Different Paths, Different Outcomes: Comparing EU ETS Revenue Recycling Scenarios in a Hybrid CGE Model

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T A Č R
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Introduction and Motivation

- The EU's *Fit-for-55* package requires Member States to update their National Energy and Climate Plans (NECPs), targeting a 55% reduction in GHG emissions by 2030 and climate neutrality by 2050 (relative to 1990 levels).
- Czechia faces particular decarbonization challenges due to:
  - high dependence on coal-based electricity,
  - carbon-intensive industrial production,
  - a predominantly ICE-based transport fleet,
  - one of the highest GHG intensities per unit of GDP in the EU.
- Assessing the green transition requires a system-wide perspective that captures interactions across sectors and the broader economy.
- We develop a hybrid CGE model for Czechia with detailed representations of the energy and transport sectors to evaluate the macroeconomic and environmental impacts of the updated NECP.

Hybrid CGE Model of the Czech Economy

- Dynamic hybrid CGE model based on [Miess et al., 2022], implemented in GAMS as an MCP
- Represents the Czech economy through 25 production sectors within a Ramsey-type growth framework
- Small open economy with Armington specification of trade and endogenous labor supply and fiscal balance maintained through a zero-deficit closure
- Integrates:
  - a technology-specific electricity sector module,
  - a discrete-choice model of passenger vehicle demand and technology adoption
- Emissions are calibrated using technology- and sector-specific coefficients from the REZZO database (Czech Hydrometeorological Institute)

Production structure

The nesting structure of production sectors

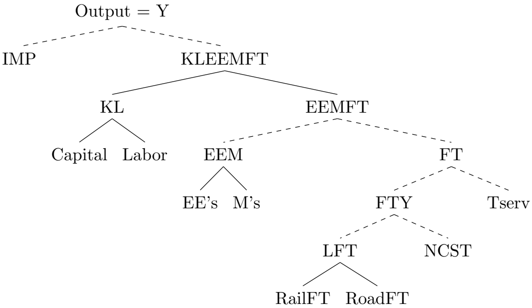

Figure 1: Nesting Structure of Producing Sectors

Consumption structure

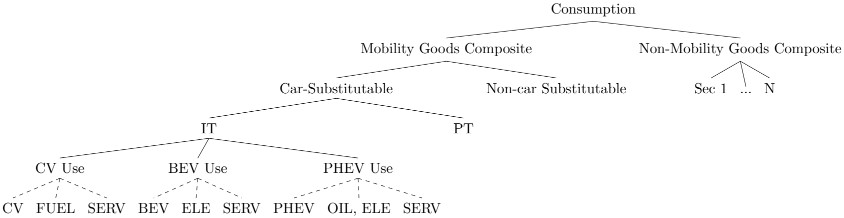

Figure 2: Nested structure of household consumption

Households are disaggregated into income deciles based on the data from SILC and Family budget survey done by the Czech Statistical office.

Private Transport Module

- Household demand for individual transport is split into vehicle purchase and vehicle use.
- New vehicle registrations are allocated across technologies using a discrete-choice model:
  - conventional vehicles: petrol and diesel,
  - plug-in hybrids,
  - battery electric vehicles.
- Choice probabilities depend on purchase prices, fuel/electricity costs, taxation, and BEV driving range.
- Vehicle stock dynamics determine future demand for fuels, electricity, maintenance, and repair.

Non-Private Transport Module

- Non-private transport is disaggregated into public transport, road and rail freight transport, other passenger transport (water, air) , , and transport support services.
- Road freight is modeled with a dedicated fuel-substitution structure, allowing shifts between diesel, natural gas, gasoline, and electricity.
- This sectoral detail captures how decarbonization policies affect both household mobility and transport-intensive production.

Electricity Sector Module

- The electricity sector is disaggregated into two activites and 8 generation technologies using engineering cost and generation data.
- A bottom-up electricity module is integrated into the CGE model through:
  - technology-specific production costs,
  - capacity constraints calibrated from TIMES projections,
  - an economy-wide electricity market-clearing condition.
- A Positive Mathematical Programming (PMP) by [Howitt's, 1995] following [Sue Wing, 2008] approach allocates inputs across technologies while ensuring consistency with the Social Accounting Matrix and observed generation structure.
- The framework captures technology substitution and the economic impacts of power-sector decarbonization.

ETS Module: Carbon Pricing

- Based on [Liu et al., 2021], CO_2 emissions are calculated from fossil fuel use and fuel-specific emission coefficients.
- ETS-covered sectors face a carbon cost proportional to their emissions:

$$CTAX_i = p^{ETS} \sum_j E_{i,j} \theta_j$$

- The carbon cost is implemented as an ad valorem tax on fossil fuel inputs.
- Higher ETS prices increase the relative cost of carbon-intensive fuels, encouraging substitution toward cleaner energy sources.
- Carbon tax revenues are collected by the government and redistributed according to the model closure.

Revenue Recycling of ETS Revenues

- Lump-sum transfers to households
- Additional government consumption
- Reduction in labor taxation
- Modernization Fund:
    - renewable energy investments,
    - energy-efficiency measures,
    - support for BEV adoption
- Innovation Fund:
    - support for R&D activities

How ETS revenues are recycled is the key determinant of economic and distributional outcomes.

Innovation and Modernization Funds

- Part of ETS revenues is allocated to targeted investment programs.
- Innovation Fund:
  - endogenous subsidy for R&D activities,
  - lowers production costs and supports technological change.
- Modernization Fund:
  - subsidies for industrial energy-efficiency investments,
  - subsidies for household energy-efficiency measures,
  - support for renewable energy and BEV adoption.
- Subsidies enter firms' production decisions (through the zero-profit condition for production and demand equation for intermediate inputs) and households' consumption choices (through the consumption function for households in the materials nest) endogenously.

Modeling Energy-Efficiency Support

ETS revenues → Energy-efficiency investment → Accumulated capital stock → Higher energy productivity → Lower energy demand per unit of output/consumption

- Separate channels for firms and households.
- Energy-efficiency investments accumulate over time.
- Accumulated investments generate productivity improvements in the energy aggregate.
- Captures long-run benefits of recycling carbon revenues into efficiency measures.

Application: ETS Revenue Recycling under the NECP

- Assess the macroeconomic effects of the Czech NECP and alternative ETS revenue recycling strategies.
- Five policy scenarios are compared against a BAU (*With Existing Measures*) baseline.
- Scenarios differ in:
  - the allocation of ETS revenues (household transfers, green investments, debt reduction),
  - the role of ETS2 and the Social Climate Fund (SCF).
- Scenario overview:
  - **NECP**: official revenue allocation in the NECP.
  - **SCF**: larger share directed to household compensation.
  - **noSocial**: no lump-sum household transfers.
  - **noETS2**: no household transfers and no ETS2.
  - **Debt**: revenues used primarily for debt reduction.

Results - GDP

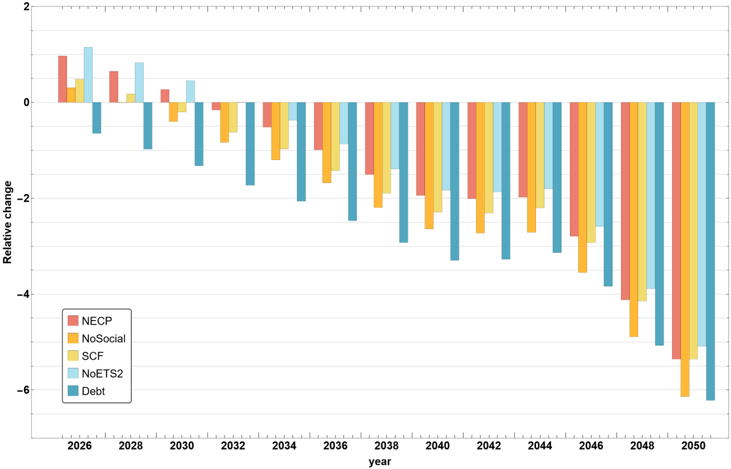

Figure 3: GDP relative difference to WEM

Results - Investment

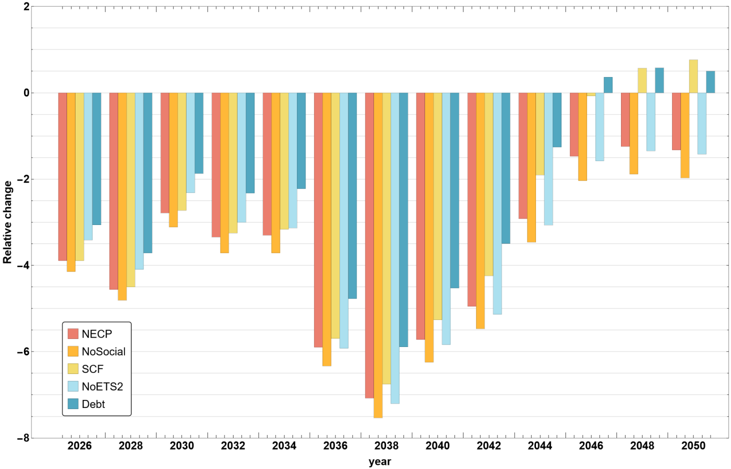

Figure 4: Investment relative difference to WEM

Results - Employment

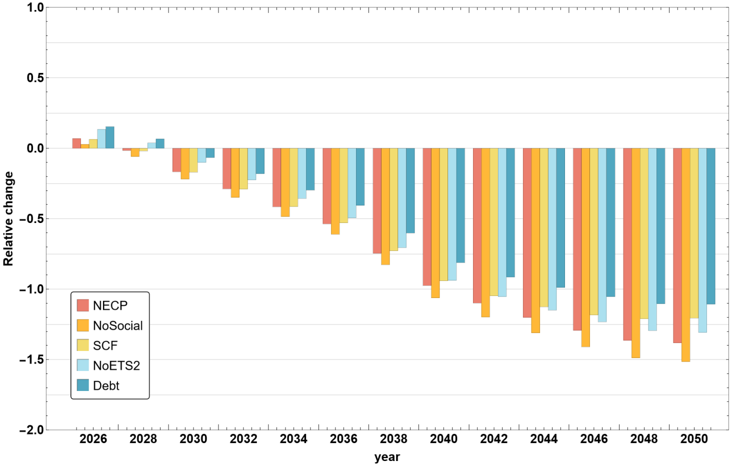

Figure 5: Employment relative difference to WEM

Results - New registrations of cars

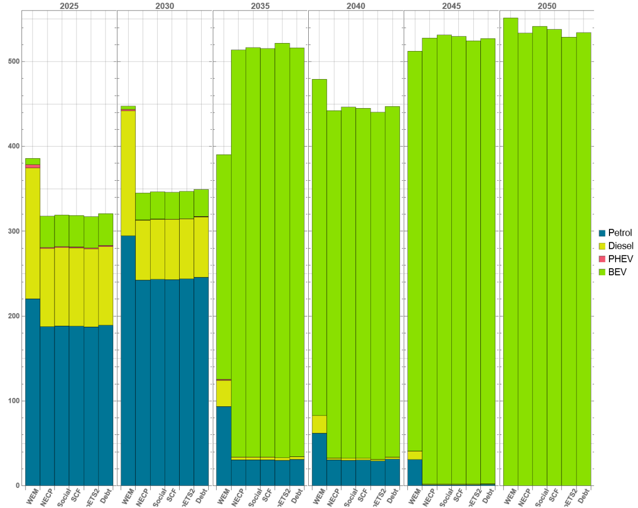

Figure 6: New registrations of cars relative difference to WEM

Results - Emissions

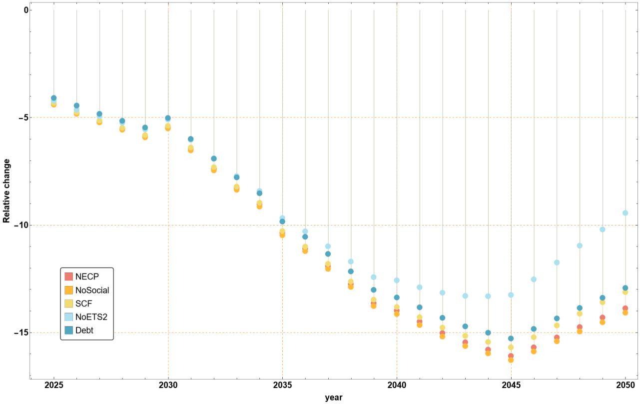

Figure 7: Emissions relative difference to WEM

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Summary of producing sectors in the SAM

Abbr.	Sector name	Abbr.	Sector name
AGR	Agriculture, forestry, fishing	RnD	Research and Development
FERR	Basic metals, nuclear fuels	CAR_SERV	Car services
CHEM	Chemical products, pharmaceutics	ELE	Electricity production
ENG	Metal products, engineering	ELE_INF	Electricity trans and distribution
CARS	Vehicles production and trade	LDH	Steam and AC supply
VEH	Other transport equipment	GAS	Gas production and distribution
OTHER	Other production and mining	COAL	Mining of coal and lignite
BUI1	Building construction, civil engineering	CRUDE	Crude oil and gas extraction
BUI2	Specialised construction activities	FUELP	Fuel for transport purposes
PT	Public passenger transport	FUELD	Fuel for transport purposes
NCST	Other passenger transport	OWNINIT	Intermediate inputs within sector
RoadFT	Freight transport	...	...rows in final demand
RailFT	Freight transport	Petrol	Conventional petrol vehicle
Tserv	Freight transport	Diesel	Conventional diesel vehicle
SERV	Services	PHEV	Plug-in hybrid vehicle
		BEV	Battery electric vehicle

Non-private transport modeling I

The general KLEEM production structure used in the model is replaced for the road freight transport sector(s) by:

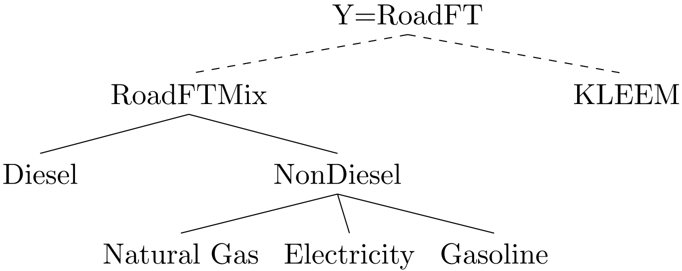

Figure 8: Nesting Structure of RoadFT sector

*Currently, RoadFT being further disaggregated into Freight services by size (EU classification) by adapting [Peters, 2016] method to transport sector → future plans.

Results - Wages

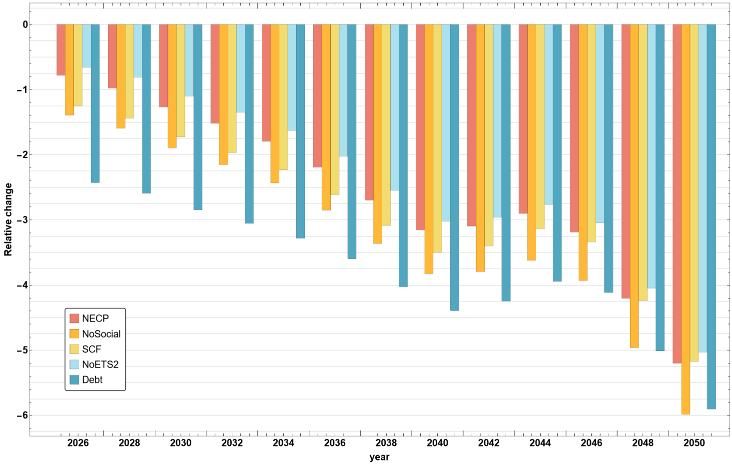

Figure 9: Wages relative difference to WEM

Results - Production

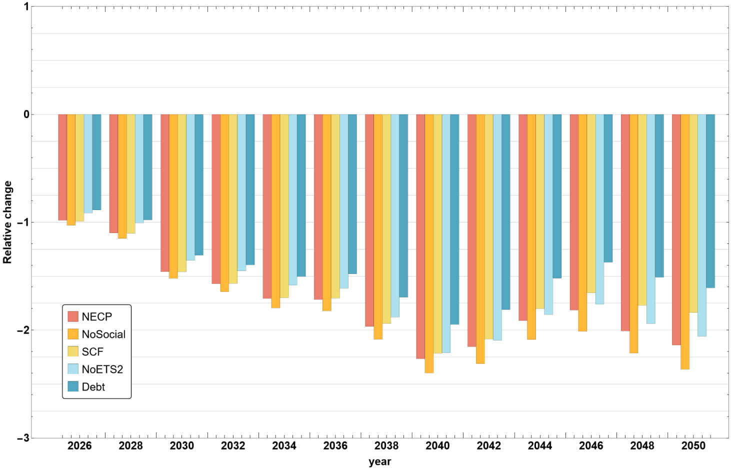

Figure 10: Production relative difference to WEM

Results - Household consumption

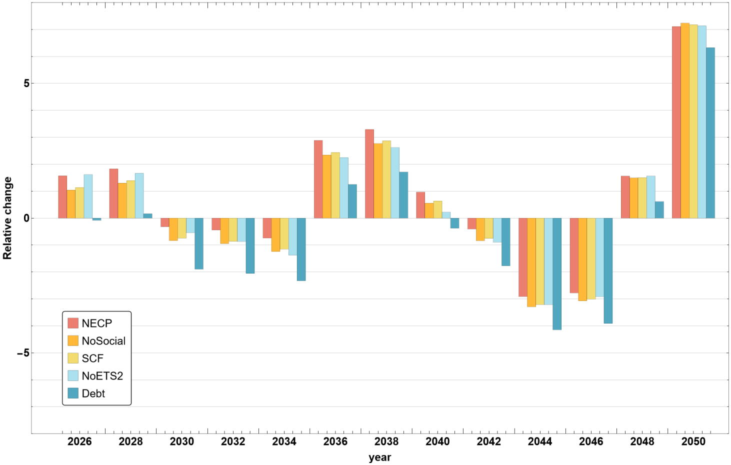

Figure 11: Household consumption relative difference to WEM

Results - Government income

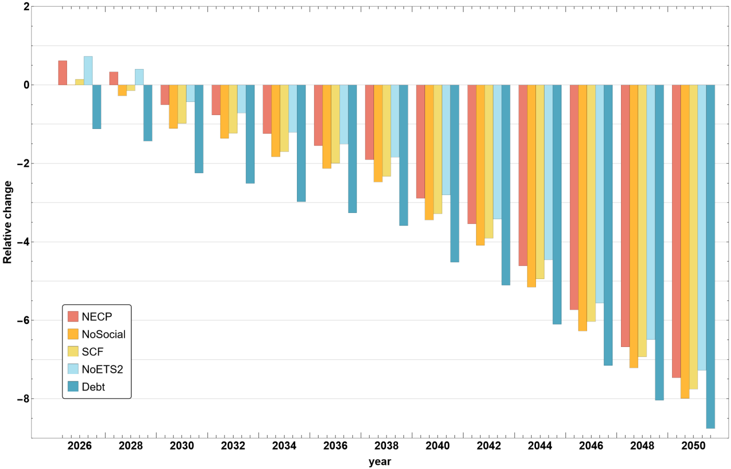

Figure 12: Government income relative difference to WEM

Results - Stock of cars

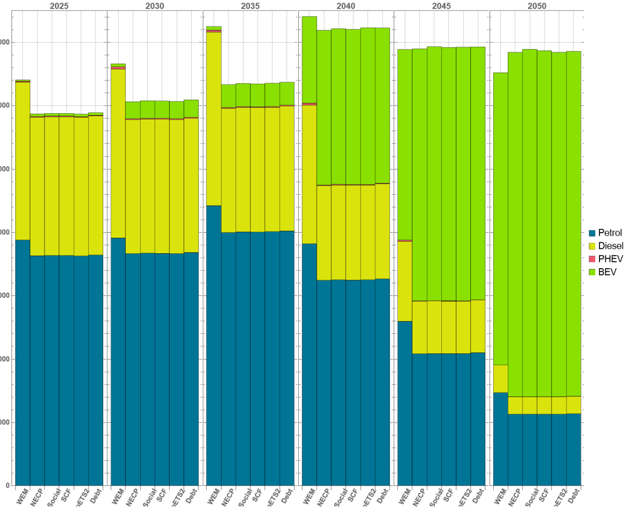

Figure 13: Stock of cars relative difference to WEM