Do Pay-As-Bid Auctions Favor Collusion? Evidence from Germany's market for reserve power

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Do Pay-As-Bid Auctions Favor Collusion? Evidence from Germany's Market for Reserve Power*

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Abstract

We analyze a drastic price increase in the German auction market for reserve power that did not appear to be driven by increased costs. Studying the market structure and bidding strategies using micro-level bidding data, we find a concentrated market with highly pivotal suppliers in an environment with completely inelastic demand and high entry barriers. We provide descriptive evidence that the price increase was triggered by an abuse of the "guess the clearing price" principle of discriminatory auctions via repeated pretended "bad guessing" of the marginal bid by the most dominant supplier. As intentional "bad guessing" of marginal bids is hard to prove, this suggests that the auction design is crucial for the competition authority's monitoring power – an issue that is often neglected in the discussion on the properties of auction designs. In fact, given regulatory threats, the deemed main advantage of pay-as-bid auctions over uniform price auctions and the popular belief that they reduce dominant suppliers' withholding incentives and diminish their ability to tacitly collude may be questioned in non-static settings. This suggests that pay-as-bid auctions may not necessarily reduce incentives for strategic capacity withholding and collusive behavior, but can even increase them when market power is high and demand inelastic, which is the case in virtually all energy markets.

Keywords: Auctions, Collusion, Market Power, Energy Markets, Reserve Power, Balancing Power

JEL Class: D43, D44, D47, L11, L13

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1 Introduction

Electricity markets are typically highly vulnerable to the abuse of market power due to inelastic demand and high market concentration. This makes their market design in general and their auction design in particular crucial to achieve efficient outcomes. Especially when bearing in mind that already little market design flaws result in tens of millions of extra costs, the evaluation of gaming incentives under different auction designs appears extremely important. It is therefore not surprising that academics as well as policymakers intensively debate on wether a uniform-price (UPA) or a discriminatory price auction (also called pay-as-bid auction, hereinafter PABA and PAB, respectively) is more appropriate in preventing electricity markets from market manipulations. Even though the UPA has several well-known crucial advantages over the PABA (e.g. Cramton and Stoft, 2007), it is widely agreed that the PABA is less prone to collusion and strategic supply reduction. However, this is not necessarily the case. By analyzing the German reserve power market we identify market conditions under which the contrary may be true.

In this paper we use unique bidding data at the firm-level which we received from the German Federal Network Agency (Bundesnetzagentur) to analyze a drastic price increase that took place in the market for secondary reserve power in Germany between 2009 and 2010.[1]

This price increase was puzzling for several reasons. First, it was not driven by increased cost as there were no similar movements on the electricity wholesale market, which represents the opportunity costs for power plants eligible to provide reserve power. Second, the number of market participants has increased in recent years due to several market design modifications aiming to increase competition and liquidity in Germany's market for reserve power.

To investigate the price increase, we analyze the market structure and the individual bidding strategies in the context of the present PABA design. Our findings suggest that the price increase was triggered by an abuse of the "guess the clearing price" principle of discriminatory auctions via repeated pretended "bad guesses" of the marginal bid. As intentional "bad guesses" of marginal bids are hard to prove this suggests that the auction design is crucial for the competition authority's monitoring power – an issue that is typically neglected in the discussion. Furthermore, it demonstrates the absurdity of the "guess the marginal price" idea

[1] In Germany as in the whole ENTSO-E (European Network of Transmission System Operators for Electricity) area there are three different qualities (and thus markets) of reserve power: Primary Reserve, Secondary Reserve and Tertiary Reserve (also called minute reserve).

in discriminatory auctions in an environment with pivotal players, inelastic demand, repeated auctions and the ex-ante knowledge about demand. While the first three characteristics can be found in virtually all energy markets, validity of our findings for energy markets in general depends on the degree of demand uncertainty.

To the best of our knowledge this is the first paper providing empirical evidence on abusive behavior in a PABA organized electricity market and thus shows that the widely shared belief that this settlement system prevents collusion and strategic capacity withholding problems is not necessarily true – on the contrary: PABA can even increase such problems. As there is a vast array of literature on auctions it is somehow surprising that one additional important difference between uniform and discriminatory pricing has been largely neglected: the competition authority's ability for legal prosecution. To our knowledge only Kahn et al. (2001) mention the greater transparency of bidding behavior under a UPA in detecting collusive or quasi-collusive pricing as "another possibly important difference". In the remainder of this paper we will show that this difference may be crucial for the detection and prosecution of abusive market power.

2 Literature

Literature dealing with the efficiency of reserve power markets is rather scarce. Most articles examine pricing in the minute reserve market and consider the level of integration with the spot market as measure of efficiency (Growitsch et. al, 2007; Müller and Rammerstorfer, 2008; Growitsch and Weber, 2008). Swider and Weber (2007) model optimal bidding under price-uncertainity in reserve power markets with discriminatory auctions. However, each supplier only offers a single bid with a probability of acceptance instead of a discrete supply curve and potential collusive behavior and pivotal power are not studied. Growitsch et al. (2010) analyze market power in the minute reserve market and find a tight oligopoly and a high concentration. As the market for minute reserve power is the most competitive reserve power market by far due to less restrictive participation requirements and due to that a higher number of suppliers, it is likely that the market for secondary reserve power is even more susceptible to market power problems. For the more specific case of secondary reserve power Just and Weber (2008) model the interdependencies between the secondary reserve market and the spot market to derive the pricing of reserves under equilibrium conditions. They provide a numerical solution procedure for this case of market interaction. Using an application of this model Just (2011) investigates the optimal duration of reserve power contracts in reserve power markets. Related to the Just and Weber (2008) paper Richter (2011) studies the problem analytically and proves that a unique efficient competitive equilibrium exists. Both articles assume competitive markets, thereby abstracting from the potential existence of market power and non-competitive bidding behavior. However, as mentioned above it seems doubtful that markets are competitive. Furthermore, auctions are modeled as UPA although they are actually PABA. Though this should not affect prices in a competitive environment, we will show later that auction design becomes an important factor when market power comes into play.

Since at least two decades scholars as well as policymakers debate on whether UPAs and PABAs are more appropriate to achieve efficient market outcomes in electricity markets. The two types differ in the way succesful bids are remunerated. In an UPA all successful bids typically receive the price of the marginal bid (first-price auction) regardless of their actual bid price. By contrast, in a PABA each successful bid gets exactly paid its bid price. While all electricity markets have been organized as UPA until the beginning of the millennium, this changed with the 2001 England and Wales electricity market reform (New Electricity Trading Arrangements, NETA)[2] and the associated adoption of a PAB settlement. The British energy regulator Ofgem (Office of Gas and Electricity Markets) initiated this switch due to a weak market performance hoping that incentives to exercise market power would be reduced considerably in a PABA. However, the switch was just one of many simultaneous changes in the market which hampers attempts to isolate single effects.[3]

For similar reasons the California Power Exchange also considered a switch from uniform to discriminatory pricing in 2001. However, the proposal was rejected after a commission of leading auction economists had argued against the PABA (Kahn et al., 2001). Even though the UPA clearly has several crucial advantages over the PABA (e.g. Cramton and Stoft, 2007), it is well known that this remuneration principle provides incentives for large companies to exercise market power by withholding some share of their capacity when demand is high as the merit order curve gets increasingly steep while demand for electricity is extremely inelastic in the short term. Thus, by withholding some generation capacity large suppliers can increase the market clearing price and thus the remuneration for all succesful bids without actively

[2]In 2005 the Scottish market joined the NETA which changed its name to BETTA (British Electricity Trading and Transmission Agreements) afterwards.

[3]Evans and Green (2004), Fabra and Toro (2003) or Bower (2002) and Newberry (2003) all differ in their conclusions.

raising their bid prices. Hence, in an UPA supply reduction may be a profitable strategy for large players as it may make expensive peak load units necessary to meet demand. By contrast, withholding capacity constitutes a risk for the respective supplier in discriminatory auctions as the supplier must additionally raise the prices for all bids and thereby has more to lose when underestimating total supply in the market.

Several empirical studies provide evidence for abusive capacity withholding in UPA. Joskow and Kahn (2002) have find abusive capacity withholding in California, Wolak and Patrick (2001) and Wolfram (1998) observe similar behavior in the England and Wales market. With regard to the California electricity market Cabral (2002) suggests that a switch from UPA to PABA would reduce much of the market power created by strategic capacity withholding and marginal plant overbidding. Similarly, Hudson (2000) argues that discriminatory auctions may potentially reduce instances of strategic capacity withholding. Holmberg (2009) states that withholding capacity can not be optimal in a PABA since suppliers have incentives to bid under the price cap and that the risk of collusion is lower in a PABA.

In a theoretical model with repeated divisible goods auctions Fabra (2003) shows that the UPA facilitates collusion more than discriminatory auctions and Fabra (2007) argues that the UPA is more vulnerable to the abuse of market power in electricity markets. Klemperer (2002) argues along similar lines and states that in electricity markets collusion is harder in a PABA because bids cannot longer be used as costless threats. In their comparison of the two auction formats Federico and Rahman (2003) conclude that a switch from UPA to PAB would generally reduce market power. However, the authors state that on the other hand such a switch would diminish entry probability of small suppliers as they cannot free-ride anymore on high prices caused by large players' bidding behavior. Their results are derived by assuming demand uncertainty for the cases of perfect competition and monopoly, however, abstracting from interaction. In the context of oligopolist interaction they argue that "on the basis of existing results from multi-unit auction theory, switching from UPA to PABA may have significant effects in this case, by changing the nature of competition from Cournot to Bertrand with an associated reduction in market power." With regard to the relationship between collusion and the auction's remuneration pricniple, they argue that due to aggressive infra-marginal bidding UPA facilitates collusive outcomes relative to PABA. Dechenaux and Kovenock (2007) analyze tacit collusion in repeated multi-unit auctions and assume a symmetric oligopoly when firms faces capacity constraints. They find that collusion is easier in UPA than in PABA and capacitiy withholding may be necessary to sustain this result.

In their seminal paper Ausubel and Cramton (2002) and in a recent extension (Ausubel et al., 2014) claim that UPA can lead to inefficiencies since it provides incentives for supply reduction while by contrast this incentive does not exist in a discriminatory auction. However, they conjecture that this is not necessarily an argument against UPA since the exercise of market power favors smaller bidders in UPA. The reason is that in an UPA smaller companies also benefit from the abuse of market power by larger companies while they do not automatically benefit from a higher marginal bid price in a PABA. Müller and Rammerstorfer (2008) use similar arguments in an analysis of the auction design in reserve power markets.

Our findings are somewhat in constrast to the cited theory but in line with the patterns found in an experimental study by Rassenti, Smith and Wilson (2003). The authors summarize that "Under the conditions of cyclic and revealed inelastic demand, the DPA (Discriminatory Price Auction) invites sellers to tacitly collude, coordinating their offers without explicit communication at the highest previously observed price in a similar period. Having established that such coordination is not present in the UPA, our experiment demonstrates that it is the incentive structure of the DPA institution that promotes this tacit collusion."

3 The reserve power market

To ensure a continuous supply of electricity one has to take into account the special nature of electricity. First, electrical energy is a grid-connected good which is not storable in an economic way. Second, the maintenance of an equilibrium between electricity fed into and withdrawn from the grid is required at each point in time. If this condition is not met, the grid frequency deviates from the default value which may cause widespread blackouts. However, deterministic and stochastic imponderables permanently lead to unavoidable imbalances between electricity production and consumption.[4] Thus, the peculiarity of non-storablity means that balancing produced and consumed electricity is only feasible through realtime adjustments of generation and/or consumption.

In Germany as in entire Europe the responsibility for a stable grid operation is centralized and lies with the transmission system operators (TSOs) and the continuous balancing of frequency deviations is one of their major tasks. TSOs therefore have to stockpile flexible reserves

[4]E.g. unforeseen power plant outages, incorrect prediction of consumer load or forecast errors of intermittent renewable energy production.

generation capacities and activate them in the case of need. We will refer to these capacities hereinafter as reserve power.[5]

3.1 Reserve power

There are two types of reserve power that utilization depends on the system's net imbalance. *Negative reserve power* is activated if generation exceeds consumption. This can be done either by reducing generation or by the activating additional load. In order to provide negative reserve power a power plant has to be already online and must operate above its must-run level.[6]

Similarly, in the case of electricity deficits in the grid, positive reserve is activated by increasing electricity production or cutting consumer load, e.g. a steel smelterey stops the production for some hours. In Germany as in virtually all European markets, reserve power is classified in three different qualities (and subsequently three different auction markets) with regard to their activation and response time, namely *primary reserve (PR)*, *secondary reserve (SR)* and *tertiary reserve* (also called *minute reserve*, hereinafter *MR*).[7]

Their activation order follows a hierarchical substitution: PR balances deviations within seconds. It restores frequency immediately and subsequently is substituted and complemented by SR after a maximum of 30 seconds. SR has to reach full response within 5 minutes. In the case of persisting system failures the TSOs activate MR within 15 minutes, thereby releasing PR and SR capacities and making them available again for further imbalances. TSOs attract reserve power in a separate market which is organized as a web-based procurement auction. However, participating in the reserve power market requires generation plants to fulfill high technical standards which they have to prove in so called *prequalifications*. Due to these requirements only a few types of plants are eligible to provide their capacities as reserve power. Furthermore, it is costly and lasts up to one year for a electric utility to go through the prequalification procedure until it can provide reserve power. This indicates that reserve power markets are not very competitive and thus susceptible to problems arising from market power.[8]

It is important to note that the amount of reserve capacity tendered by the TSOs is computed

[5]There is a long list of synonymously used terms such as control power/energy, regulating power/energy, balancing power/energy or reserve capacity.

[6]Pumped storage power plants represent an exception as they can provide negative reserve power by pumping water from a lower basin to a higher basin and thus participate on the demand side. Due to their fast response time they can provide the negative reserve power without being already online.

[7]A good overview is provided by the 2012 ENTSO-E survey.

[8]According to the German Federal Network Agency's 2011 monitoring report there were 8 suppliers of PR, 11 for SR and 28 for MR in 2011. The German Monopolies Commission stated in their 2007 special report power and gas, that they do not expect effective competition in the markets for PR and SR in the foreseen future.

on the basis of stochastic criteria (i.e. shortfall probabilities) and serves as an ancillary service. As this ancillary service is essential for the functioning of the system, TSOs are legally obliged to procure the reserve capacity reserve in order to ensure a determined level of supply security – regardless of the price. Thus, a TSO's demand for reserve power is fully inelastic. Moreover, because plant outages and incorrect load prediction were the main sources of net imbalances until recently, the rising share of fluctuating renewable energy in total energy generation is expected to significantly increase forecast errors of electricity generation and hence the demand for reserve power. In other words: an efficient reserve power market design becomes increasingly important.

3.2 The market design

In most European countries reserve power markets are organized as procurement auctions. The main difference is the auction's settlement method which is either PABA or UPA.[9] In Germany the reserve power markets are organized as PABA due to the expectation that this makes them less vulnerable to the abuse of market power.[10]

While MR auctions take place day-ahead right before the spot market auctions of Europe's leading energy exchange, the EEX (European Energy Exchange), those for SR and PR took place on a monthly basis during the observation period.[11]

Each bid consists of a bidden capacity and two price components (multi-part auction): the capacity price serves as a capacity option and remunerates the succesful bids for keeping the capacity available, thereby acknowledging the fact that the same capacity can not be sold twice and thus is dead for the spot market trade. By contrast, the second component, the energy price, is only paid when the reserves are actually activated. In a well-functioning market capacity prices should reflect opportunity costs such as foregone spot market profits while energy prices should mirror the actual generation costs. Bids are selected solely on the basis of their capacity price. TSOs accept the lowest bids required to cover demand (multi-unit auction). The successful bids are then activated in the order of their energy prices if there are imbalances. As suppliers can submit multiple bids by splitting their available capacity, one speaks of divisible good auctions. Moreover, suppliers do not bid plants but capacities

[9] See Rivero et al. (2011) for a comparison of the different auction designs in several European countries.
[10] According to §8 of the Electricity Network Access Ordinance (StromNZV).
[11] This changed in June 2011 with the adoption of a weekly auction for PR and SR. Beforehand, until December 2007, they took place biannually.

and in the case of need they decide in a short-term portfolio optimization which plants they should activate. Furthermore, no supplier has any information on the other suppliers' offers which makes it a sealed-bid auction. As TSOs publish the required reserve capacity before the auctions take place, there is no uncertainty about the total demand on the supplier side.

4 Price increase during observation period

Several adjustments of the market design and the requirements for the participation in the market have been implemented during recent years, aiming to reduce entry barriers and increase intensity of competition. The creation of a uniform market for secondary reserve, realized with the start of the German Grid Control Cooperation (GCC), can be considered as the most important change since the adoption of the common web-based procurement auction in December 2006 (tertiary reserve) and December 2007, respectively (primary and secondary reserve).[12]

Indeed, although secondary reserve has already been procured jointly in a common tender since 2007, the four TSOs had to balance their control areas independently of one another which caused an uncoordinated balancing between them. As this permanently led to situations in which positive reserve power was needed in a certain control area while at the same time negative reserve was called in another one, there has been inefficient capacity utilization beforehand which resulted in an excessively high provision of reserve capacity. These inefficiencies were eliminated in May 2009, when three of the four German TSOs started the GCC; it was completed in May 2010 with the accession of the fourth TSO Amprion.

Even though it was expected that these modifications will contribute to increase competition, the German Federal Network Agency was confronted with a sharp rise of prices for negative secondary reserve in the nighttime (SR Neg NT), which almost tripled in the time span between January 2009 and December 2010. This sharp rise was surprising as at the same time there were no notable developments on the wholesale market for electricity which serves as a substitute market for the owners of prequalified units. The development of the prices for SR Neg NT and the electricity wholesale prices (EPEX spot prices) are illustrated in Figure 1. Moreover, there was an increase in the number of market participants from 5 to 8 between 2009

[12]Beforehand the four German TSOs had to procure reserve capacity for their control areas individually. With the implementation of a web-based procurement auction in December 2007, the four formerly divided reserve capacity markets were transferred into a common unified market with joint tenders.

and 2010 in the SR Neg NT market suggesting that competitive pressure has increased.[13]

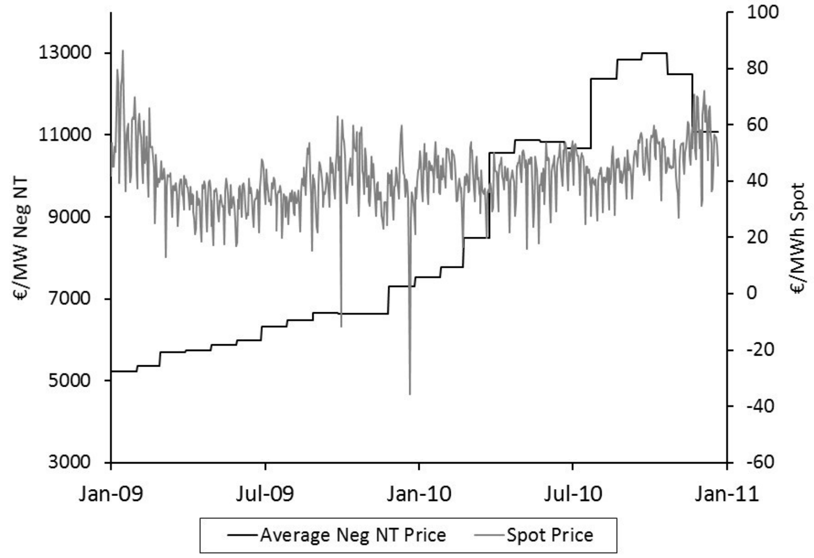

Figure 1: Price development for Neg NT and Spot

Also, as can be seen in Figure 2 the drastic price increase was accompanied by a temporary decrease on the supply side which caused situations in which the TSOs were not able to cover the demand for SR Neg NT. Putting it differently, the capacity tendered by the TSOs exceeded the total capacity offered in the auctions. This observation was also surprising for the following reasons: the demand for reserve power is fully inelastic, the reserve power auctions take place before the start of the spot market auctions (and thus are not already tied up in the spot market and, last but not least, the German Federal Network Agency had no information on technical restrictions of prequalified plants in this magnitude for the relevant period.

[13]Unfortunately, a (marginal or opportunity) cost estimate cannot be accomplished as information on the prequalified units is confidential. Moreover, as mentioned earlier, bidders do not bid plants but capacities The German Federal Cartel Office tried to collect data of the activated plants for the 2011 sector inquiry; however suppliers were unable to reliable reconstruct the activation procedure ex post, especially in the case of negative reserve.

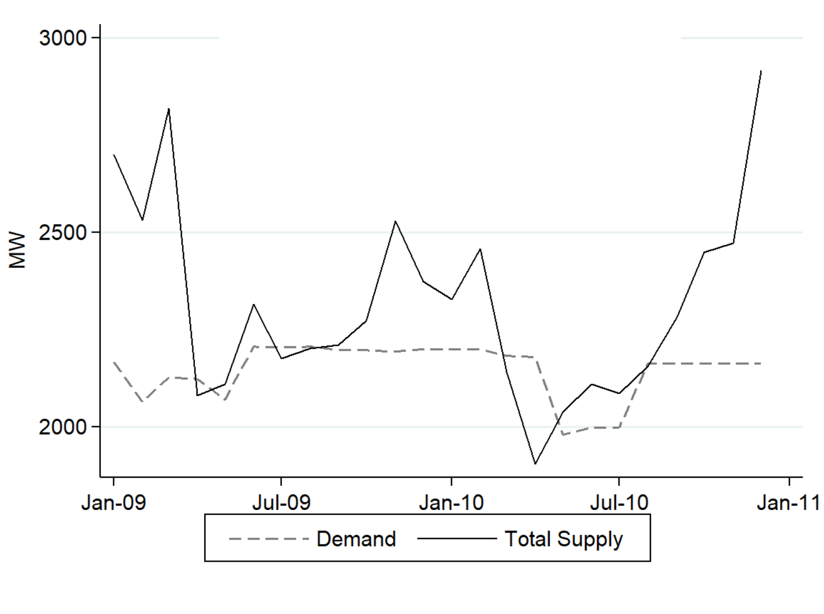

Figure 2: Development of liquidity in the market for negative secondary reserve during the night-time (Neg NT)

As the development of wholesale prices did not suggest that the price increase of SR Neg NT was caused by increased costs, the Federal Network Agency provided us with anonymized bidding-data for the relevant years 2009 and 2010 in order to deeper examine this development.

Using this unique dataset we investigate the degree of market power and the observed bidding strategies trying to figure out if there are signs pointing towards collusive behavior in the course of this paper. We analyze market structure and market power in a first step and examine individual bidding strategies afterwards.

5 Data and summary statistics

The data provided by the German Federal Network Agency contain detailed bid information for the 24 monthly secondary reserve power auctions that took place in 2009 and 2010.[14] In total we have firm-specific but anonymized information for all 3,958 bids from the four SR products: Positive SR in the night-time (Pos NT), Positive SR in the day-time (Pos DT), Negative SR in the nicht-time (Neg NT), and Negative SR in the day-time (Neg DT). Each bid consists of the anonymized firm name (e.g. supplier 1, supplier 2. . .), bidden capacity in MW, charged

[14]Unfortuantely, more recent data are not available. The data used in the paper are confidential and were provided to us by the German Federal Network Agency back then to analyze the drastic and unexplainable price increase. After we provided our analysis to the German Federal Network Agency the market rules have been changed in that only accepted bids get published now. Despite the fact that the market rules have changed in order to prevent the observed phenomenon in the future we have still tried hard to get more recent data. However, we could not get more recent data, particularly due to the veto of the involved suppliers of reserve power.

capacity price, charged energy price, corresponding month and status of acceptance (yes/no). For negative reserve power in the night-time (Neg NT) we have individual data for 978 bids. Due to the observed price increase, our analysis focuses on this reserve product. The data enable a detailed analysis of market power and individual bidding strategies. Table 1 shows the descriptive statistics. The bids had an average volume of 56.9 MW, however, varying in a wide range from 10 MW to 500 MW. In some auctions every bid was accepted. The number of participants per auction varies between 5 and 8 with 5 at the beginning and 8 at the end of the observed period. The new entrants, however, can be assigned to the competitive fringe as they are very small and in total only sum up to less than 5% of the total capacity offered in the market.

Table 1: Summary statistics for negative secondary reserve in the nighttime.

	mean	min	max	std. dev.
Bid size in MW	56.9	10	500	61.2
Capacity charge in €/MW	9811.4	3990	27996	3477.5
Number of suppliers	6.5	5	8	1.1
Bids per month	40.75	20	76	15.1
Share of accepted bids in %	92.2	61.8	100	0.092

6 Empirical Analysis

6.1 Market Power

Conceptually, market power represents the ability of one or more firms to influence prices in their favor and thereby realize higher profits. The traditional method for measuring market power in energy markets is via concentration indices.[15] The most common indices of this kind are the Herfindahl-Hirschman-Index (HHI) which for instance is used by the US Department of Justice and the Federal Trade Commission in their Horizontal Merger Guidelines, and Concentration Ratios (CRn) of the n suppliers with the highest market shares. The latter one for instance is used in the German Act against Restraints of Competition (GWB) to identify dominant market players. Although the explanatory power of such measures is viewed critically in

[15] Schmalensee and Golub (1984).

the context of energy markets, we start our analysis with the computation of the Herfindahl-Hirschman Index (HHI) and the Concentration Ratios (CR) to provide a first indication on the market structure.[16] The HHI is calculated by summing up the squared market shares of all suppliers multiplied by 10.000. The HHI on the basis of individual turnovers has a value of 2,674 and is thus above the critical values of 1,800 and 2,500, respectively, which define a highly concentrated market.[17] The CRns measures the joint market shares of the n largest players. The CRs indeed point towards a high market concentration and the critical values are always exceeded as shown in Table 2.

Table 2: Concentration ratios and critical values for the market for negative secondary reserve in the nighttime.

	CR1	CR3	CR4	CR5
Concentration ratio for negative Secondary reserve in the nighttime (Neg NT)	0.37	0.84	0.95	0.98
Critical values	0.33	0.50	0.67	0.67

However, as energy markets differ fundamentally from conventional goods in many regards, the explanatory power of concentration based indices may be fairly limited. The main critique is their static perspective. Energy demand varies during the day, so that even if concentration is not very high on average, there are hours in which a substantial level of concentration exists. Furthermore, market-share based indices only consider the supply side. This ignores that even for low HHI and CR values some suppliers can have significant market power if the quotient of demand and available capacity is small and price elasticity of demand is low.[18] Figure 2 shows that this is clearly the case in the observed market and in some auctions total supply is even below total demand.[19]

To address these properties, further measures are additionally used to quantify market power. The Pivotal Supply Index (PSI) is a binary index and measures the percentage share of auctions in which a certain supplier is essentially needed to cover demand, and thus is called pivotal. The results of the PSI are depicted in Figure 3. The PSI reveals Supplier 5 (S_5) as most

[16]Despite substantial criticism most regulatory and competition authorities apply market-share based indices such as CR or HHI (e.g. FERC or the German Federal Cartel Office).

[17]While in the US Horizontal Merger Guidelines the critical HHI value was raised from 1800 to 2500 in 2010, most economic articles still use 1800.

[18]See Borenstein et al. (1999) for a discussion on the weakness of concentration measures in the electricity sector.

[19]When TSOs cannot cover demand a second auction is conducted. Nevertheless, they still were not able to attract sufficient reserve capacity in some cases.

dominant supplier since it is pivotal in all auctions. Suppliers 2 (S_2) and 10 (S_{10}) are both pivotal in over 80 percent and Supplier 1 (S_1) is pivotal in over 60 percent of all auctions. Although the aggregated fringe suppliers make up just 5 percent of the revenue based market share according to the Concentration Ratios displayed above, they are pivotal in one out of two auctions.

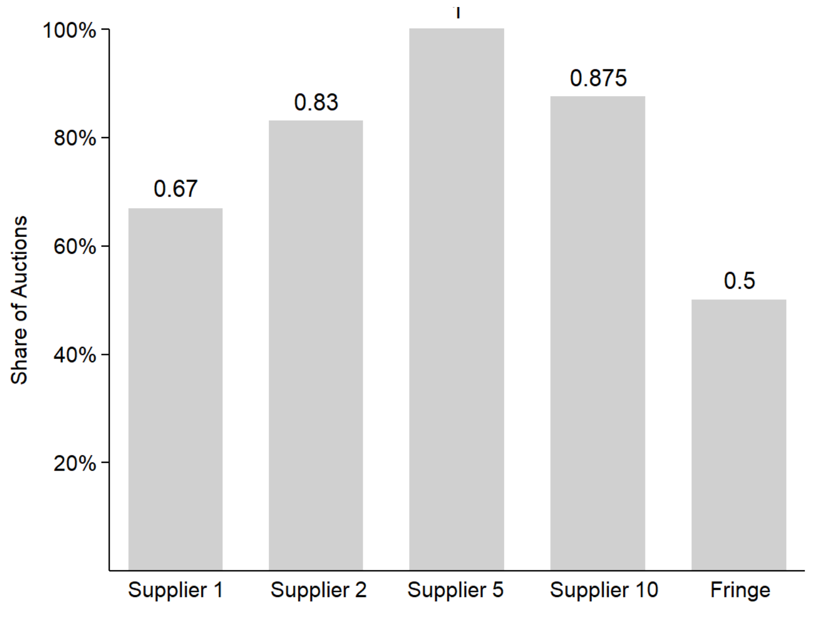

Figure 3: Pivotal Supplier Index (PSI)

A continuous variation of the PSI is the Residual Supplier Index which measures the percentages of the total demand which can be covered after deduction of a certain supplier j's capacity with $RSI_j = \frac{\sum_i^n Supply_i - Supply_j}{TotalDemand}$ and suppliers $i = 1, ..., n$ with $j \in i$.[20] Whereas PSI only reveals whether a certain supplier is pivotal or not, the RSI displays the individual degree of pivotal power.[21] The RSI outcomes are illustrated in Figure 4. Again, S_5 appears as the most dominant player and is pivotal for almost up to the half of the price-inelastic demand in some auctions. Moreover, its RSI value is always above 75 percent which makes him pivotal for at least a quarter of demand. The RSI additionally reveals S_2 as the second most dominant supplier. Although the existence of market power must not necessarily cause its exercise, it clearly offers opportunities to behave strategically. We therefore analyze individual bidding strategies in greater detail in the next section.

[20]e.g. Sheffrin (2001), Sheffrin (2002a), Sheffrin (2002b).
[21]Twomey et al. (2004) provide a good overview on methods to measure market power in electricity markets.

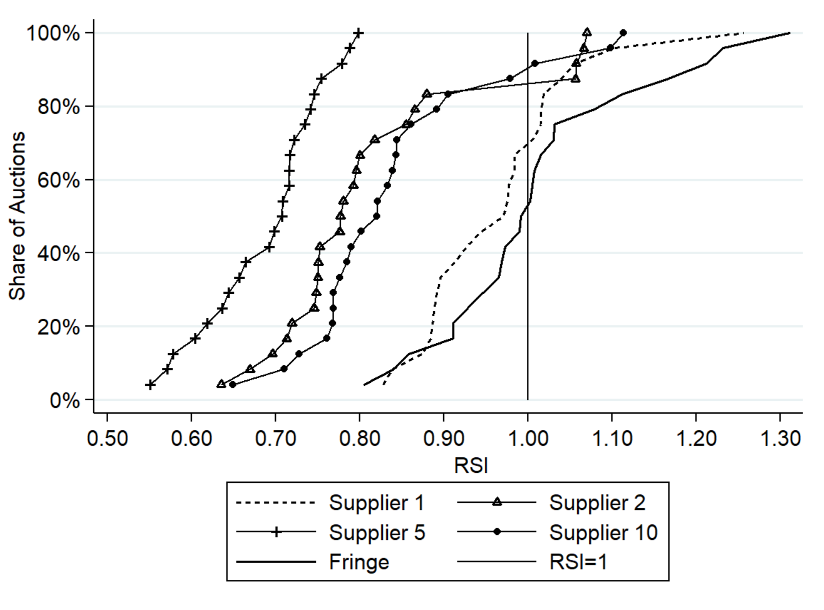

Figure 4: Residual Supply Index (RSI)

6.2 Price and Bidding Strategy Analysis

Pay-as-bid inherently yields to individual prices for every bid. Whereas in a uniform-price setup price-taking suppliers have strong incentives to charge marginal or opportunity costs, they are forced to deviate from that tactic in discriminatory auctions. However, bidding above marginal costs has nothing to do with exercising market power in a PABA. To maximize their profits and cover their investment costs suppliers have to try to bid as close as possible below the expected marginal price even in a perfectly competitive environment. For this reason, it is often argued that bidding in discriminatory auctions corresponds to the "guess the marginal price"-principle.

A first indication of unilateral exercise of market power is provided by considering individual average prices per MW. Table 3 reveals that the most dominant suppliers S_2 and S_5 achieve significantly higher prices than both S_1 and S_{10}.[22] Moreover, S_5 and S_2 supply the highest capacity on average, however, they differ considerably in their bidding strategies. Whereas S_5 only supplies a small number of bids but with high capacity, S_2 chooses the contrary strategy with a multitude of little volume bids. We will closer investigate this phenomenon later on. Furthermore, S_2 sets the marginal price in the vast majority of all auctions.

[22]The even higher average prices of the fringe suppliers are due to their later entries when prices were already on a higher level.

Table 3: Supplier specific descriptive statistics for the Neg_NT auctions

	S_1	S_2	S_5	S_{10}	*Fringe*
Supplied capacity per auction (MW)	247.9	570	840	516.8	58.9
Bid size (MW)	65.4	43.4	148.1	39.4	12.7
Accepted capacity per auction (MW)	245.5	493.9	753.1	503.2	50.49
Quant. weighted capacity charge (€/MW)	7 083	8 908	8 559	7 813	10 515
Bids per auction	3.8	13.1	5.7	6.8	4.6
Variance of asked bid prices per auction	136.9	1 897.1	579.3	605.9	628.4
% of auctions where supplier X determines the marginal bid	0	58.3	16.7	4.2	20.8

In the next step we consider the development of the market's liquidity. It turns out that the significant reduction in liquidity and the related bottleneck was mainly triggered by the most dominant supplier S_5, that had meanwhile reduced its supply by more than half of its initial volume from 1,294 MW to 595 MW (Figure 5). This also explains the sharp horizontal shift of the RSI values of all suppliers except of S_5 in the upper region of Figure 4.

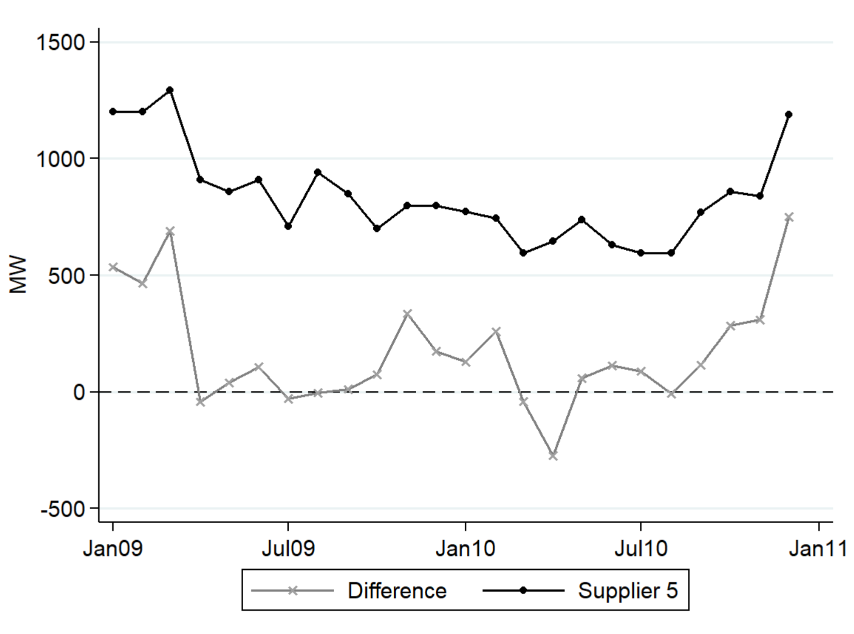

Figure 5: Development of Supplier 5's supply and difference between total supply and demand

S_5's reduction in supply resulted in situations in which the TSOs were not able to procure the tendered demand. In these auctions every bid was accepted due to completely inelastic demand. However, it is clear that a supplier does not have to reduce supply in order to increase prices for its pivotal capacity. If it wants to achieve higher prices, it can just charge them and bids still get awarded. The crux is that a regulatory authority monitors the market and if a pivotal supplier unilaterally raises its prices, this would be suspicious and could possibly lead to the opening of abuse of market power procedures. In fact, charging prices above marginal costs (often called financial or economic capacity withholding) is in principle forbidden to dominant suppliers at the EEX, which is organized as UPA.[23] The alternative and more popular (because less detectable) abusive withholding strategy in UPA is physical or quantity withholding.[24] The main advantage of abusive physical withholding is that suppliers do not have to increase their prices themselves but rather let the market do this job. Thus, those firms that charge high prices at the margin need not to be the ones exercising market power but may just have higher marginal costs. Nevertheless, their bids only get awarded due to the fact that beforehand a dominant firm has bidden less than its available capacity and thereby has shortened total supply abusively. Both types of withholding are subject to exploitative abuse.[25]

There are two potential explanations: S_5's capacity was either withheld abusively or was not available due to technical restrictions. Initially, abusive withholding may seem unlikely as the limited possibility to exercise market power by withholding capacity is considered to be the main advantage of discriminatory auctions as stated above. Besides the claimed reduction of incentives for collusive behavior, it is the main reason why discriminatory auctions are implemented and even determined by law in several reserve power markets that are thought to be particularly vulnerable to market power problems (Vandezande, 2011).

However, the German Federal Network Agency also had no information on technical restrictions or plant outages of prequalified plants in this magnitude for the relevant period and ruled out a capacity reduction due to unavailability. Thus, despite the claimed advantage of PABA regarding the minimization withholding incentives, abusive withholding remains the only explanation for the capacity reduction.

In the next step we uncover the individual bidding strategies showing that strategic capacity withholding may still be a profitable strategy when certain market characteristics are met.

We start by examining the overall marginal prices and the most expensive accepted bids of the most dominant suppliers S_5 and S_2, to which we will refer to as the marginal price of

[23]According to the interpretation of the German Federal Cartel Office of Act against Restraints of Competition (GWB) §§19, 29 and Art. 102 Treaty of the Functioning of the EU (TFEU) in the 2011 Sector Inquiry.

[24]As it is hard to identify whether a bidder shortens supply due to technical restraints or rather withholds quantity abusively, estimating marginal costs is the easier task.

[25]§19 GWB and Art. 102 TFEU.

S_5 and S_2 hereinafter. They are illustrated in Figure 6. Two conspicuities can be pointed out: S_2 determines the overall marginal price in most of the auctions, especially in the initial phase of the price increase. Furthermore,S_5 seems to set its individual marginal prices according to the previous period's overall marginal price and thus basically follows the lagged individual marginal prices of S_2. This procedure is highlighted in Figure 7 which depicts S_2's and S_5's individual marginal prices lagged by one period.

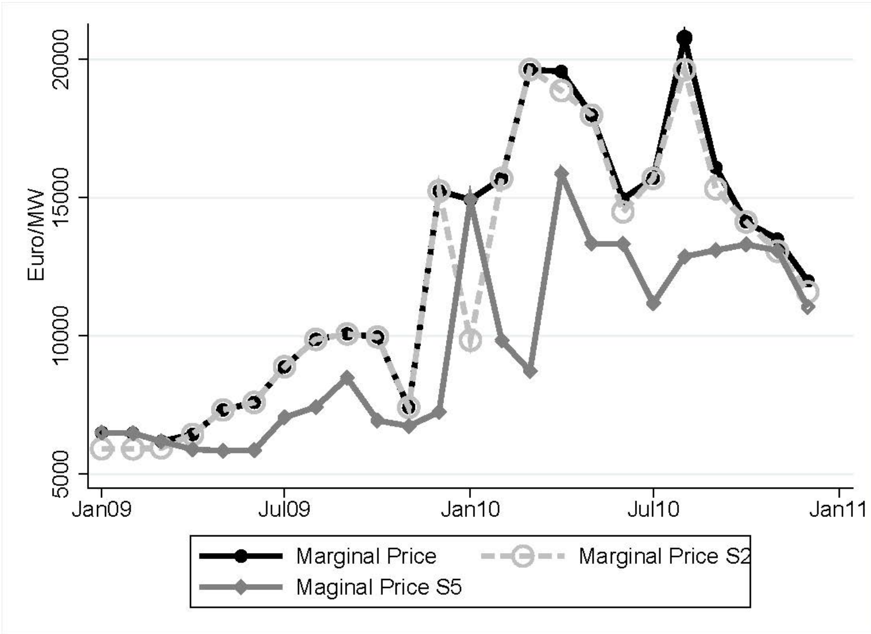

Figure 6: Development of overall marginal prices, marginal prices of Supplier 2 and marginal prices of Supplier 5

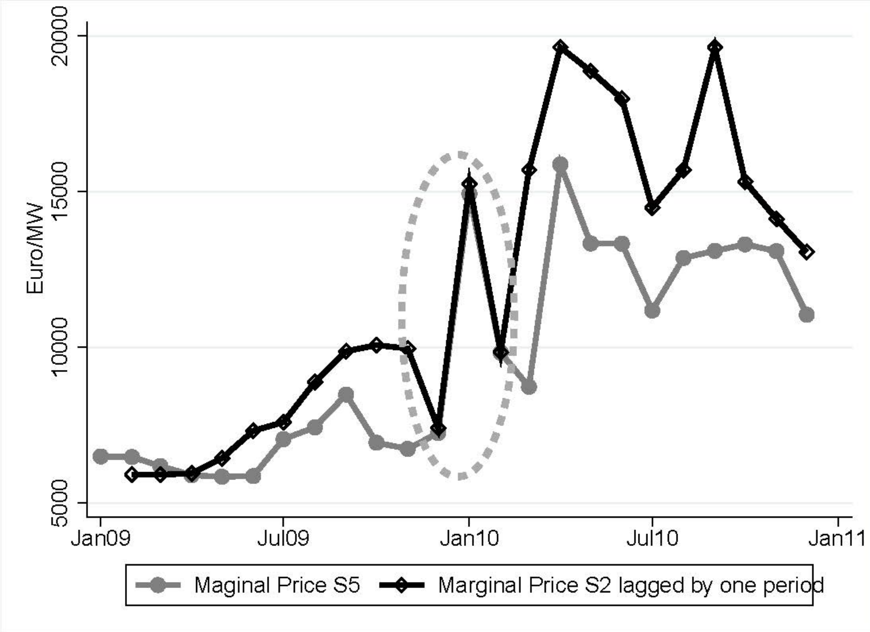

Figure 7: Marginal prices of Supplier 5 and marginal prices of Supplier 2 lagged by one period

Now both curves have similar trends and are almost identical in some periods. It seems that S_5 chooses its prices completely independently from its costs or opportunity costs (in the sense of lost spot-market profits), since it is doubtful that S_5's costs equal the lagged costs of S_2. Let us have a look at S_5's behavior in the circled area: S_5 chooses a marginal price which is only slightly below the marginal price realized by S_2 in the previous period. However, by doing so S_5 clearly determines the overall marginal price himself. In the following month S_5 decreases his individual marginal price just slightly below the marginal price which would have emerged if S_5 would not have been the marginal supplier. At first sight it does not seem rational to do so since it is pivotal and its bids have been accepted. However, S_5 might wish to avoid being the marginal supplier and had expected a further increase of S_2's marginal prices.

With this strategy S_5 can not be blamed for abusing his dominant position by setting excessively high prices and can justify his bidding behavior with the "guess the clearing price" principle of discriminatory auctions.[26] As orienting on historical marginal prices is a typical bidding strategy in PABA, this strategy can be justified easily by the market participants.

We now provide some correllations of S_5's bidding pattern by estimating the following model:

[26] Indeed the Federal Network Agency confirmed that the underlying idea in the auctions for reserve power actually is the "guess the marginal price" principle and it is thought to diminish market power.

$$\begin{aligned} log(p^{marg}_{S_5,t}) &= \alpha + \beta_1 \times log(p^{marg}_{-S_5,t}) + \beta_2 \times log(p^{marg}_{-S_5,t-1}) \times I(p^{marg}_{-S_5,t-1} \geq p^{marg}_{S_5,t-1}) + \\ &\quad \beta_3 \times log(p^{marg}_{-S_5,t-1}) \times I(p^{marg}_{-S_5,t-1} \leq p^{marg}_{S_5,t-1}) + \\ &\quad \beta_4 \times log(p^{marg}_{S_5,t-1}) \times I(p^{marg}_{-S_5,t-1} \leq p_{S_5,t-1}) + \varepsilon_{1,t} \end{aligned} \quad (1)$$

The population of suppliers is described by $S \in \{S_1, ..., S_N\}$. $-S_5$ denotes the continuum of suppliers excluding supplier 5. The marginal price of S_5 in t is denoted by p^{marg}_{t,S_5}, while $p^{marg}_{t,-S_5}$ denotes the marginal price within the group of suppliers $-S_5$. The indicator $I(p^{marg}_{t-1,-S_5} \geq p^{marg}_{t-1,S_5})$ is a binary variable which is equal to one if the condition $p^{marg}_{t-1,-S_5} \geq p^{marg}_{t-1,S_5}$ holds and is equal to zero otherwise. Similarly, $I(p^{marg}_{t-1,-S_5} \leq p^{marg}_{t-1,S_5})$ is equal to one if $p^{marg}_{t-1,-S_5} \leq p^{marg}_{t-1,S_5}$ and is equal to zero otherwise.

In most of the auctions the marginal price is set by S_2. Thus, we replace $p^{marg}_{t,-S_5}$ by p^{marg}_{t,S_2} and additionally estimate:

$$\begin{aligned} log(p^{marg}_{S_5,t}) &= \gamma + \delta_1 \times log(p^{marg}_{S_2,t}) + \delta_2 \times log(p^{marg}_{S_2,t-1}) \times I(p^{marg}_{-S_5,t-1} \geq p^{marg}_{S_5,t-1}) + \\ &\quad \delta_3 \times log(p^{marg}_{S_2,t-1}) \times I(p^{marg}_{-S_5,t-1} \leq p^{marg}_{S_5,t-1}) + \\ &\quad \delta_4 \times log(p^{marg}_{S_5,t-1}) \times I(p^{marg}_{-S_5,t-1} \leq p_{S_5,t-1}) + \varepsilon_{2,t} \end{aligned} \quad (2)$$

where P^{marg}_{t,S_2} denotes S_2's individual marginal prices in t. The results from both equations support our hypothesis of S_5's bidding strategy and are displayed in Table 4. The marginal price within the group $-S_5$ is not significant in t while it is significant for the previous period's marginal price and has a very high impact on S_5's marginal price in t independently whether the marginal supplier was one of the $-S_5$ suppliers or S_5 himself. In other words, even if S_5 sets the overall marginal price in the previous period it does not use it as "best guess" for the next auction although its bid was accepted. Instead S_5 orients on the lower marginal bid of the $-S_5$ suppliers – which in most cases is set by S_2. This strongly supports the hypothesis that S_5 aims to prevent being the marginal bidder.

Table 4: Supplier 5's marginal price.

Dep. Var.: $log(p_{t,S_5}^{marg})$	(1)		(2)	
$log(p_{t,-S_5}^{marg})$	0.008	(0.144)		
$log(p_{t-1,-S_5}^{marg}) \times I(p_{t-1,-S_5}^{marg} \geq p_{t-1,S_5})$	0.810***	(0.0937)		
$log(p_{t-1,-S_5}^{marg}) \times I(p_{t-1,-S_5}^{marg} \leq p_{t-1,S_5})$	0.595***	(0.161)		
$log(p_{t-1,S_5}) \times I(p_{t-1,-S_5}^{marg} \leq p_{t-1,S_5})$	0.227	(0.228)		
$log(p_{t,S_2}^{marg})$			-0.014	(0.089)
$log(p_{t-1,S_2}^{marg}) \times I(p_{t-1,-S_5}^{marg} \geq p_{t-1,S_5})$			0.850***	(0.055)
$log(p_{t-1,S_2}^{marg}) \times I(p_{t-1,-S_5}^{marg} \leq p_{t-1,S_5})$			0.725***	(0.123)
$log(p_{t-1,S_5^{marg}}) \times I(p_{t-1,-S_5}^{marg} \leq p_{t-1,S_5})$			0.140	(0.164)
$Intercept$	1.484***	(0.575)	1.325***	(0.385)
Adj. R^2	0.868		0.871	

Note: Standard errors robust to heteroskedasticity and autocorrelation in parantheses. Significant for * p<0.1, ** p<0.05, *** p<0.01.

Even though bidding on the expectations of marginal prices is rational behavior in PABA, it seems unlikely that S_5 does not have a better estimate than the previous auctions' marginal prices. In PABA higher marginal prices caused by supply reduction do not directly lead to higher prices for all suppliers. However, the correlation between S_5's supply andS_2's accepted capacity is significantly negative. Due to the fact that S_2 can sell more capacity if S_5 decreases its supply, it is of particular interest to take a look at the individual bid functions.

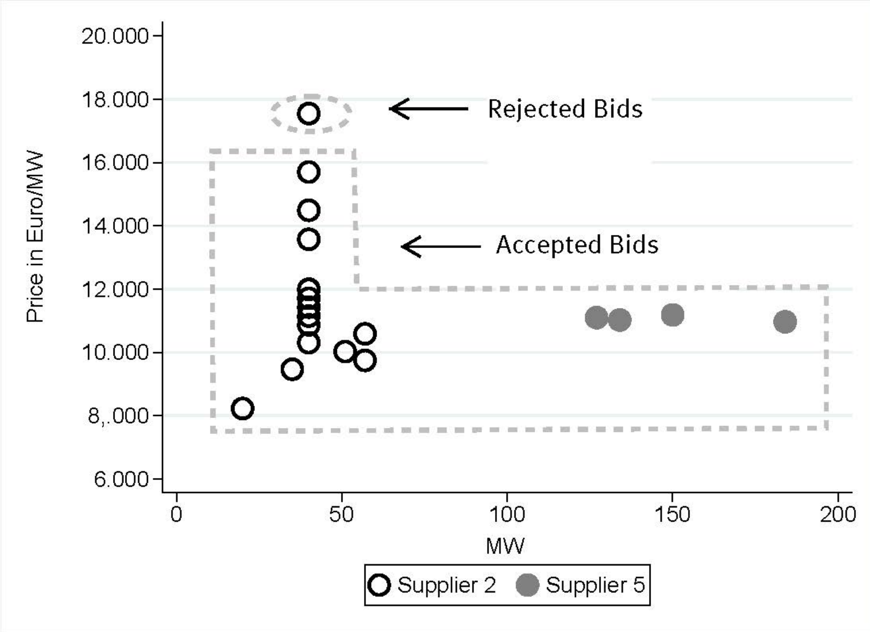

Figure 8: Bidding strategy of the two most dominant suppliers S_2 and S_5; exemplary: bids in July 2010

Figure 8 shows why both suppliers achieve similar average prices for a sold unit capacity (Table 3) even though S_2 obtains significantly higher marginal prices in most auctions. The reason is the sizeable spread between S_2's lowest and highest price. While S_2 supplies a large number of bids with comparatively low quantity and a steep price function, S_5 choses a flat supply curve with only a small number of large volume bids. The described strategy has already emerged from Table 3 where S_5 and S_2 significantly differ in their average number of bids, average bid size and average standard deviations of the capacity prices per auction.

However, Figure 8 additionally reveals that the majority of the supplied capacity of both suppliers is within the same price interval. As a consequence of S_5's supply reduction, more expensive bids of S_2 are awarded. Although S_2 realizes higher marginal prices with its bidding strategy in scarcity situations, it does not earn higher prices per MW on average which supports the belief that withholding capacity is less attractive in discriminatory auctions. However, S_2's marginal prices serve as a price booster for the subsequent periods. Due to the low capacity per bid, S_2 does not suffer high losses if an expensive bid is rejected but increases its expected returns for the following periods since it can raise prices for the majority of its capacity and legitimate it with the *guess the marginal price* principle of PABA. This bidding strategy of S_2 is sometimes referred to as the *hockey-stick-tactic* in academic literature when it comes to discussions about UPA and can be a profitable strategy in scarcity situations. But its validity for discriminatory auctions is either neglected or negated (e.g. Rothkopf (2001), Harlbut et al. (2004), Cramton (2004)). However, our example clearly shows that in contrast to UPA this strategy obviously cannot work in a static game but may be profitable and hard to prosecute in repeated discriminatory auctions with highly pivotal suppliers.

The impact of S_5's supply on S_2's marginal prices is shown in the descriptive regression below and reveals a significant negative correlation between S5's supply andS_2's marginal prices. Estimating

$$ln\, P^{marg}_{t,S_2} = \alpha + \beta_1 ln\, SUPPLY_{t,S_5} + \beta_2 ln\, P^{marg}_{t-1,S} + \varepsilon_t \quad (3)$$

and

$$ln\, P^{marg}_{t,S_2} = \alpha + \beta_1 ln\, SUPPLY_{t,S_5} + \beta_2 ln\, p^{marg}_{t-1,S_2} + \varepsilon_t \quad (4)$$

yields to the results shown in Table 5.

Table 5: Supplier 2's marginal price and Supplier 5's capacity supply

Dep. Var.: $ln\, P_{t,S_2}$	(1)	(2)
$ln\, SUPPLY_{t,S_5}$	-0.610***	-0.610***
	(0.113)	(0.146)
$ln\, P^{marg}_{t-1,S}$	0.611***	
	(0.0792)	
$ln\, P^{marg}_{t-1,S_2}$		0.584***
		(0.100)
$Intercept$	7.706***	7.981***
	(1.449)	(1.886)
Adj. R^2	0.779	0.746

Note: Standard errors robust to heteroskedasticity and autocorrelation in parantheses. Significant for * p<0.1, ** p<0.05, *** p<0.01.

Table 5 suggests that a 10 percent reduction of S_5's supply leads to a 6 percent increase of S_2's marginal prices on average. Bearing in mind that S_5's supply has an impact on S_2's marginal prices and thereby with one month delay on S_5's marginal and average prices, S_5 may obviously increase its future prices by reducing its supplied capacity and stages itself as 'follower' while doing so. It can be noted that the drastic price increase was triggered by S_5's supply reduction in combination with S_2's bidding strategy. At the end of the observed period

S_5's supply returned to its initial level. However, prices remained at a higher level and all suppliers recorded significantly higher revenues. Even during the period of capacity reduction S_5 did not suffer a drop in revenues but could even considerably increase them. Moreover, S_5 might have achieved additional revenues by selling the withheld quantity at the spot market, provided that it was not unavailable because of technical restrictions. The development of S_5's supply and revenues in the years 2009 and 2010 are illustrated in Figure 9.

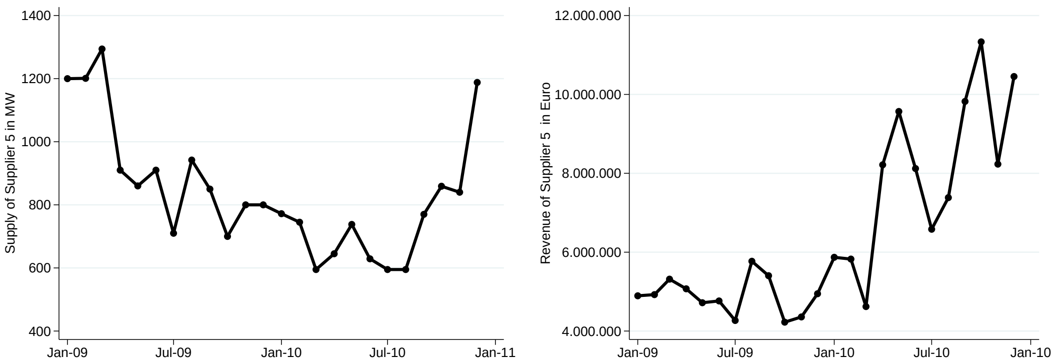

Figure 9: Development of Supplier 5's supply and revenue

Given the small number of observations due to the monthly auction iteration, technical possibilities and robustness of econometric analyses are fairly limited. Nevertheless, the analysis provides a first picture of gaming incentives in PABA when suppliers are pivotal, auctions are repeated regularly and demand is predictable but inelastic – charecteristics which which are present in virtually all energy markets.

7 Conclusion and Policy Implications

Motivated by a drastic price increase we analyzed the German market for negative secondary reserve. As there were no conspicious movements on the EEX spot market, which represents the oppurtunity costs, the price increase did not appear to be supported by increased costs. We identified a concentrated market with highly pivotal suppliers in an environment with completely inelastic demand and high entry barriers. Against this background, we trace back the price increase to a reduction in supply of the most dominant supplier and the interaction of the two most powerful suppliers' bidding behavior afterwards.

All market participants profited from this interaction through repeated pretended "bad guessing". Thereby, a spiraling price increase was initiated and prices maintained at a higher level even after supply returned to the initial volume.

Thus, given regulatory threats, the deemed main advantage of pay-as-bid auctions (PABA) over uniform price auctions (UPA) and the popular belief that they reduce dominant suppliers' withholding incentives and diminish their ability to tacitly collude may be questionable as a general rule in non-static settings. In fact, while strategic capacity withholding immediately leads to higher average prices for all suppliers in UPA, in PABA bidders do not directly benefit from it but can generate extra profits in the next period. This supports Kahn et al.'s (2001) proposition, that repetition of bidding procedures lend itself to collusion and changes of the auction design would not alter this. However, even if problems arising from market power are present under both frameworks, the regulatory authority's power to deter its abuse is a crucial element for the efficiency of the market. Our findings suggest that the auction's settlement rule has a decisive role in explaining the price increase and reveals a particular argument against discriminatory auctions in electricity markets, which is broadly overlooked in the existing literature. As mitigation of the exercise of market power is one key task regulators have to deal with, power of deterrence instruments is inalienable to attain more efficient markets. This postulates that detection and legal prosecution of abusive behavior is feasible.

However, the present PAB settlement legitimizes that bids may be unrelated to costs which diminishes the regulatory authorities' scope in comparison to UP. Due to the inelastic demand, suppliers theoretically can charge infinitely high prices for the share of their capacity for which they are pivotal and bids would still get awarded. Assuming that a regulatory authority monitors the market, which is the case in virtually all energy markets, prices cannot diverge arbitrarily far from their costs under a UP framework. Since regulatory authorities should have at least a rough estimation of the cost levels, marginal suppliers would be confronted with the suspicion of market power abuse if their bids exceed a certain price limit according to the Act against Restraints of Competition (GWB) and the Treaty of the Functioning of the EU (TFEUS). In the US, FERC has the legal power to intervene when prices exceed an "unjust and unreasonable" level as observed 2001 in California.[27] Hence, UPA have a fictional price limit which is directly linked to the marginal supplier's costs. If it exceeds it, he cannot justify its price-setting anymore and has to fear regulatory measures. The PABA does not have such a price limit since prices do not have to reflect costs but inherently legitimates and even forces inframarginal suppliers to charge prices above marginal or opportunity costs. In a competitive

[27] see Wolak (2004).

environment suppliers in PABA choose prices on the means of their expectations on the current marginal unit's costs and often the prices realized in the previous period is the best guess. Accordingly, price shocks do not (or at least slowly) decline even if costs decrease in future periods. This is in line with Swider (2007) who argues that a slow decrease in minute reserve prices after a shock in 2007 was due to slow adjustments of price forecasts in PABA. However, even in the case of dominant suppliers, which is typical for energy markets, suppliers can rely on the "guess the clearing price" principle of PABA and pretend to guess prices. Then, due to the low level of liquidity and the inelastic demand, a dominant supplier can reduce its capacity and still realize higher profits without having actively raised its prices beforehand in a PABA if auctions take place frequentely and demand uncertainity is low. Hence, with inelastic demand pivotal suppliers can divide the market tacitly between them and individually profit from that with lower fear of regulatory measures compared to a UPA.

We conclude that proving abusive behavior becomes harder in discriminatory auctions since suppliers can hide behind the "guess the clearing price" principle. Against the background that pivotal suppliers are rather the rule than the exception and there is only little demand elasticity in electricity markets in general (e.g. Borenstein et al., 2002), validity of our findings for other markets depends on the ex ante knowledge of the market's liquidity and the frequency of similar market situations. As both theoretic and experimental studies on auctions do not adequately take monitoring power as a deterrence instrument into account, there is space for further research on this topic.

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