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Harmonization of the European balancing power auction: A game-theoretical and empirical investigation

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ABSTRACT

The shift towards renewable energies is accompanied by great volatility on the supply side, demanding European-wide instead of national balancing services. For the integrated European procurement of balancing reserves, the European Commission proposes a multi-attributive auction mechanism which is very similar to the current German auction. The key difference, however, is a switch from pay-as-bid to uniform pricing. We develop a game-theoretical model of the current German and the future European balancing market design. Both market designs have desirable economic properties in their one-shot version, i.e., an efficient auction outcome and competitive prices. We show that a switch to uniform pricing does not induce bidders to report their true costs in their bids, but leads to underbidding. We contrast the equilibrium outcomes with German market data and find a substantial discrepancy, i.e., non-competitive prices. We provide a game-theoretical grounded explanation that is based on the regular repetition of the auction combined with the invariant supplier side.

1. Introduction

The European-wide goal of increasing the share of final energy consumption from renewable sources to 30% by 2030 has a substantial impact on the volatility of the electric energy (henceforth energy) supply (European Commission, 2016). The reason for this is that the shift towards renewable sources (mainly wind and solar) comes along with a less predictable energy production. In consequence, the requirements for the European power grid change tremendously, in particular, it must react highly flexible on supply deviations. Therefore, European-wide ancillary services for the power grid become increasingly important and mandatory. Here, especially the stability of the power grid frequency at 50 Hz needs to be ensured: If the grid frequency deviations are too extreme (upwards and downwards higher than 0.2 Hz), area-wide power outages occur and generators connected to the grid are damaged due to a disharmonious operation. Therefore, the most important short-term ancillary service is balancing power, ensuring immediate stability of the power grid frequency by balancing the power demand and supply.

One way to further increase the flexibility of the European power grid is the harmonization of balancing power markets. Here, first cooperations of transmission system operators (*TSOs*) have already been established across Europe. For example, since 2011 eight European countries participate in the so-called "International Grid Control Cooperation (*IGCC*)" which enables the netting of a certain demands for balancing power across the participating countries.[1] Opposite and unnecessary activations of balancing power

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[1] The IGCC refers to Primary balancing power. The participating countries in the IGCC are: Austria, Belgium, the Czech Republic, Denmark, France, Germany, The Netherlands, and Switzerland.

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are avoided, resulting in financial benefits of around 300 Mio. Euro since 2011 (Transnet BW, 2016).[2] Therefore, the extension of the current IGCC to a European-wide and completely integrated cooperation is sensible in terms of supply reliability and financial savings. Yet, this makes a common market design indispensable. Ocker et al. (2016) show that there is no predominant design for balancing power markets, but a great heterogeneity across Europe. It is for this reason that the European Commission gives instructions for harmonized markets (entso-e, 2017; European Commission, 2017). These markets are organized as multi-attributive procurement auctions, as it is usual in most international countries (e.g. Bushnell and Oren, 1995; Chao and Wilson, 2002; Ocker et al., 2016). Within these auctions, prequalified suppliers compete for the provision of balancing power: They submit bids that indicate the costs for keeping balancing power available to the grid, and are awarded accordingly.

However, there is empirical evidence for imperfections in the current European balancing power markets. In particular, the regular repetition of the auctions and the required prequalification of suppliers facilitates collusion. In Germany, for example, suppliers not only abused their market power (Heim and Götz, 2013), but also successfully coordinated on non-competitive price levels (Ocker and Ehrhart, 2017). The case of Germany becomes even more important, since the future European market design is very similar to the current German.

Against this background, the European Commission (2017) implements two essential design modifications: First, the pricing rule is to be switched from pay-as-bid (*PaB*) to uniform pricing (*UP*), and second, an additional market after the regular auction is to be implemented. The former shall incentivize bidders to report their true costs in their bids, and therefore – in comparison to PaB – generate efficient auction outcomes. The latter shall guarantee a higher degree of competition (e.g. German Federal Ministry for Economic Affairs and Energy, 2015; Morch and Wolfgang, 2016; European Commission, 2017).

In order to assess whether the future market design is appropriate, the understanding of the auction mechanism is crucial. Since auctions are a subfield of game theory, a game-theoretical model is necessary. However, such a model seems to be lacking for any (European) balancing power market design. Therefore, we present such a model for both the current German auction and the future European auction. We analyze the market institutions with regard to their game-theoretical equilibria, and hereby concentrate on the two essential policy targets: efficiency and market prices. We find that the market equilibrium in the applied German auction has all desirable theoretical properties. The modifications in the future European auction have no impact on this equilibrium. In particular, UP does not induce bidders to truthfully report their costs in their bids. On the contrary, UP sets undesirable incentives: bidders understate their costs in their bids. The additional market after the regular auction, however, is sensible to foster competition and therefore impede collusive behavior.

The remainder of this paper is structured as follows. Section 2 provides a brief overview of related literature, and Section 3 offers an introduction to balancing power markets. Section 4 presents our game-theoretical model. In Section 5, we discuss the theoretical properties of the one-shot auction under different market designs. Section 6 confronts theoretical findings with empirical data from Germany, and Section 7 extends the analysis to results of repeated games. Section 8 concludes and illustrates further need for research.

2. Related literature

Since (repeated) balancing power auctions are complex market mechanisms, the presented analysis is based on and draws from complementary streams of research.

First, our work relates to the general research on multi-unit auctions. In a balancing power auction, the auctioneer (i.e., the regulator or TSO) demands multiple goods (i.e., multiple units of reserved power).[3] The related literature on single-unit auctions is elaborated and many aspects are also relevant in the context of energy markets. Information acquisition (Gretschko et al., 2014), information disclosure (Bergemann and Wambach, 2015), collusion (Skrzypacz and Hopenhayn, 2004; Hortacsu and Puller, 2008), competing sellers (McAfee, 1993), sequential auctions (Hörner and Jamison, 2008) etc., are well-understood. However, compared to single-unit auctions, the bidders' strategy spaces are considerably larger and richer in multi-unit auctions. In particular, it is often challenging to find unique equilibria even with symmetric bidders, since strategic supply reduction becomes an issue.[4] Furthermore, the insights of single-unit auctions do often not extend to multi-unit auctions. This paper provides a specific multi-unit model for balancing power markets. We thereby concentrate on the upcoming challenge of implementing harmonized European balancing power markets.

Second, we consider scoring auctions. In scoring auctions, other attributes than the price (multi-attributive) are considered for the evaluation of bids (Che, 1993; Branco, 1997; Asker and Cantillon, 2008, 2010). For example, for the construction of highway roads, it is of equal importance how fast and at what price a road is built (Herbsman et al., 1995). Therefore, a rule is to be defined that considers all parameters that are of relevance for winner determination. Bichler and Kalagnanam (2005) represent such scoring auctions through integer programming problems. The effects of different payment rules and auction settings are analyzed in David et al. (2006). Regarding balancing power markets, Bushnell and Oren (1995) and Chao and Wilson (2002) investigate different scoring auctions from a theoretical standpoint. In more detail, they describe essential elements for scoring rules to ensure an efficient allocation. Yet, the analyses do not consider strategic interactions of the bidders. In our work, the interdependencies between bidders are modelled with the help of a game-theoretical approach.

Third, this paper contributes to the discussion of pricing rules in auctions. In multi-unit auctions, there are typically two rules for pricing the winners of the auctions, namely PaB or UP. If PaB is applied, winning bidders pay (in sell-auctions) or receive remunerations (in buy-auctions) that are equal to their bids. On the contrary, if UP is applied, winning bidders pay (receive) a uniform payment that is usually based on either the highest rejected bid or the lowest accepted bid. There is a controversy debate in scientific literature whether one of the pricing rules is superior (e.g. Milgrom and Weber, 1982; Kremer and Nyborg, 2009; Ausubel et al., 2014). This also transfers to energy markets. Kahn et al. (2001) examine whether a shift from UP to PaB is appropriate for the Californian power market, and argue that changing the pricing rule does not yield efficiency gains. Federico and Rahman (2003) investigate the change from an auction with UP in the wholesale market to PaB. Son et al. (2004) analyze UP and PaB mechanisms in a power market by presenting the strategic behavior of a big player and a small player in a short-term auction game. Regarding the design of balancing power markets, Müsgens et al. (2014) argue that UP is superior to PaB, since it minimizes strategic behavior among the suppliers. However, this argumentation does not build on a game-theoretical

[2] The IGCC did not encompass a fully integrated market until now, i.e., an Austrian supplier cannot offer balancing power in the French market boundlessly and across all balancing power qualities. Further information is available at www.regelleistung.net/ext/static/market-information?lang=en.

[3] For examples of multi-unit auctions, see Ausubel et al. (2014).

[4] For an overview, see Ausubel et al. (2014) and for the relevance in energy markets see Wolfram (1997).