ACTIVE INTRATEMPORAL PROSUMER BIDDING

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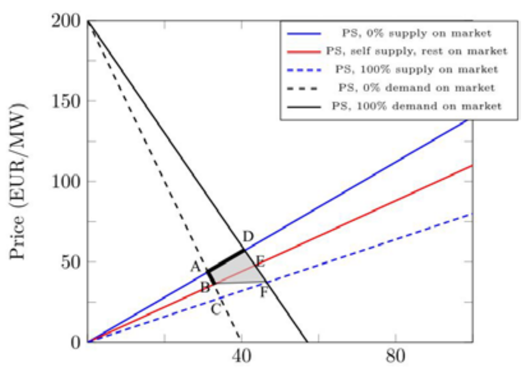
Overview

This paper is based on three recent and still ongoing developments in the electricity market: firstly, we can observe an increasing decentralization of generation, additionally sped up by steadily decreasing investment costs for e.g. photovoltaic systems or electricity storage units (Hanna et al. 2017). Secondly, the ownership structure is also changing from the traditional system of several owner firms towards generation being owned and operated by small agents, like e.g. homeowners, farmers, or small businesses (NYISO 2017). And thirdly, with regard to high feed-in-tariffs the most profitable strategy was to offer 100% of the produced electricity on the markets; however, with decreasing tariffs and increasing retail electricity prices, this strategy may no longer be optimal (Oberst and Madlener 2014). This means that an active decision about whether to offer the generation on the markets or to use it for one's self supply can be substituted for the previous "passive" strategy. In comparison to models based on the idea that demand and/or supply can be shifted in time from low price zones to high price zones or vice versa, we focus on the additional possibility to decide for each bidding period about the optimal bids, hence: intratemporal.We relax the common assumption of price taking and argue that the industry's aggregate demand and supply functions can be rotated by the prosumer by strategically offering or withholding load and supply capacity, thus creating several windows of opportunity for actively and profitably bidding into the market. Requirements for this to be possible are, firstly, the possibility to participate and bid into a market. And secondly, a market maker who aggregates load and supply bids and determines a market clearing price, like e.g. the day-ahead market of EPEX SPOT or the secondary control market of the Austrian transmission system operator APG (APG 2017).

Methods

In our general model we set up linear functions to depict the aggregate industry demand and supply curves, as they are bid e.g. into the day-ahead market. We introduce two decision variables: a) quantity produced for self supply, and b) quantity produced for market supply, with which the prosumer can influence the market clearing price (see Figure below). Key assumptions are the existence of one prosumer, complete information about the competitive fringe, that the prosumer's generation cost and willingness to pay are lower or equal to the respective industry maximum, constant prosumer demand C_{dem}^{PS}, and no transmission congestion (copper plate). In addition, we explicitly allow for capacity withholding and we relax the price taking assumption.



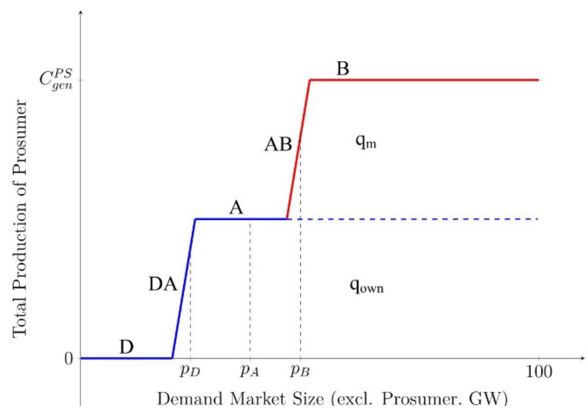
In the first part, based on the profit function below, we analytically derive conditions for interior solutions:

$$\pi^{PS}_{(q_m^{PS}, q_{own}^{PS})} = \underbrace{p^* q_m^{PS}}_{\text{revenues}} \underbrace{-(p^* + trans)(C_{dem}^{PS} - q_{own}^{PS})}_{\text{costs for demand}} \underbrace{-c^{PS}(q_m^{PS} + q_{own}^{PS})}_{\text{costs of generation}}$$

where $p^*(q_m^{PS}, q_{own}^{PS})$ is the market clearing price, q_m^{PS} and q_{own}^{PS} are the decision variables, c^{PS} and C_{dem}^{PS} are the prosumer's production costs and demand, and *trans* is the retail price markup. Since the decision variables are constrained, we solve the problem using the according Karush-Kuhn-Tucker conditions. In the second part we use hourly supply and demand day-ahead EEX bid data from 2014-2015 to estimate hourly elasticities based on Bigerna and Bollino (2014). We use these results to calibrate the linear functions of our model in order to calculate the profit advantage of active prosumption for different scenarios of prosumer's demand C_{dem}^{PS} and production costs c^{PS}.

Results

In our general setup, two cases must be distinguished: a prosumer's generating capacity exceeding her demand, $C_{gen}^{PS} > C_{dem}^{PS}$, and vice versa. In the former, we find two windows for profitably adjusting q_m^{PS} and q_{own}^{PS} (line sections DA and AB, see Figure below), and one window in the latter, both depending on residual market demand.



The impact of active prosumption, i.e. the size of these windows, increases when residual market demand and supply are smaller, i.e. when the prosumer controls a larger market share. Moreover, the general profitability of the prosumers' strategies depends on the difference between the retail and wholesale prices which means that the activity of prosumers on a market can be influenced or regulated indirectly by in- or decreasing this difference e.g. via transmission charges or taxes. The empirical calibration of our analytical model yields information on the distribution of this profit advantage according to possible prosumer's production costs c^{PS} and according to time again depending on the hourly size of market demand (keeping industry's production capacity fixed).

Conclusions

Translated to market structures, designs based on Locational Marginal Pricing allows for the highest benefits of this active prosumer strategy since load pockets can be used by the prosumer to generate additional profits. Also, the effect of active prosumers resembles the strategy of physical capacity withholding; i.e. a careful analysis with regard to market power is necessary especially when multiple prosumers are aggregated and their decisions are coordinated.

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