The Impact of Uncertainty on the European Energy Market: A scenario aggregation approach

Kjell Arne Brekke, Rolf Golombek, Michal Kaut, Sverre A.C. Kittelsen and Stein W. Wallace

1 Overview

Agents in the European energy market face considerable uncertainty. Recently, the region experienced a severe recession with declining energy demand. In the future, climate treaties may have substantial impact on the sector. Such abundant uncertainties can have huge consequences on investments in capacities. At the same time, if there is reluctance to invest in some technologies, for example, due to expectations about high future taxes on emissions of greenhouse gases, the market looks more promising for other technologies, like renewables. Thus to fully analyze the impact of uncertainty, we need to take into account the interdependence of different technologies, energy carriers and end users – this calls for a numerical equilibrium model. But it is not trivial to solve such a model when all agents face uncertainty. Thus it is not surprising that most analyses assume full certainty, or if uncertainty is analyzed, rely on simulations instead of examining agents optimizing under uncertainty.

2 Methods

In this paper we present a simple method to transform a numerical deterministic model where several agents simultaneously make decisions into a stochastic model. We then use this method to transform LIBEMOD, a numerical deterministic multi-market equilibrium model of the Western European energy markets, into a stochastic model. The stochastic version of LIBEMOD is used to analyze the impact of uncertainty on the European energy markets.

In spirit, our approach to modeling uncertainty is similar to the discussion of uncertainty in Debreu's classic 'Theory of Value', where uncertainty is represented by a discrete event tree. In our terminology, each branch of Debreu's event tree is called a scenario. Hence, in our model uncertainty is represented by a set of scenarios. Each scenario is one possible future realization of the uncertainty.

The models presented in this paper have two periods. In period 1, some agents make decisions under uncertainty, typically to determine their future capacities through investments. In the beginning of period 2, the uncertainty is resolved and all agents learn the true state of the economy. Then all agents make decisions; producers determine how much to produce (given the predetermined capacities) and consumers determine how much to consume. For each realization of the uncertainty, that is, for each scenario, the model determines supply of, and demand for, all goods from all agents, and the corresponding vector of prices that clear all markets.

3 Results

When we use the stochastic version of LIBEMOD to analyze the impact of uncertainty, we distinguish between two sources of uncertainty; either there is uncertainty about GDP growth and fossil fuel prices (henceforth referred to as economic uncertainty), or there is uncertainty about future climate policy (henceforth referred to as political uncertainty). The results indicate that uncertainty has a considerable impact on optimal investments. First, investment in electricity transmission is considerably higher when there is economic uncertainty than in the case of no uncertainty. Second, the composition of investment in electricity technologies differs significantly between the case of no uncertainty and the two uncertainty cases (economic uncertainty and political uncertainty). For example, optimal investment in wind power is much higher under economic uncertainty than in the case without uncertainty.

We also compare Monte Carlo simulations to the true optimal solutions under uncertainty. The average of the Monte Carlo simulations is usually closer to the optimal outcome than the deterministic solution (no uncertainty). However, in some cases, and in particular for single countries and single technologies, the average of the Monte Carlo simulations may produce numbers that are far from the optimal ones.

4 Conclusions

Our paper demonstrates that it is possible to solve large computable equilibrium models with significant uncertainty in several variables. Our approach builds on elements of scenario aggregation, a numerical method developed to solve decision problems under uncertainty. Scenario aggregation, and more generally stochastic programming, examines a *single* optimizing agent under uncertainty. Choosing a planner as the optimizing agent, one can find the efficient outcomes of an economy. Our contribution is to use scenario aggregation in order to analyze uncertainty – within numerical multi-market equilibrium models - when *many* optimizing agents make decisions simultaneously. For a given specification of scenarios, our method finds the optimal solution under uncertainty.