Designing electricity auctions: Introduction and overview

1. Introduction

The unique defining characteristic of electricity markets is the physical requirement that production and consumption of electricity must balance at all times everywhere in the power system. Imbalances cause costly fluctuations in system frequency, with blackouts as the most visual consequence. In regulated markets typically a large vertically integrated utility upholds system balance by optimizing dispatch and transmission. In a liberalized (restructured) electricity market, one cannot rely on the market solution to guarantee instantaneous system balance. Market interaction is not frequent enough to yield continuous market clearance. Because of structural separation between production and transmission, no single producer has the power to correct imbalances on its own. Usually a system operator is called upon to secure short term balancing of the market, in some cases by utilizing reserve capacity. With the continuing intervention of the system operator in the allocation of resources, liberalized electricity markets are best described as markets with managed competition. To facilitate system management and dispatch optimization, wholesale electricity markets are organized around a set of rules formalizing the bidding procedures and resource allocations. This is the *auction design*.

What are the boundaries of the market in a system with strong requirements on centralized management of power flows, production and consumption? To what extent can decisions be decentralized to market participants? Increasing shares of volatile intermittent energy production place additional strain on the transmission system and on alternative production sources to absorb the fluctuations. Are the current balancing markets designed to handle extreme short-term fluctuations? Do wholesale electricity markets provide ample investment signals, or is it necessary to introduce additional capacity markets? If so, how should these markets best be designed?

In Sweden and elsewhere, a perpetual discussion revolves around whether electricity producers make excessive profits at the expense of consumers. Electricity markets are vulnerable to the exercise of short run market power because demand is price insensitive, and production is concentrated to a small number of firms. How do electricity markets really perform? And if markets are susceptible to the exercise of market power, are there more efficient auction designs which distribute more of the surplus to consumers?

The answers to these questions are far from obvious, as witnessed by the numerous auction designs circulating in the universe of liberalized electricity markets. To get a grip on the issues, the Research Institute of Industrial Economics (IFN) assembled a group of world leading researchers on electricity markets in Stockholm, September 2009 for the two-day workshop “Designing Electricity Auctions”. The purpose was to discuss policy implications for the design of electricity auctions in the light of recent scientific findings. The seven papers collected in this Special Issue are the outcome of this workshop.

2. Overview of the papers

The first paper, *Three-part auctions versus self-commitment in day-ahead electricity markets*, by Ramteen Shioshansi, Shmuel Oren and Richard O’Neill studies the efficiency of decentralization. The paper compares two simulated models of the New England electricity market (ISONE), the first with centralized dispatch, and the other is a competitive model with decentralized dispatch. Shioshansi, Oren and O'Neill report substantial production inefficiencies in competitive equilibrium. This result is surprising as decentralization alone should not be the cause of any distortions. According to the first theorem of welfare economics, competitive markets are efficient. No centralization is required because all necessary information about opportunity costs is contained in the prices faced by producers and consumers. As it turns out, a portion of the recorded inefficiencies are due to inappropriate auction design, not decentralization. In accordance with how most power exchanges operate, electricity prices are linear in the decentralized model. All electricity at a single location in a single trading period is sold at the same price. Most generation units incur start-up costs. In competitive equilibrium, the lowest average cost generators are dispatched first because the generators require a price equal to average cost to be willing to produce. Ranking generators according to average cost is not efficient in all situations. Since production is bid into the market in steps, it is sometimes necessary to ration supply at the market clearing price. Shioshansi, Oren and O'Neill show that inefficient peak load units sometimes replace efficient base load units under rationing in decentralized equilibrium because the former have lower average costs at low volumes. This production inefficiency does not arise under centralized dispatch because the generators do not need to recover all costs through the market. By assumption, the system operator can compensate startup costs separately and therefore does not rank the generators in order of increasing average cost. These results indicate that some of the inefficiencies of decentralized electricity markets can be mitigated by adopting auction designs with more sophisticated pricing policies, for example by allowing non-linear electricity prices in situations of supply rationing.

The second paper, *Production inefficiency of electricity markets with hydro generation*, by Andy Philpott, Ziming Guan, Javad Khazaei and Golbon Zakeri examines the effects of decentralization in a market where a large share of production comes from hydro generation. In a hydro power facility the main production cost is the opportunity cost of not being able to release the hydro power to the market in the future, the water value. To assess market performance, hydro markets must be examined with this inter-temporal aspect in mind. Philpott et al. present the results of a hydro simulation model of the New Zealand wholesale electricity market (NZEM). A main finding is that the (simulated) centralized dispatch model delivers systematically lower reservoir levels across the year than what is observed in reality. The market appears much more conservative in releasing water than what would be the case under centralized dispatch. As a consequence, real production costs are higher than under centralized dispatch because fossil fuel power plants replace hydro production in the decentralized market. With the current model it is not possible to determine whether market performance reflects supplier risk-aversion or if the higher costs represent a real inefficiency as a result of strategic manipulation of hydro production, say.

In the third paper, *Are the British electricity trading and transmission arrangements future-proof?* Richard Green questions whether the current auction design can efficiently handle the large scale wind and infrastructure investments necessary to meet the UK renewable target. In the UK, as well as many other liberalized electricity markets, electricity prices are uniform within the boundaries of the market. Prices are only allowed to fluctuate over time. Locational price signals would facilitate short term production planning and guide the location of new production and transmission facilities, but are missing. Instead, shortages are handled by the system operator outside the centralized market. Green voices his skepticism to this implicit solution. He simulates the UK electricity market and predicts large fluctuations in wind power production. In particular, extreme supply shortages will occur that need to be backed up by reserve capacity. As they will operate only a few hours per year, these new facilities would require extreme prices in order to be profitable - price levels that the current system does not allow. Green argues in favour of the "US standard auction design" with locational prices and capacity markets as a solution to the challenges facing the UK.

In the fourth paper, *Using forward markets to improve electricity auction design*, Lawrence Ausubel and Peter Cramton propose a forward capacity auction to facilitate private investment in plants whose main purpose is to clear the market under extraordinary demand or supply conditions. Building those types of plants are extremely risky investments. Prices would then have to soar in those rare occasions when their production was in demand for the risky production facilities to be profitable. For political reasons electricity prices often are capped, either explicitly by a price ceiling or implicitly by utilization of the system operator's reserve capacity. In a forward capacity auction, the regulator reduces investor risk by making upfront payments for the production of new capacity. The auction format minimizes expected production cost by awarding the contract to the lowest bid. Whoever gets to build the capacity then signs a *call option* with a physical requirement for the regulator to exercise if expected electricity prices are sufficiently high, i.e. in periods of scarce supply or excess demand. The strike price of the call option effectively places a cap on spot market electricity prices.

In the fifth paper, *Virtual power plant auctions*, Lawrence Ausubel and Peter Cramton give an account of a particular kind of forward contract, the virtual power plant. The product is an option which gives its holder the right to utilize a certain amount of an incumbent's production. Forcing an incumbent to sell off parts of its production allows new firms to enter into the market without having to invest in physical capacity, hence the name virtual power plant, VPP. In addition to facilitating entry, the VPP should induce the incumbent to behave more competitively in the wholesale market because it now receives a fixed price for a share of of its production. Ausubel and Cramton review a common format for selling VPPs, the ascending clock auction, and discuss design choices for the auctions. Based on the experiences from France in particular, Ausubel and Cramton conclude that VPP auctions indeed are effective tools for facilitating new entry and for developing wholesale markets, but the scale of the auctions has so far been too small to have had a serious impact on market concentration.

The sixth paper, *The supply function equilibrium and its policy implications for wholesale electricity auctions*, by Pär Holmberg and David Newbery surveys the economic theory of wholesale electricity auctions. They analyze the effects on auction performance of market concentration, forward contracting, and restrictions in the offer curves. In particular, Holmberg and Newbery demonstrate that changing the bidding format from a uniform price (all suppliers receive the same price) to pay-as-bid (every supplier's remuneration depends on its offer curve) may not have particularly large effects on average prices. Under pay-as-bid suppliers inflate their offer curves to avoid being stuck with low prices in low demand situations. The more competitive is the market, the less important becomes the choice of bidding format.

The seventh paper, *Using restructured electricity supply industries to understand oligopoly industry outcomes*, by Frank Wolak takes a broad perspective to electricity markets and argues that many determinants of competition in concentrated markets can be fruitfully analyzed in wholesale electricity markets. Well defined market rules determine the strategies available to the market participants, supply bidding yields information behaviour - even out of equilibrium, and rich data sets allow detailed empirical testing. Armed with this superior information, the empiricist can relax many of the restrictive assumptions underlying empirical studies of other oligopoly markets. Wolak shows how electricity markets can be used to test the fundamental assumption of profit maximization, measure market performance and estimate the market impact of mergers. Generation companies do seem to maximize expected profits, producers exercise market power under the right conditions, and forward markets are important for mitigating market power.

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