Challenges in Top-down and Bottom-up Soft Linking: The Case of EMEC and TIMES-Sweden

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Why, Aim and Philosophy

Why:
The development of the future energy system depend on the future demand of energy. The future demand of energy partly depend on the economic development. The sector development partly depend on the energy prices.

⇒ Everything is linked!

Aim:
The overall aim has been to develop a method for how to soft-link a CGE model with an Energy System model to improve energy and climate policy decision processes.

Philosophy:
To develop a method allowing the models to interact in a transparent manner while at the same time maintaining each model's strengths
Litterature

- **Incorporate more technological detail in a CGE model**
  - Frei et al. (2003)
  - McFarland et al. (2004)
  - McFarland and Herzog, 2006)
  - Böhringer and Rutherford (2008)

- **To extend an energy bottom-up model with economic interactions**
  - Messner and Schrattenholzer (2000), MESSAGE with MACRO
  - Chen (2005), MARKAL-China with MACRO
  - Remme and Blesl (2006), TIMES with MACRO
  - Strachan and Kannan (2008), MARKAL-UK with MACRO
  *MACRO is a one-sectorial general equilibrium module

- **Combine the strengths of both type of models by soft-linking to existing models**
  - Wene (1996), ETA-MACRO with MESSEGE
  - Jaccard et al. (2003)
  - Schäfer and Jacoby (2006), EPPA (based on GTAP4E) with MARKAL model of transport technology
  - Altamirano et al. (2008), GEMINI-E3 with MARKAL-CHRES

- **Common for most studies:**
  - Hard-linking where one existing full-scale model is linked with a simplified model capturing the other part (macroeconomic or energy system).
  - A substantiated description of the soft-linking procedure and its challenges are missing.
Approach

I. Identifying the models

II. Identifying what to link (based on Wene, 1996)

III. Deciding how to link
I. Identifying the models

II. Identifying what to link (based on Wene, 1996)
   - Identifying basic differences between the models.
   - Identifying the dominant model, when overlap.
   - Identifying and decide upon common exogenous variables.

III. Deciding how to link
   - Transferring information from EMEC to TIMES
   - Moving information from TIMES to EMEC
   - Deciding where to start
I. Identifying the models

CGE model – EMEC: Provides a consistent description of how different economic sectors interact with each other.

Energy system model – TIMES-Sweden: Provides a technology detailed description of the energy system and capture the most important interactions within the energy system.
II. Identifying what to link

1. IDENTIFYING BASIC DIFFERENCES BETWEEN THE MODELS
2. IDENTIFYING THE DOMINANT MODEL, WHEN OVERLAP
3. IDENTIFYING AND DECIDE UPON COMMON EXOGENOUS VARIABLES
## Identifying basic differences

<table>
<thead>
<tr>
<th></th>
<th>EMEC</th>
<th>TIMES-Sweden</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Focus</strong></td>
<td>EMEC focuses on <strong>monetary flows</strong> from energy, materials, capital and labour, and in addition calculates emissions in metric tonnes.</td>
<td>TIMES-Sweden focuses on <strong>physical flows</strong> of energy, materials, emission and certificates.</td>
</tr>
<tr>
<td><strong>How prices are treated</strong></td>
<td>Prices are normalized to the base-year value at current prices. Only <strong>relative price changes</strong> are modeled.</td>
<td>Prices are normalized to a base-year. Energy carriers with exogenous prices have a <strong>specified price for each time period.</strong> Fuels traded on the global market in line with official projections.</td>
</tr>
<tr>
<td><strong>How energy conversion technologies are described</strong></td>
<td>Continuous production functions, where substitution elasticities are key parameters (CES-production functions).</td>
<td>Discrete processes / techniques with defined techno (efficiency, availability, etc.) and economic (capital, operating costs, etc.) parameters. Parameters that vary over time to capture techn. develop.</td>
</tr>
<tr>
<td><strong>Time Dimension</strong></td>
<td>Static</td>
<td>Dynamic</td>
</tr>
<tr>
<td><strong>Base-Year</strong></td>
<td>2008</td>
<td>2000 and calibrated to 2005</td>
</tr>
<tr>
<td><strong>Sector breakdown</strong></td>
<td>Based on national accounts, follows the industry and sector breakdown in the national accounts.</td>
<td>Based on energy statistics and follows the industry and sector breakdown in the energy statistics.</td>
</tr>
</tbody>
</table>
EMEC treat the economic develop in each sub-sector while TIMES-Sweden analyze the effect from the development in end-use

Mapping sectors

- Which end use sector goes with which?
  - Not straight forward!

- What does it mean that a sub-sector is growing?
  - EMEC: Internal trade within a sector can also generate growth

- What to do when sub-sectors and end-use don’t match?
  - Sometimes it doesn’t matter: What is big in the economy doesn’t necessary demand energy.
  - Sometimes simplifications are needed

⇒ The Mapping depend on the direction!

EMEC → TIMES
TIMES → EMEC
TIMES $\rightarrow$ EMEC

Sum EMEC transportation fuels in Sector 24-26 & Households

= Sum TIMES-Sweden fuel consumption in TC-***
Overlapping sectors:

- There are many overlaps in sector break-down:
  - The mapping will be different when going from EMEC to TIMES-Sweden compared to when going from TIMES-Sweden to EMEC.

Overlapping endogenous variables, *identify the “Dominant Model” (DM), and which model that should adapt*:

- **Energy mix:**
  - DM: TIMES-Sweden

- **Energy intensity (energy/produced unit):**
  - DM: TIMES-Sweden

- **Energy level (EMEC in SEK while TIMES-Sweden in TJ):**
  - The two models should converge
III. Deciding how to link

1. TRANSFERRING INFORMATION FROM EMEC TO TIMES

2. MOVING INFORMATION FROM TIMES TO EMEC

3. DECIDING WHERE TO START
Yearly change in demand:
\[ YT_{i,1} = \alpha_i \cdot YE_{i,1} \]

Energy efficiency parameter:
\[ EE_{i,2} / YE_{i,2} = ET_{i,1} / YT_{i,1} \]

Energy mix: Over write the existing substitution elasticity (make \( \sigma = 0 \)), and define the share of each fuel for each industry/sector.

Energy price: Mark-up on capital in the electricity and heat sector.

“Translation models”
Policy Analysis
This is an illustrative example – We have not evaluated to what extent the results are plausible

Will the iteration between the models change the reference scenario?

**REFERENCE SCENARIO:**
- A reference scenario puts the economy and energy at the "right level"
- The reference scenario is based on the Long-term scenario developed at the NIER, but without energy efficiency parameters.

**CLIMATE SCENARIO:**
- CO2-taxes in the non ETS sectors increased with 50%
- CO2-prices within EU ETS increases to 30 €/ton CO2 in 2020 and stays on this level over the modeling period (2035)
Iteration Process

EMEC-Climate \[\text{CE1iT0i}_R0\] \(\rightarrow\) TIMES-Climate \[\text{CE1iT1i}_R0\] \(\rightarrow\) Climate NL-Climate

EMEC-Climate \[\text{CE1iT1i}_R0\] \(\rightarrow\) TIMES-Climate \[\text{CE0iT1i}_RE1i\] \(\rightarrow\) Climate NL-Ref

EMEC-Ref \[\text{RE1iT0i}\] \(\rightarrow\) TIMES-Ref \(\rightarrow\) R-1 iteration/Ref NL

EMEC-Ref \[\text{RE1iT1i}\] \(\rightarrow\) TIMES-Ref \(\rightarrow\) R-2 iteration

EMEC-Ref \[\text{RE2iT1i}\] \(\rightarrow\) TIMES-Ref \(\rightarrow\) R-3 iteration

EMEC-Ref \[\text{RE2iT2i}\] \(\rightarrow\) TIMES-Ref \(\rightarrow\) R-4 iteration/Ref SL

EMEC-Ref \[\text{RE3iT2i}\] \(\rightarrow\) TIMES-Ref \(\rightarrow\) C-1 iteration

EMEC-Ref \[\text{RE3iT3i}\] \(\rightarrow\) TIMES-Ref \(\rightarrow\) C-2 iteration

EMEC-Ref \[\text{RE4iT3i}\] \(\rightarrow\) TIMES-Ref \(\rightarrow\) C-3 iteration/Climate SL
Change in demand as an input to TIMES from EMEC through the Transition model

NL: No Linking
SL: Soft-Linking

### Yearly demand in 2035 (Mt)

- Järn och stål
- Aluminium
- Koppar
- Cement
- Papper-Hög kvalitet
- Papper-Låg kvalitet

Legend:
- 2005
- R-1 iteration (NL)
- R-2 iteration (SL)
- R-3 iteration (SL)
- R-4 iteration (SL)
Change in demand as an input to TIMES from EMEC through the Transition model

NL: No Linking
SL: Soft-Linking

- Iron and steel
- Aluminium
- Copper
- Cement
- Pulp & Paper - High Quality
- Pulp & Paper - Low Quality

2005
Ref NL
Ref SL
Climate NL-Ref
Climate NL-Climate
Climate SL
Resulting CO2-emissions in year 2035, and the reduction between the Reference and the Climate scenario

ETSCO2:
CO2 in EU-ETS sectors

NETSCO2:
CO2 in Non EU-ETS sectors

NL: No Linking
SL: Soft-Linking

CO2 emissions (1000 ton) in year 2035

<table>
<thead>
<tr>
<th>Scenario</th>
<th>ETSCO2</th>
<th>NETSCO2</th>
<th>Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref NL</td>
<td>6879</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climate NL-Ref</td>
<td>7509</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ref NL</td>
<td></td>
<td>6792</td>
<td></td>
</tr>
<tr>
<td>Climate NL-Climate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ref SL</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Climate SL</td>
<td></td>
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</tbody>
</table>
Main Conclusions from Iteration

Iteration Process
- The first iteration result in a significant adaptation of the economy affecting the energy use. The following iterations only result in smaller changes. → Crucial that the demand assumptions reflect the scenario assumptions
- The electricity price has been proven an important component

<table>
<thead>
<tr>
<th></th>
<th>Reference Scenario Iteration</th>
<th>Climate Scenario Iteration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic development</td>
<td>The difference is greatest for the energy-intensive industries.</td>
<td>Relatively small effects on industries' economic development.</td>
</tr>
<tr>
<td>Energy level (volume)</td>
<td>Decreases</td>
<td>Relatively large differences in fuel use in the electricity and district heating sector.</td>
</tr>
<tr>
<td>Fuel mix</td>
<td>Fuel mix change as when the energy level decreases.</td>
<td>The fuel mix changes differently than in the reference iteration. Especially fuel choice for road transport.</td>
</tr>
<tr>
<td>CO2-emissions</td>
<td>Decreases</td>
<td>Reduction from Reference scenario is similar. However when the absolute levels are lower, the reduction will be easier facilitated.</td>
</tr>
</tbody>
</table>
Identified Challenges

Translation parameters (EMEC → TIMES-Sweden):
More research is needed on the relation between economic growth and “useful demand”.

Representation of new energy carriers (in EMEC); for example hydrogen

Energy prices:
- The representation of the cost associated with delivered electricity need to be improved in TIMES-Sweden in order to capture the same features as in EMEC.
- The calibration of past years should in addition to the energy balance also include calibration of prices.

Investments:
- Some studies uses the total system cost from TIMES/MARKAL.
- However there are many overlaps in the total system costs.
- We suggest to instead only use the “investment parts” from the system costs.

Calibration of Base-year:
- Similar Base-year is less important.
- Calibrate both regarding volume, mix and endogenous prices.

Do not underestimate the differences in “mind-set”
- Communication across borders
- Both expertise are crucial for the result
Further Questions?

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HTTP://WWW.KONJ.SE/991.HTML

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