Environmental Assessment

Fachbereich 2 Informatik und Ingenieurwissenschaften

Strategic behavior – exercise

You are a project developer of a 6 MW wind turbine

- your power plant generates E=15 GWh per year for 20 years
- your LCOE (without profit margin) is 4.5 €-cents/kWh for 4-7, 5 €-cents/kWh for 8-9, 5.5 €-cents/kWh for 10, 4 €-cents/kWh for 2-3, 3.8 €-cents for 1
- the maximum bid is restricted to 7 €-cents/kWh
- the deposit is 30 €/kW (returned after realization)
- you face annual costs C = 60,000 € + 30,000 $\cdot\, n$ € with n as number of projects
- with a debt of 300,000 €/project you are bankrupt ☺
- the interest rate is 5 %

Evaluation of the game

bidding under excessive demand

- it took several rounds until rational behavior has gained ground: place a maximum bid

→ uniform pricing

→ pay-as-bid pricing

Evaluation of the game

competitive pay-as-bid bidding, 5 rounds

- round 1: $\bar{p} = 5.19$ €-cents/kWh on average for successful bids
- round 2: $\bar{p} = 5.07$ €-cents/kWh on average for successful bids
- round 4: $\bar{p} = 5.05$ €-cents/kWh on average for successful bids

→ usually decreasing average prices

→ advantages for multi-unit bidders

Evaluation of the game

competitive pay-as-bid multi-unit bidding, 2 rounds

- round 1: $\bar{p} <$ LCOE, 1 realized project with $p >$ LCOE
- round 2: $\bar{p} <$ LCOE, 0 realized projects

$\rightarrow$ group 1: $\Pi =$-228,000 €/project

$\rightarrow$ group 2: $\Pi =$-30,000 €/project

$\Rightarrow$ realization rate 5 %

$\Rightarrow$ “investments” in future profits

Model simplifications

- direct realization/non-realization

$\Rightarrow$ exposure to future price changes

- no uncertaintiy

$\Rightarrow$ bidding for real options (Matthäus *et al.*, 2021)

- equal distribution of money

$\Rightarrow$ execution of market power

From game to reality – Germany

conditions for participation

- construction permit, deposit of 30 €/kW
- deadline for finalization: 2 years
- pay-as-bid

exemptions for citizens' energy projects

construction permit not needed, deposit of 15 €/kW

- deadline 4 years
- uniform pricing

⇒ significant advantages for citizens' energy projects

Citizens’ energy projects

requirements for citizens’ energy projects

- the bidding company is owned by at least 10 natural persons
- more than 50 % of the shareholders have their main residence in the district the power plant will be located
- none of the shareholders is allowed to be a shareholder of another citizens’ energy project within 2 years
- all requirements must be fulfilled for two years after the power plant started operating

Reverse auctions in Germany – 2017 results

- volume-weighted average price of the first auction: 5.71 €-cents/kWh
- 23 % lower than the comparable FIT-guaranteed remuneration at the same time

- statement of the Federal Ministry for Economic Afairs and Energy (2017):

  "The fact that we have seen this high level of competition which has brought prices down this much and that there has been such broad-based public participation shows that the paradigm shift we have initiated away from fixed funding rates stipulated by government to market-based pricing has worked well."

Doubts about the success

- 90 % of successful bidders were citizens' energy projects while their share was significantly lower before
- on June 2, 2017 officials of the German state Baden-Württemberg requested more stringent admission requirements for citizens' energy projects driven by the

$\rightarrow$ fear of a high non-realization-rate

$\Rightarrow$ tactical bidding behavior

- speculation on a further price drop (bidding for real options)
- crowding-out of weaker competitors
- execution of market power for negotiations with manufacturers

Market concentration

- auction 1: 35 % of awarded capacity belonged to the two small companies ENERTRAG and Prowind
- auction 2: 69 % of awarded capacity belonged to the company UKA
- auction 3: 41 % of awarded capacity belonged to the UKA again

Buying market power

- deposit of 15 €/kW → about 1 % of investment cost
- no other admission requirements for citizens' energy projects
- total amount of tendered capacity in 2017: 2,800 MW

⇒ for the manageable commitment of 42 million €, market participants could "buy" a potential investment of a complete year summing up to 4.2 billion €

⇒ provides a strong position for negotiations with manufacturers

Reverse auctions for RES in Germany

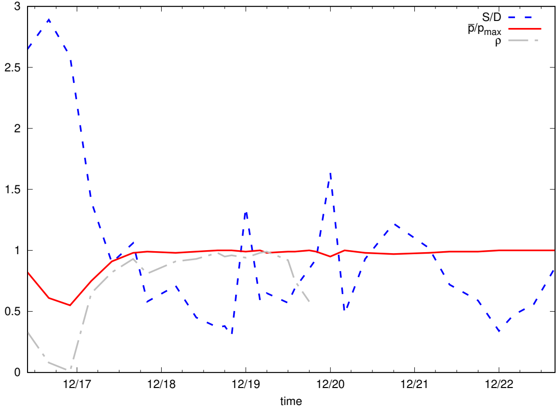

Figure: S/D depicts the ratio of supply and demand with $S/D > 1$ indicating excessive supply and $S/D < 1$ excessive demand. $\bar{p}/p_{max}$ depicts the ratio of the weighted average and the admitted maximum price p_{max} with values close to 1 indicating that almost all bidders bid the maximum price. ρ corresponds to the share of successful bids which were realized before expiration (data is restricted to those auction rounds with expired realization periods); taken from Schäfer (2023)

Bidding strategies

excessive demand

- it is rational to place a maximum bid under uniform and pay-as-bid pricing (analogous to bid shading in classical auctions)

excessive supply

- bidding for real options (like buying a put option)
- switch to long-run profit maximization

→ crowding out of competitors

→ increase market share

The price quantity problem...

- regulator chooses a price
- price can be too high or too low

$\rightarrow$ additional profits

$\Rightarrow$ undesired redistribution from consumers to producers

$\Rightarrow$ too many/few wind turbines are built

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The price quantity problem...

- regulator chooses a quantity
- quantity can be too high or too low

$\rightarrow$ too low competition

$\Rightarrow$ additional profits

$\rightarrow$ too high high competition

$\Rightarrow$ monopolization of the market

$\Rightarrow$ additional profits in the long run

$\Rightarrow$ undesired market impacts can occur (e.g. Germany 2017)

$\rightarrow$ high non-realization rate

$\Rightarrow$ endangering effectiveness

Approaches for reforms

- during the 2017 market distortion calls for a higher auction volume occurred

⇒ volume was increased

- after several auctions with excessive demand calls for a lower auction volume occurred

⇒ experiment: the volume was cut at 90 % of demand

⇒ no significant effect

- Why a general volume cut at 90 % of supply is problematic particularly with respect of multi-uni bidders?

Reverse auction with endogenous quantity

general idea

- the regulator announces a procedure which allows to choose the best quantity

the regulator's two objectives

- RES-based electricity generation shall be expanded (**effectiveness**)
- redistribution (additional profits) shall be limited (**efficiency**)

→ applies to the **high price period** only!

→ approach follows Schäfer (2023)

Quantification of the regulator's objective

For the following analysis we assume a reverse auction with **single unit bidders** under **uniform pricing** and (at first) **truthful bidding** of l successful bidders out of n total bidders.

- an increase of installed wind turbines is proportional to the number of l awarded bidders

$$\chi(l) := \min\left\{\frac{\sum_{i=1}^{l} q_i}{Q_{max}}, 1\right\}$$

⇒ the higher the value of $\chi(l)$, the better for the regulator (except for values above Q_{max})

⇒ increasing $\chi(l)$ corresponds to higher **effectiveness**

Quantification of the regulator's objective

- the share of uncovered cost $C(I)$ on subsidies $S(I)$ is an indicator for redistribution

$$\varphi(I) := \frac{C(I)}{S(I)}.$$

- with uncovered cost

$$C = K - R$$

$\Rightarrow$ the higher the value of $\varphi(I)$, the better for the regulator

$\Rightarrow$ increasing $\varphi(I)$ corresponds to higher **efficiency**

Quantification of the regulator's objective

- the regulator can easily calculate the individual subsidy rate

$$s_i = p_i - \overline{p}_{spot}$$

  which corresponds to uncovered LCOE under truthful bidding
- allowing to calculate uncovered cost under the assumption of truthful bidding

$$C(I) = \sum_{i=1}^{I} s_i q_i$$

- and eventually

$$S(I) = s_I \sum_{i=1}^{I} q_i$$

The regulator's objective function

- determination of the optimal quantity turns into utility maximization for the regulator

$$u = \left[\alpha\varphi(I)^{\theta} + \beta\chi(I)^{\theta}\right]^{1/\theta},$$

- with $\alpha + \beta = 1$ and $\alpha \geq 0 \leq \beta$ ensuring constant returns to scale
- the chosen CES utility function includes the whole range of substitution elasticities from perfect complements ($\sigma = 0$, $\theta = -\infty$) to perfect substitutes ($\sigma = \infty$, $\theta = 1$)
- for $\sigma = 1$ the function corresponds to a Cobb-Douglas utility function $\varphi(I)^{\alpha} \cdot \chi(I)^{\beta}$

$\Rightarrow$ very flexible

Exercise

- Use the data given on CampUAS to calculate $\chi(l)$ and $\varphi(l)$ assuming $Q_{max} = 1,000$ MW.
- Calculate the utility u for $\alpha = 0.5$, $\alpha = 0.7$ and $\alpha = 0.8$ using a Cobb-Douglas utility function

$$u_l = \varphi(l)^{\alpha}\chi(l)^{1-\alpha} \tag{1}$$

- Which bidder places the last successful bid?
- Calculate the savings induced by the endogenous reverse auction when compared to usual uniform pricing.

Strategic bidding behavior

- Considering single unit bidders, we know from standard auction theory

→ in a pay-as-bid auction there exists an incentive to increase price bids (analogous to bid shading)

→ in a uniform price auction this incentive does not exist

- Does this apply to the suggested auction design with endogenous quantity, too?

→ in contrast to a usual uniform price reverse auction, a manipulated bid may influence endogenous quantity and thus the price

⇒ in the following we compare a situation with true bids and inflated bids

Strategic bidding behavior

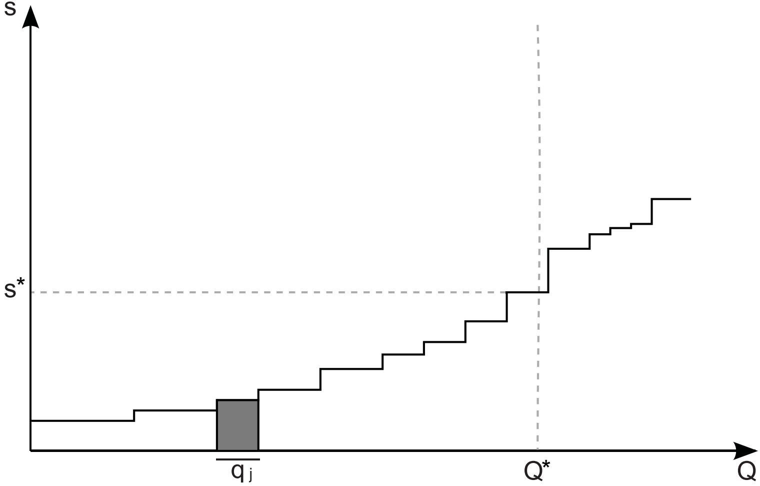

Figure: Exemplary merit order before deception. Bidder j is the deceiver. The gray area corresponds to the deceiver's true expectations about uncovered costs c_j.

Strategic bidding behavior

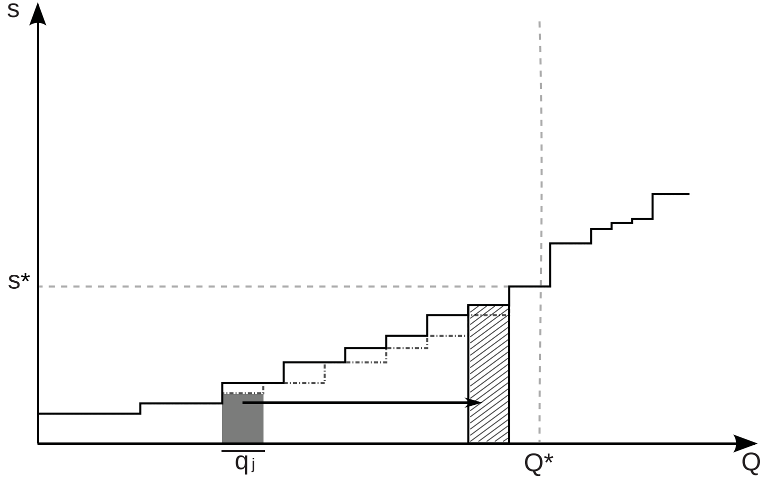

Figure: Exemplary merit order after deception. The deceiver changes from j to k while bidders $j+1$ to former position k all slide down one position.

Impact of an inflated price bid

- According to the illustration of the two preceding slides, we assume the deceiver places an inflated price bid and thus changes from position j to $k \geq j$
- the analysis is carried out from the regulator's point of view who interprets price bids as generators' expected unit costs.

$\Rightarrow$ **for the regulator** an increased price bid **indicates an increase** of expected unit costs although actual **expectations** about unit costs do not change.

Impact of an inflated price bid

- the difference in expected aggregated uncovered costs (from the regulator's view) is

$$\Delta C(I) := \sum_{i=1}^{I} (\hat{s}_i - s_i)\, q_i.$$

- with $\hat{s}_i$ indicating the subsidy rate of bidder i after inflation of the price bid of former bidder j.
- the difference in expected subsidy equals

$$\Delta S(I) := (\hat{s}_I - s_I) \sum_{i=1}^{I} q_i.$$

Impact of an inflated price bid

- using the two preceding equations together with $\varphi(I) := \frac{C(I)}{S(I)}$, yields

$$\begin{aligned}\Delta\varphi(I) :&= \hat{\varphi}(I) - \varphi(I)\\ &= \frac{\Delta C(I)}{S(I) + \Delta S(I)} - \frac{\Delta S(I)}{S(I) + \Delta S(I)}\varphi(I)\end{aligned}$$

- with $\hat{\varphi}(I)$ corresponding to the respective value under an inflated price bid while $\Delta S(I)$ and $\Delta C(I)$ indicate the change of $S(I)$ and $C(I)$ after deception yielding $\hat{C}(I) = C(I) + \Delta C(I)$ and $\hat{S}(I) = S(I) + \Delta S(I)$.
- Demonstrate that the two lines of the equation are equal.

Impact of an inflated price bid

- $\Delta S(l)$ and $\Delta C(l)$ show a distinct behavior depending on the bidders' position in the merit order
- $S(l)$ is the product of the last successful bider's subsidy rate $\hat{s}_l$ and the sum of quantities $\sum_{i=1}^{l} q_i$

⇒ any change induced by deception is propagated from one bidder to the next

⇒ changes increase between position j and k while $\Delta S(l)$ is zero after position k

⇒ We find

$$
\begin{aligned}
0 = \Delta S(l < j) &\leq \Delta S(l = j) \leq \Delta S(l = j + 1) \leq \cdots \leq \Delta S(l = k) \\
&\geq \Delta S(l = k + 1) = 0 = \cdots = \Delta S(l = n)
\end{aligned}
$$

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Federal Ministry for Economic Afairs and Energy (2017). State Secretary Baake: "Citizens' energy wins first onshore wind auction". Available at: `https://www.bmwi.de/Redaktion/EN/Pressemitteilungen/2017/20170519-staatssekretaer-baake-buergerernergie-gro%C3%9Fe-gewinner-der-ersten-ausschreibungsrunde-wind-an-land.html`, accessed August 31, 2018.

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