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# Modelling Mobility in the IHS Hybrid CGE Model

## Some Points about Possibilities to Depict Mobility in the IHS CGE model

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# Literature Review

- Steininger et al. (2007): CGE model for Austria to analyse sustainability impacts of car road pricing.
- Schäfer and Jacoby (2005): EPPA, a multiregional CGE model of the world economy, is linked with the bottom-up model MARKAL to obtain technology detail on transport in a multisector CGE model.
- Paltsev et al. (2004): Further description of incorporation of transport sector in EPPA.
- Böhringer and Rutherford (2008): Integrating bottom-up into top-down in a mixed complementarity (MCP) format.
- Böhringer and Rutherford (2009): Decomposing bottom-up and top-down. Iterative solution algorithm reconciling a top-down and a bottom-up model.

# A Mobility Good in the CGE Model I

The first step will be to introduce a mobility good in the household consumption nest (average amount of km covered per year by household type). It will be a composite of several other goods (representing modes of transportation), among them

- Public transport, which is an aggregate of railways, busses, trams, etc.

Individual transport, which is a composite of transport via

- Conventional vehicles (CVs) powered by gasoline/diesel, as well as hybrid electric vehicles (HEVs), also powered by fossils, but with a higher energy efficiency,
- Electric vehicles (EVs) powered by electricity, and plug-in hybrid electric vehicles (PHEV), which run on a mix of electricity and fossil energy (at least 80 % electricity).

# A Mobility Good in the CGE Model II

- For individual transport modes, the goods will be a composite of an "investment in a durable good" (**car, fixed costs**), and variable costs, consisting of **fuel inputs** (OIL, ELE) and **service/maintenance** (SERV) costs.
- The nesting structure chosen has large implications on the data required (elasticities, SAM disaggregation) and on the focus and functioning of the model.
- As the focus of the hybrid CGE model will be two-fold (electricity market and e-mobility), nesting structure has to incorporate both factors.

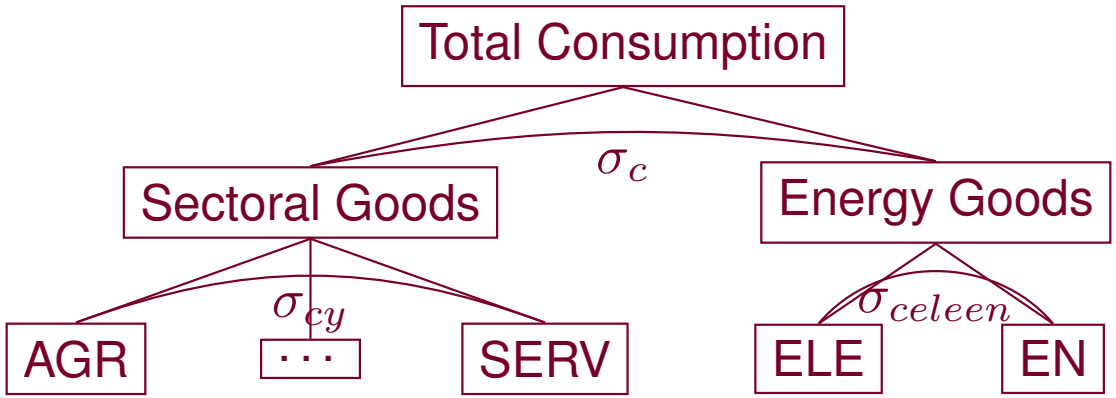
The way this good is nested, and how the difference between fixed costs of investment decisions (car purchase) and variable costs is treated, will decisively shape the DEFINE project.

# Stock Flow Consistency

Vehicles are durable goods that form a stock which is used by the household. It will be a major problem set for DEFINE to include this stock-flow perspective for the following reasons:

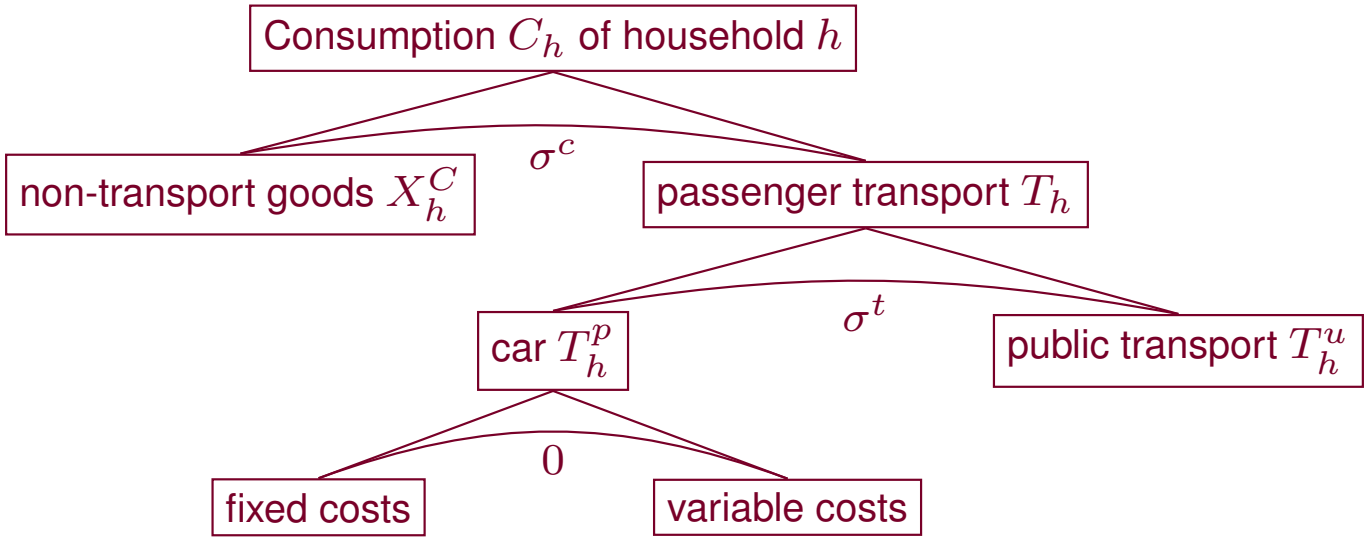
- Introducing electromobility on a large scale and assessing its cost, which is the aim of the project, means substituting a *stock* of CVs with a stock of EVs and PHEVs (HEVs providing energy efficiency gains)
- The stock, *not the purchase-flow* of vehicles every period, determines the energy demand of CVs, HEVs, PHEVs and EVs.
- Since the interaction with the electricity sector is one of the major research areas for DEFINE, the stock of vehicles and its energy demand somehow have to be taken into account.
- Different stock development for each car type in the benchmark. Calibration possible?

# Example I: Current Nesting Structure of Consumption in MERCI



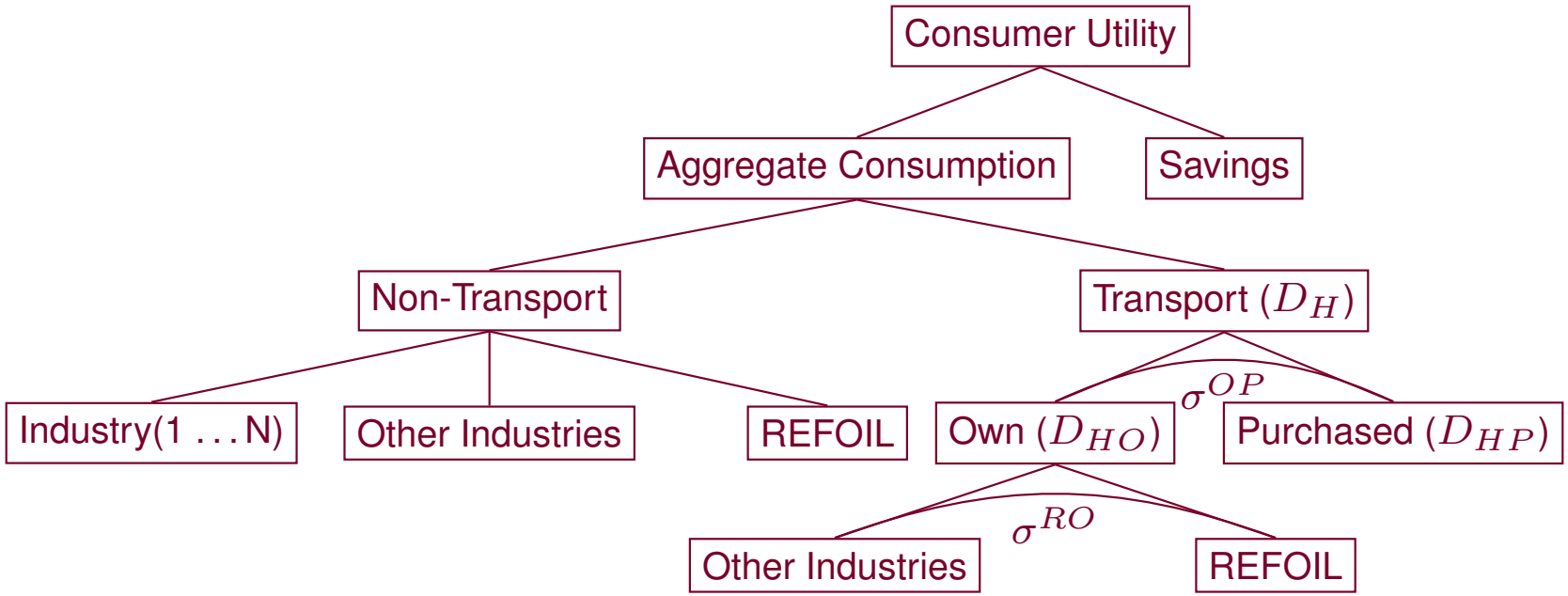

*Source: IHS Vienna, 2012*

# Example II: Nesting Structure of Household Demand incl. Traffic



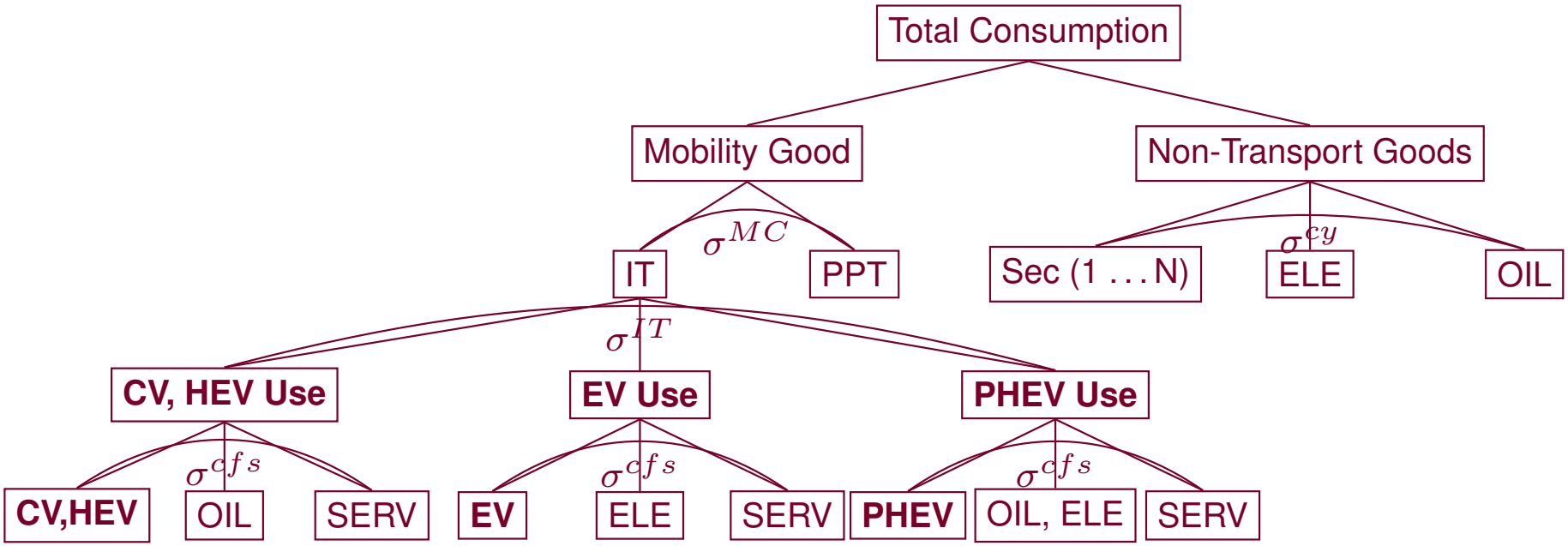

*Source: Steininger et al. (2007), p. 61*

# Example III: Nesting Structure of Consumer Utility incl. Traffic



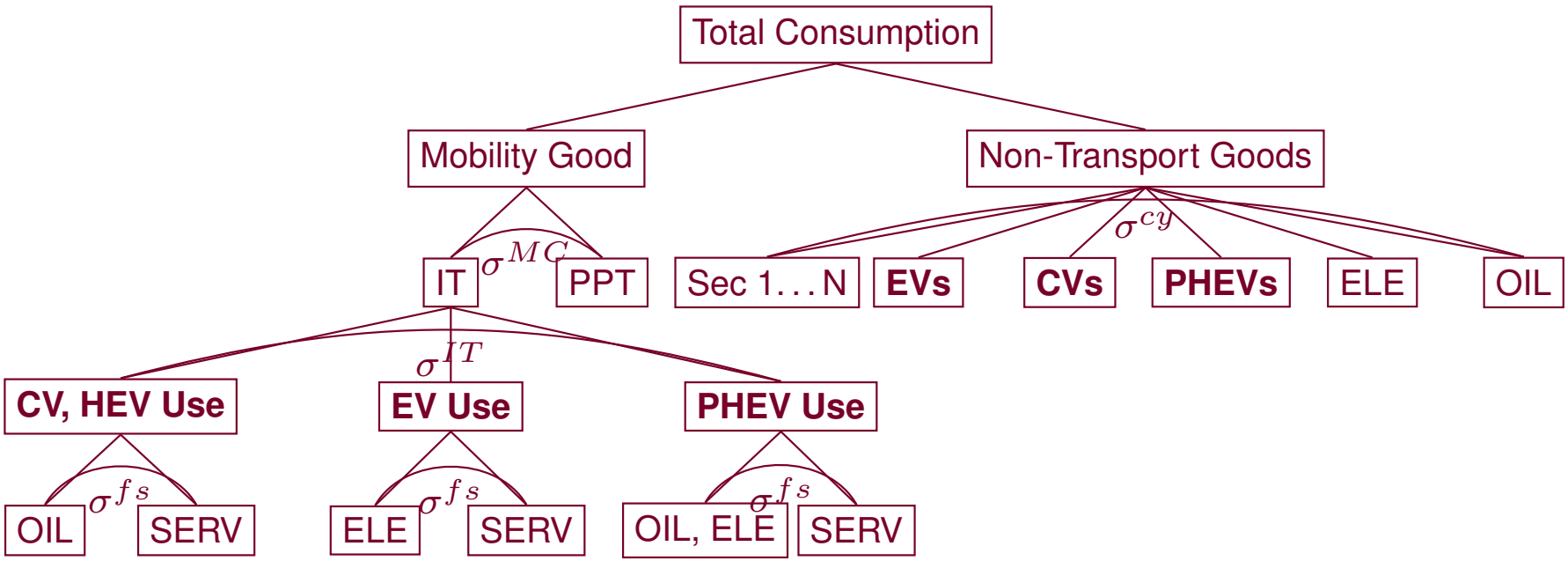

*Source: Schäfer and Jacoby (2005), p. 6*

# Example IV: Option 1 for MERCI - Mobility Goods in Composites




*Source: IHS 2012*

# Example V: Option 2 for MERCI - Mobility Goods in Different Nest than Car Purchases




*Source: IHS 2012*

# Option 1

Cars are directly part of the mobility good, fits CES structure.

Assuming low elasticities of substitution in the vehicle use nests ($\sigma^{cfs}$), and a high elasticity in the IT nest ($\sigma^{IT}$), the household will e.g. react with lower purchases of CVs if oil prices go up, etc.

Cost shares of vehicle, fuel, service can be scenario variables, e.g. higher efficiency of CVs, etc., see Paltsev et al. (2004).
Is it possible to change the activity technologies per year of the car types in MPS/GE?

*User costs* (oil, electricity and maintenance) have to follow the vehicle stock!

*Vehicle input in activity*:

1. Either: The purchase payment flows for new cars.
2. Or: Annualized costs of buying a vehicle.

# Option 1 - Vehicle Input: Purchase Payment Flows

For each car type: Benchmark relations between purchases (new cars) and total consumption of fuels/maintenance services (old and new cars) have to be taken out of data (Problem?).

General problem: how to incorporate lags between development in stocks and the fuel use?

- The Vehicle Use nests specify a fixed relation between new car purchases and fuel input.
- What if stocks go up (e.g. EVs), but flows (new purchases per year) remain approximately the same?
- How to model the energy input necessary to satisfy the stock?

# Option 1 - Vehicle Input: Annualization of Costs

Split total car purchase payments per year in a fraction over average tenure of car (e.g. $1/12$ of purchase price, vehicle "depreciation").

In each year, a fraction (e.g. $1/12$) of the purchases of the 11 previous years will enter the fixed costs part of using individual transport:

The vehicle input into the activity in year t equals

$$\sum_{i=t-11}^{t} \frac{1}{12} \text{ (car purchase payments)}_i$$

Small "distributional" error: Spikes in car sales for different years "smoothed" in CGE model.

Actual new car sales are approximated by sum of fraction of car sales of previous year. This approximation is most wrong if the stock of cars of one type (e.g. CVs) is substitued gradually by a different type (e.g. EVs, PHEVs).

# Option 1 - Comparison

Advantage of annualized cost approach:

- Vehicle input, fuel input and maintenance input in activity grow with the stock.
- Leontief nest possible!

Advantage yearly purchase payments approach:

- New car purchase payments explicitly available as a variable for stock accounting.

# Option 2

Vehicle Purchases are in separate nest from their use. How to incorporate the decision made by household in CES structure?

- The car purchases should influence the use. Purchases must be upper limit for the use.
- Changes in fuel input prices should influence purchase decision by household.

**Advantage:** Yearly car purchases represented as a variable. Account of stock easily possible.

Then specify a **functional relationship** (across different nests!) of vehicle stock and fuel/services inputs for vehicle use. Then: Easy to incorporate energy efficiency (change functional form parameters)

$\Rightarrow$ Can the MCP/MPSGE format accomodate for this?

# Vehicle Stock like Capital Stock?

Could it be possible to model the different vehicle stocks like the *capital stock* in a dynamic model?

- The purchases of new cars constitutes investment, the stock of cars is used by the household.
- Price of investment: purchase price of cars.
- Price of using the cars: fuel and maintenance costs.
- What should determine the prices for cars and use of cars (functional forms)?
- Is any of the previous options (better) suited for this approach?

# Calibrating the Benchmark

UBA and OEI will provide *estimates of stock developments* (market penetration rates) of different vehicle technologies:

- This would be an *endogenous result* of the CGE model.
- Calibration to externally given benchmark values (different growth rates of sectors and vehicle stocks) possible in MPSGE?
- Alternatively: Calibrate to normal growth path and install modal shift/different vehicle stock developments in BAU run.
- But: Scenarios should consider the specific stock growth paths!

In EPPA, see Schäfer and Jacoby (2005) p. 12, a modal shift is achieved by setting the elasticity to zero (between transport modes), and adjusting the share parameters in the CES function over time.

# Inclusion of Freight Transport

- Idea: simple representation of freight transport based on I/O data
- To what extent should DEFINE consider this dimension?
- Problems, benefits we can encounter?
- A simple way of “electrifying” freight transport could be a mode shift to rail.

# SAM Disaggregation I - Mobility Good

- The different goods that make up mobility have to be present in the SAM (vehicles, maintenance sector, fuels), as well as *public passenger transport (PPT)*.
- Austrian I/O tables feature a consumption table, where the fuel component for vehicles can be taken from. German, Polish I/O tables?
- Problem: how to construct an EV, PHEV sector from the traditional CV sector? Our Ideas: chassis remains the same, just swap motor with battery. Now we need to know: what are the components of the motor within the traditional CV - sector, where does the battery come from? Data!
- Will we encounter problems with collinearity of CV and EV sector?

# SAM Disaggregation II - Households by Region

- Households have to be disaggregated into at least 3 categories: **urban**, **rural**, **suburban**, because mobility behaviour is very different for these 3 types (easier e.g. to shift to PPT in urban areas than in rural ones).
- Approach: We know average mobility behaviour for each household type (mode choice, total km covered by transport technology) from data survey (WP 3) and existing data. We have different elasticities of substitition for Austria from data survey (WP 3) and micro-simulation (Germany, Poland?). Thus, each household type will have a different composition of the mobility good, as well as a different share of mobility in total consumption (include in survey!).
- For simplicity, the consumption patterns for other goods than transport should be assumed equal for all household types.

# SAM Disaggregation III - Households by Income?

- In Consortium Plan, reference was made to possible disaggregation of household agent according to income levels.
- This might provide some insights, since high-income households might be a much more likely candidate for the uptake of EVs (sensitivity to ecological issues, financial purchase power to act on it, etc.).
- Structure of incentives by the government could be different for income classes.
- However, even for 3 income classes, together with 3 regionally disaggregated household types, complexity and data efforts might be too high (possible data-source for disaggregation: EU-SILC, variable degree of urbanisation...?)
- Open for discussion

# Elasticities

- In DEFINE, a data survey and micro estimation shall provide sufficient empirical support for the CGE model.
- We have to take into account the various elasticities derived from WP 3 (micro-simulation AT) and WP 8 (micro-simulation PL)
- Can we use varying elasticities for different years, derived from micro-simulations (a “changed-preferences” scenario)?

# Possibilities for Links between Micro and Macro Models

- The integrated approach, see e.g. Decaluwé et al. (1999).
- A sequential approach, either top-down or bottom-up, in Peichl and Schaefer (2009) or in Bourguignon et al. (2003).
- The top-down bottom-up approach, see e.g. Savard (2003) or Böhringer and Rutherford (2009).

# Linking Micro and Macro in DEFINE

The amount of micro and macro links conducted in DEFINE remains to be seen:

- At least, the estimated elasticities from the micro-survey and estimation will enter the hybrid CGE model as behavioural parameters.
- Probably: results of CGE model further disaggregated in micro model onto a detailed household level.
- Micro-Macro Links might be explored in the next technical workshop in fall 2013.
- Maybe: the implementation of the decomposition technique proposed by Böhringer and Rutherford (2009) into the hybrid CGE model could be used for a micro-macro link?

# Conclusions

Open for discussion:

- To Decide: which Option is better, option 1 or option 2? Is option 2 even possible in MCP framework?
- How can we calibrate model to exogenous vehicle stock developments from UBA/OEI?
- How to achieve Stock-Flow consistency?
- Connection between vehicle use and energy sectors (fuels), especially electricity production.
- Inclusion of freight transport? Is there a simple, stylized way to deal with it?

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# Thank you for your attention!

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