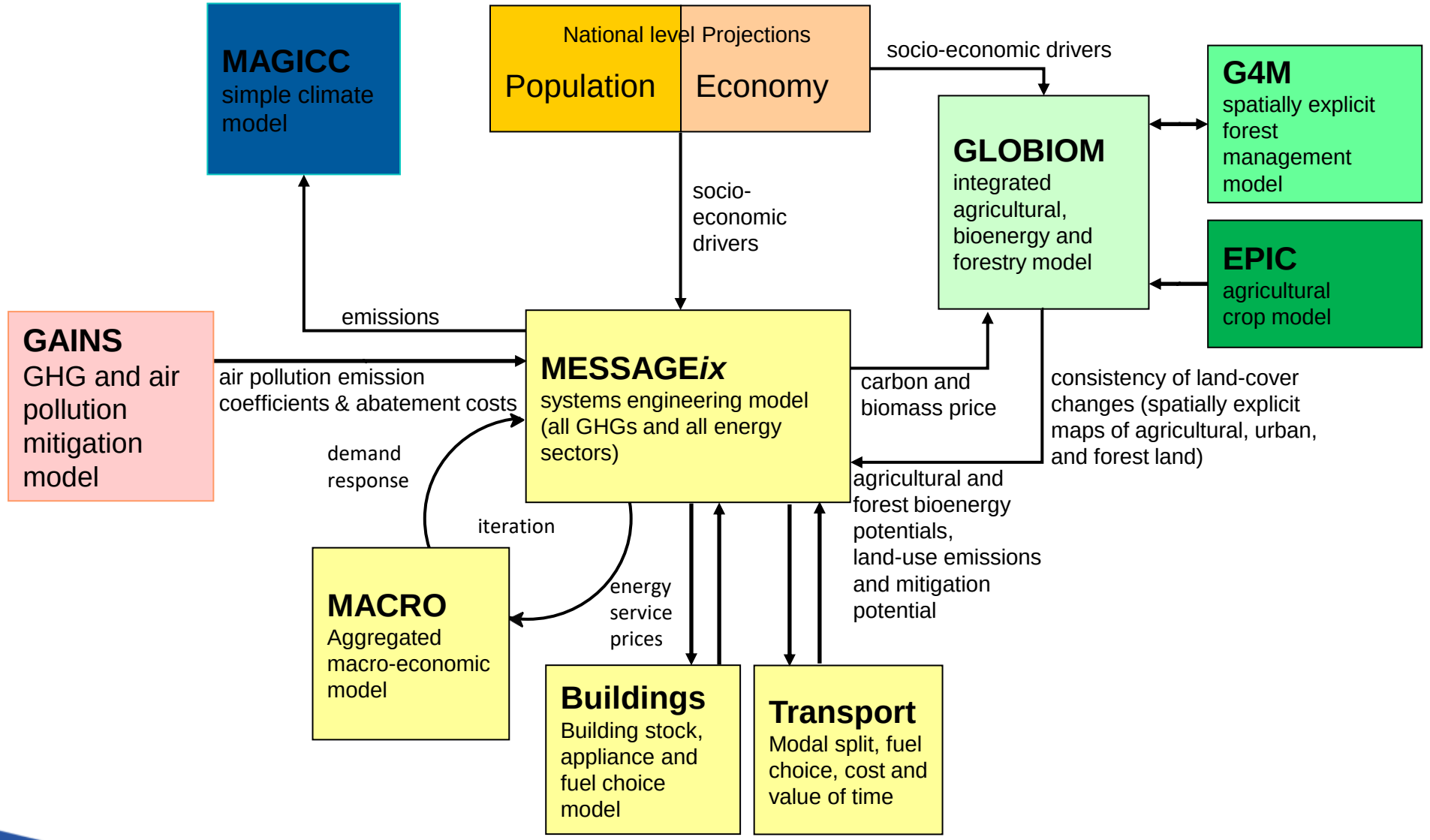
Some comments on MACRO

Volker Krey

NTNU course: Integrated Assessment Modelling (EP8900)

Example: IIASA Integrated Assessment Framework



MACRO is…

- an aggregate single-sector macro-economic model,
- maximizing the intertemporal utility function of a single representative producer-consumer,
- representing main macro-economic variables such as capital stock, available labor, and commodity inputs,
- determining total output of an economy according to a nested constant elasticity of substitution (CES) production function,
- linked to MESSAGE to estimate consumption, GDP and demand impacts due to policy shocks.

Utility maximization

The utility function which is maximized sums up the discounted logarithm of consumption of a single representative producer-consumer over the entire time horizon of the model.

$$UTILITY = \sum_{n} \Bigg(\sum_{y|((ord(y)>1)\wedge(ord(y)<|y|))} udf_{n,y} \cdot \log(C_{n,y}) \cdot duration\_period_{y} + \sum_{y|(ord(y)=|y|)} udf_{n,y} \cdot \log(C_{n,y}) \cdot \left(duration\_period_{y-1} + \frac{1}{FIN\_TIME_{n,y}}\right) \Bigg)$$

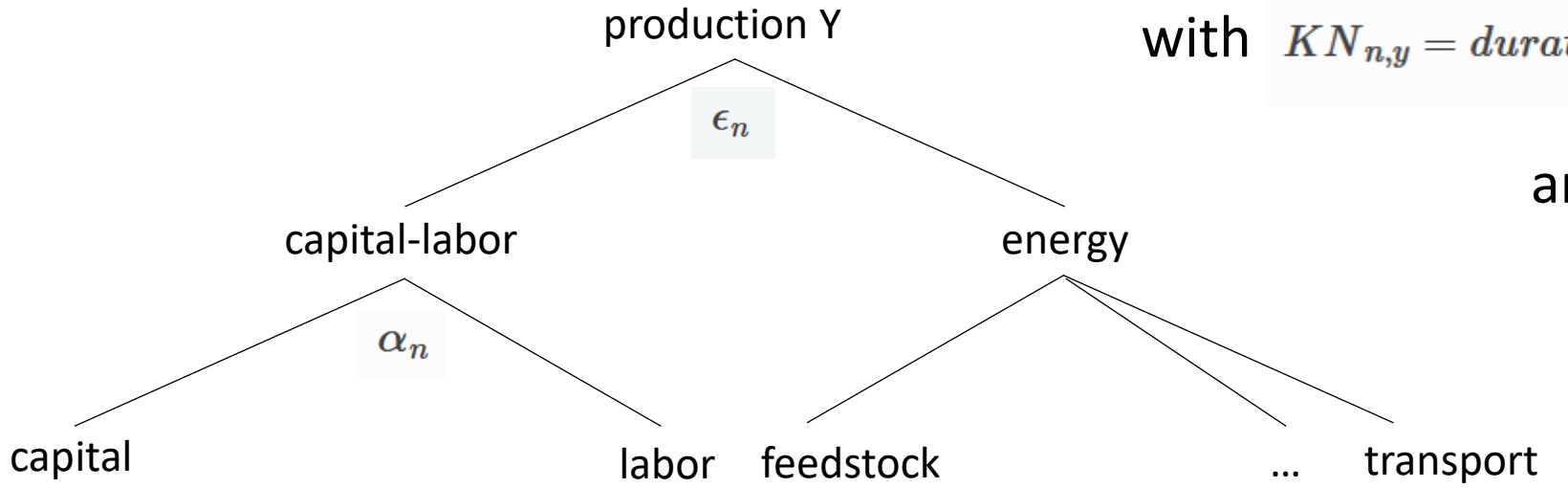
$UTILITY \sim log(C_y)$

Production function

MACRO employs a nested constant elasticity of substitution (CES) production function with capital, labor and the (commercial) end-use services represented in MESSAGE as inputs.

capital labor energy

$$YN_{n,y} = \left(a_n \cdot KN_{n,y}^{(\rho_n \cdot \alpha_n)} \cdot newlab_{n,y}^{(\rho_n \cdot (1-\alpha_n))} + \sum_s (b_{n,s} \cdot NEWENE_{n,s,y}^{\rho_n}) \right)^{\frac{1}{\rho_n}}$$



with $KN_{n,y} = duration\_period_y \cdot I_{n,y}$

and $\rho_n = \epsilon - 1/\epsilon$

Labor

In MACRO labor is chosen to be the numeraire, relative to which other changes are measured. There is no “labor” variable, but an exogenous labor supply parameter.

labor(y+1) = labor(y) * (1 + grow(y))**duration_period

newlab(y) = labor(y) - labor(y-1)*(1 - depr)**duration_period

grow is labor supply/productivity growth and sometimes referred to as potential GDP growth.

Total capital and production (incl. depreciation)

- Total production in the economy (excluding energy sectors) is the sum of production from assets that already existed in the previous period, depreciated with the depreciation rate, and the new vintage of production from current period.

$$Y_{n,y} = Y_{n,y-1} \cdot (1 - depr_n)^{duration\_period_y} + YN_{n,y}$$

- Total energy production for the energy sectors modeled in MESSAGE.

$$PRODENE_{n,s,y} = PRODENE_{n,s,y-1} \cdot (1 - depr_n)^{duration\_period_y} + NEWENE_{n,s,y}$$

- Total capital stock (excluding energy sectors modeled in MESSAGE).

$$K_{n,y} = K_{n,y-1} \cdot (1 - depr_n)^{duration\_period_y} + KN_{n,y}$$

Linking MESSAGE and MACRO

- Capital constraint, linking production, consumption and investment.

$$Y_{n,y} = C_{n,y} + I_{r,y} + EC_{n,y}$$

based on MESSAGE

- Energy system costs are based on a previous MESSAGE model run. The approximation of energy system costs in the vicinity of a MESSAGE solution are approximated by a Taylor expansion.

$$\begin{aligned} EC_{n,y} =& total\_cost_{n,r} \\ &+ \sum_{s} eneprice_{s,y,n} \cdot (PHYSENE_{n,s,y} - enestart_{s,y,n}) \\ &+ \sum_{s} \frac{eneprice_{s,y,n}}{enestart_{s,y,n}} \cdot (PHYSENE_{n,s,y} - enestart_{s,y,n})^2 \end{aligned}$$

from MESSAGE

- Relationship between physical energy (MESSAGE) and energy in production function (MACRO).

$$PHYSENE_{n,s,y} \geq PRODENE_{n,s,y} \cdot aeei\_factor_{n,s,y}$$

calibrated to MESSAGE

$$aeei\_factor_{n,s,y} = aeei\_factor_{n,s,y-1} \cdot (1 - aeei_{n,s,y})^{duration\_period_y}$$

Clarification of MACRO notation

For a few MACRO parameters there is differences between the mathematical notation used in the documentation and the names in the GAMS code (and Excel dump):

GAMS code	Documentation	Description
kgdp	kgpd	Initial capital-to-gdp ratio in base year
lakl	a_n	production function coefficient of capital and labor
prfconst	$b_{n,s}$	production function coefficient of energy sectors
kpvs	α_n	capital value share (production function)
esub	ϵ_n	elasticity of substitution btw. capital-labor and energy
lotol		tolerance for lower bounds on MACRO variables
p_ref/demand_MESSAGE		input for MACRO calibration from MESSAGE

Thank you very much for your attention!

Volker Krey
Integrated Assessment & Climate Change (IACC) Group
Energy, Climate & Environment (ECE) Program
International Institute for Applied Systems Analysis (IIASA)
Laxenburg, Austria
krey@iiasa.ac.at
www.iiasa.ac.at