Green Transitions in Coal-Dependent Economies: A Hybrid Computable General Equilibrium Analysis of the Czech National Energy and Climate Plan

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Introduction I

- Environmental policies are essential for addressing climate change and promoting sustainable development
- EU Member States must update National Energy and Climate Plans (NECPs) to align with the Paris Agreement and Fit-for-55 targets.
- Fit-for-55 aims for a 55% reduction in GHG emissions by 2030 and set the path to achieve climate neutrality by 2050 (relative to 1990 levels).
- Central and Eastern European economies, like Czechia, face unique challenges due to high coal dependency and elevated emission intensities.
- The economy remains heavily industrialized, with one of the highest GHG intensities per unit of GDP in the EU.

Introduction II

- Decarbonization is hindered by reliance on coal-fired power, carbon-intensive industries, and a predominantly ICE-based transport fleet.
- A systemic modeling approach is needed to capture the full economic and environmental effects of Czechia's green transition.
- We develop a hybrid CGE model for the Czech Economy that integrates detailed sectoral analysis (energy and transport)
- Aim to assess the macroeconomic impacts of Czechia's NECP

Methods I

Computable General Equilibrium models...

- Optimization-based models
- Combine Arrow-Debreu's abstract GE structure with real economic data
- Solves for the levels of supply, demand, and equilibrium-supporting prices
- Commonly used in ex-ante RIA of Env. Policies

However, among other things, standard CGEs have been criticized for lacking detailed technological information

Methods II

- energy and climate-oriented CGE have thus moved towards a hybrid formulation [Faehn et al., 2020]
- Hybrid CGE models incorporate technological detail within its "Top-Down" structure.
- Bottom-Up models (like ESOMs) provide a detailed representation of the energy system
- Given the strengths and weaknesses of TD and BU models, hybrid modelers have developed various linking techniques

Methods III

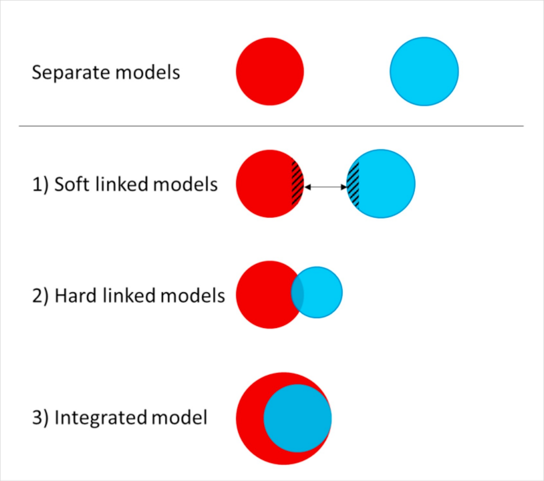


Figure 1: Hybrid Model Classification [Helgesen et al., 2018]

A hybrid CGE of the Czech economy

- We employ a recursive-dynamic hybrid CGE based on [Miess et al., 2022] written in GAMS as an MCP
- Model starts with 24 cost-competitive sectors
- Standard neoclassical labor supply (Cons-Leisure choice)
- Small open economy with fixed imports/domestic shares
- zero deficit closure rule
- Endogenous demand for tech-specific IT according to DC model
- Emission coefficients come from the EMEP/EEA air pollutant emission inventory guidebook

Electricity Sector Modeling

The BU module of the electricity sector is modeled after [Böhringer and Rutherford, 2008]:

1. Tech-specific zero-profit conditions

$$\Pi^E_{tec} = p_{\text{ELE}} - \sum_m a^Y_{tec,m} p_m - a^K_{tec} r_K - a^L_{tec} p_L - \sum_f a^F_{tec,f} p_f - \mu_{tec}$$

2. Tech-specific capacity constraints
3. Overall Electricity Market Clearing

The disaggregation of the electricity sector is done following [Sue Wing, 2008], yielding:

- 2 activities (Generation and T&D)
- 8 generation technologies
  (Nuclear, Natural Gas, Wind, Coal, PV, Oil, Hydro, Rest)

Nesting Structure of Productive Industries

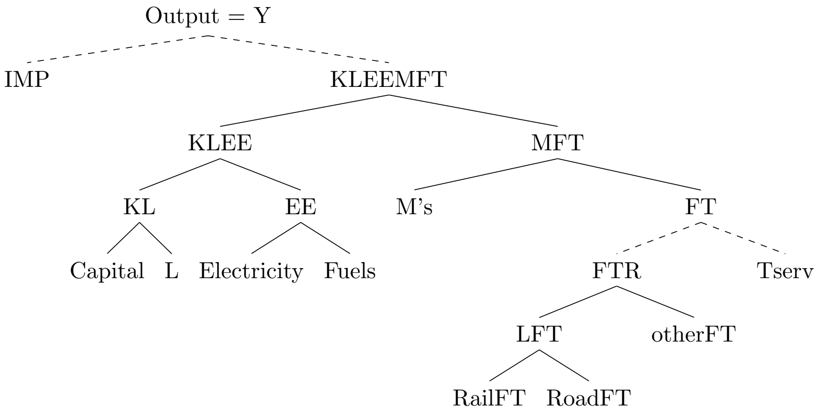
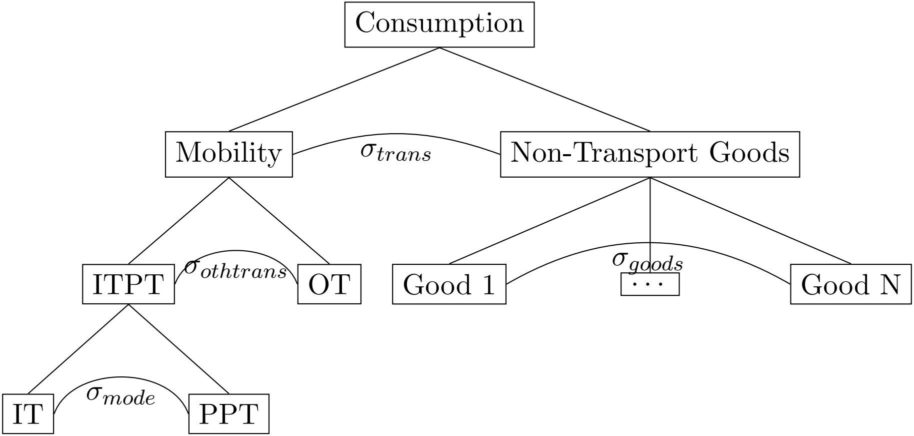


Figure 2: Nesting Structure of Producing Sectors

Nested structure of household consumption



Individual transport I

- The CGE model integrates endogenous demand for low-emission, energy-efficient technologies using a DCM
- The market shares across vehicle types are allocated based on consumer preferences elicited with a DCE related to costs and driving range:
  - Conventional vehicles (CV): petrol and diesel.
  - Plug-in hybrid electric vehicles (PHEV).
  - Battery electric vehicles (BEV).
- A mixed logit specification is used to estimate utility parameters. These, combined with vehicle attributes, determine the indirect utility of each vehicle type.
- Indirect utilities generate choice probabilities, which define market shares for new vehicle purchases.
- These market shares, combined with aggregate household demand for transport, determine fuel and electricity demand by vehicle type.

- Demand for vehicle types influences new car registrations.

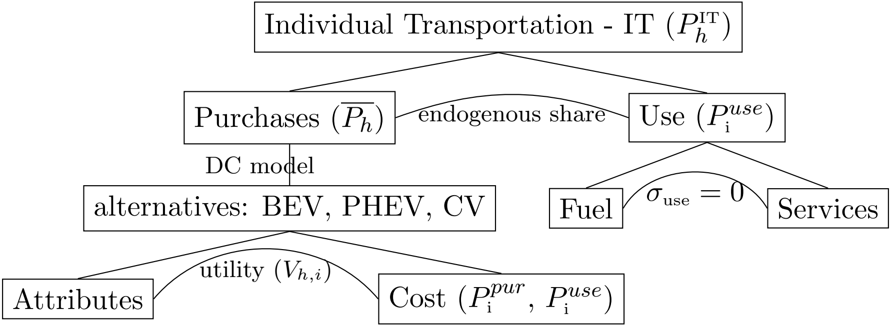


Figure 3: Individual transport consumption structure (DC model of the purchase decision)

Individual transport III

- In addition to preferences, market shares respond to:
  - Purchase prices,
  - Bonus/Malus,
  - Fuel and electricity prices (Endogenous in Macro module)
- Annual new vehicle registrations by type feed into a dynamic vehicle stock accumulation model.
- Vehicle stocks evolve with a standard depreciation process assuming a share of vehicle stock depreciates each year:

$$st_i(t) = st_i(t-1) + nr_i(t) - dc_i(t), \quad \forall i, \forall t$$

- Operation costs are determined according to technology-specific stock developments
- Activity of car-producing sectors linked to new registrations

Scenarios

- **WEM** (BAU) scenario:
  - World without Fit-for-55
  - ETS1 system is present
  - Emission allowance prices correspond to the DG Climate Action's recommended harmonized trajectories for WEM
  - No reduction emissions target for GHGs is enforced
  - Only Modernization Fund is implemented.
- **WAM** scenario:
  - Emission prices are taken from the DG RHTs for WAM
  - ETS2 becomes operational in 2027
  - Assume full use of revenues from the EU ETS including dedicated funds for decarbonization and mitigation of social impacts in accordance with the approved legislation from FF55
  - Coal is phased out from electricity generation by 2033
  - New registrations of new conventional vehicles not allowed after 2035

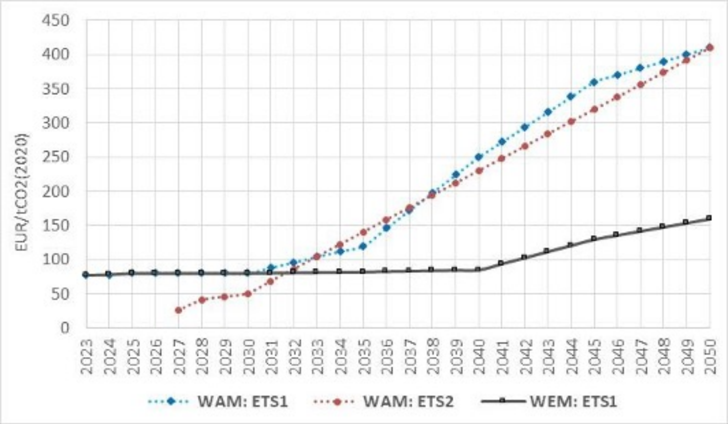


Figure 4: Emission Allowance Prices— HCT WEM and WAM

Results

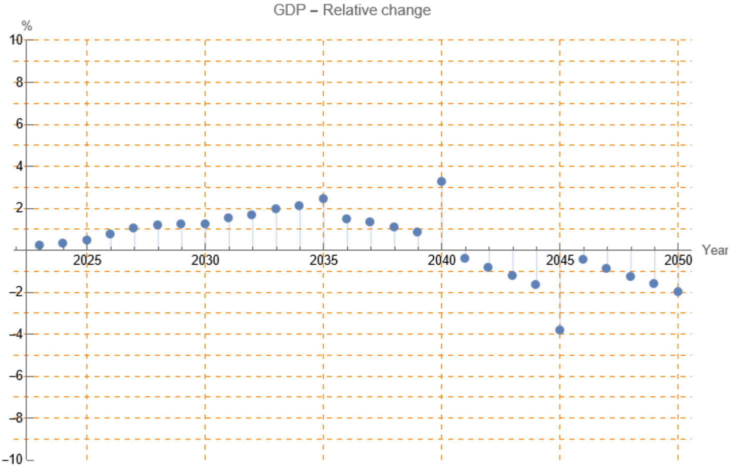
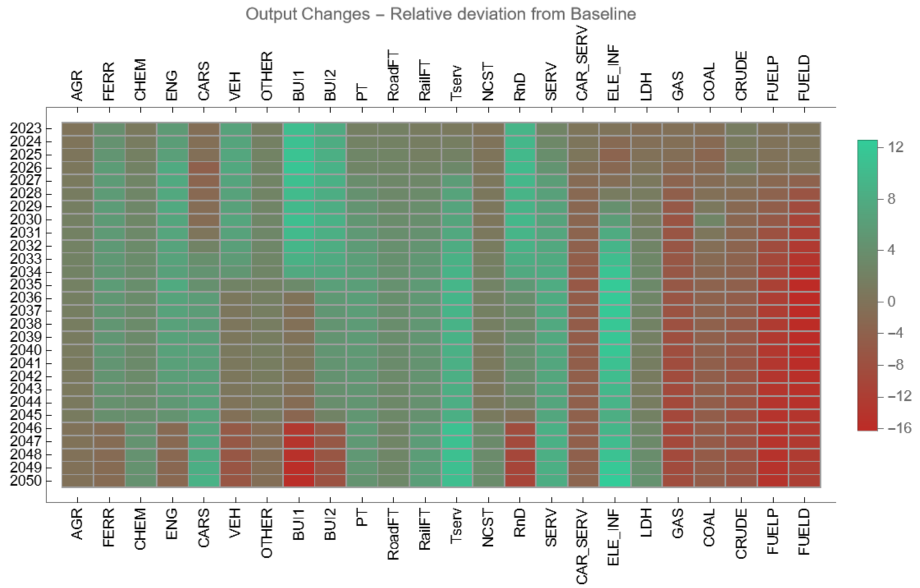


Figure 5: Relative change in GDP in WAM

Results - Output



Electricity Generation

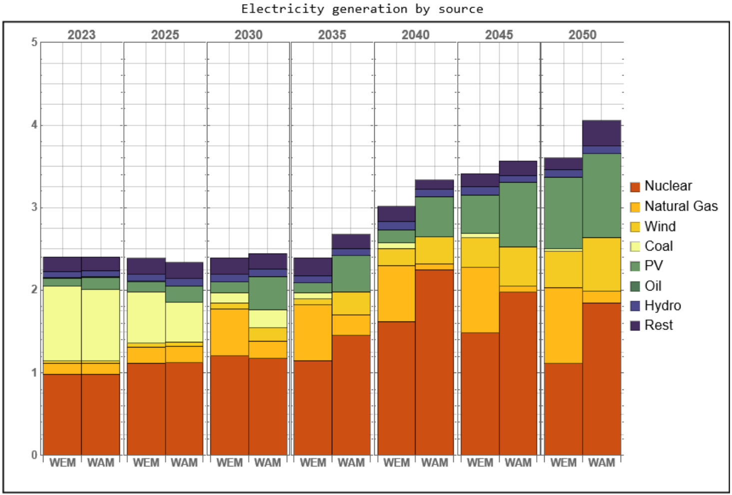


Figure 6: Electricity generation by technology in WEM and WAM

Individual Vehicles (thousands)

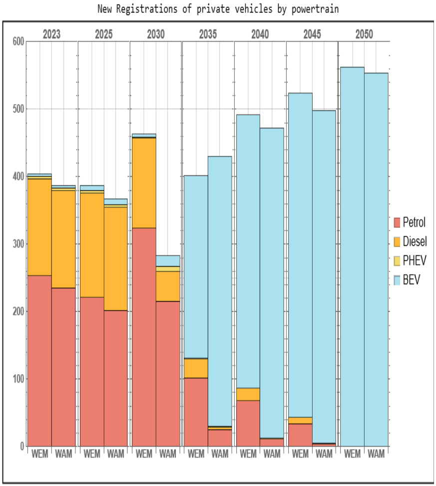


Figure 7: Stock of private vehicles by technology

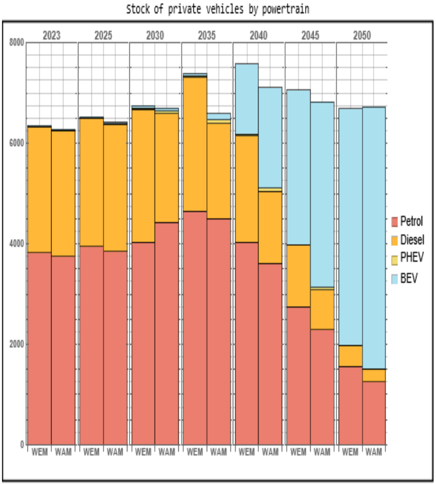


Figure 8: New registration of private vehicles by technology

Results

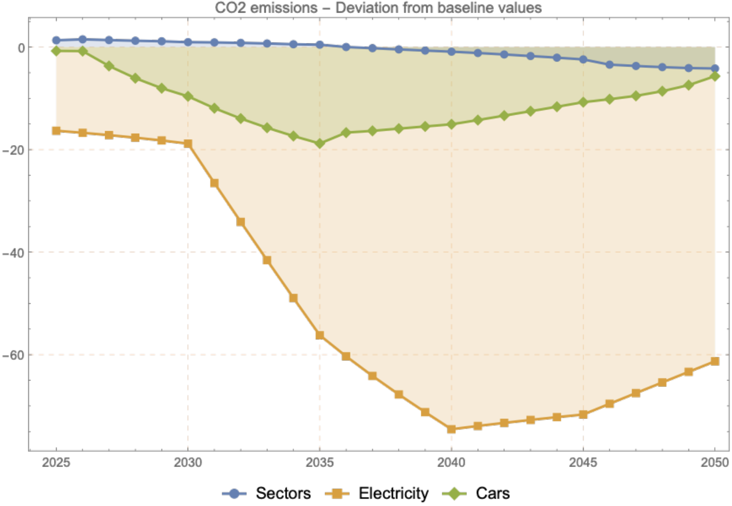


Figure 9: Relative change of CO2 emissions

QUESTIONS?

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References I

Böhringer, C. and Rutherford, T. F. (2008).
Combining bottom-up and top-down.
Energy Economics, 30(2):574–596.

Faehn, T., Bachner, G., Beach, R., Chateau, J., Fujimori, S., Ghosh, M., Hamdi-Cherif, M., Lanzi, E., Paltsev, S., Vandyck, T., et al. (2020).
Capturing key energy and emission trends in CGE models: Assessment of status and remaining challenges.
Journal of Global Economic Analysis, 5(1):196–272.

Helgesen, P. I., Lind, A., Ivanova, O., and Tomasgard, A. (2018).
Using a hybrid hard-linked model to analyze reduced climate gas emissions from transport.
Energy, 156:196–212.

References II

Miess, M., Schmelzer, S., Šcasnỳ, M., and Kopecná, V. (2022).
Abatement technologies and their social costs in a hybrid general equilibrium framework.
The Energy Journal, 43(2).

Sue Wing, I. (2008).
The synthesis of bottom-up and top-down approaches to climate policy modeling: Electric power technology detail in a social accounting framework.
Energy Economics, 30(2):547–573.