

BIDDING STRATEGIES OF RENEWABLES IN THE IBERIAN ELECTRICITY SPOT MARKET

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Overview

Across Europe, ambitions to further integrate solar and wind power plants into electricity wholesale markets are increasing and it becomes crucial to understand this development's underlying economics. Traditionally, renewables are subject to support schemes and incur very low marginal costs. Therefore, their energy is typically offered for price bids near zero to wholesale markets. While aggregate effects of this behavior on markets (merit-order effect) and renewables' profits (cannibalization effect) have been studied extensively, potential motives for deviations from this strategy still lack an understanding (Gelabert, Labandeira, & Linares, 2011; Sensfuß, Ragwitz, & & Genoese, 2008; Hirth, 2013; Prola, Steininger, & Zilbermanca, 2020). Fabra & Llobet (2020) and Knaut & Obermüller (2016) provide game-theoretical assessments of renewables' strategic behavior in electricity markets when exerting market power. Zhang, Gao, Wu, Liu, & Liu (2012) develop a model optimizing wind power plant bids taking into account sequential markets. For portfolios including both renewables and conventional power plants, strategic behavior in sequential electricity markets was studied by Ito & Reguant (2016) and Kraft, Russo, Keles, & Bertsch (2021), amongst others. We theoretically derive optimal strategies of a renewable producer receiving a market premium in a sequential wholesale market and empirically study bidding behavior of Spanish solar power plants in the Iberian electricity spot market. Applying regression analyses to a unique dataset of unit-wise price bids and sales to the Iberian day-ahead and intraday auctions, we can provide evidence for one particular market actor to follow a day-ahead bidding strategy that exploits options in subsequent intraday market auctions leading to price bids at the level of an expected intraday market price.

Methods

Firstly, we derive theoretically optimal strategies in the Iberian electricity day-ahead market for a renewable producer who sells her production in the day-ahead and intraday market and receives a market premium. Making several simplifying assumption, we can formulate her ex-post profit function Π_t dependent on available capacity Q_t in period t as follows:

$$\Pi_t(Q_t) = q_t^{DA} p_t^{DA} + q_t^{ID} p_t^{ID} + (q_t^{DA} + q_t^{ID}) s_t \quad (1)$$

with q_t^{DA} and q_t^{ID} representing quantities sold in the day-ahead and intraday market for prices p_t^{DA} and p_t^{ID} , respectively and s_t constituting the market premium. We argue that a renewable producer's ex-ante optimal strategy in the day-ahead market depends on her risk-preference. Particularly, for a risk-averse actor, we suggest that it is optimal to maximize support scheme revenues by always offering her full available quantity for a price bid equal to 0. In contrast, for a risk-neutral actor, we propose that it is optimal to maximize wholesale market revenues by submitting her full available quantity at the expected intraday market price to the day-ahead market. The rationale behind this strategy is to ensure maximizing wholesale market revenues by selling all of one's production in the market with the highest expected price. This strategy, however, comes at the risk of meeting an illiquid intraday market.

Secondly, we exploit the data transparency of the Iberian electricity market to empirically assess the validity of these theoretical propositions by studying bidding behavior of Spanish solar power plants in the spot market in a sample period of 2017-2020. Using publicly available data provided by the Iberian nominated electricity market operator OMIE, we build a dataset of bids submitted to the day-ahead and all six intraday market auctions by bidding units that we can identify as solar power plants bids in Spain in the period of 2017-2020 (OMIE, 2021; OMIE, 2021; REE, 2021). Since the raw data includes up to 25 steps per hour in the day-ahead and the six intraday market auctions, we focus on the maximum submitted and the maximum accepted price bids of all identified solar power plants in the sample period as well as equilibrium prices and quantities in Spain. Among the 40 firms owning 131 solar bidding units in the data, five are observed to submit prices larger than zero. For our empirical analysis, we start by focusing on the only firm of those five that (i) merely produces solar power, such that its strategy is not influenced by general portfolio optimization and (ii) public information as well as its bid structure do not indicate the existence of other revenues, such as self-consumption or a PPA. Particularly our, sample consist of this firm's 16,460 bids for an aggregate of different solar power units that add to a relatively small maximum capacity of 4

MW. Furthermore, we add the following controls to the dataset: generation by plant type, hourly day-ahead and intraday forecasts of renewable production, hourly day-ahead forecast of load and its realization, bidding zone imbalance and daily EUA- and gas-prices from different public sources (Entso-E, 2021; MIBGAS, 2022; ICAP, 2021).

Our empirical assessment of firm's rational consists of two steps. Firstly, we intend to explain when the firm submits a price bid larger than zero. This is the case for almost 13,000 of the 16,460 price bids in our sample. Based on our theoretical considerations, we test if submitting a price bid of zero is affected by the (i) absolute difference between maximum intraday and day-ahead price ($Diff_{th}$) and (ii) total volume traded in all six intraday auctions (Liq_{th}^{ID}). To explain the rationale behind submitting a price bid > 0 for solar power units, we estimate the effect of two variables on a binary variable PD_{th} that is equal to 1 if the firm submits a price bid larger than zero and 0 otherwise. We estimate the following regression equation with controls describing the current market situation (X_{th}) as well as seasonal and daily fixed effects (D_{th}):

$$PD_{th} = \beta_0 + \beta_1 Diff_{th} + \beta_2 Liq_{th}^{ID} + \beta_3 X_{th} + \beta_4 D_{th} + u_{th} \quad (2).$$

We hypothesize that a higher difference in prices and a higher intraday market liquidity make it more likely to follow the riskier strategy assuming that the firm forms valid expectations on these variable ($\beta_1 > 0$ and $\beta_2 > 0$). To account for serial correlation and the binary nature of the dependent variable, we apply different methods and specifications to estimate (2). Namely, we apply both OLS and probit estimators and include lagged variables. Since the expected intraday market variables are likely to be endogenous, we also apply a weekend and an afternoon dummy that are shown to be correlated with $Diff_{th}$ and Liq_{th}^{ID} as instrumental variables.

Secondly, we try to explain the amount of the price bid p_{th} in a given hour th . Particularly, we test the hypothesis that the maximum hourly price bid of the firm equals the expected intraday price. Simply looking at the correlation between the firm's maximum price bid and expected intraday price, we find a high correlation coefficient of 0.8465. To assess the causality of this correlation, we regress all price bids that are larger than 0 (12,917 observations) on the maximum intraday price of the six sessions in a given hour including the same market controls and dummies as above:

$$p_{th} = \gamma_0 + \gamma_1 E(p_{th}^{ID}) + \gamma_2 X_{th} + \gamma_3 D_{th} + u_{th} \quad \text{for } p_{th} > 0 \quad (3)$$

Our hypothesis is that $\gamma_1 = 1$. We estimate (3) using an instrumental-variables approach accounting for possible endogeneity in the intraday market price, applying load, renewables' market shares and commodity prices as instruments. As above, we apply different lagged variables.

Results

Our results support our hypotheses. Estimating (2) results in significantly positive effects on the dummy variable of the difference in intraday and day-ahead market price as well as total hourly intraday market volume throughout all methods and specifications. The impacts are particularly large for the instrumental-variable-approaches that are more likely to represent the actual effect. Estimating (3) using the described instrumental-variables approach results in a coefficient close to 1 and therefore, provides evidence that the price bids indeed are intent to meet expected intraday prices.

Conclusions

Our analyses provide evidence that one particular seller of solar power in the Iberian electricity spot market is more likely to submit a price bid larger than zero in hours, when both the absolute difference in expected intraday market and day-ahead price as well as intraday market volume are higher. Moreover, our results suggest a causal nature of the clear correlation between the firm's price bid and the hourly maximum market price among the six intraday auctions. The implications are two-fold. Firstly, considering increasing ambitions to integrate renewables into wholesale markets, it is important to consider such strategies that deviate from the general assumption of price bids near zero when predicting prices resulting in markets with high shares of renewables. If prospectively, the analyzed strategy is applied by more market actors that operate in sequential markets, in equilibrium, the markets' prices should converge. Potentially, this would mitigate the cannibalization effect in the day-ahead market at the expense of decreasing intraday market prices. For further insights on a generalization of our result, motives of the other marketers of Spanish solar power plants who deviate from the zero-price-bid assumption should be subject of future work. Secondly, our results suggests that at least for the studied actor, the intraday market auctions in the Iberian market are an instrument of revenue optimization rather than a mere possibility to adjust her position to balance forecast errors. This result is in line with Ito & Reguant (2016)'s analysis for the overall Spanish market. In terms of market design, this raises the question, if such behavior is desirable from a welfare-perspective or if it requires to be addressed with adequate instruments.

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