Working with TIMES and Monte Carlo in a Policy Setting

72TH SEMI-ANNUAL ETSAP MEETING, ETH Zürich, Switzerland, December 11, 2017

Kristoffer S. Andersen, Advisor, Danish Energy Agency and PhD student, Technical University of Denmark
IntERACT

Integrated Energy and Economic Tool

Developers:

Danish Energy Agency
DTU
Esma
Agenda

1. Why consider uncertainty

2. Implementing uncertainty in the IntERACT model

3. Working with uncertainty in a policy setting
IntERACT: Two optimizing criterias

1. Determine least cost low carbon transition pathways

2. Minimize costs of pathway uncertainty related to:
   - Investment cost
   - Fuel and emission prices
   - Policy
   - Behavior
Why we consider uncertainty

Externally
1. Means of quantifying the uncertainty associated with a policy proposal
2. Facilitates dialogue with stakeholders as it provide additional insight into a complex model (opening the black box)

Internally
1. A means of testing the model and identifying possible weakness in assumption and model structure
2. Gives a higher degree of confidence in the model
Agenda

1. Why consider uncertainty

2. Implementing uncertainty in the IntERACT model

3. Working with uncertainty in a policy setting
Reconciling Engineers and Economists

TIMES-DK
- Optimizes Danish energy system towards 2050
- 12 Economic sectors
- Power and district heat sector
- Residential sector
- Transport sector
- Electricity exchange with neighbouring countries
- 32 time slices

CGE model
- 20 economic sector
- One household
- Government
- Foreign trade

Soft-link
- 12 Economic sectors
- Power and district heating sector
- Residential sector
Household Heat Services in TIMES-DK

Heat services are measured as Mm2 in the model.

The building are split in before and after 1972 and in multi-story (multi storey+non-detached) and detached (detached+farm houses).

In the current version we do not assume any rebound effect on heat demand from changing the price of heat service.
Industry structure in TIMES-DK

12 Economic sectors
- Agriculture, forestry, fishing, gravel & stone
- Food, beverages, tobacco industry
- Chemical industry (excl manufacture of basic metals)
- Metals, machinery and transport equipment industry
- Cement and bricks, glass and ceramics
- Other commodity production
- Wholesale and retail trade
- Private service industries (incl support for transportation and postal activities)
- Public services industries
- Construction
- Other utilities
- Motor vehicles - purchase and repair

Fuel input
- Electricity
- District heating
- Coal
- Natural gas
- Diesel
- Fuel oil
- Solid biomass
- Biogas
- Biofuels

Taxes and subsidies
- Sector and energy service specific

Conversion technologies
- Sector and energy service specific

Capacity constraints
- Sector and energy service specific

Energy services demand
- High temperature (>150°C)
- Medium temperature (<150°C)
- Room heat
- Electric motors and cooling
- Light and IT
- Tractor services etc (agriculture sector only)
- Fork lifts

Savings potentials
- Sector and energy service specific

Sector specific demand drivers from CGE model
IntERACT: Iteration routine

Top-down assumptions: Growth assumptions, elasticities, macro closure.

Bottom-up assumptions: Choose TIMES scenario

TIMES -> CGE
Electricity and district heat production and prices
Fuel use supply sector (%TIMESbaseline.gdx)

CGE reference
Baseline scenario (2012-2050)

CGE->TIMES
Adjusted demand projection (%ZZ-CGE_Linking.dd)

CGE productivity indices 2012-2050

Report (2012-2050)

CGE alternative
Alternative scenarios 2012-2050

TIMES-DK
Baseline scenario 2010-2050

TIMES-DK
Alternative scenario 2010-2050

CGE->TIMES
Electricity and district heat prices, fuel mix, subsidies and taxes (%TIMESscenario.gdx)

IntERACT cockpit
(MS Excel)
Defining baseline and alternative scenarios

CGE alternative
Alternative scenarios 2012-2050

TIMES-DK
Baseline scenario 2010-2050

CGE->TIMES
Adjusted demand projection (%ZZ-CGE_Linking.dd)
**IntERACT: Monte Carlo routine**

1. Define the processes and/or commodity sets for which uncertainty is to be considered
2. Define the uncertainty distribution(s) in R
3. Start loop in R, where each loop-iteration draws samples from the uncertainty distribution(s).
   i. Write the draws into a dd-file used by TIMES
   ii. Run IntERACT iteration routine inside R
      i. Baseline
      ii. Policy
   iii. Save relevant output in R
4. Look at results
1) Define MonteCarloPRC(\textit{PRC})

2) Define Uncertainty Distribution

3) Run R loop, draw from distribution and write the draw into dd-file

\[
\text{ACT\_EFF(\textit{REG},\textit{ALLYEAR},\textit{PRC},"ACT","\text{ALL\_TS}")\_MonteCarloPRC(\textit{PRC}) = ACT\_EFF(\textit{REG},\textit{ALLYEAR},\textit{PRC},"ACT","\text{ALL\_TS}") \times 0.97}
\]
Agenda

1. Why consider uncertainty

2. Implementing uncertainty in the IntERACT model

3. Working with uncertainty in a policy setting
Working with uncertainty in a policy setting

- Reduce tax on electricity for heating in order to incentivize the adoption of heat-pumps for room-heat in households and industry.

- How does uncertainty with to the cost effectiveness of heat pump and market price of electricity affect the adaption of heat pumps in IntERACT?
## Working with uncertainty (timeline)

<table>
<thead>
<tr>
<th></th>
<th>September</th>
<th>Early October</th>
<th>Late October</th>
<th>November</th>
</tr>
</thead>
<tbody>
<tr>
<td># of sensitivity Iterations</td>
<td>100</td>
<td>100</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td># of sensitivity input parameters</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td># of scenarios</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td># of IntERACT iterations by each scenario</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td># of IntERACT model iterations</td>
<td>600</td>
<td>1200</td>
<td>750</td>
<td>750</td>
</tr>
<tr>
<td># of hours</td>
<td>10</td>
<td>20</td>
<td>12.5</td>
<td>7.5</td>
</tr>
</tbody>
</table>
Household demand response from a reduction in tax on electricity for heat (PJ)

Preliminary results based on IntERACT v. 1.0.0
Household and industry electricity demand response following different levels of reduction in tax on electricity for heat (PJ)

Preliminary results based on IntERACT v. 1.0.4
Take ways

1. Sensitivity analysis on TIMES can be implemented fairly easy in R, which allows for a high degree of flexibility in both in input variation and visualization of results.

2. Using uncertainty analysis has proven to be a key tool both internally for model testing and externally for quantifying policy uncertainty.

3. Further work focus on how to develop and refine the use of sensitivity analysis in the IntERACT model.