Stefan Lorenczik and Raimund Malischek

ON THE IMPACT OF MARKET CONCENTRATION ON INVESTMENT DECISIONS AND SECURITY OF SUPPLY IN ELECTRICITY MARKETS – AN AGENT-BASED ANALYSIS

Stefan Lorenczik: Institute of Energy Economics at the University of Cologne (EWI),
Vogelsanger Str. 321, 50827 Cologne, Germany
Phone: +49 221 277 29 495, Fax: +49 221 277 29 400, e-mail: stefan.lorenczik@ewi.uni-koeln.de

Raimund Malischek: Institute of Energy Economics at the University of Cologne (EWI),
Vogelsanger Str. 321, 50827 Cologne, Germany
Phone: +49 221 277 29 220, e-mail: raimund.malischek@ewi.uni-koeln.de

Overview

Fifteen years ago, the European electricity sector was liberalized and, consequently, electricity grid operation and power production became unbundled. The latter is now organized in a competitive market. In the formerly monopolistic market, investment decisions were not exclusively driven by the need to recover investment costs in competitive markets but also took the aspect of security of supply into consideration. With current markets being arranged solely around an energy-only market, security of supply no longer exists as an explicit target, nor is there an explicit price for it.

Thus the question arises whether energy-only markets are able to incentivise generation companies to build sufficient secured capacity to cover electricity demand at all times (assuming limited elasticity of demand), which is frequently doubted (e.g., due to measures taken to prevent the exertion of market power, see Cramton and Stoft, 2006). This question becomes especially relevant as over-capacities from before the liberalization are diminishing and renewable energies, which provide almost no secured capacity, increasingly penetrate the wholesale energy market, reducing the full load hours of conventional power plants.

We focus our analysis on the revenue opportunities of strategic players on the spot market and the associated investment decisions given different degrees of market concentration using agent-based modelling. Our main contributions are as follows: a) We analyse the potential for price mark-ups above marginal costs assuming different degrees of market concentration under a realistic spot market representation using step-function offer curves, b) we analyse the effect of an increasing share of renewable energies and storage capacities, c) we analyse the interaction between achievable wholesale prices and investment decisions and d) apply our model to the case of Germany.

Methods

Agent-based models have been repeatedly used to model electricity wholesale markets, mainly focussing on different learning algorithms or spot-market designs (see, e.g., Weidlich et al., 2008 for an overview). In contrast to classic approaches assuming either Cournot- or Betrand-like competition, agent-based models are able to represent more realistic market settings. In accordance with current spot market regulations in Germany, we implement supply curve competition using step-function offer curves. More concretely, we implement the spot market learning algorithm proposed and theoretically analysed in Kimbrough and Murphy (2013) and extend their approach by including storage capacities into the model to be able to analyse a more real-world setting.

We combine the spot market model with investment decisions for power plants. Investment decisions are made based on players' risk preferences, previously achievable and observable mark-ups and players' expectations on how these mark-ups will develop over time. In our model, we vary the degree of market concentration and show how these changes lead to different prices, capacity investments and levels of security of supply.

Models including investment decisions in agent-based models are rather rare, with Botterud et al. (2007) and Ortega-Vazquez and Kirschen (2008) being the notable exceptions. We extend their approaches by combining investment decisions with a realistic spot market model that is, in our view, indispensable for the evaluation of investment decisions.

Results

We were able to validate our spot market representation by comparing our results with theoretical models using a simple model set-up. Having only one supplier, prices approach monopoly prices; whereas with an increasing amount of players, prices approach short-run marginal costs. In addition, when calibrated to the German electricity market, our model is able to replicate historic data regarding prices and quantities produced by conventional power plants. Modelled prices show a typical hockey stick shape, with price mark-ups (prices above short-run marginal costs) being low (close to Bertrand prices) when demand is low and mark-ups being high (approaching Cournot prices) if capacity is scarce.

The model reveals, under different assumptions concerning market concentration and agents' spot market behaviour, how investments in generation capacity and thus secured capacities may develop. This enables us to evaluate if and under what circumstances an energy-only market can produce sufficiently high prices to cover long-term generation costs. The increasing share of renewable electricity generation as well as storage capacities reduce the potential to achieve prices above marginal costs and thus reduce the amount of economically advantageous investments.

Conclusions

We show how agent-based models can be applied to real-world market settings which cannot be analysed using game theoretical approaches. We analyse how different degrees of market concentration affect prices (i.e., the ability to exert market power), capacity expansions and security of supply in the electricity market. Ignoring the assumptions generally made in analytical electricity market modelling (i.e., that peak prices are sufficiently high to cover long- and short-term generation costs), we find that sufficiently large generation capacities to cover (almost) inelastic electricity demand are not guaranteed. Strategic (and rationally bounded) market participants making decisions concerning power plant investments with regard to optimising profits on the spot market may underinvest from a social welfare point of view. Revealing potential market malfunctions using agent-based modelling thus can contribute to a better understanding of electricity markets, especially in a setting with an increasing share of electricity produced by renewable energy technologies.

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