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The Electricity Sector in the CGE Model - Modelling Challenges and Connections to Mobility

Presentation at DEFINE Technical Modelling Workshop

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Outline of this Presentation

The Hybrid Structure of IHS' Model

- **Top down:** depicts the relationships between 12 economic **sectors** (services ,industry, agriculture, ...) and **agents** (household, government, rest of world).
  - Only **one production sector** for each good!
  - **Demand** for electricity is generated.
- **Bottom up:** depicts (currently 7) technologies: Hydro, Biomass, Wind, Solar/Photovoltaic, Gas, Coal, Oil
  - **Many technologies** produce the **same good**!
  - The **prices** and the **technology mix** are determined.
- The two parts are solved together in an **integrated** fashion.

The Bottom Up Part of IHS' Model

- **Electricity** is produced by the **technologies** hydro, coal, oil, gas, biomass, wind, solar.
- Cheaper technologies are used first.
- When the price/demand rises, more expensive technologies enter the market.
- **Prices** and **technology mix** are generated in the bottom up part.

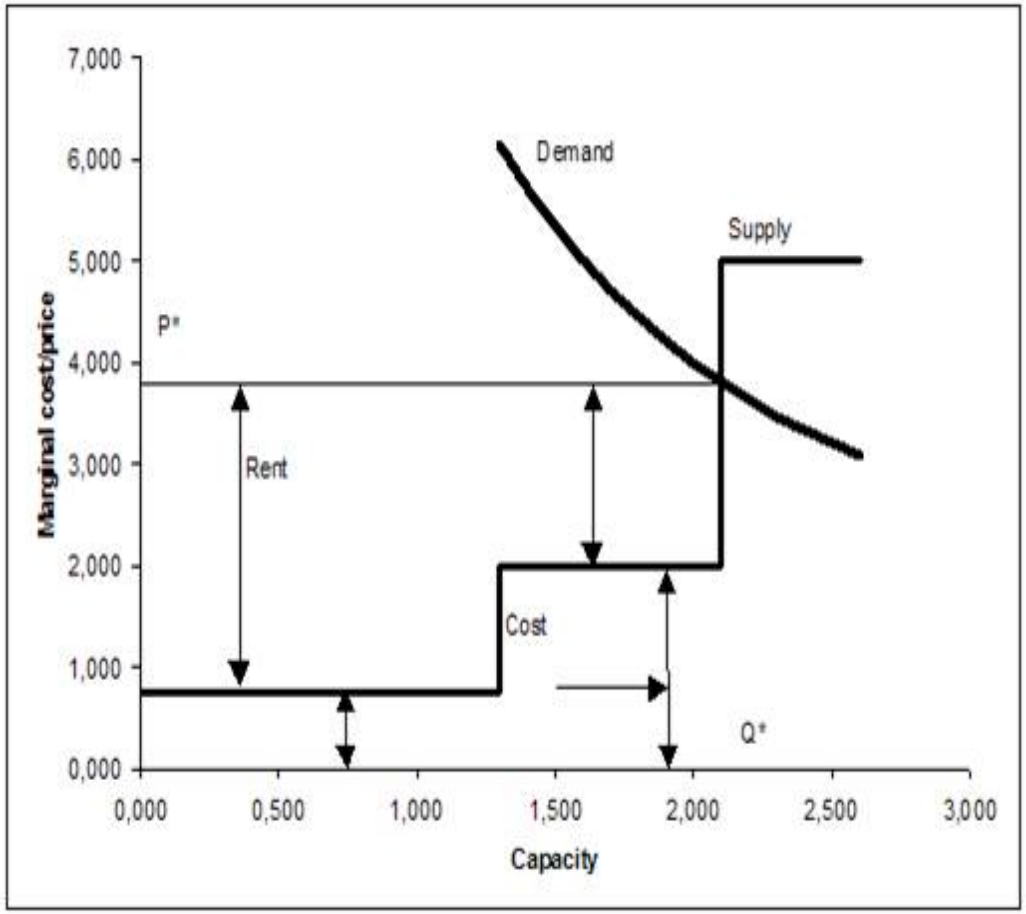
Bottom-Up integration

The energy sector is considered as a linear programming problem which seeks to find the **least-cost** schedule for meeting an **exogenous** set of energy **demands** using a given set of energy **resources**.

$$
\begin{aligned}
& min \sum_t \bar{c}_t y_t \\
s.t. & \sum a_{jt} y_t = \bar{d} \quad j \in \{energy\ goods\} \\
& \sum b_{rt} y_t \leq K_r \quad r \in \{energy\ resources\}
\end{aligned}
\tag{1}
$$

The first order conditions are included in the MCP format.

Figure: Dispatching under Technology Constraints



Suitability of Current Representation of Electricity Sector for DEFINE

The current representation by technology seems too aggregated to correctly assess the costs/benefits of a large-scale introduction of electromobility for the energy system.

Thus, with the help of model outputs of TUW/DIW, we aim to go to the level of the type of power plant installed (older and newer equipment will have different production costs).

Data input comes from electricity market models, either according to:

- Least cost schedule, or
- CO_2 minimizing ("Green Scenario") schedule

Inputs Desired from DIW/TUW Electricity Market Models

Inputs would comprise the following information:

- Yearly production of electricity in GWh per type of power plant,
- Production costs per GWh of electricity per power plant type,
- Investment costs incurred for building of new power plants,
- Amount of subsidized electricity per year ("Ökostromförderung").

Aspects of Interaction between Electromobility and Energy System to be Considered in DEFINE

A project goal of DEFINE is to assess the costs and savings of introducing electromobility for the energy system. Possible components:

- Costs of producing additional electricity to satisfy demand of EVs, PHEVs, including investment costs into new power plants.
- Savings in building new power plants because EVs, PHEVs can serve as *storage technology* (especially connected to increased share of renewables in electricity production, “Energiewende”)
- Savings by less imports of fossil fuels (e.g. gasoline, diesel),
- Infrastructure costs incurred for introduction of electromobility, e.g. grid investments (extensions, smart grids), charging stations for EVs. etc.
- Other factors relevant? (for Discussion)

What Should Enter the CGE Model

Most factors mentioned above cannot be represented in the hybrid CGE model because it would most probably be redundant/too complex. What should be represented, however:

- Aggregate investment costs for new power plants, in connection to demand schedule for different electricity producing technologies (as input from electricity market models), in sectoral decomposition of CGE model (economic effects induced by these investments!)
- Aggregate investment in infrastructure for introduction of electromobility (grids, charging stations, etc.), also in sectoral decomposition of CGE model (as an exogenous estimate)
- Realistic electricity prices replicating the results from the electricity market models
- other factors? (Discussion)

Reconciliation with DIW/TUW Electricity Market Models

Modelling objective: CGE model has to deliver the same results as the much more disaggregated and specialized electricity market models of DIW/TUW on a more aggregated level.

Thus, similar to the vehicle stocks, the model should meet certain parameters provided by the electricity market models, among them:

- Similar relative electricity price changes,
- Same technology mix on a more aggregated level,
- Investment costs for new power plants,
- Similar subsidy rates leading to the same share of renewables in electricity production.

How can this be done in MCP/MPSGE?

Simulating Investment in Power Plants

Difference between simulating investments in power plants as

1. Investment in one year/several years,
2. Capital inputs for technologies (Depreciation of investment plants considered here?)

Do the capital inputs of technologies actually represent investment costs in power plants?

How can on best consider the sectoral decomposition of investments in new power plants to assess the economic effects (GDP, Jobs, etc.) of building new power plants?

Investments costs and benchmark calibration?

Energy Consumption of Vehicles - Stocks and Flows

Increase/decrease of energy consumption by vehicle type has to be explicitly considered in electricity production and fossil fuel imports.

CGE model has to adapt to **two** exogenously given reference paths:

- The vehicle stock projection by UBA/OEI (depending on the extent it is possible to model a vehicle stock!)
- The electricity producing “technology mix” (DIW/TUW), together with the corresponding price level.

These two paths have to be replicated in the benchmark (or BAU?) run, even though they would be endogenous outcomes of the CGE model, and should serve as the reference path for all policy scenarios.

EV/PHEV Feedback into Electricity Production?

In principle, EVs/PHEVs could feedback into electricity production during peak load times.

Does not seem to pay off with current technology, mostly because of battery degradation (studies done by TUW).

Could maybe be considered in electricity market models (?). In the bottom-up part of the CGE model, it probably won't make sense to explicitly include it because of the following reasons:

- Yearly aggregation
- Is not really an electricity-producing technology: sum of input and output is 0.

Everybody in the room agrees?

A First View on Scenarios - Discussion

Different **market penetration rates** for the vehicle technologies (i.e. *vehicle stock developments* for EVs, HEVs, EVs and PHEVs) will be the main scenario variable.

These will be influenced by different factors, among others

- Car purchase prices
- Prices of fuels (gasoline/diesel, electricity)
- Infrastructure: EV/PHEV charging stations (home and work), fast charging?
- Subsidies and incentives by the state
- Interaction between EVs and Renewables (leading to incentives, e.g. to store electricity).

Thank you for your attention!

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