Nuclear Phase-out and Climate Policy in Switzerland: An Integrated Top-down Bottom-up Assessment

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TWO PAGES MAXIMUM

(1) Overview

We examine the economic effects of a nuclear phase-out under climate policy constraints in Switzerland in a model that integrates a top-down dynamic general equilibrium model with a detailed bottom-up description of the Swiss electricity sector. The electricity-sector model features perfect foresight, exhibits a high level of technological and temporal resolution, is parameterized to represent resource potentials for renewable energy sources in Switzerland, and takes into account electricity trade between Switzerland and its neighboring countries. Consistently linking the electricity model to an economy-wide general equilibrium framework allows us to assess different policy options in terms of sound economic cost metrics while being able to explore the implications of alternative technology pathways.

(2) Methods

To shed light on the mechanics that drive the cost of Swiss electricity production and to provide an estimate of the additional cost imposed by a nuclear phase-out in a carbon-constrained world, this paper develops a hybrid energy economic model of the Swiss economy. The model we propose in this paper builds on the decomposition technique developed by Böhringer and Rutherford (2009) as applied by Lanz and Rausch (2011). We integrate a copperplate bottom-up model of Switzerland's electricity generation, capacity expansion and trade into a top-down computable general equilibrium (CGE) model that represents Switzerland as a small open economy. However, we improve the literature in two ways. On the one hand no full grown hybrid model has yet been used to analyze the energy transition in Switzerland, and second, the hybrid modeling literature restricted itself to static or recursive-dynamic models so far. Since in both our submodels agents exhibit perfect foresight, the resulting integrated model exhibits perfect foresight as well.

The general equilibrium model we employ is of the classical Ramsey-type with endogenous depreciation and capital adjustment costs as developed in Imhof (2011). Firms have perfect foresight and maximize their present value profit over the whole model horizon. The employed version of the model includes 10 sectors producing 17 goods.

Our model of electricity dispatch maximizes the total surplus in the electricity market given some physical, economic and political conditions. The model takes the consumer surplus of the foreign consumer (the buyer of exports) into account to represent the fact that Switzerland is a small open economy, that acts as a price taker, but nevertheless its export decisions may influence the market price. Compared to other electricity dispatch models, an important feature of our model is the handling of trade in electricity. While most dispatch models do not pay major attention to trade issues, for Switzerland foreign electricity trade is very important, and thus an adequate electricity model for Switzerland has to take foreign trade into account. While imports are modeled to be perfectly elastic, we model export demand using a linear demand function. The model represents four load segments per day (night, morning, midday and evening) for each day of the 365 days in every modeled year, making a total of 1460 load segments per year.

In principle, a bottom-up representation of the electricity sector can be integrated directly within a GE framework by solving Kuhn-Tucker equilibrium conditions that arise from the bottom up cost-minimization problem, along with general equilibrium conditions describing the top-down model (Böhringer and Rutherford, 2008). In applied work, this approach may be infeasible due to the large dimensionality of the bottom-up problem. Moreover, the bottom-up model involves a large number of bounds on decision variables, and the explicit representation of associated income effects becomes intractable if directly solved within a GE framework (Böhringer and Rutherford, 2009).

Our computational strategy is to use a block decomposition algorithm put forward by Böhringer and Rutherford (2009) that involves an iterative procedure between both submodels solving for a consistent general equilibrium response in both models. Each iteration in the solution algorithm comprises two steps. Step 1 solves a version of the CGE model with exogenous electricity production where electricity sector outputs and input demands for fuels, capital, labor, and other materials, are parameterized based on the last available solution of the bottom-up model. The subsequent solution of the bottom-up model in Step 2 is based on a locally calibrated demand function for electricity and a vector of candidate equilibrium prices for fuels, capital, labor, and materials. The key insight from Böhringer and Rutherford (2009) is that a Marshallian demand approximation in the electricity sector provides a good local representation of general equilibrium demand, and that rapid convergence is observed as the electricity sector is small relative to the rest of the economy.

(3) Results

In all scenarios we assume that Switzerland adopts a stringent carbon policy that is in line with the European targets as well as the proposals in the *Energiestrategie 2050*. The target is a reduction of carbon emissions by 20 % below 1990 levels in 2020, and a reduction of 80 % in 2050. We assume a linear reduction path that reduces emissions by 2 percentage points every year until 2050, where it will remain at 80 % thereafter. To achieve this reduction target we implement a CO2 tax which revenues are redistributed back to consumers lump-sum, leaving the tax reform to be revenue neutral.

While the business-as-usual scenario has only a CO2 target and no restrictions on the electricity generation, we compute phase-out policies in the counterfactual. In those counterfactuals we assume that no new nuclear plants will be build, and that the existing ones will be put to rest at the end of a 50 years life-span. Thus, we compute scenarios where the power sector has to deal with a short-fall of almost 40% of its benchmark generation capacity, which has been operated at a high and stable availability of around 90 %. We compare counterfactuals which differ with respect of the technologies allowed. We compute the phase-out scenario for counterfactuals where geothermal plants can penetrate the market or gas prices may be 20 % higher than the benchmark predictions.

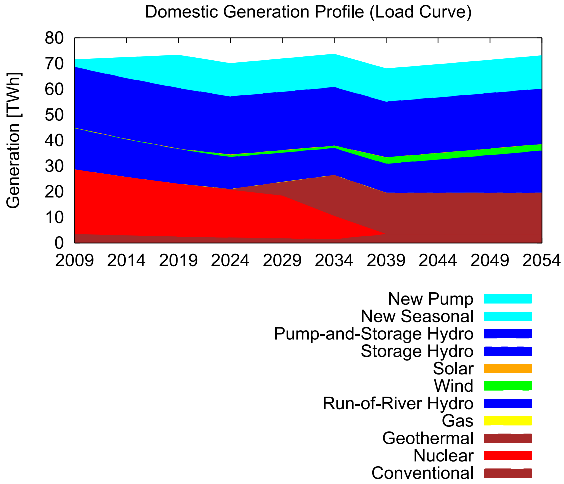

Fig. 1: Generation Mix with Geothermal

Figure 1 displays the generation mix in a sample scenario where nuclear plants are gradually phased-out until 2039, and where large scale geothermal plants are allowed to be build. The presence of a cheap alternative for base load power, makes the associated societal cost smaller. Renewable generation technologies as solar and wind do not gain a large market share in a scenario, where geothermal generation technologies present a cheaper alternative.

(4) Conclusions

Preliminary results suggest that a nuclear phase-out policy that forbids to build new plants and restricts the lifespan of the existing nuclear plants to 50 years does not add much additional cost in a low carbon future. However, availability of cheap alternatives, as large scale geothermal generation units or carbon capture and storage technologies could decrease the cost considerably. We find that conventional gas powered plants may well serve as a 'bridge' technology, but are likely to be too expensive once a severe carbon tax is put in place.

References

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