How do Energy-Economy Model Responses to Carbon Pricing Compare? First Insights from the ADVANCE Open Community Model Diagnostics Study

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Model Diagnostics – Motivation

• Understand model characteristics and differences
  ➢ Bottom-up: compare model structure and assumptions
  ➢ Top-down: compare model response characteristics in diagnostic model runs

• Classify models according to their response and structural characteristics

• Establish standard diagnostic experiments to benchmark models
Model Diagnostics – Recent Work

• AMPERE work on model diagnostics
  • Identified indicators of model behaviour
  • Developed preliminary model classification scheme

• Selection criteria for diagnostic indicators
  - identification of heterogeneity in model responses
  - relevance for climate policy analysis
  - applicability to diverse models
  - accessibility and ease of use

• PIAMDDI work on model diagnostics
  • U.S. IAM diagnostics (Wilkerson et al., Energy Policy, 2015)
  • Studies on technology impact, system elasticities, hindcasting
### AMPERE Diagnostic Indicators

<table>
<thead>
<tr>
<th>Model</th>
<th>Relative Abatement Index</th>
<th>CoEI Indicator</th>
<th>Transformation Index (primary energy)</th>
<th>Cost per Abatement Value</th>
<th>Model type</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>PE or GE</td>
<td>...</td>
</tr>
</tbody>
</table>

**Characterize system response to emissions price**

\[ \text{Low system response leads to high carbon price for fixed emissions reduction} \]

**Characterizes cost response to emissions price**

\[ \chi = \text{Magnitude of mitigation costs} \]

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Kriegler et al., 2015, Diagnostic indicators for integrated assessment models of climate policy. *Technological Forecasting and Social Change* 90A: 45-61
## AMPERE Model Classification („fingerprints“)

<table>
<thead>
<tr>
<th>Model</th>
<th>Relative Abatement Index</th>
<th>CoEI Indicator</th>
<th>Transformation Index (primary energy)</th>
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</tr>
</thead>
<tbody>
<tr>
<td>AIM-Enduse</td>
<td>Low</td>
<td>Mixed</td>
<td>Mixed</td>
<td>TBD</td>
<td>PE – med response</td>
</tr>
<tr>
<td>DNE21+</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Mixed</td>
<td>PE – low response</td>
</tr>
<tr>
<td>GCAM</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
<td>PE – high response</td>
</tr>
<tr>
<td>GEM-E3</td>
<td>Low</td>
<td>High</td>
<td>TBD</td>
<td>Medium</td>
<td>GE – low response</td>
</tr>
<tr>
<td>IMACLIM</td>
<td>Low</td>
<td>High</td>
<td>Mixed</td>
<td>High</td>
<td>GE – low response</td>
</tr>
<tr>
<td>IMAGE</td>
<td>High</td>
<td>Low</td>
<td>Mixed</td>
<td>Low</td>
<td>PE – high response</td>
</tr>
<tr>
<td>MERGE-ETL</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>GE – high response</td>
</tr>
<tr>
<td>MESSAGE</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>GE – high response</td>
</tr>
<tr>
<td>POLES</td>
<td>Mixed</td>
<td>Mixed</td>
<td>Low</td>
<td>Low</td>
<td>PE – med response</td>
</tr>
<tr>
<td>REMIND</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
<td>GE – high response</td>
</tr>
<tr>
<td>WITCH</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
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</tr>
</tbody>
</table>

Kriegler et al., TFSC, 2015
ADVANCE Diagnostics Exercise - Motivation

- Establish community database of diagnostic runs
- Test validity of model fingerprints identified in AMPERE on a larger set of models
- Explore new diagnostic indicators to characterize broader set of model behaviour
- Further integrate information on model structure and input assumptions with model response characteristics to improve understanding of model differences
ADVANCE Diagnostics Exercise - Design

Mandatory runs:
- 1 baseline
- 4 x CO2 price
Mandatory runs:
• 1 baseline
• 4 x CO2 price

6 Recommended runs:
• 4 x CO2 price
• 2 x CO2 budget

7 Optional runs:
• Add reference
• Anticipation
• Late shocks
• Higher budgets
• Hybrid
## Participating models (open for newcomers)

**DR CGE, Intertemporal GE, Dyn-rec PE, Intertemporal PE**

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<thead>
<tr>
<th>Model</th>
<th>Solution Concept</th>
<th>Solution Method</th>
</tr>
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<td>AIM/CGE</td>
<td>GE (closed economy)</td>
<td>Recursive-dynamic (myopic)</td>
</tr>
<tr>
<td>DNE21+</td>
<td>PE</td>
<td>Inter-temporal (foresight)</td>
</tr>
<tr>
<td>EPPA</td>
<td>GE (closed economy)</td>
<td>Recursive-dynamic (myopic)</td>
</tr>
<tr>
<td>FARM</td>
<td>GE (global CGE)</td>
<td>Recursive-dynamic (myopic)</td>
</tr>
<tr>
<td>GEM-E3</td>
<td>GE (closed economy)</td>
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<td>GE (closed economy)</td>
<td>Inter-temporal (foresight)</td>
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<td>KEI-Linkages</td>
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<td>TIAM-UCL</td>
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</tbody>
</table>

**Additional Models:**

- **DR CGE**
- **Intertemporal GE**
- **Dyn-rec PE**
- **Intertemporal PE**
Future Extensions of the Analysis

- Model inertia and path dependency in response to carbon pricing
- Non-CO2 emissions response
- Regional response patterns
- Emissions target vs. carbon pricing response
- Integrating model input and structure information to improve understanding of differences
ADVANCE diagnostics infrastructure

• ADVANCE diagnostics database hosted by IIASA
• Includes automatic calculation of AMPERE diagnostic indicators and climate response (using the latest version of MAGICC)
• Graphical user interface allowing teams to compare results across models
Open to participation ...

Continuous process:

• global, regional or national energy-economy models running until 2050 which can describe emissions response to carbon pricing

• submission of at least five core diagnostic runs

• teams get access to the database GUI after submission (allowing them to compare their results with others).

All information on how to submit: https://tntcat.iiasa.ac.at/ADVANCEWP1DB

This analysis:

• Any new submission would need to come well ahead of writing up the analysis (~ end of July)

• Teams will review the interpretation of their results

• Researchers from teams can join the analysis of results on demand.

• Analysed part of the database will be published results with the paper.