CASE STUDY: APPLICATION OF EXPERIENCE CURVES IN THE ASTRA TRANSPORT MODEL

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PRIMES REFERENCE SCENARIO EU28 FOR TRANSPORT

Efficiency increase included, but low shift to low-carbon technologies

Transport activity & final energy demand

Final Energy Demand by fuel

- Electricity
- Liquified hydrogen
- Methanol & ethanol
- Biogas
- Gas
- Biofuels (liquids)
- Oil (LPG, Gasoline, Diesel, Kerosene, others)

Passenger transport activity (Gpkm)
Freight transport activity (Gtkm)
Final Energy Demand (in Mtoe)
ASTRA - ASSESSMENT OF TRANSPORT STRATEGIES

ASTRA model: www.astra-model.eu

Main characteristics:

- System Dynamics
- Vensim® software
- 1995 to 2050 (dt = ¼ a)
- ~ 9,000 variables
- Modular structure
- EU28 + CH/NO
- Calibration of modules in sequence

3 Companies: TRT Trasporti e Territorio, M-FIVE, Fraunhofer ISI
Development of vehicle fleet by technology for a specific scenario

Comparison of different scenarios

Source: Michael Krail (2012), Project GHG-TransPoRD, ASTRA model
DIFFUSION OF TECHNOLOGIES

EXEMPLARY RESULTS: EMISSIONS, CAR PRICES

Development of emissions for different scenarios

Development of car prices by technology

Source: Michael Krail (2012), Project GHG-TransPoRD, ASTRA model
VEHICLE FLEET MODULE

SIMULATING FLEET DEVELOPMENT IN 4 SUB-MODULES

- New vehicles registered
- Choice of fuel technology
- Ageing of the vehicle stock
CHOICE OF FUEL TECHNOLOGY

SCHEME ON SIMULATING THE CHOICE IN ASTRA

Drivers of the choice:
- Investment costs
- Fuel / electricity prices
- Consumption per vkm
- Taxes, insurance, road charges, maintenance costs
- Filling/ Charging station infrastructure
- Range of vehicles

Discrete choice to estimate the behaviour:
- Cost for energy consumption
- Fuel procurement cost

Logit function

Technology share
PURCHASE PRICES BY TECHNOLOGY

SEVERAL FACTORS USED FOR CALCULATION

- Basic vehicle price * Price level adjustment by country
- Additional costs for alternative fuel cars by technology

Development of car prices reflecting the **trend** of more expensive safety, efficiency and convenience

**Price increase** to achieve the CO₂ emission limits affecting only fossil-based cars

**Price decline for BEV and FCEV** representing higher economies of scale induced by R&D derived from GHG-TransPoRD with an assumed learning rate in a one-factor learning curve of 10%. Underlying diffusion scenario with a share of 65% on total fleet until 2050.
EXPERIENCE CURVES FOR CAR PRICES
IMPLEMENTED IN SD BY INFLOWS IN STOCK

Source: Michael Krail (2012), Project GHG-TransPoRD, ASTRA model
COMPONENT-BASED APPROACH

SUMMATION TO CAR PRICE BY TECHNOLOGY

Technology-dependent

- with learning
  - Price for major technology-dependent components
    - for Electric Vehicles (Power electronics, Transmission,...)
    - Price for further parts related to a technology
      - for Internal Combustion Engines (exhaust system,...)

- without further learning

Technology-independent

- Base price for all parts that are independent of the technology (Chassis, seats, etc.)
COMPONENT-BASED APPROACH
LEARNING CURVES FOR SINGLE COMPONENTS

Main technology-dependent components to be considered for learning curves:

- **Battery (kWh)**, Battery management system, Electric motor (kW)

- **Fuel Cell stack (kWh)** incl. BOP (balance of plant), Hydrogen tank (kWh)
EXPERIENCE CURVES FOR CAR PRICES
COMBINING ENDOGENOUS & EXOGENOUS DATA

Endogenous in ASTRA for EU 28 + CH/NO

Exogenous for Rest of World via Model 'TE3'

Cost of first unit
Learning rate
Experience curve function
Car purchase price

New vehicle purchases in EU + CH/NO per time-step (¼ year)
Accumulated sales as stock

Model TE3 (KIT-IIP): Sales for USA, China, India, Japan
Factor for Rest of World based on ASEAN Automotive Federation Statistics on production

Cumulative sales (production)

exchange of sales numbers until prices are stable
## Issues for Implementation

### Diverse Aspects at Some Point in Question

| Learning across fleet types and need for exogenous data for RoW for trucks, light duty vehicles and busses |
| Spillover effects from stationary storage on battery prices |
| Technology change, e.g. new battery types |
| Time-step ¼ year – combination with 1 year for RoW |
| Component-based instead of vehicle-based |
| Proceeding in case of lack of data for components: Option to deviate learning curve parameters, e.g. by grouping parts with similar learning types? |
| Transfer from learning to prices – adaptations required: e.g. OEMs sell alternative fuel cars for first 5 years without margin, after 5 years smoothly to margins above the Learning Curve line |

Scaling effects on prices for larger batteries
FURTHER TECHNOLOGICAL LEARNING IMPACT IN ASTRA FOR FLEET & ENVIRONMENT

- Capacity / range of vehicles
- Weight of batteries
- Bio-fuels
- PtX-fuels
- Consumption / energy efficiency
- Emissions
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