The Swiss Energy Transition: Economic Evaluation of Bottom-Up Modelling Results

Florian Landis, ZHAW Center for Energy and the Environment, +41 (0) 58 934 79 84, florian.landis@zhaw.ch

Overview

I present an approach for integrating bottom-up energy system modeling results into a top-down computable general equilibrium model of the Swiss economy. The approach aims for a “tight” link between the two models eventually ensuring full consistency of joint solutions in comparative static analyses. I present a list of conditions for the model coupling to satisfy that ensure a tight link and lay out some innovative steps to achieve this. An exemplary application showcases the additional insights that can be gained from integrating energy system modelling into a general equilbrium economic analysis. Bottom-up modeling with high temporal and technological resolution can yield results that are hard to replicate with low dimensional stylized models. Model linking has the benefit of integrating bottom-up modeling complexity into general equilibrium models of entire national economies.

I find that energy system cost for decarbonizing the Swiss economy at fixed levels of energy service provision overerstimates the welfare cost for the overall economy in general equilibrium. General equilibrium GPD losses are higher than the energy system costs at fixed energy service provision. Decarbonizing the Swiss economy using standards and technology mandates can be expected to be progressive: the impacts on consumer welfare relative to baseline expenditures are more negative for high income households than they are for low income ones.

Methods

A “tightly-linked” model coupling is one where (i) model parts shared between models (that is, the quantities and prices describing pertaining to the parts) are consistently defined and interpreted in both models, (ii) data used for calibrating the model parts yield agreement for quantities and prices in the baseline equilibrium, (iii) the model mechanisms governing the coupled models are logically consistent, and (iv) model iterations for solving the model under counterfactual scenarios are carried out until convergence has been achieved, i.e., until no model part changes it own solution upon getting the interfaced solution of the other model anymore. Advantages of tight linking are consistency of the solution in both model parts on the one hand and additional checks on data harmonization, code, and coupling concept by virtue of needing to arrive at a common solution of both models on the other.

For the top-down CGE model, I use a forward calibrated one-period static small-open-economy model of the Swiss economy based on national input–output tables that have been extended by information about energy and environmental accounts. For the bottom-up energy system model, I employ the model Swiss Energyscope – ETH (SES-ETH; see Marcucci et al., 2021). SES-ETH minimizes the cost of providing the Swiss economy with exogenously given levels of energy services over one year. It’s temporal resolution is hourly and the capital costs are annualized investment costs. The energy system according to SES-ETH is a price-taking cost-minimizer which fits well with the assumptions of how economic sectors behave according to the top-down CGE model.

Activities and energy goods in SES-ETH are aggregated and the CGE model is extended to include this aggregated representation of the energy system as a set of activities represented by Leontief production functions. All greenhouse gas (GHG) reduction constraints are within the energy system (all GHG emissions outside the scope of the energy system are considered fixed and “hard to abate” and are compensated by negative net emissions of the energy system) and the net-zero target according to the CGE model is entirely represented by a restructuring of the reduced form energy system.

The comparative statics analysis of this study compares a business as usual scenario (BAU), where the Swiss energy sector emits 20 $MtCO_2e$ in 2050, with a decarbonization scenario (DECARB), where the energy system has net negative emissions of −9 $MtCO_2e$.

Results

Table 1 shows summary statistics for macroeconomic indicators. Figure 1 shows how impacts of the DECARB scenario compared to BAU on consumer welfare (as equivalent variation, or short, EV relative to baseline spending) is distributed across households of different income quintiles and how the impacts are composed of price effects (e.g., more expensive consumption basket) and income effect (e.g., less income from wages, capital rents, or transfers).

Table 1: Macroeconomic outcomes

		SES-ETH		GemEl	
		BAU	Decarb	BAU	Decarb
ES Cost	Total (GCHF)	18.16	24.21	18.15	20.66
	Change (GCHF)		6.05		2.50
GDP	Total (GCHF)			975.34	967.59
	Change (GCHF)				−7.75
	Change (%)				−0.79
Real consumption	Total (GCHF)			501.37	495.68
	Change (GCHF)				−5.69
	Change (%)				−1.13
Consumer price	Change (%)				−0.01
Wages	Change (%)				−0.92
Capital rents	Change (%)				−0.60

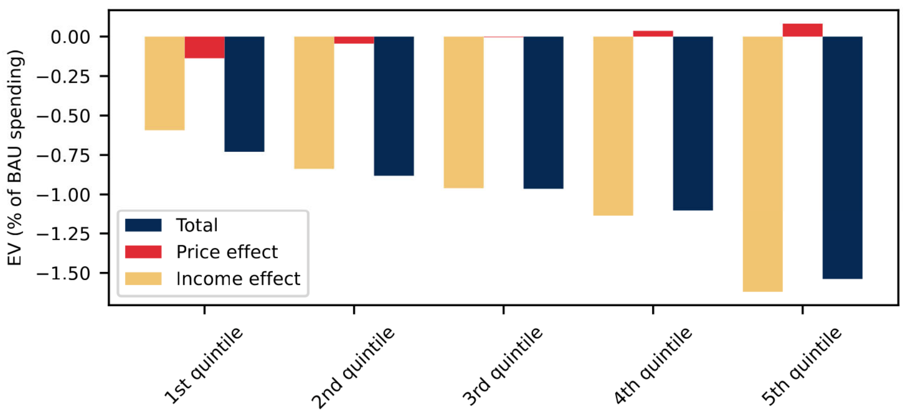

Figure 1: Welfare impacts on income quintiles of of Swiss population.
Impacts are decomposed into price effect (red) and income effect (yellow)

Conclusions

The study provides a proof of concept for a tight coupling of bottom-up energy system and top-down CGE models. The tight link makes possible a consistent analysis of intricate interrelations within the energy system on the one hand and the far-reaching implications throughout the economy on the other, while maintaining full microeconomic consistency across the coupled model.

The findings suggest that system costs in energy system models with fixed energy service supply slightly overstate the overall economic welfare cost of the energy transition. The distribution of welfare impacts does not on average hurt low income households disproportionately if the energy transition.

References

Marcucci, A., G. Guidati and D. Giardini (2021). *Documentation of the Swiss Energy Scope - ETH model.* https://doi.org/10.3929/ethz-b-000540917