Market Design and Investment in Flexible Generation

BY BERT WILLEMS

A low carbon energy system will require sufficient flexible energy resources such as storage, flexible conventional generation and demand response. In an ideal competitive electricity market, market processes will guarantee that those resources are available: Short-run spot market prices become more volatile, which provides firms the correct incentives to invest in flexible energy resources. Electricity markets are however not perfectly competitive. In this project we look at one deviation from the ideal market model: the presence of start-up costs. Those are the additional cost that are incurred during the start-up phase of power plants, which could take several hours for some larger plants. Start-up costs are problematic because they make production costs non-convex. This implies that market equilibria, in which firms make investment and production decision on the basis of market prices, are no longer Pareto efficient. The standard welfare theorems no longer hold.

In practice, markets deal with start-up costs in different ways. In this project we compare two stylized market designs: a European-style power exchange and a North American-style power pool and derive bidding and investment decisions. (See Figure 1).

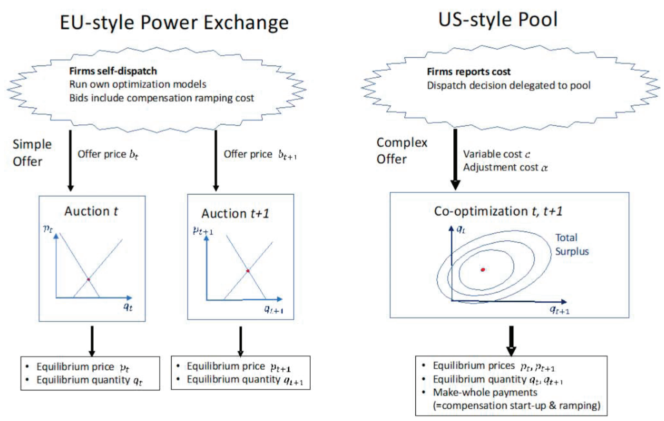

Figure 1: Market Design in a EU-style power exchange (left) and US-style pool operation (right).

In Europe, energy firms offer bids into separate hourly power markets. The auctioneer collects the bids for a particular period, clears the market and determines the equilibrium price. Bids are relatively simple: a bid indicates the willingness to supply electricity at a particular price and is not plant specific. Firms are responsible for scheduling their own power plants, taking into account start-up costs and ramping constraints. Hence, those ramping costs and start-up costs need to be internalized in the price bids.

In most North American markets, firms submit complex bids into a power pool. Those bids are plant specific, and represent the plant's operational characteristics: not only its production costs, but also ramping constraints, minimal production levels, and start-up costs. Those complex bids are collected by the auctioneer who optimizes total market surplus for all operating hours, taking into account all plant characteristics. The optimization model provides production decisions, energy prices and side-payments. Those side-payments are lump-sum payments to firms, to compensate generators for start-up costs. (For an overview on how side-payments can be determined see Liberopoulos & Andrianesis, 2016)

Bert Willems, is an Associate Professor of Economics at Tilburg University, Netherlands, and Research Associate at Toulouse School of Economics. Email: willems.bert@gmail.com

Hence, Europe relies on a simple market model, which requires firms to internalize start-up costs in their bids, whereas North-America relies on a more complex market model, in which firms are directly compensated for incurred start-up costs. We are interested how this different treatment of start-up costs affects investment incentives.

We extend the standard optimal investment portfolio model (See for instance Crew et al., 1995) and introduce start-up costs. It is assumed that firms can invest in a continuum of production technologies that vary from base-load to peak technology (similar to Zöttl, 2010). Each technology is characterized by its marginal cost $c c$, capital cost $k(c) k(c)$ and start-up cost $\alpha\alpha$. As in the standard portfolio model, firms are risk neutral price-takers, and there are no-entry barriers. Demand is price responsive and stochastic. Intra-day demand variation is represented by two representative hours. In the spot market, firms submit bids before demand is realized.

Market outcome

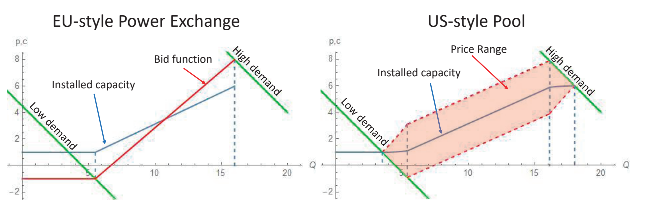

Figure 2: Installed capacity (blue) and possible equilibrium prices (red) for EU-style power exchange (Left) and US-style pool (right). The area in red indicates the set of feasible prices. We assume additive, uncorrelated, and uniformly distributed price shocks.

Figure 2 represents results under both market designs for a particular set of parameters. In an EU-style market design (Figure 2, left) competitive bidders submit offers that differ from their marginal cost (blue). Baseload companies offer below costs as they are likely to be producing in subsequent time periods. Hence they try to avoid incurring start-up costs by bidding low. Peakers offer bids above their costs, as they are unlikely to be producing in subsequent time periods. By bidding higher they are guaranteed to receive a compensation for their start-up costs. The blue line represents the equilibrium portfolio, the industry merit order curve. Investment decisions are such that all technologies make zero profit. In a US-style market design (Figure 2, right), firms bid their marginal cost c c and the adjustment cost $\alpha\alpha$. Equilibrium prices are determined by the auctioneer and depend on the realized demand shocks for both periods. Prices can be above or below the marginal costs cc, depending on the particular combination of shocks. As we have a continuum of small firms in our model side-payments do not arise in equilibrium. Hence, the US-style market design is Pareto efficient. The investment portfolio (blue) corresponds to the free entry equilibrium.

Conclusion

Our initial simulations indicate that the US-style market design leads to efficient short-term operation and optimal investments. The EU-style market design has inefficient short run operation as it lacks coordination of scheduling decisions. This distorts investment levels: Too little is invested in peakers and too much in baseload. In practice the European market design is not as bad as modeled here. Some co-optimization already takes place as firms can submit block bids which cover multiple time periods at once (Meeus et al. 2009); demand shocks are correlated, which reduce coordination failures; and spot markets clear in multiple rounds, which allows firms to learn about market prices. The European market design might also provide larger incentives to invest in lower start-up costs, which in combination with fewer gaming opportunities, might shift the balance in favor of the European market design.

References

Crew, M. A., Fernando, C. S., & Kleindorfer, P. R. (1995). The theory of peak-load pricing: A survey. Journal of regulatory economics, 8(3), 215-248.

Liberopoulos, G., & Andrianesis, P. (2016). Critical review of pricing schemes in markets with non-convex costs. Operations Research, 64(1), 17-31.

Meeus, L., Verhaegen, K., & Belmans, R. (2009). Block order restrictions in combinatorial electric energy auctions. European journal of operational research, 196(3), 1202-1206.

Zöttl, G. (2010). A framework of peak load pricing with strategic firms. Operations Research, 58(6), 1637-1649.

Dual Plenary Session 1: Energy Modernization and Transition

SUMMARIZED BY ANTHONY FRATTO, M.S. CANDIDATE, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

As nations and localities seek to decarbonize their energy system, the policy, experiences, and motivation is critical to understand. These three speakers addressed the role we as economists play, as well as highlighting the issues, and institutional foundations necessary for such an energy transition.

Chris Knittel (Massachusetts Institute of Technology), opened up the plenary emphasizing economists' role in helping influence energy transition policy and goal setting. He asserted that 2nd/3rd best policies should be supported if they are welfare enhancing and their costs are on visible. Furthermore, Knittel noted that it is imperative we complete more work on the effect of these policies on the most vulnerable populations, including a redesign of ratemaking. Economists are critical players in this energy transition, providing key analysis of goals, costs/benefits, impacts. However, Knittel argues, we are not policy makers, and should avoid predicting which policies are feasible but rather stating which ones are welfare enhancing.

ZhongXiang Zhang (Tiajin University) spoke to the experience of China's energy transition, addressing their issues of price elasticity, inflation effects, and the curtailments of wind and solar as they seek a low carbon society. Zhang argues the transition will require regionally coordinated action and institutional innovation. He concluded by offering up a few reforms in China which include liberalizing parts of the coal value chain and establishing a competing power market separate from transmission and distribution.

Lastly, Johanne Gélinas spoke to the role of Transition énergétique Québec in helping Québec reach its energy modernization goals. Québec's energy transition ecosystem includes a carbon market whose monetary returns go into a "Green Fund." This fund is used to address Québec's Climate Action Plan and facilitated by Transition énergétique Québec, who design programs that will reduce GHG emissions and ensure a low carbon Quebec. Québec's future targets include enhancing energy efficiency by 15%, reducing the consumption of petroleum products by 40%, and increasing renewable energy production by 25%.