Marginal Abatement Curves and GHG Concentration in GMM Model

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Outline

• The energy-system GMM model
• Marginal abatement curves for CH$_4$ and N$_2$O
• GHG atmospheric concentrations
• An illustrative scenario
• Final remarks
The Energy-Systems GMM Model

- Global, five-region, energy-systems MARKAL model (Barreto, 2001; Rafaj et al., 2005)
- Calibrated to year-2000 statistics
- Clusters approach to technological learning
- Time horizon 2000-2100, 10-year steps
- Relative detail in energy supply technologies
- Stylized representation of end-use technologies
- Current version under ANSWER (Noble, 2005)

Marginal Abatement Curves (MAC)

- Implementation of MACs for methane (CH₄) and nitrous oxide (N₂O) following approach of MERGE (Manne and Richels, 2003)
- Three categories: exogenous baseline, endogenous baseline, non-abatable emissions
- Data from the U.S EPA (2003) study, potentials are relative to baseline emissions
- Technical-progress multipliers to extrapolate abatement potentials beyond 2020
GHG Atmospheric Concentrations

• Atmospheric concentration of CO₂, CH₄ and N₂O are computed using linear models of decay (so-called box models), following the MERGE Model (Manne and Richels, 2004)
• Five (5) boxes are used for CO₂ and one box each for CH₄ and N₂O
• This procedure allows computing scenarios with stabilisation of GHG concentrations

CO₂ Atmospheric Concentration

• Simplified model based on a linear impulse response function represented by the weighted summation of five exponential functions or “boxes” (Joos et al., 1996):

\[ G(t) = \sum_{i=1}^{5} a_i \cdot e^{-t/\tau_i} \]

\[ \sum_{i=1}^{5} a_i = 1 \]

• Each exponential function represents the decay over time of a given fraction \(a_i\) of the injected CO₂, which has a given atmospheric lifetime, represented by the coefficient \(\tau_i\) (in years).
A Multi-GHG Baseline Scenario

GHG Emissions (CO₂+CH₄+N₂O, Mt C-eq)

GHG Concentrations – Baseline Scenario

CO₂ Concentration (ppmv)

CH₄, N₂O Concentration (ppbv)
An Illustrative Mitigation Scenario

GHG Emissions (CO₂+CH₄+N₂O, Mt C-eq)

Baseline

CO₂ Concentration (ppmv)

Baseline

CO₂ Atmospheric Concentration
Final Remarks

- Marginal abatement curves allow incorporating the effects of non-CO₂ GHGs (CH₄,N₂O) into the energy-system GMM model
- Atmospheric concentrations are CO₂, CH₄ and N₂O are implemented in the GMM model using linear decay functions ("boxes")

Acknowledgements

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- These developments are based on the MERGE model (Manne and Richels, 2004)
Climate forcing as function of concentrations

Approximating the Forcing Function for CO2 (Watts/m²) using linear relations and needed corrections

Extension to Forcing

Therefore if we want to apply a constraint on forcing that implies a concentration limit of 450 ppmv we should define the constraint as

\[
\Delta F_n = c_0 \cdot \ln\left(\frac{C_n + \Delta n}{C_0}\right) \leq 1.047233 \text{ W/m}^2 \quad \text{which is equivalent to} \quad \Delta F_n = c_0 \cdot \left(\frac{C_n + \Delta n}{C_0} - 1\right) \leq 1.156757 \text{ W/m}^2 \quad \text{but the latter is linear!}
\]

| Concentration \(C_n\) ppmv | Forcing \(c_0 \cdot \ln\left(\frac{C_n + \Delta n}{C_0}\right)\) Ex W/m² | Approximation \(c_0 \cdot \left(\frac{C_n + \Delta n}{C_0} - 1\right)\) Pr W/m² | Error \(1-E/P\) (%) | CFCF | adjusted \(\Delta F_n\) W/m²
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Table 2: CO2 Forcing in W/m² and Carbon Forcing Correction Factors (CFCF)