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Market design and supply security in imperfect power markets

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ABSTRACT

Supply security in imperfect power markets is modelled under different market designs. In a uniform price auction for electricity with two firms, strategic behaviour may leave firms offering too few capacities and unable to supply all realized demand. Market design that relies on capacity markets increases available generation capacities for sufficiently high capacity prices and consequently decreases energy prices. However, equilibrium capacity prices are non-competitive. Capacity markets can increase security of supply, but cannot mitigate market power, which is exercised in the capacity market instead of the energy market.

1. Introduction

During the last two decades most industrialized countries have deregulated their electricity sector and thereby introduced a more decentralized approach to investment decisions and to security of supply. The extent to which liberalized power markets can ensure a secure supply of energy has been discussed ever since. Large-scale blackouts, as for example substantial supply breakdowns in Europe and North America during the last decade, stress this debate's relevance.[1] In today's power systems, increasing shares of renewable intermittent power sources add further uncertainty to investment decisions, and thereby highlight the need for a functioning power market design even further.[2]

The regulatory debate over supply security resulted in a variety of different market designs across power systems. Although market designs differ, virtually all electricity markets are, to different degrees, characterized by dominant generating firms. The relation between strategic firm behaviour and supply security, and how market design affects this relation, is largely unexplored. While a large strand of literature analyses market power in power markets, most studies on supply security assume competitive markets.

This article analyses the effects of market design on supply security in imperfect power markets. It first stylizes the two main competing power market designs: the energy-only market and the capacity market design. While up to now in Europe mostly energy-only markets exist, in a majority of U.S. markets regulators rely on various forms of capacity mechanisms.[3] Energy-only markets rely on high peak-time prices to induce sufficient investment. Due to inelastic demand, regulators cap energy prices, however only at an estimated value of lost load which usually lies several hundred times above the marginal costs of peak generation technologies. In the capacity market design, regulators introduce significantly lower price caps to constrain high energy price spikes in order to protect consumers. To account for the low price cap, regulators implement capacity mechanisms that find a price for available capacity and thereby reward available generation regardless of whether or how much these capacities produce. In an ideal world, capacity markets generate rents that level out all missing revenues that result from the price cap in the energy market, stimulate new generation capacity despite the price cap, and reduce market power and price volatility in the energy market during times of peak demand.

Previous contributions to the relation of market design and supply security led to ambiguous conclusions. Hogan (2005) argues in favour of energy-only markets. He states that arguments for capacity mechanisms merely assume that pure energy-only markets are politically not feasible as they allow for high price spikes. Also Oren (2000) finds that capacity mechanisms are the least desirable tool to enhance power market reliability. He concludes that risk management and price hedging tools, including demand side participation, yield efficient investment. On the contrary, Cramton and Stoft (2005) and Cramton et al. (2013) argue that capacity markets, if well designed, hedge energy market risk, suppress market power and avoid regulatory risk. Similarly, Besser et al. (2002) find that capacity markets lower peak-time prices and decrease price and reliability risks for consumers.[4]

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[1] See The International Energy Agency (2005).

[2] See The International Energy Agency (2007).

[3] In Europe, the introduction of capacity markets is currently debated, as for instance in the 2013 EC DG Energy public consultation on “Generation adequacy, capacity mechanisms and the internal market in electricity”.

[4] Arguments for capacity markets differ from those for standard forward markets as first put forward by Allaz and Villa (1993), whose setting is not directly applicable to the capacity market context. While in their analysis the same commodity is traded in the forward and in the spot market, on capacity markets the commodity is capacity itself instead of energy that eventually is traded in real-time.

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Joskow and Tirole (2007), however, derive that energy price caps and exogenous capacity payments cannot re-enforce an optimal market outcome when generating firms instead of the regulator alone choose the amount of capacity obligations. In a similar vein, Meunier and Finon (2007) model a game between firms and the power system operator, and show that otherwise under-investing firms increase their investment when being faced with the threat of system operator intervention; they find that the system operator cannot restore the long-run optimum in this way. Creti and Fabra (2007) explicitly model capacity markets and, focussing on the monopoly and the competitive case, derive opportunity costs of committing capacity to the home market instead of selling it to foreign markets.

Motivated by the fact that most electricity markets are oligopoly or duopoly markets, and that concerns of underinvestment are especially valid with only few generating firms, this article introduces dominant firm behaviour on both the energy and the capacity market. The model used for the analysis relies on a duopoly auction framework. Production capacities are given and constrained, and thus allow for strategic firm behaviour. Market entry in the long run, possibly resulting in Bertrand competition is neglected. Hence, the capacity market modelled here should be interpreted as contracting capacity in the short or medium term. The goal of this article is to ask to what extent energy-only markets can deliver security of supply, and how capacity markets may affect energy markets when generating firms behave strategically on both the energy and the capacity market.[5]

The findings show that imperfect energy-only markets indeed can result in a shortage of supply if firms are relatively similar in size. In this case capacity withholding becomes attractive and firms may free-ride on each other to satisfy residual demand, indicating a public good nature of supply security. By contrast, for a wide range of asymmetric firm sizes, the free-riding effect disappears and energy-only markets cover the full support of stochastic energy demand. In this case, the largest firm in the market has an incentive to avoid blackouts by offering sufficient capacity to satisfy all possible realizations of demand. In both cases, equilibrium energy prices exceed marginal costs.

In the environment studied, aggregate available market capacities in energy-only markets are independent of the energy price cap. Capacity withholding only depends on each competitor's offered quantity but not on the level of the energy price cap. This result suggests that lifting otherwise constraining price caps is not effective vis-á-vis tight generation capacities. Capacity mechanisms remain as an alternative instrument to ensure sufficient supply.

When capacity markets are introduced to counteract a potential shortage of supply, capacity withholding is relaxed and energy prices decrease. However, equilibrium capacity prices are non-competitive and include a mark-up that compensates for any loss of market power in the energy market. This mark-up depends positively on the energy price cap because the energy price cap increases energy market profits, and for higher energy market profit generating firms require higher mark-ups in the capacity market to leave their energy-only market optimum and supply additional capacity. This finding contradicts the perception that capacity mechanisms are a costless tool to decrease market power during peak times and to stimulate additional generation capacity. Within the framework studied, equilibrium capacity prices are always below the value of lost load, and therefore might tempt regulators to implement capacity markets and insure against system outages. As capacity prices in equilibrium however are non-competitive and do not accurately reflect capacity scarcity relative to the demand for capacity, regulators are likely to then bias and compromise on correct signals for the entry of new firms.

The remainder is organized as follows. Section 2 briefly stylizes the energy-only and the capacity market approach and highlights the differences between both market designs. Section 3 presents a duopoly model for energy-only markets and derives energy prices and firm-individual and aggregate generation capacities. Section 4 analyses the capacity market design by deriving capacity market equilibrium conditions and by examining resulting effects on the energy market. Section 4 also discusses resulting market design implications and different options for the procurement of available capacity. Section 5 draws relevant policy implications and concludes.

2. The market design problem

In energy-only markets, energy is traded. High demand induces high and volatile price spikes that signal profitability of new capacities. In addition, high prices encourage the demand side to consume less power during peak times. However, traditionally consumers are not able to properly react to price signals. Due to inelastic demand, price caps are imposed on energy-only markets, usually at the estimated value of lost load. Today, for example the Scandinavian NordPool and the Australian national electricity market are following this pure market approach.

In the capacity market design, energy markets are price-capped at significantly lower levels, often at or around marginal costs of peaking units, but then joint by capacity mechanisms. Energy and capacity are rewarded.[6] The price cap lowers the energy price and price volatility. However, to maintain sufficient and reliable energy supply despite the price cap, the regulator or the system operator (SO) sets a critical required capacity level that has to be available on the energy market and ready for dispatch in real-time. The SO procures capacity to meet this requirement, and then resells this capacity to retailers, who are obliged to buy capacity proportional to their customers' demand.[7] If generation capacity is scarce, such capacity mechanisms generate extra rents that in the ideal case level out all forgone peak unit profits when market prices are capped and in an energy-only market would be above the price cap. Capacity that is contracted in the capacity market is rewarded regardless of whether these units actually produce energy or not. However, rewarded capacity commits to be available and thus becomes a relevant strategic variable for the energy market.[8] The regulatory rationale of capacity mechanisms hence lies in securing sufficient generation capacity via rewarding idle capacities on secondary markets, while at the same time abolishing market power and high energy price spikes via energy price caps.[9]

Although capacity markets in practice are more elaborate than described above, their existence always distorts the energy price and accordingly influences all energy forward markets. The SO's decision on the available capacity requirement becomes the main driver of the energy market outcome. Depending on the system, the SO obliges retailers to purchase capacity ranging between 110 and 120% of their individual expected peak load. Stoft (2002) refers to installed capacity requirements generally being around 118% of expected peak load.

3. The energy-only benchmark

The model for the energy-only benchmark relies on Harbord and von der Fehr (1993), Fabra et al. (2006) and Fabra et al. (2011). Related

[5] In the following analysis supply security is referred to as the relation of available capacities to maximum energy demand, neglecting prices, or price volatility.

[6] For an overview of reliability mechanisms see Batlle et al. (2007). For a general overview of electricity market structure, see Wilson (2002).

[7] Often retailers have the option to buy capacity on their own, but have to notify the SO about the amount they bought forward, before the SO is procuring all remaining capacity as a single buyer on the capacity spot market.

[8] The timing of such commitments differs. In the New York capacity market, for instance, capacities clear monthly and commit to be available and bid into the energy market during the following month. In the New England capacity market, in contrast, cleared resources oblige to provide capacity several years ahead.

[9] Power demand is highly volatile and sufficient capacity has to be ready for dispatch at all time to cover real-time demand. Otherwise consumers have to be rationed and in extreme cases black-outs occur. Thus capacity markets reward generation capacity and ensure instantaneously balanced grids at the same time, as also mentioned by Stoft (2002).