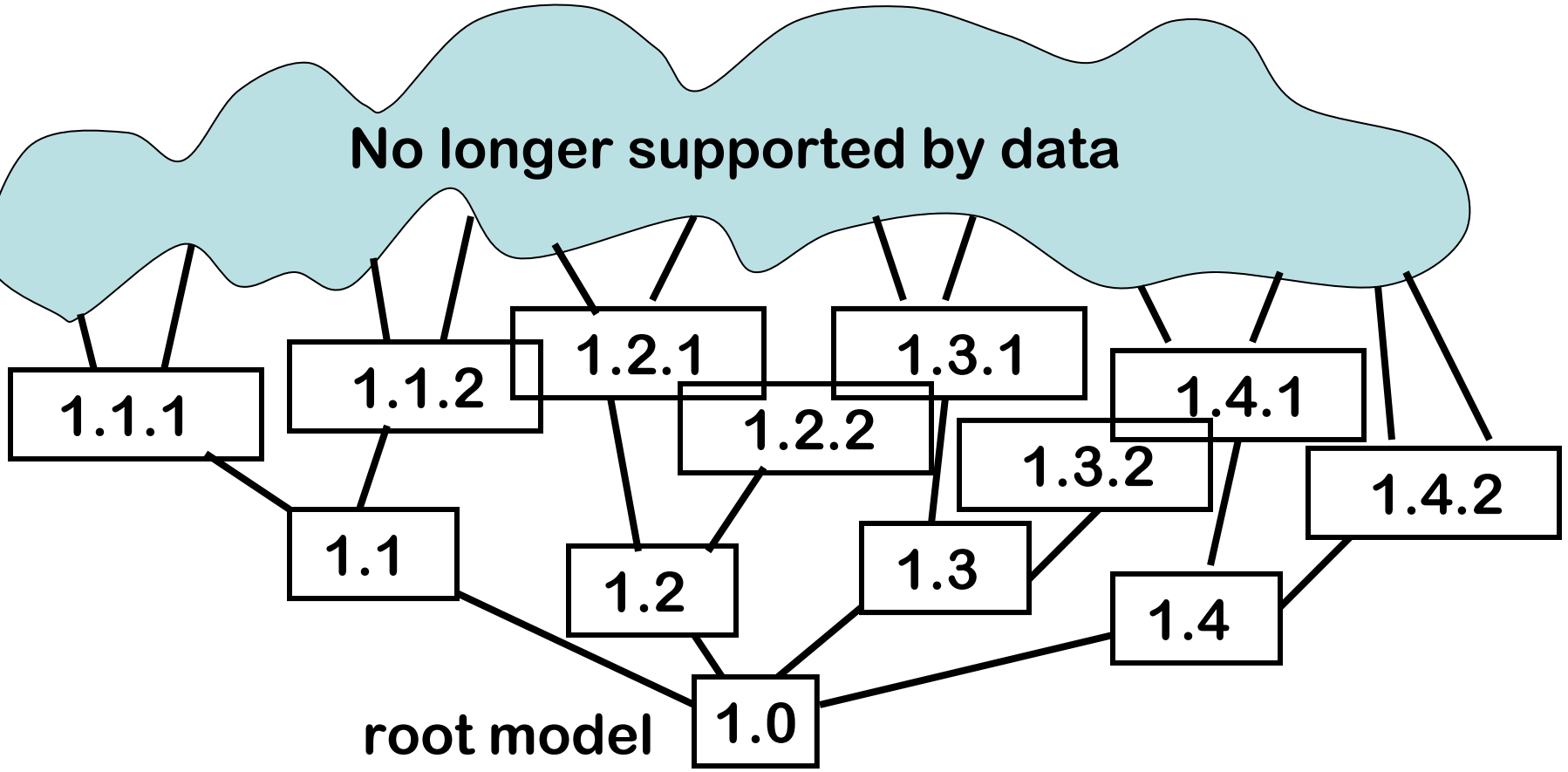

MADIAMS modelling approach

- keep it simple and understandable
- develop models as a hierarchy
- translate the numerous excellent

  verbal models of the economy (Charles Mackay, Adam Smith, Karl Marx, John Maynard Keynes, Joseph Schumpeter, Hyman Minsky……)

  into

  visual models

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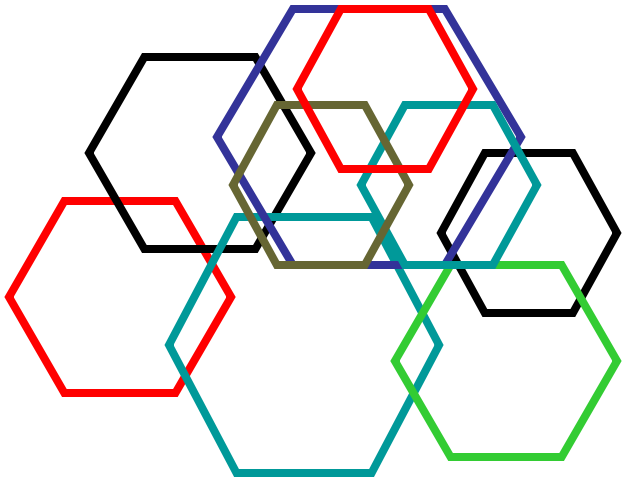
Narratives (qualitative) → *verbal* models of the economy (Charles Mackay, Adam Smith, Karl Marx, John Maynard Keynes, Joseph Schumpeter, Hyman Minsky……)

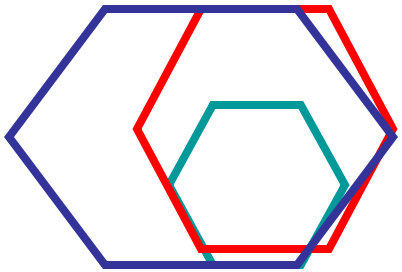
into

Graphs (quantitative) → *visual* models

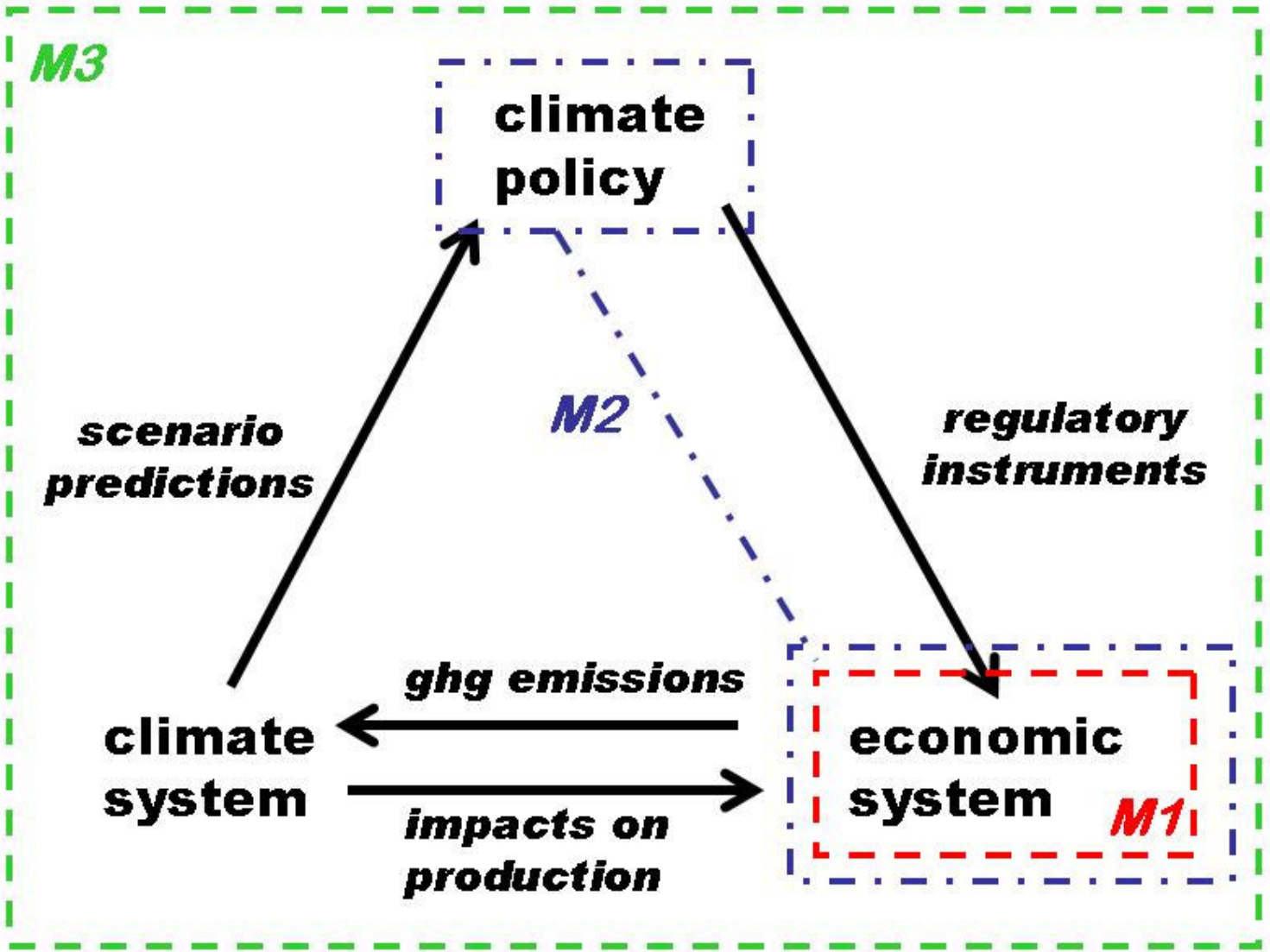
A model *family* rather than a hierarchy

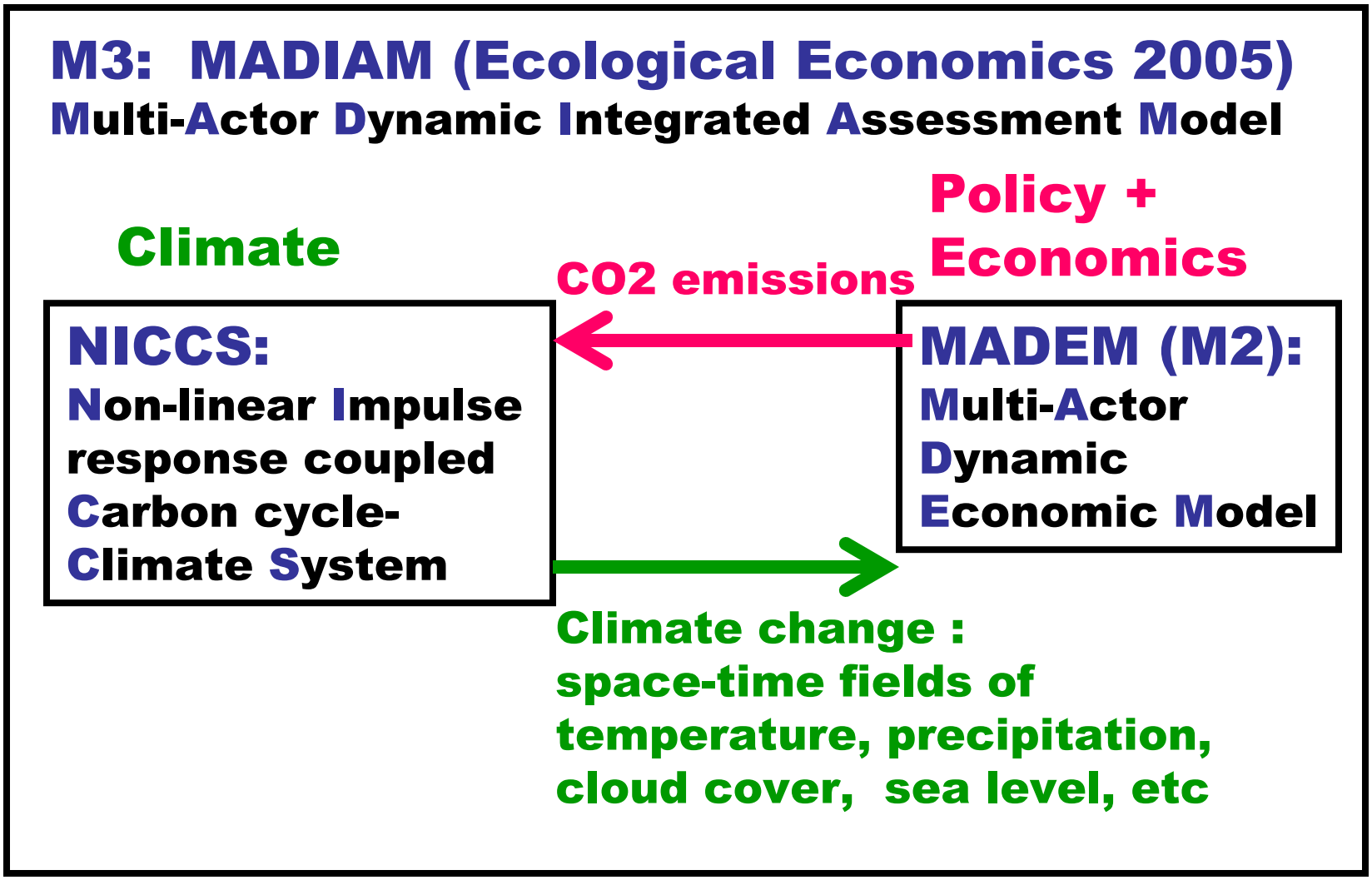


An example: the present three levels of MADIAMS



Three levels of the Multi-Actor Dynamic Integrated Assessment Model System (MADIAMS = M1, M2, M3)




M3: MADIAM (Ecological Economics 2005)
Multi-Actor Dynamic Integrated Assessment Model
Climate
Policy + Economics
CO2 emissions
NICCS:
Non-linear Impulse response coupled Carbon cycle-Climate System
MADEM (M2):
Multi-Actor Dynamic Economic Model
Climate change :
space-time fields of temperature, precipitation, cloud cover, sea level, etc

NICCS principle:

The response of a highly complex nonlinear system

$y_i(t)$ **(the climate)**

to a small forcing by a single scalar variable

x(t) (the CO2 concentration)

can be represented by impulse functions $R_i(t)$:

$$y_i(t) = \int R_i\,(t-t')\;\; x(t')\; dt'$$

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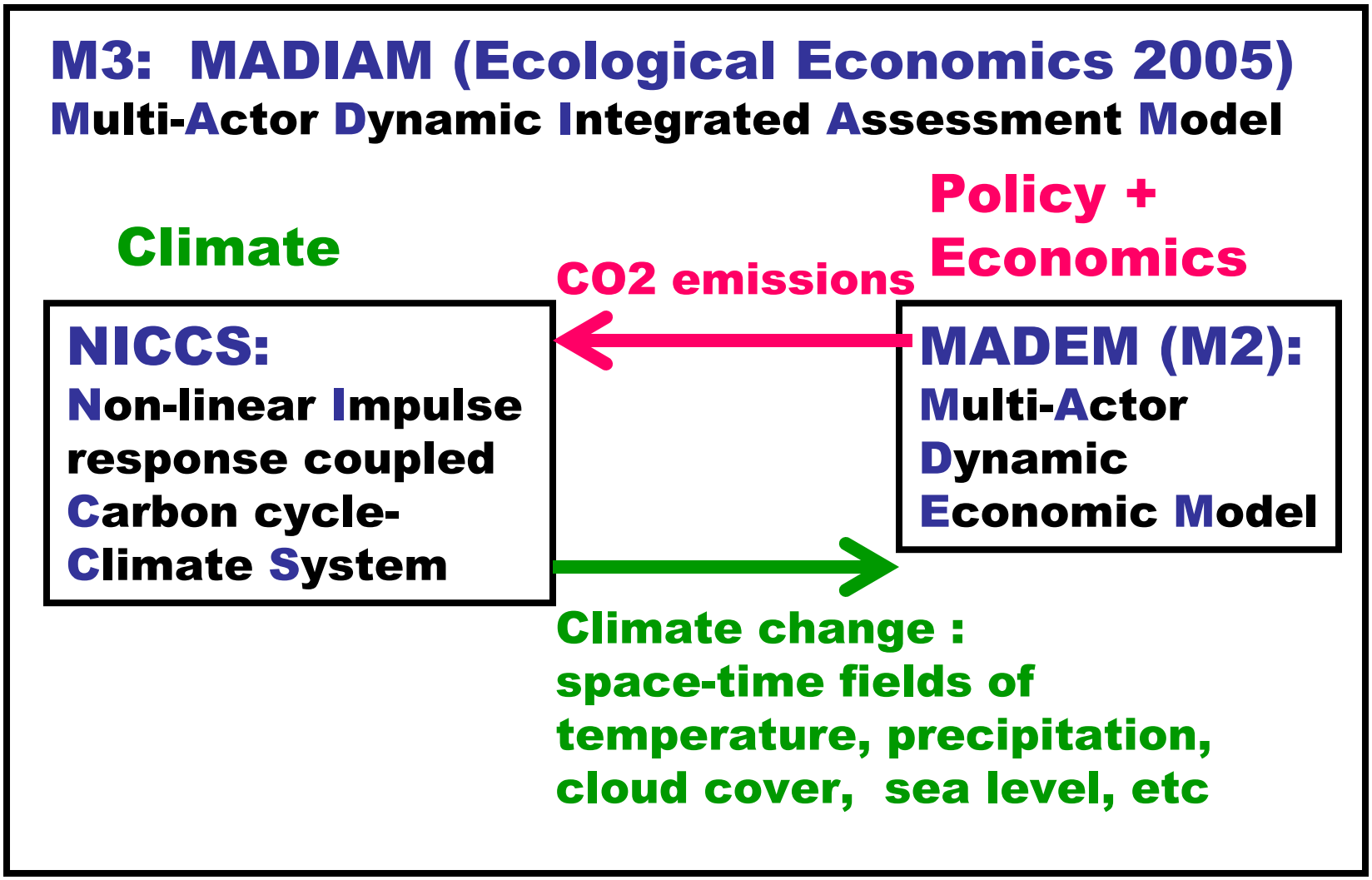
$$y_i(t) = \int R_i\,(t-t')\;\; x(t')\; dt'$$

The response functions R_i **can be calibrated empirically by a single simulation with a state-of-the-art high resolution climate model (response to a delta-function input). They contain the same detailed information as the state-of-the-art climate model.**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M2 (MADEM :Multi-Actor Dynamic Economic Model)

Actors	Goals
Firms	Maximize profits
Workers	Maximize wages
Governments	Maximize GDP
Banks	Stabilize money supply

All actors strive to achieve individual goals while jointly committed to avoiding dangerous climate change (classical “tragedy of the commons” conflict)

M2: mathematical structure

state variables:

physical goods $x = (x_i)$
money assets $y = (y_i)$
actor control variables $z = (z_i)$

Evolution equations:

$dx/dt = f(x,y,z)$ (conservation laws)
$dy/dt = g(x,y,z)$ (conservation laws)
$dz/dt = h(x,y,z)$ (actor behaviour)

State variables :
human capital, physical capital, employment level, wages, household and firm savings, government budget deficit, energy intensity, carbon intensity, fossil resources

Actor algorithms and control parameters:

Firms:

- Investments in physical capital
- Investments in productivity
- Investments in emissions reduction
- Credit uptake/Savings

Consumers/Wage earners:

- Wage negotiations
- Credit uptake/Savings
- Consumer preferences (climate friendly or climate adverse goods)

Governments:

- Emissions tax
- Recycled taxes (in consumption or subsidies in renewables)

Principal driver of economic growth:
Investments in technological change (human capital)

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(Basic idea expressed by classical economists of all persuasions - Adam Smith, Karl Marx, Joseph Schumpeter, … – but ignored in traditional economic equilibrium models)

Implications for mathematical formulation:

Production function

Y = Y(K,L,H) (K=capital, L labour, H technology)

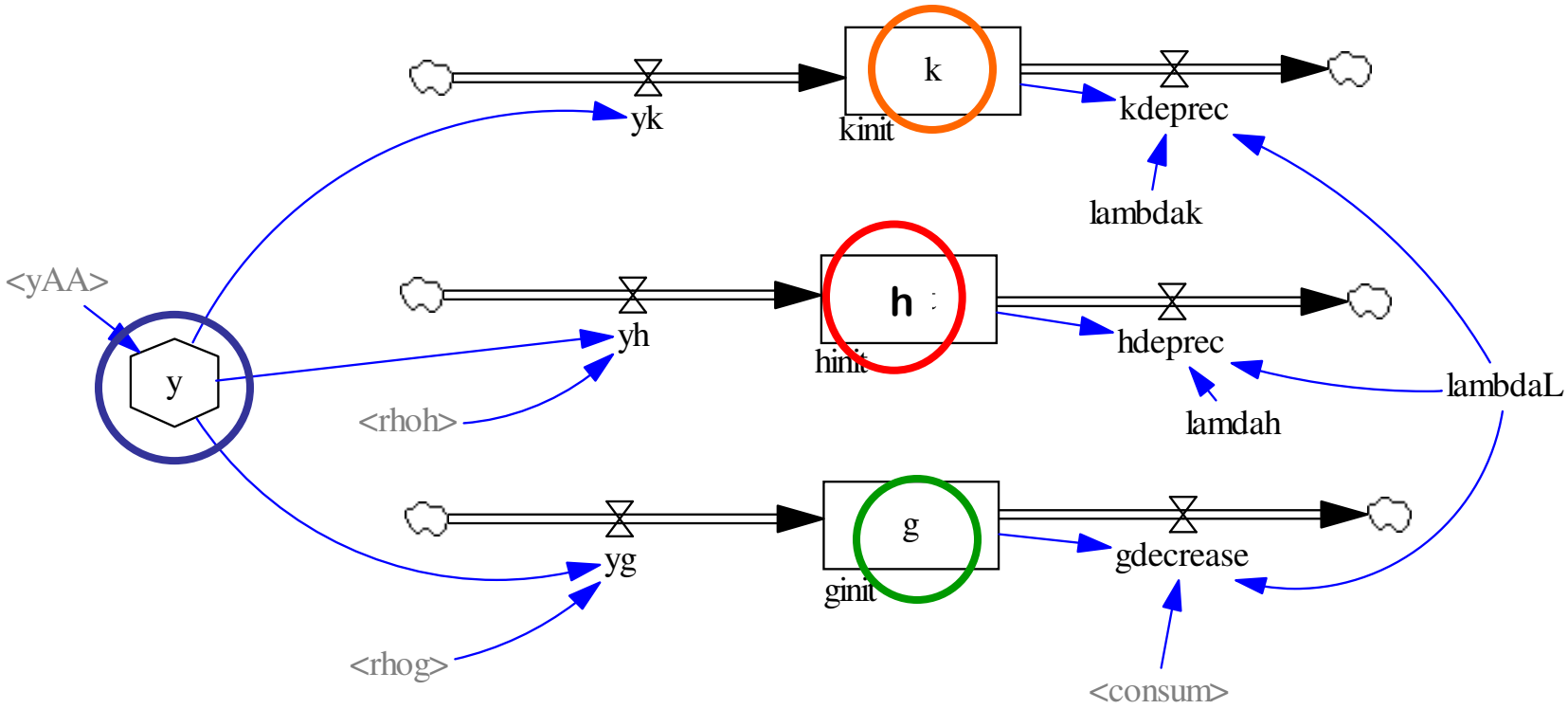
reduces to (extended Leontief, 1944)

Y=Y(H) with

K=K(H),

L=L(H) (no L, K substitutability:
H determines both L and K)

MADIAM model of the "real economy": production flows in physical units (VENSIM program)

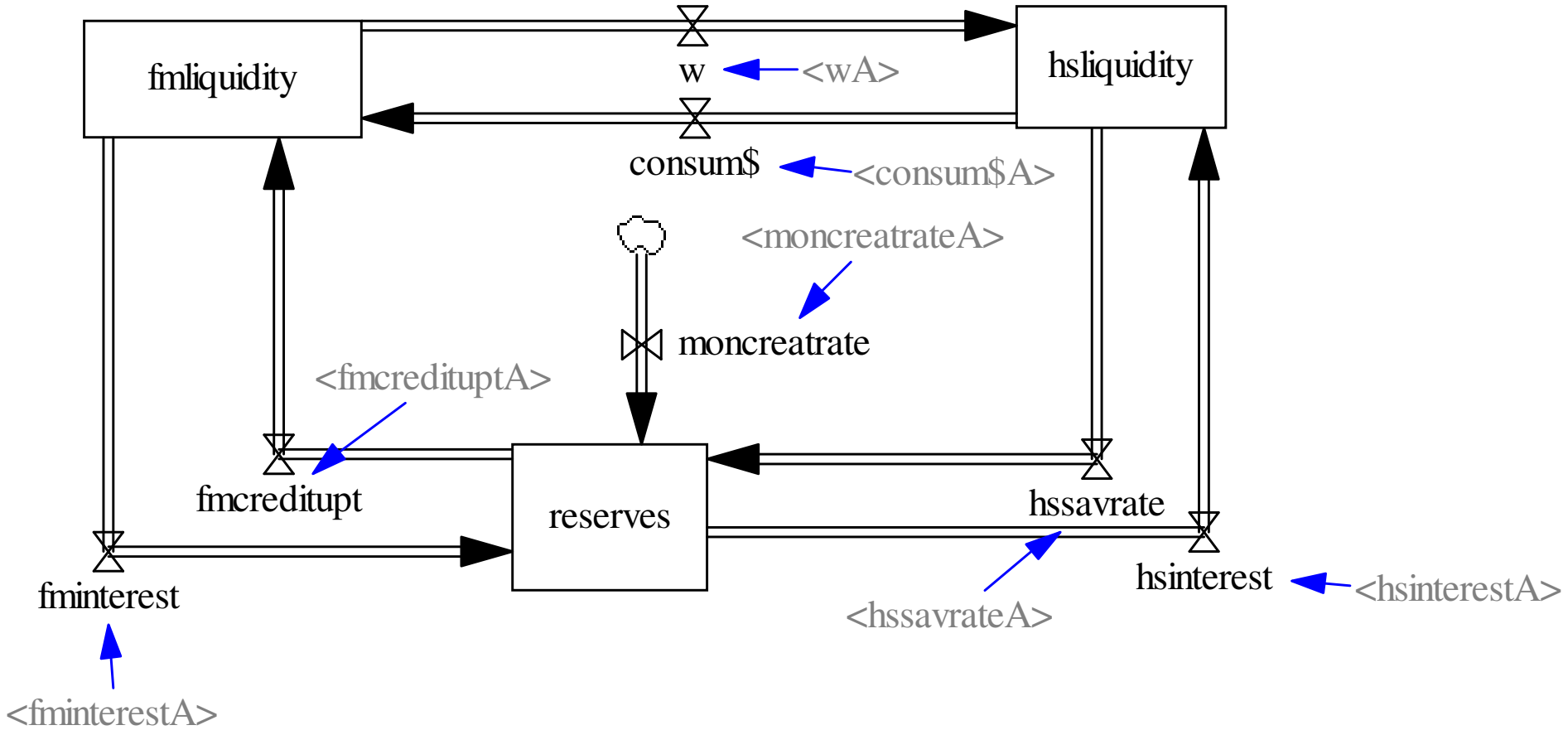


y: total production, invested in:

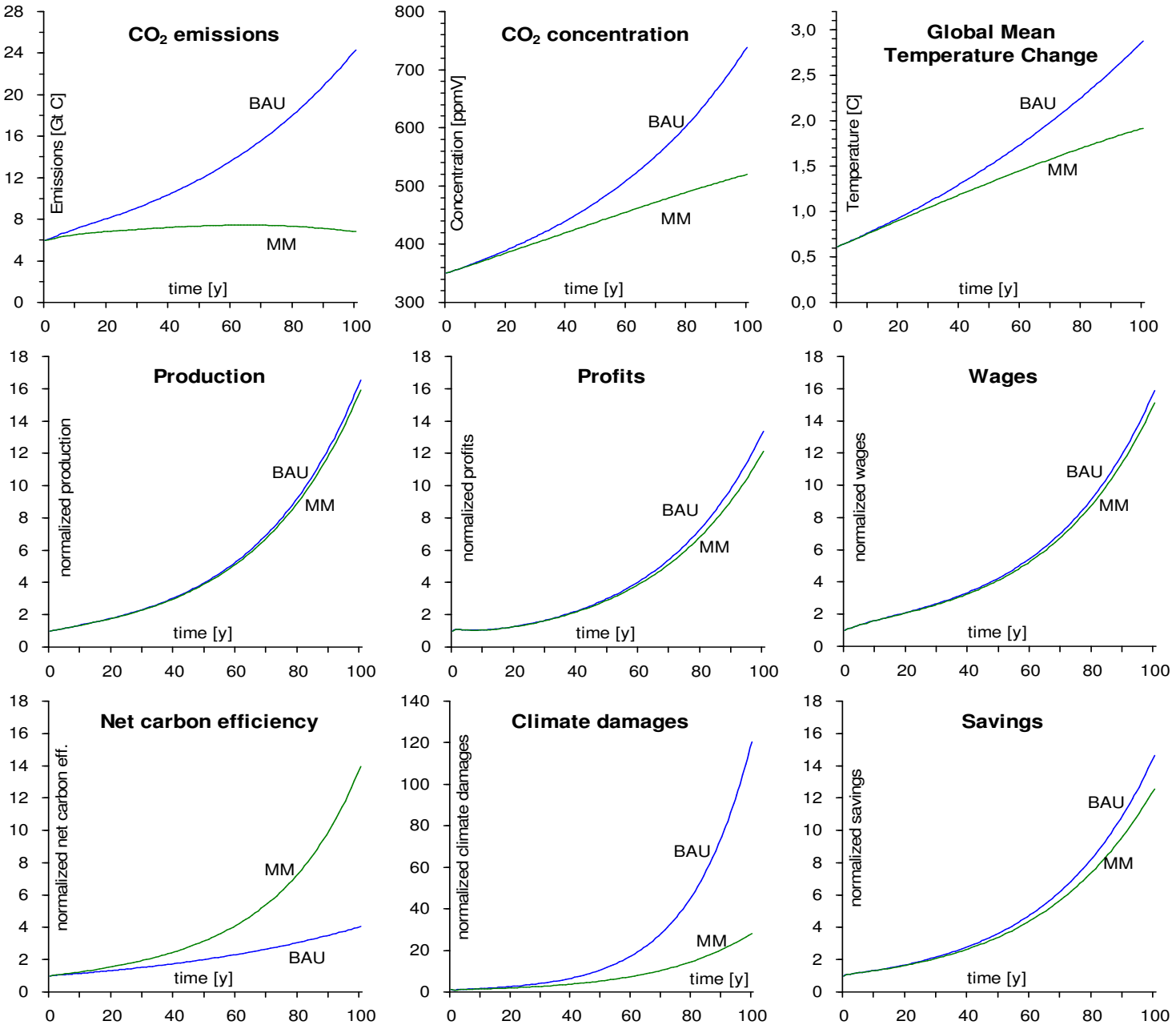
- **k: physical capital**
- **h: human capital**
- **g: consumer goods and services**

growth governed by distribution of production between these three investment streams

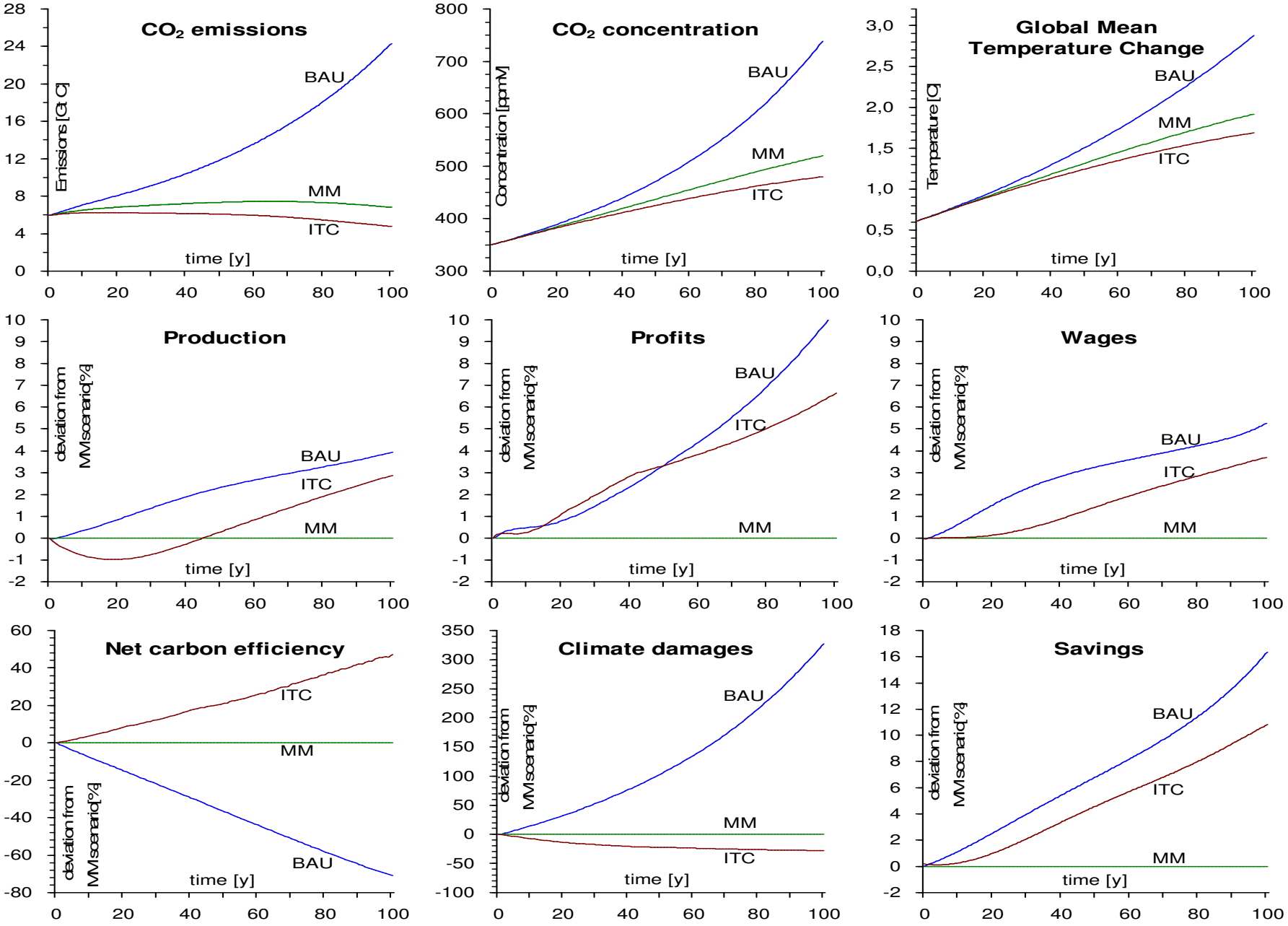
The “virtual economy” (financial system): money circulation between firms, banks and households



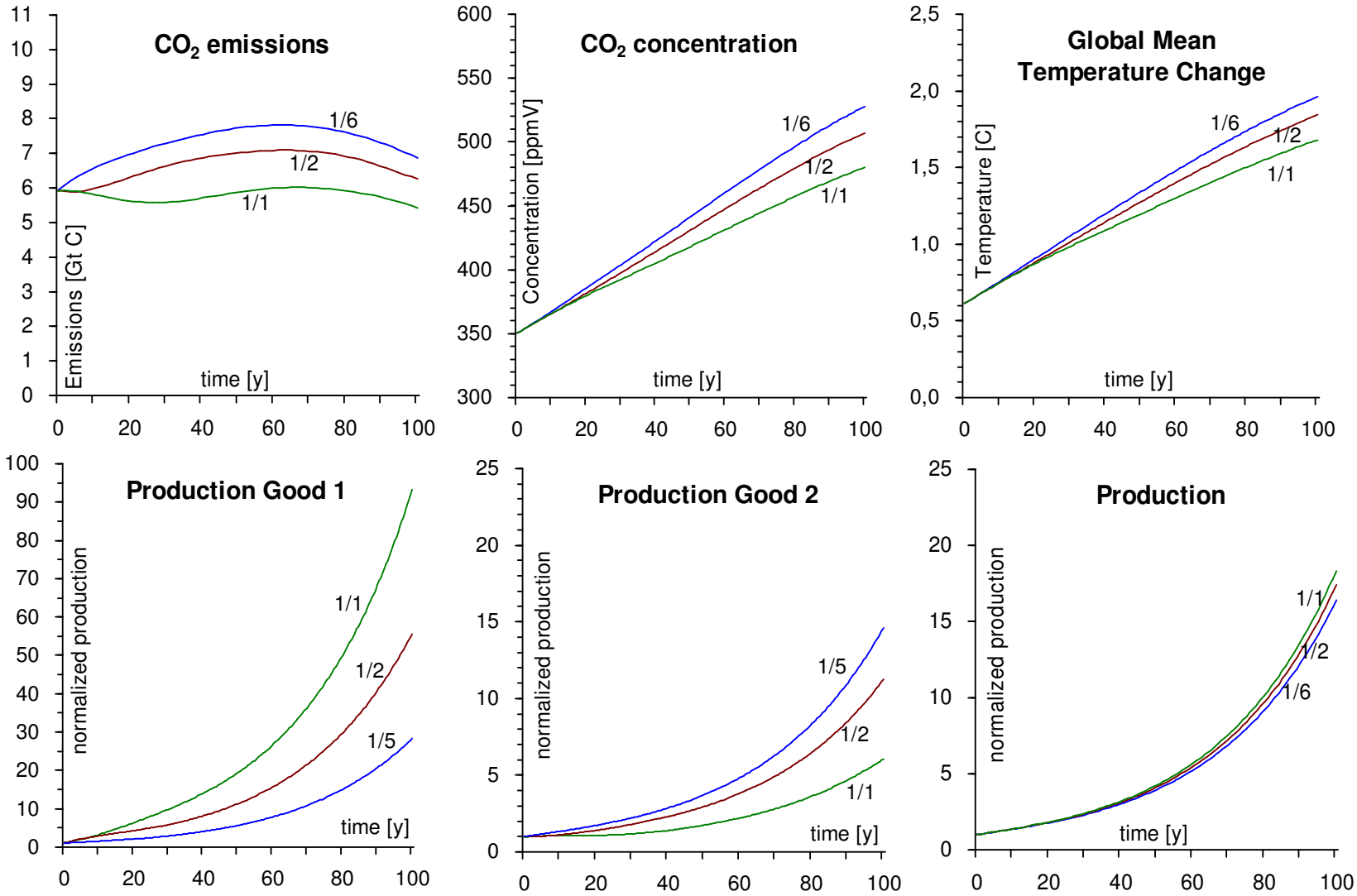
BAU / MM (Moderate Mitigation)



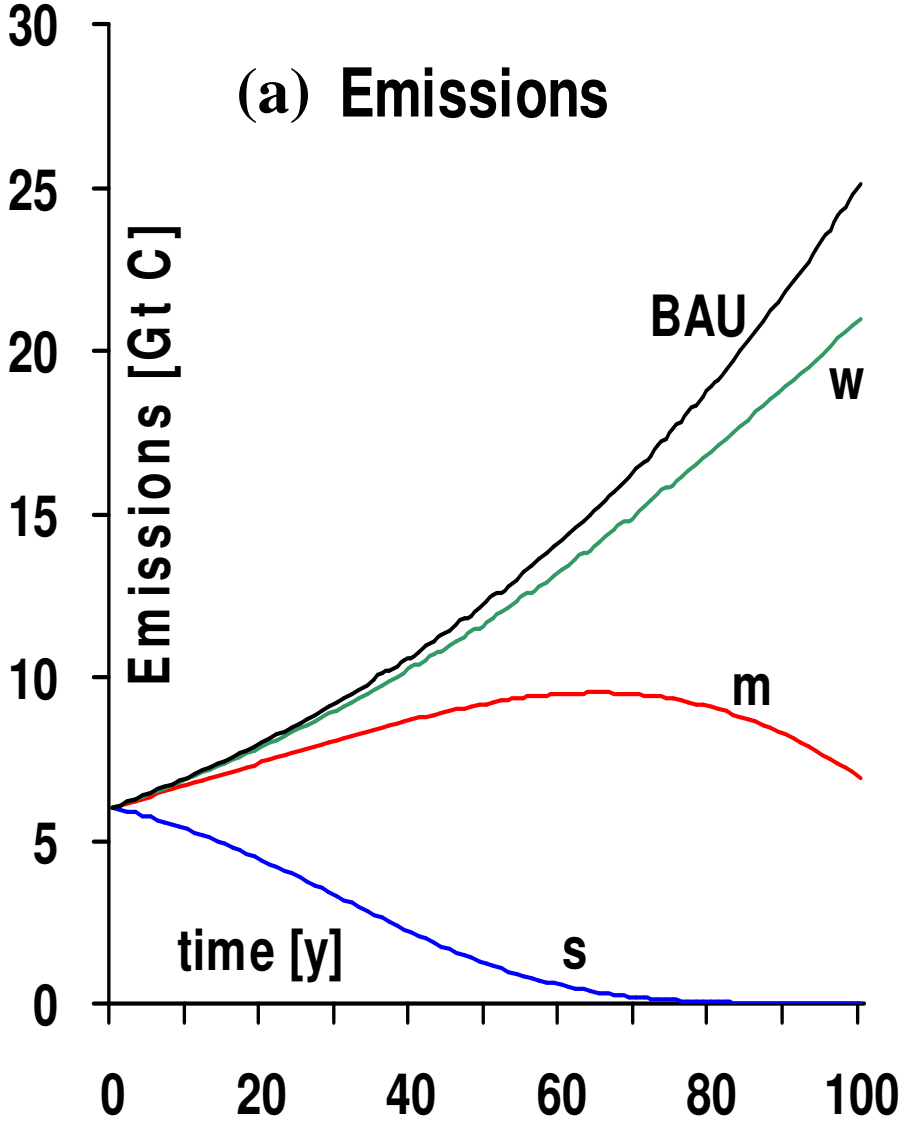
ITC (Induced Technological Change)

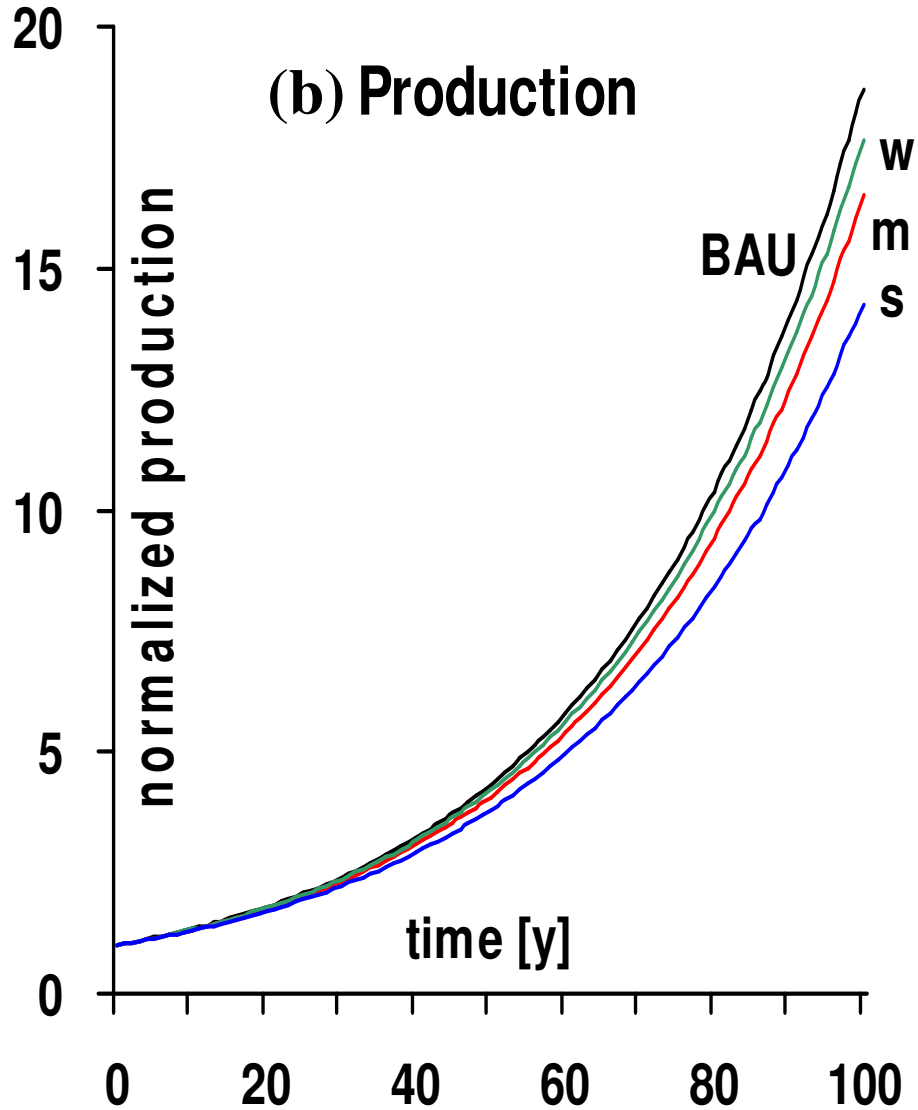


Relative demand
Good1(climate-friendly)/Good2(climate-hostile)



mitigation measures: w: weak, m: moderate, s: strong





Estimates of the costs of climate change mitigation:

1 % of GDP

Consistent with:

IPCC 4th Assessment Report, 2007

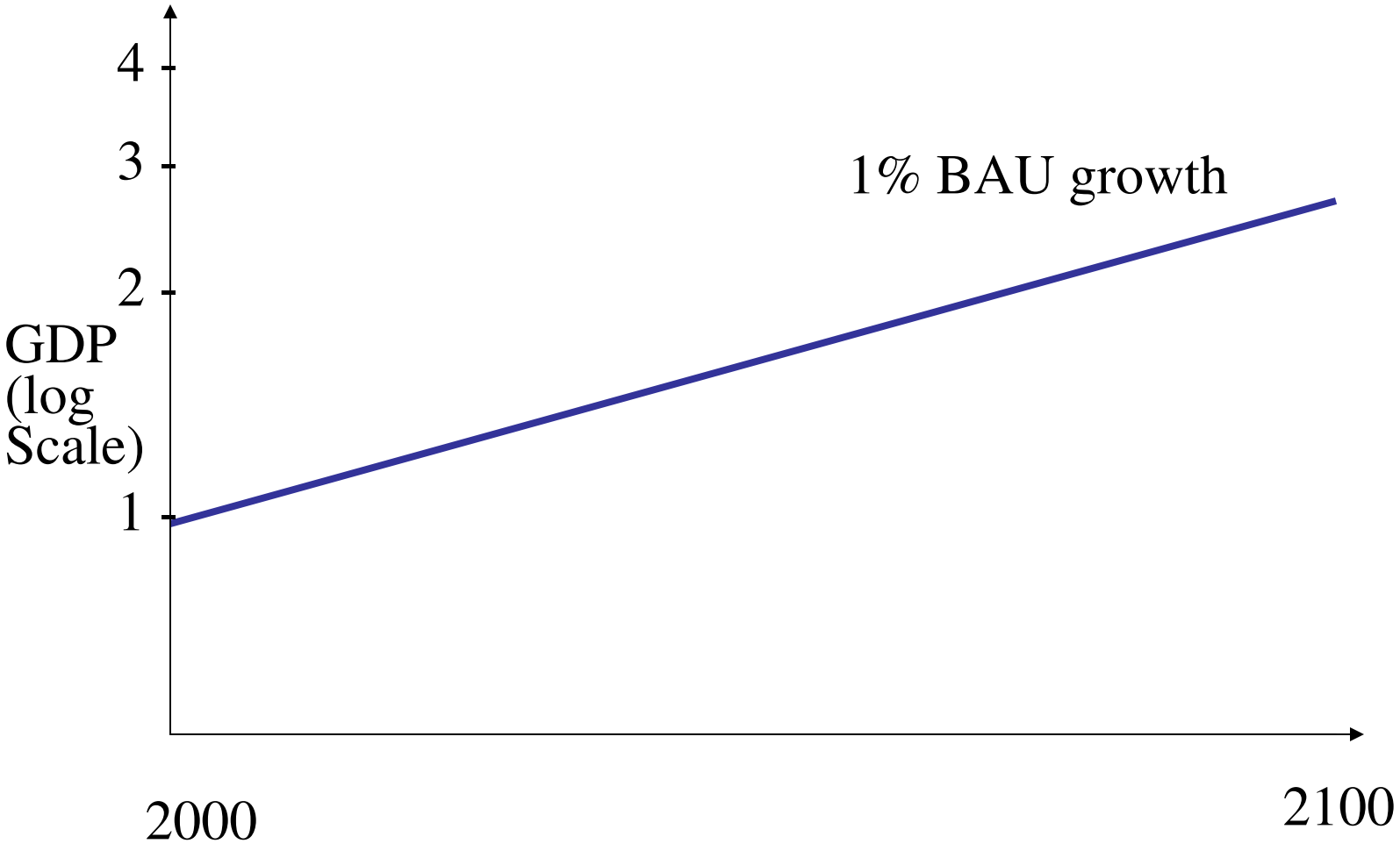
macro-economic model intercomparison, The Energy Journal, Special Issue, 2006

Stern Report, 2007.

Range of other estimates:

-1 % to + 4% of GDP

Is climate change mitigation affordable?



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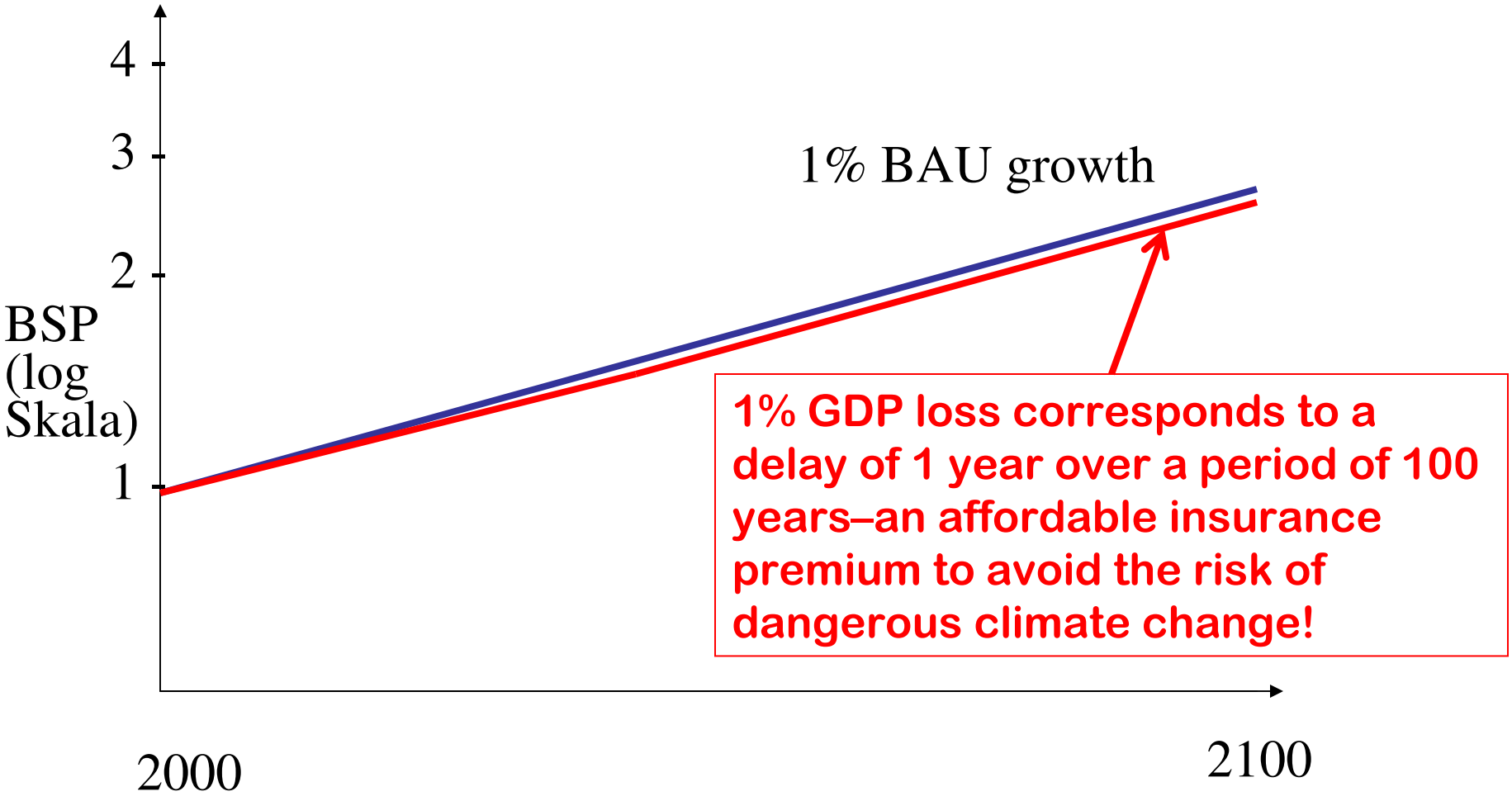

Ongoing extensions of MADIAM M3:

1. Several regions
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   Analysis at model level M1
   (no government, no climate)
   of agent-based dynamics of the
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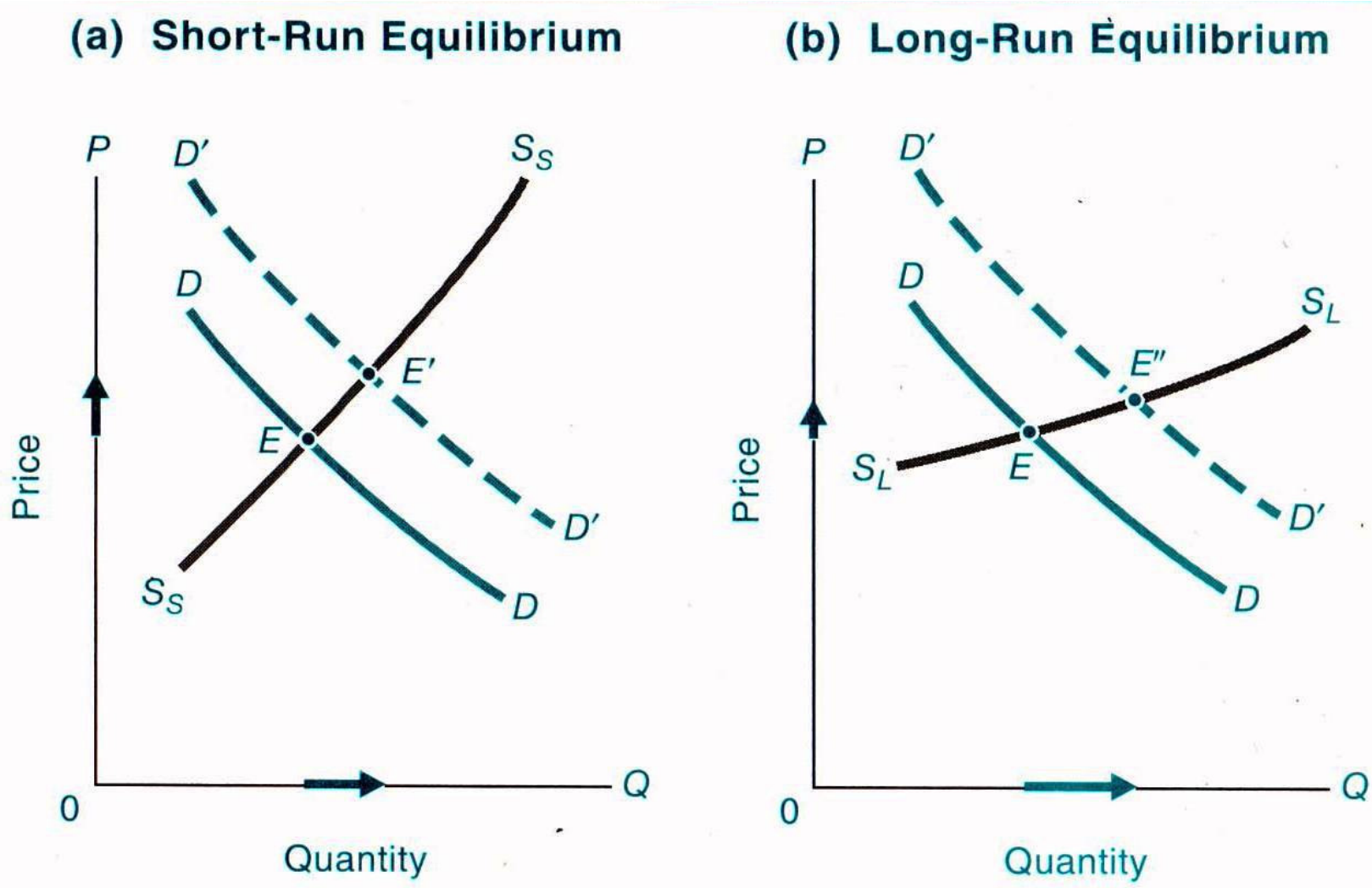
Textbook view of equilibrium in supply and demand in relation to price (Samuelson and Nordhaus)



System dynamics representation of supply-demand-price interdependence

$dS/dt = F(S,D,P)$	(S = supply)
$dD/dt = G(S,D,P)$	(D = demand)
$dP/dt = H(S,D,P)$	(P = price)

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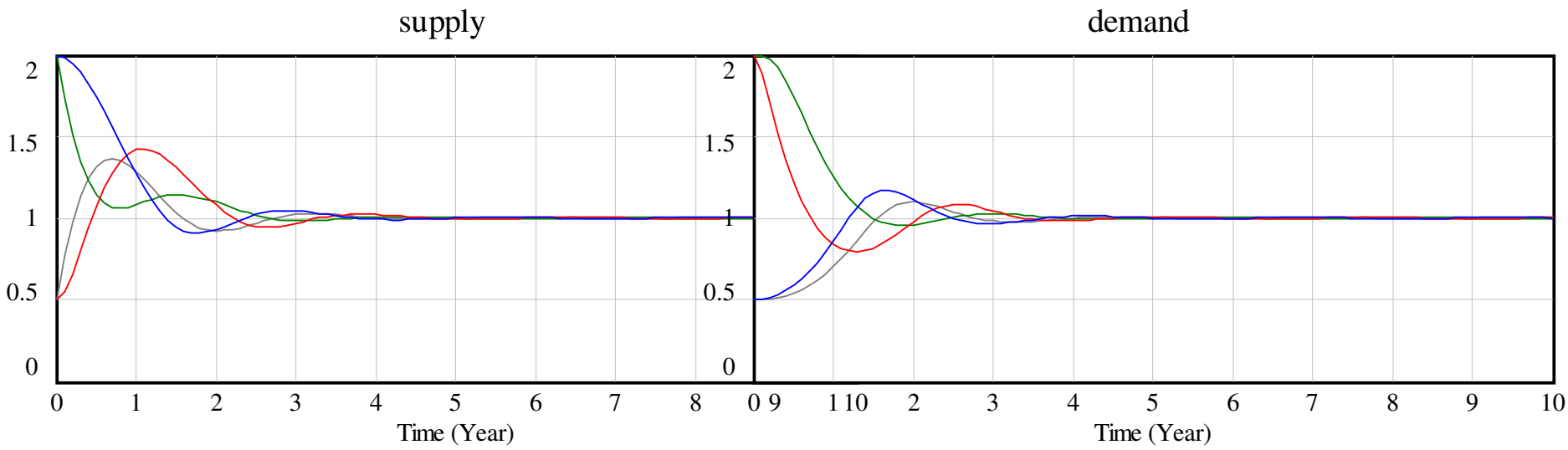
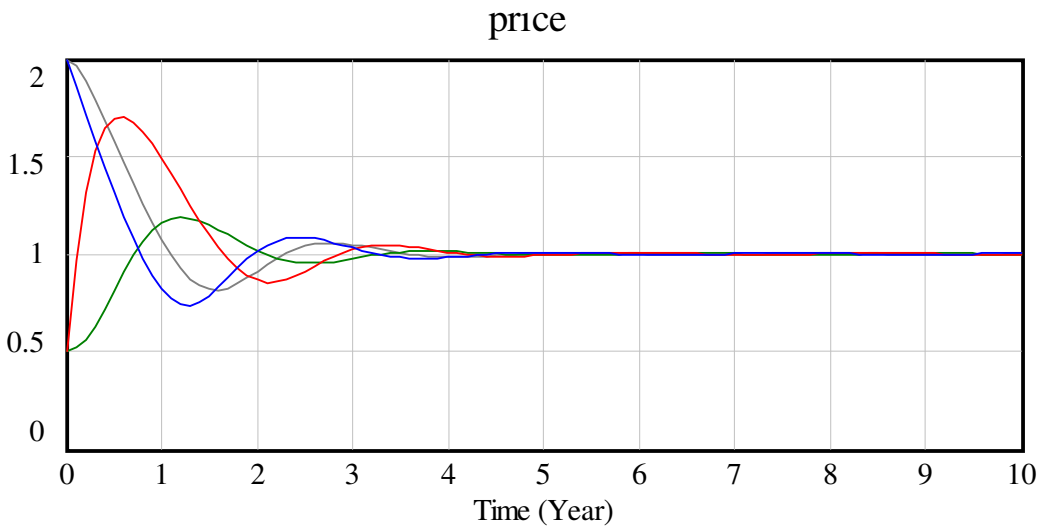
General result: A Lorenz system of three 1st-order differential equations can have solutions representing:

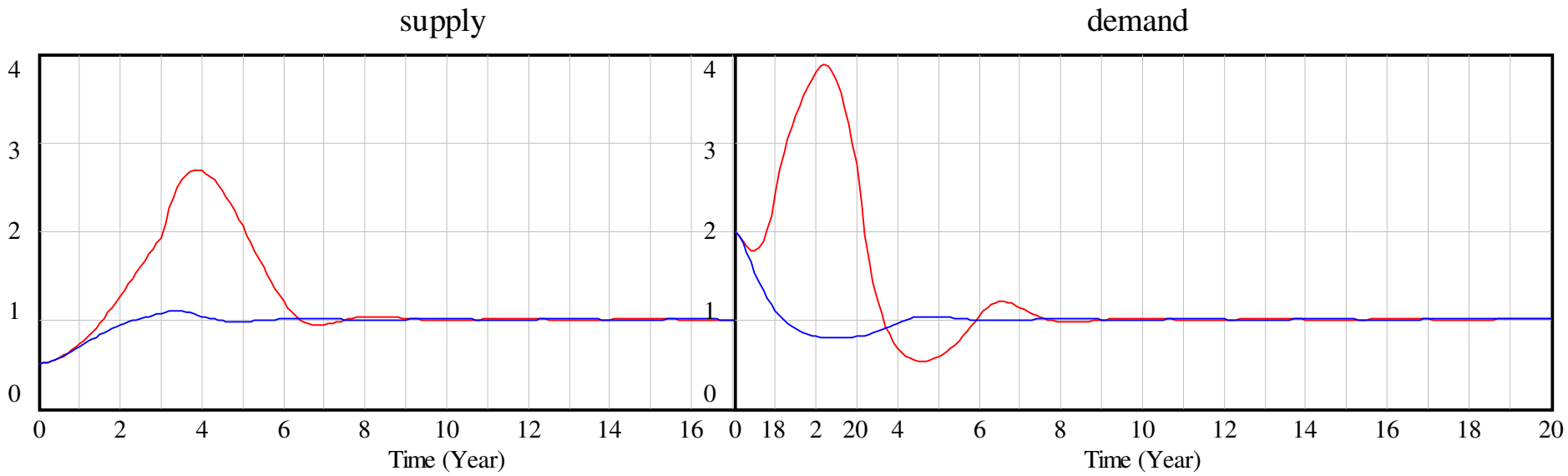
- a damped periodic, monotonic or non-monotonic (e.g. boom-bust) transition to an equilibrium point
- a stable convergence to a periodic attractor
- an unstable trajectory diverging to infinity
- a bounded, non-periodic chaotic trajectory

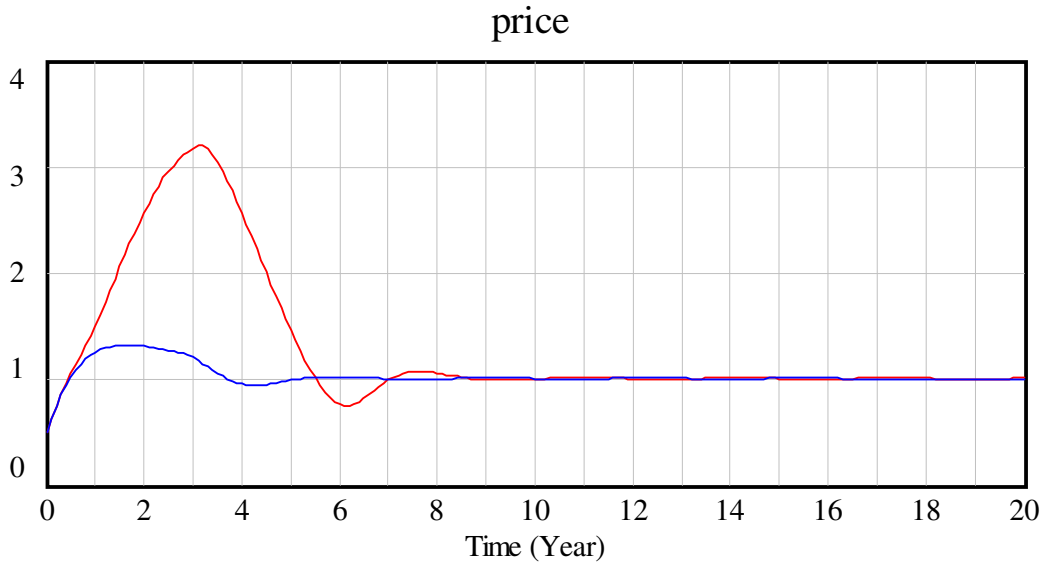
Which type of solution is realized depends on the initial conditions and the behaviour of the economic actors





General equilibrium model: evolution to joint equilibrium in supply, demand and price for four different initial conditions





Boom-bust model:

Equilibrium model:

Business cycle model: two-feedback loops, one postive (unstable), one negative (stabilizing)

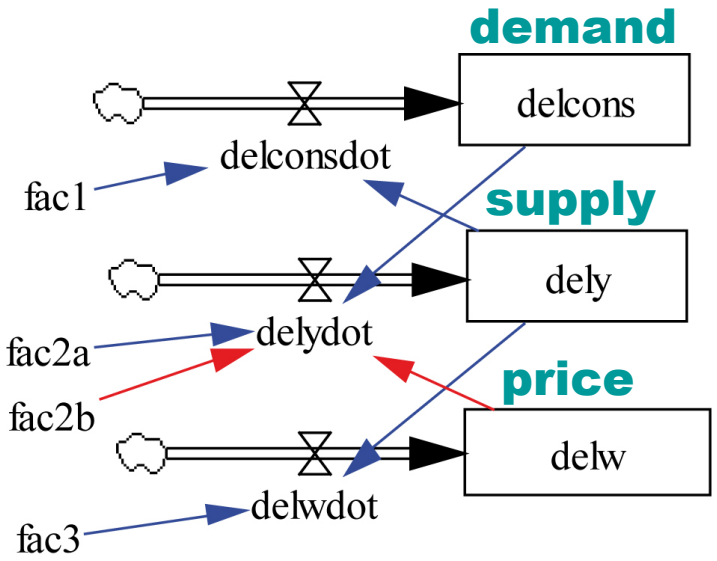
positive loop

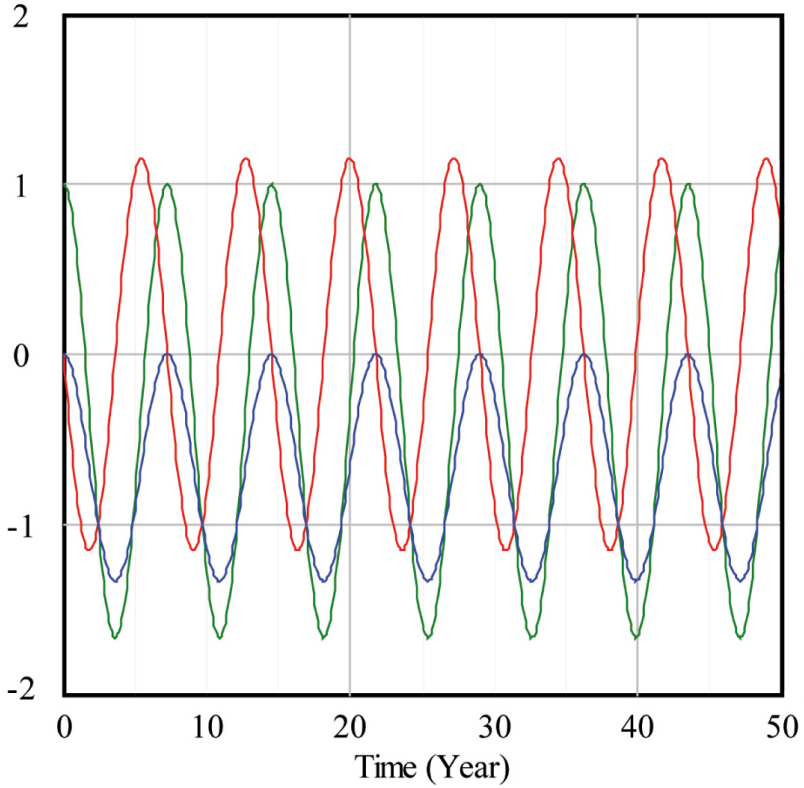
consumption decrease *delcons*

production decrease *dely*

increase

negative loop wage decrease *delw* → employm. increase





Ongoing extensions of MADIAM M3:

1. **Several regions**
2. **Several sectors**
3. **Inclusion of basic instabilities in demand-supply-price relation**

Analysis at model level M1
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Summary: All instability forms can be discovered in the present global financial crisis and recession

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4. **Inclusion of time delays in information transfer and decision processes**

A multi-actor model of the evolution and implementation of climate policy

Scenarios from

1970 (first serious warnings of climate change) to

2100 (end of IPCC scenarios)

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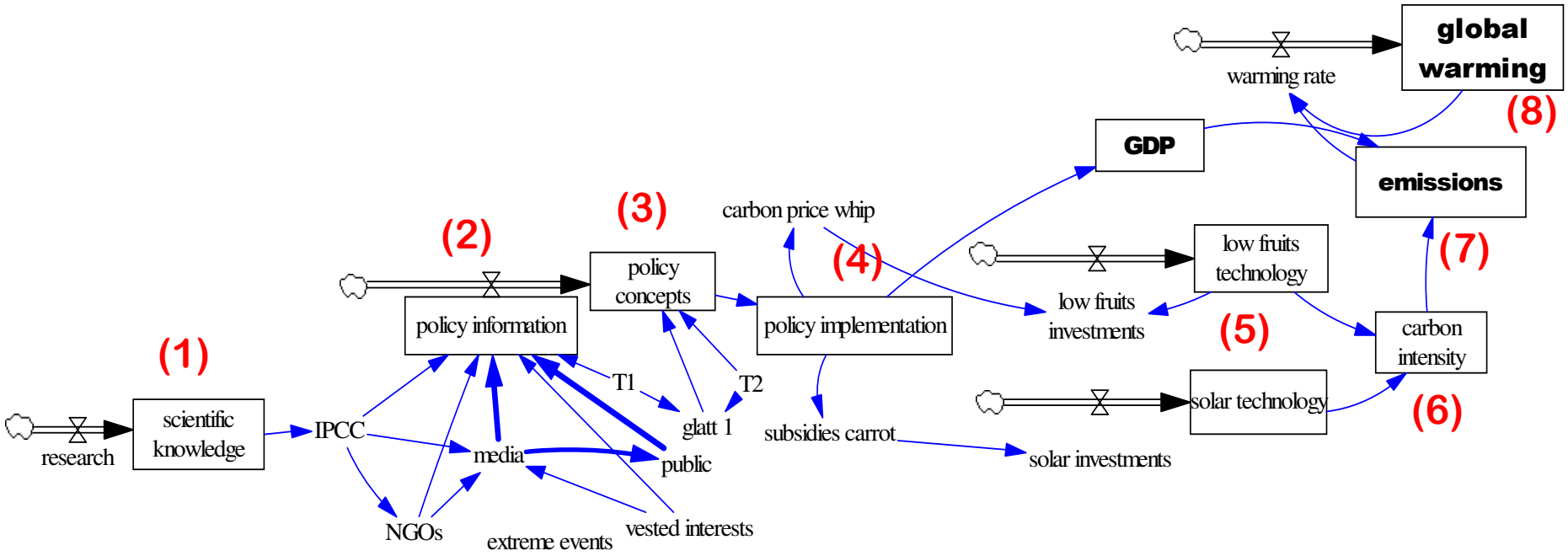
Simplified MADIAM, extended to include

- interaction of scientific knowledge, interest groups, media, etc in climate policy development and implementation

- assessment of alternative policies, e.g. stick (= carbon price) v. carrot = (subsidies)

A Vensim model of the climate-policy obstacle course: from scientific knowledge (1) to reduced global warming (8)

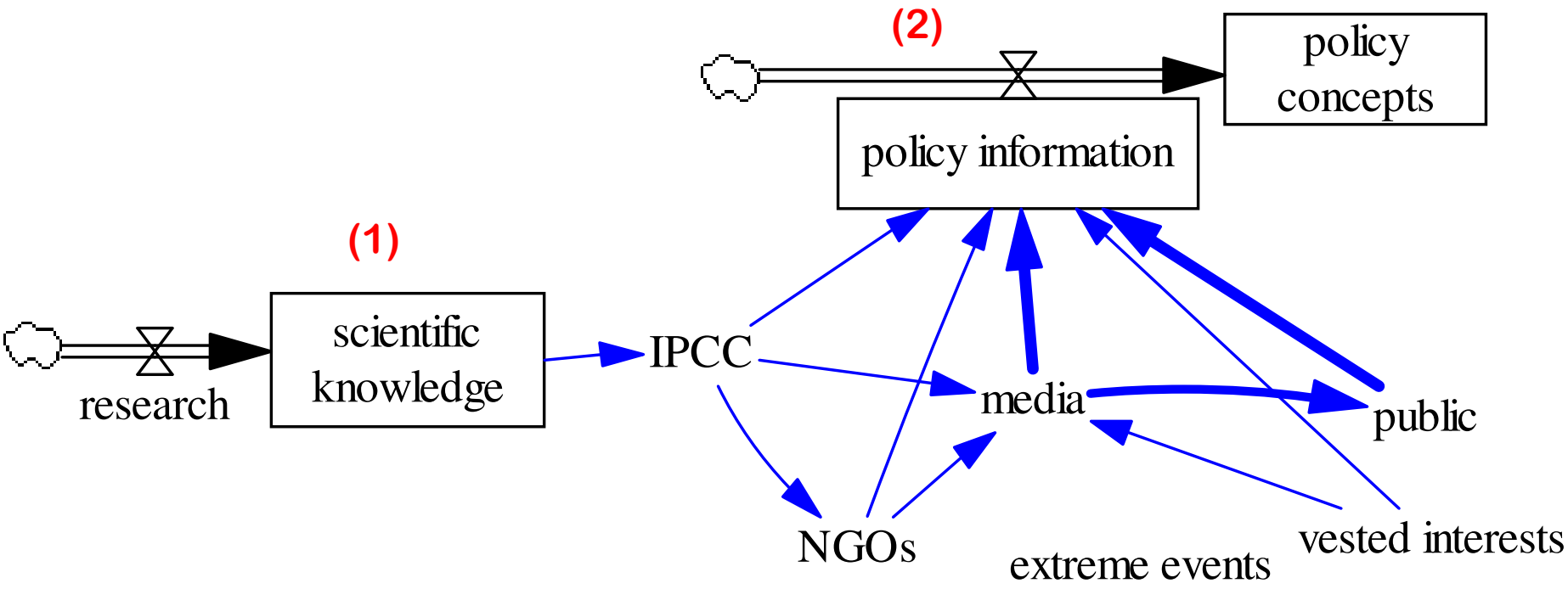


Three stages: 1: scientific knowledge (1) to policy information (2)

2: Information (2) to mitigation technology (5)

3: mitigation technology (5) to global warming (8)

Stage 1: From scientific knowledge (1) (IPCC) to policy information (2) via the media, vested interests, extreme events, etc.



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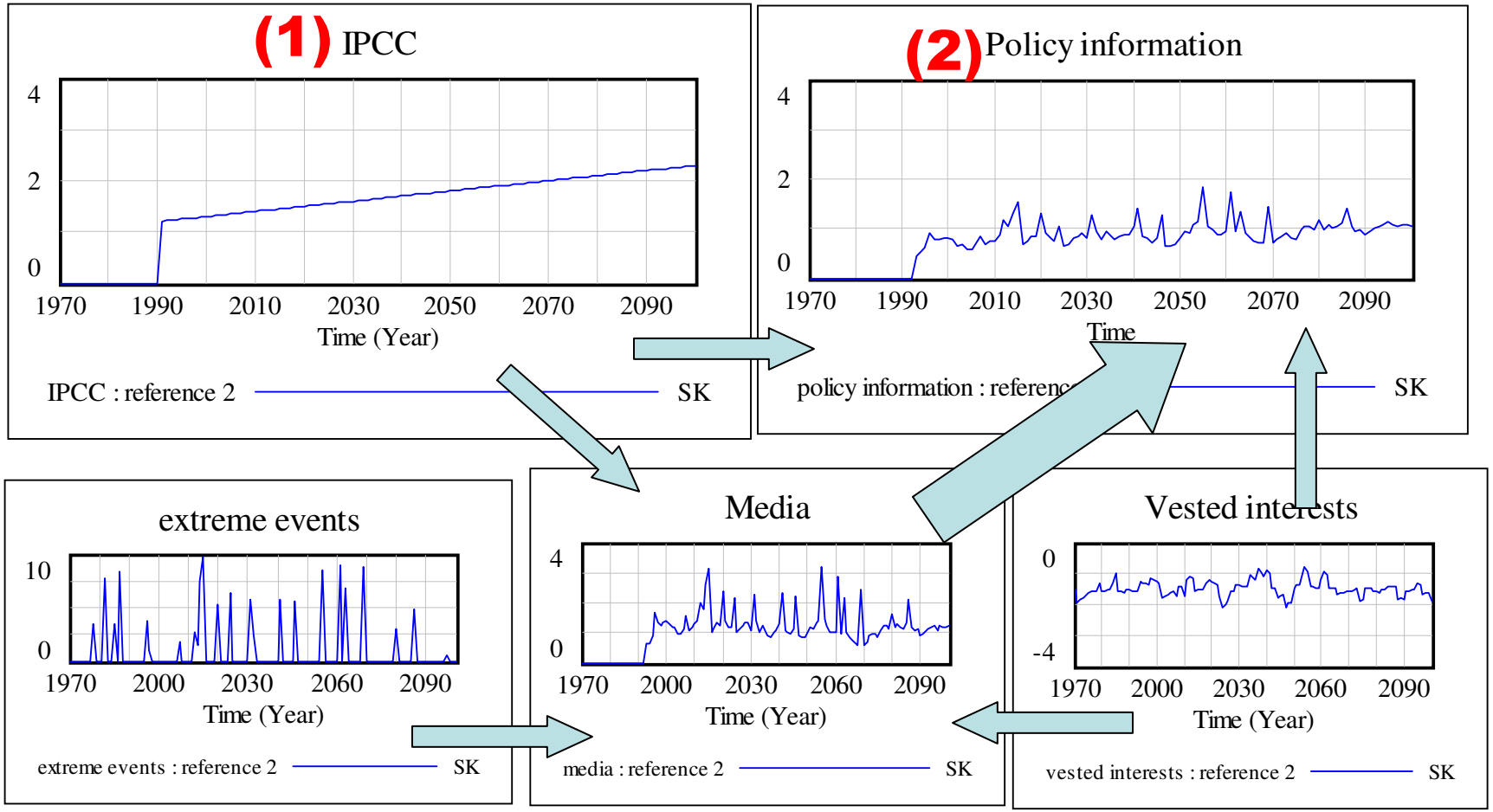
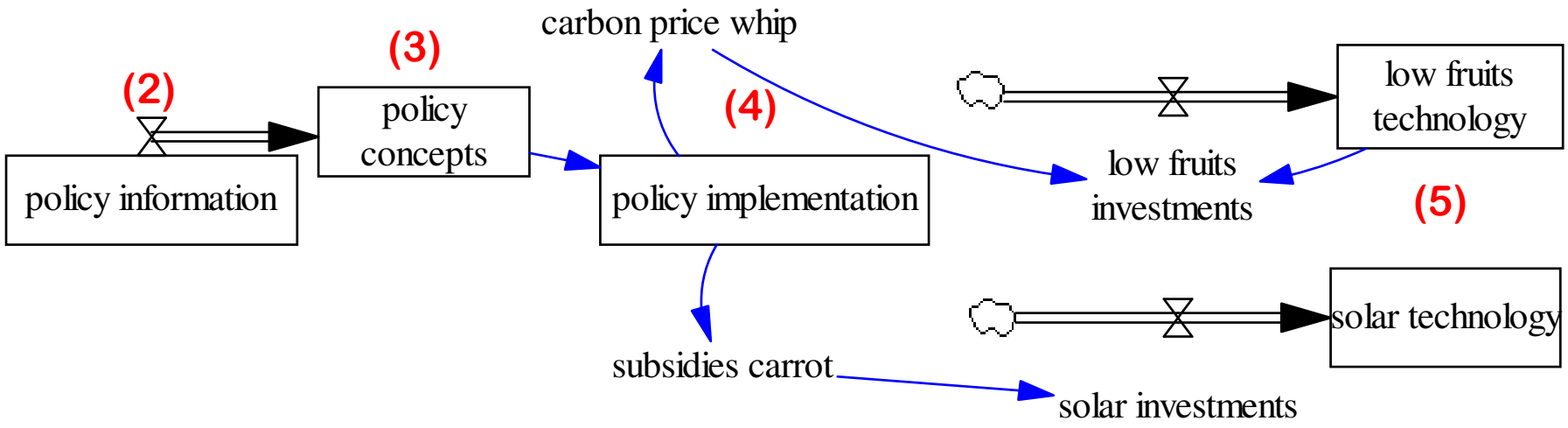


Stage 2: The delay cascade: Information (2) to mitigation technology (5)



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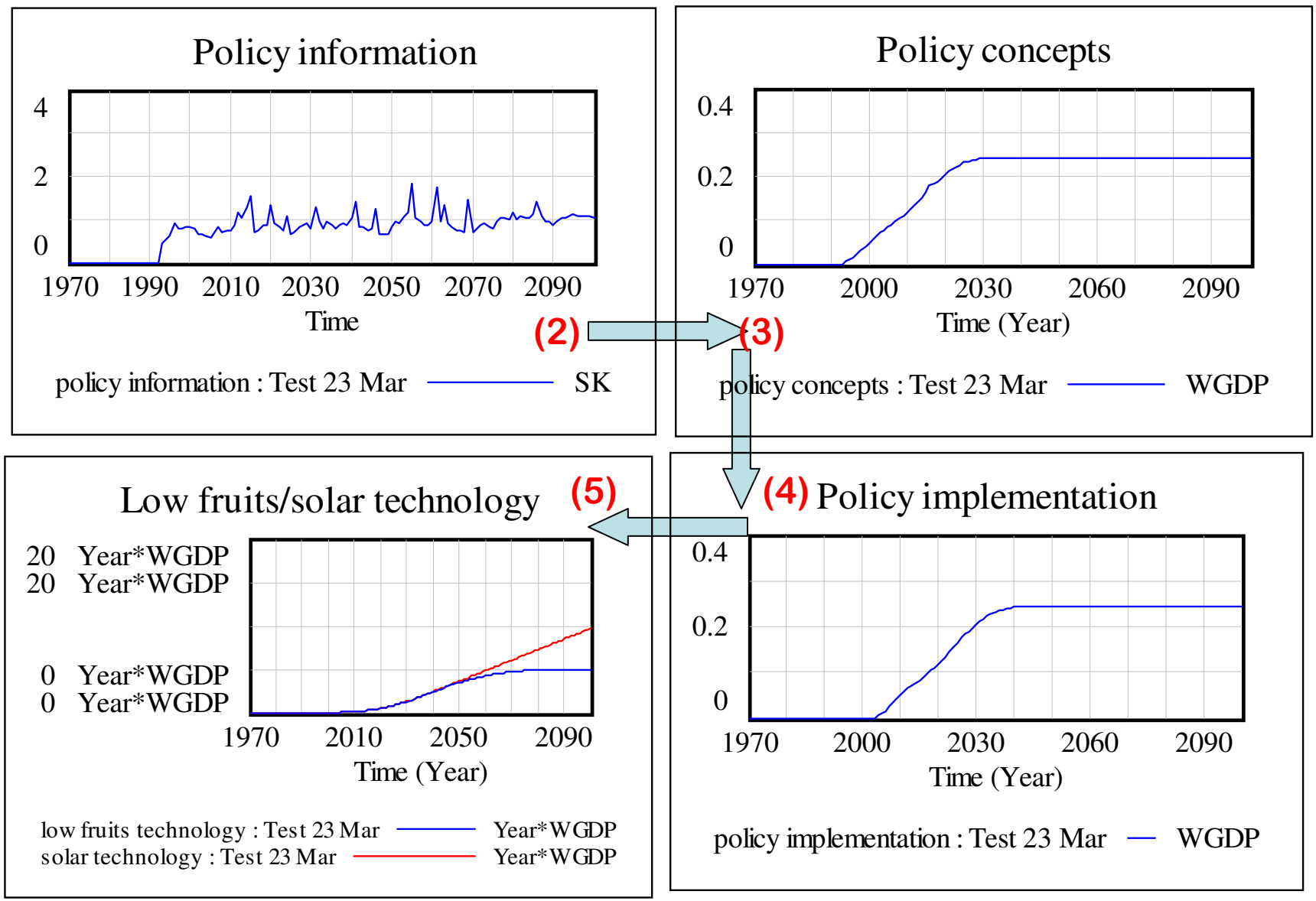

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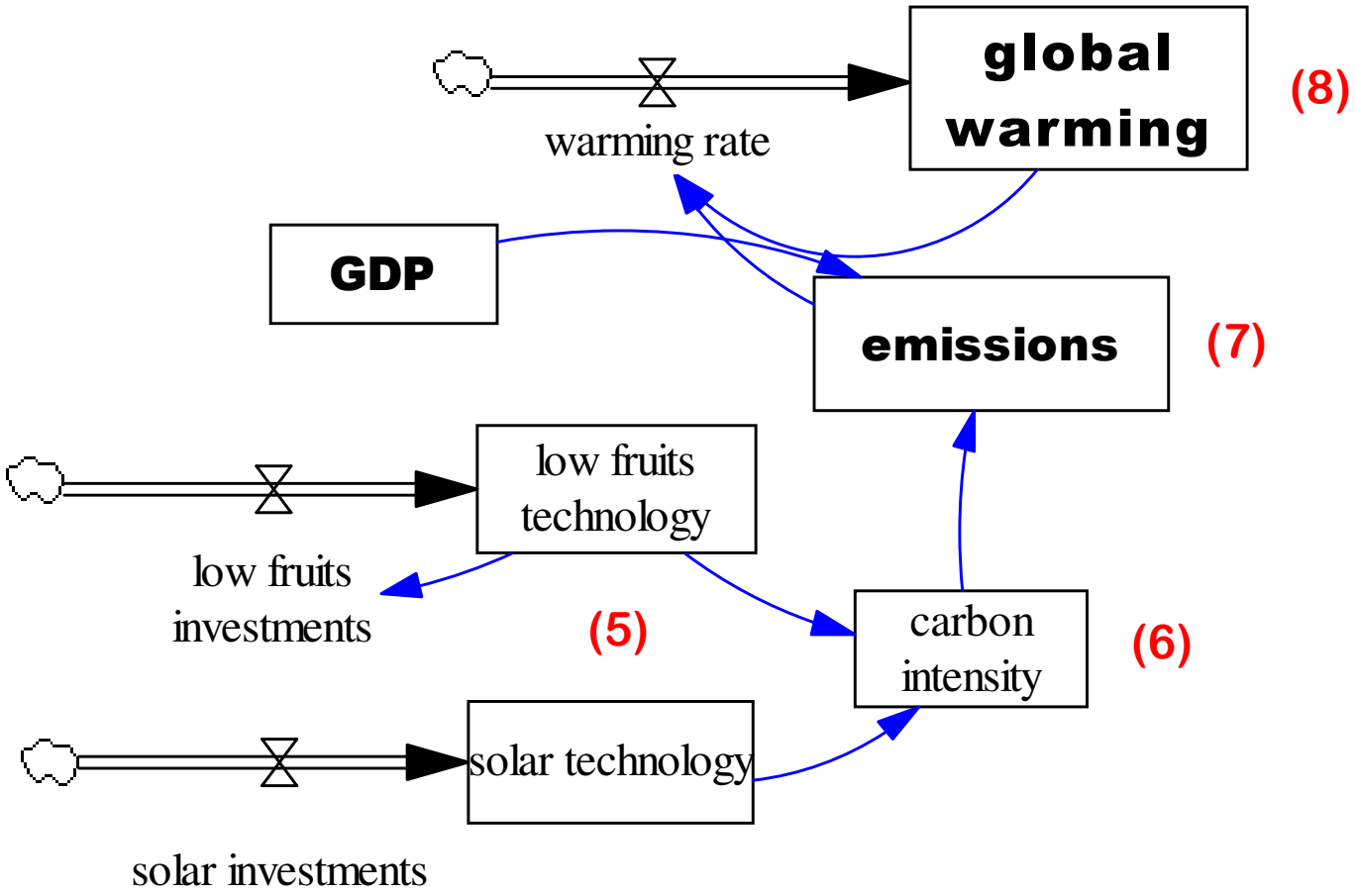

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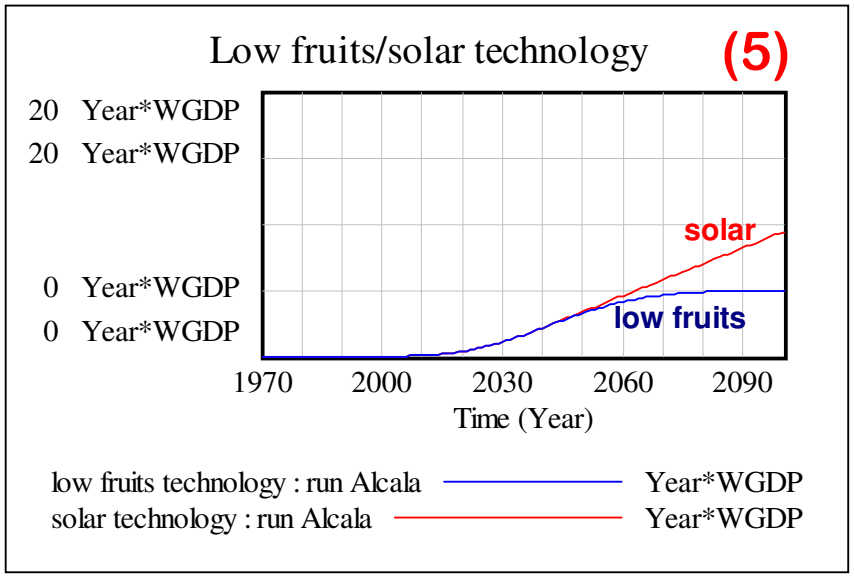

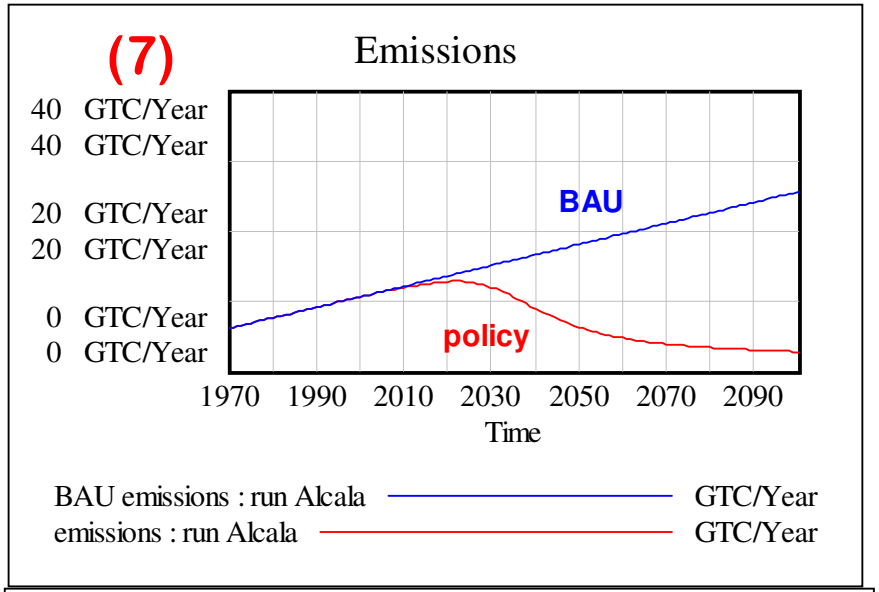

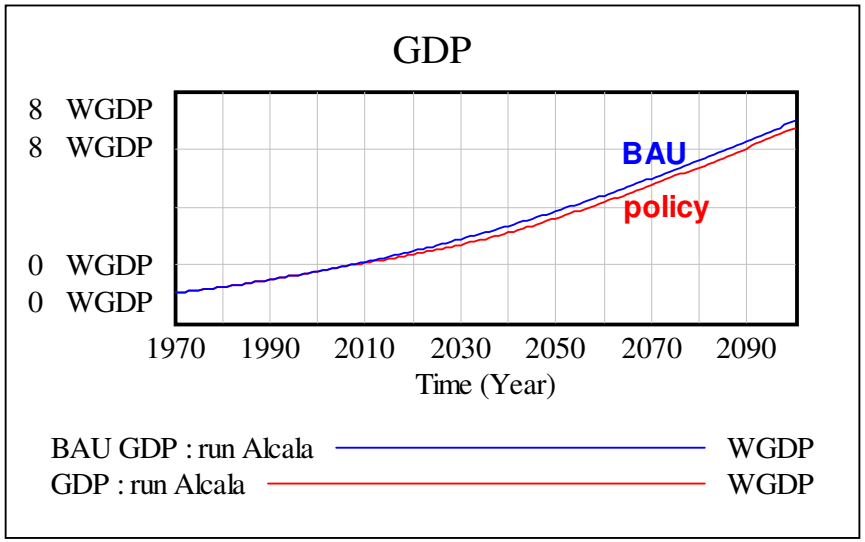

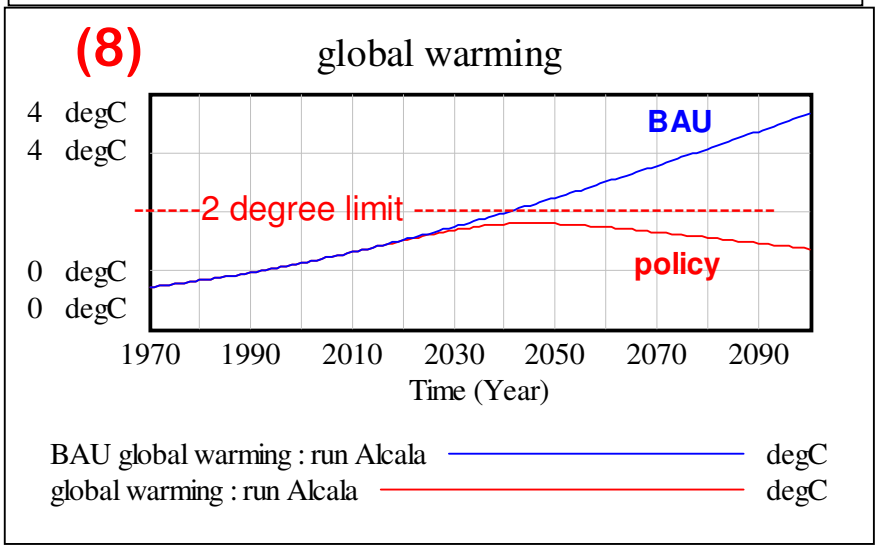

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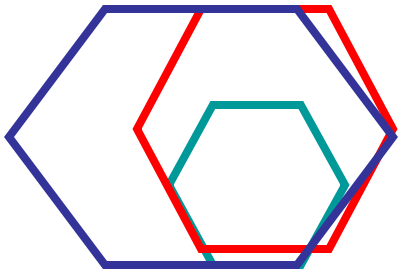
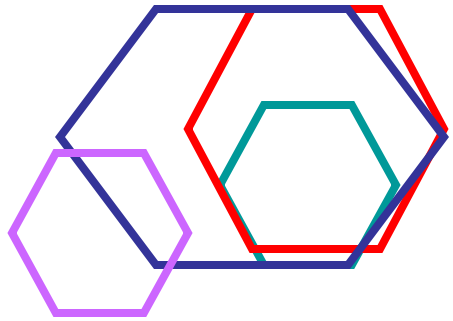
- **the carrot factor: the subsidies level, in particular for solar energy**
- **the delay factor: time delay between policy concepts and implementation**
- **the anticipation factor: anticipation of future climate policies and/or market developments**

An example: the present three levels of MADIAMS



Extended MADIAMS components



Information-cascade model

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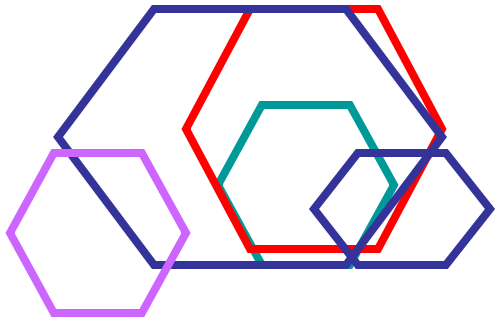
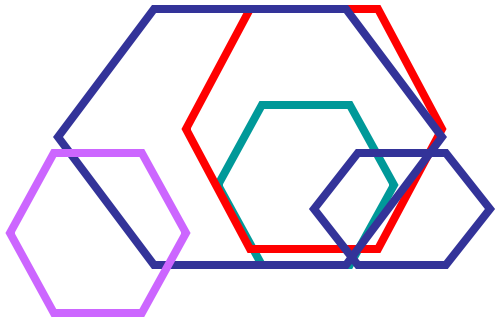


trained and
untrained labor

Information-cascade model

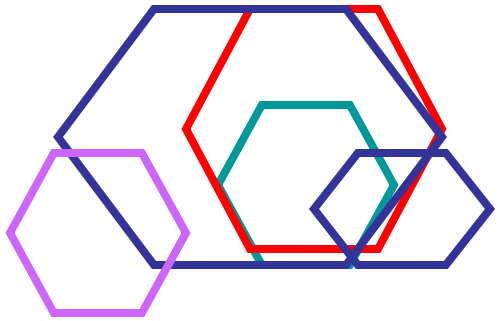
Extended MADIAMS components



trained and
untrained labor

Information-cascade model

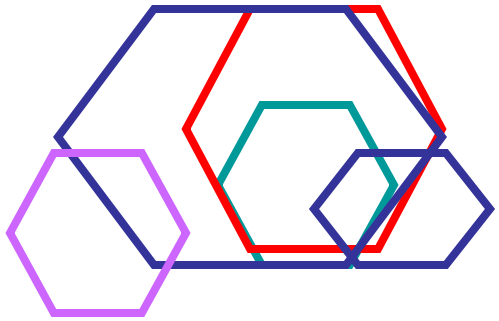
Extended MADIAMS components



Other family extensions, see Bert's list:

networks, evolutionary concepts, technology diffusion and niches, better psychology of actors, heteorogeneous actors, imitation, etc. etc.

Extended MADIAMS components



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Lets start a project…..(see my IPCC WG2-3 complaint)