Supplier rationing and efficient procurement: Renewable energy auctions in India

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Introduction

Motivation:

- At 109GW, India is one of the top 5 countries for installed solar and wind energy capacity.
- Most of it is contracted via auctions.
- Novel feature for theory: Quantity asymmetry, open descending-price auction, and residual award to the lowest price loser (Asymmetric case of Holmberg and Wolak, 2018).
- Awarding residual (or rationing) is a simple rule to clear market and foster competition.

Questions:

Theory: Key feature of equilibrium bids?
Response: Highest quantity bidder is less aggressive, bunches at the reserve. Inefficient selection.
Empirical and Policy: Tweaks to improve social welfare or auctioneer payments?
Response: Discriminatory price auction improves social welfare, without affecting auctioneer payment.

Institutional Background

- Auctioneer: Government agencies.
- Object auctioned: Power purchase agreement for a utility-scale solar/wind project at fixed price for 25 years.
- Pre-auction: Procurement target M, reserve bid announced.
- 2 stages:
  - Capacity and price bids in qualifier round,
  - Price bids in final round, capacity revealed.

Bidder	Qualifier		Final	Award
	q_i	p_i^I	p_i^{II}	
B_1	100	1.5	1.5	100
B_2	50	2.6	2.1	50
B_3	200	2.8	2.1	200
B_4	450	3.0	2.1	150
B_5	150	3.2	3.0	0
B_6	100	3.4	2.5	0
B_7	300	3.5	NQ	-

Table 1: Allocation rule, with $M = 500$

B_4 is rationed to clear the market.

- B_4 could concede at 2.5 and get 150.

Data and Stylized facts

- Data: Public documents inviting the bidders, published auction results from Solar Energy Corporation of India (SECI); contracts 54GW capacity.
- Observables: firms, final bids, awards.
- 54 auctions with 374 bids.
- 45 auctions with positive residual;
  27 have no competition by residual winner.

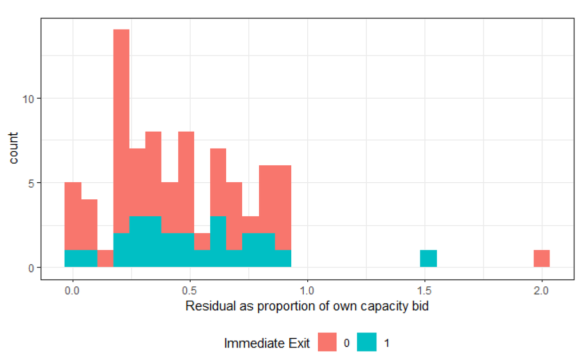

Fig. 1: Decision to concede immediately

Theory

Simple model with 2 bidders:

- Target $M = 1$ revealed, $1 > q_1 > q_2$, $q_1 + q_2 > 1$.
- Quantities and other information from qualifier round assumed exogenous for final round.
- Final round modelled as descending clock auction.
- Assume same reserve, b^R, for each bidder.
- Private information: B_i's constant marginal cost $c_i \in [0, \bar{c}]$.
- Common knowledge: Quantities q_1, q_2, and $c_i \overset{i.i.d}{\sim} F(c)$ (IPV), $\sigma(c) = f(c)/F(c), \forall c, \sigma'(c) < 0$, $f(c) > 0$, very small atom at $c = 0$.
- First bidder to exit gets residual award, sets the tariff.

B_i's bid b_i is the price at which she exits if opponent hasn't exited (cutoff strategy).

Ex-post payoffs:

$$\pi_i^W(b_i; c_i, \mathbf{q}, b_{-i}) = q_i(p - c_i)$$
$$\pi_i^L(b_i; c_i, \mathbf{q}, b_{-i}) = (1 - q_{-i})(p - c_i)$$

where $p = \max\{b_1, b_2\}$.

Semi-separating Bayes Nash Equilibrium:

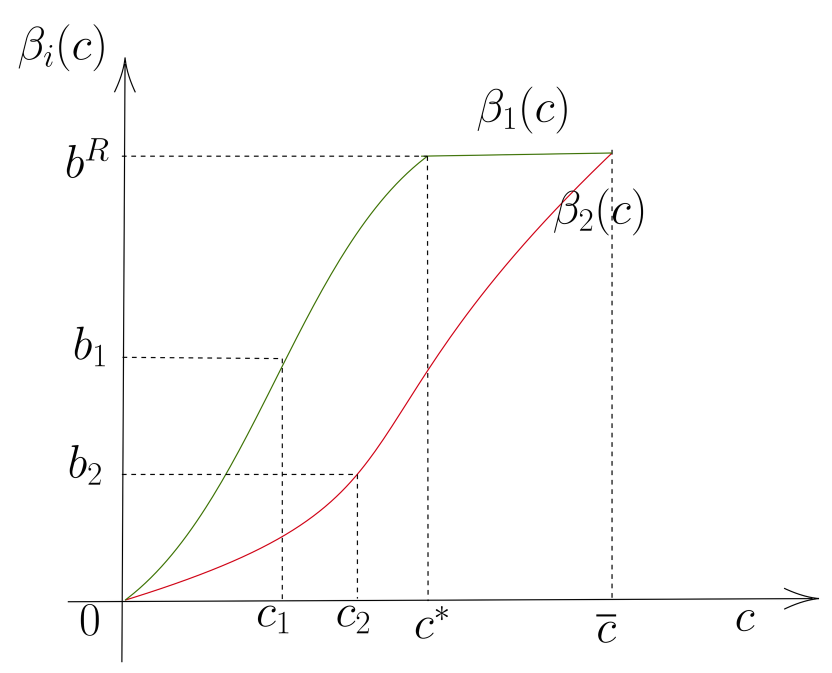

Fig. 2: Equilibrium bidding functions

Intuition: B_1 has high residual ($q_1 > q_2 \implies 1 - q_2 > 1 - q_1$). At any given bid:

- B_1 gains lower in quantity if she wins, and
- B_1 loses more in amount if she loses.

So, she is less aggressive, and bunches at the reserve.

Formal results:

Lemma 1. *(Characterisation) For each B_i, $\beta_i(c)$ constitutes a semi-separating Bayes Nash Equilibrium of the 2 player clock auction with rationing if and only if it satisfies following properties:*

1. *$\beta_i(c)$ is non-decreasing in c.*
2. *$\beta_i(c)$ is continuous and atomless for $b < b^R$ for both i.*
3. *$\beta_i(0) = 0$.*
4. *For each player B_i, $\beta_i(c)$ solves:*
$$\sigma(\beta_{-i}^{-1}(\beta_i(c)))\beta_{-i}^{-1'}(\beta_i(c))(\beta_i(c) - c) = \frac{1 - q_{-i}}{q_1 + q_2 - 1}$$
for $c > 0$.
5. *$\beta_2(\bar{c}) = b^R$, $\exists c^*$ such that $\beta_1(c) = b^R, \forall c \in [c^*, \bar{c}]$.*

Theorem 1. *The equilibrium described in Lemma 1, exists and is unique.*

Extensions:

- 3 bidders with $1 > q_1 > q_2 > q_3$, $q_1 + q_2 > 1$.
- Asymmetric cost distribution if $\sigma_1(c) > \sigma_2(c), \forall c$, i.e., B_1 is more likely to have higher costs.
  - B_2 is less aggressive if $\sigma_2(c) > \sigma_1(c)\frac{1-q_2}{1-q_1}$.

Identification and Estimation

Identification:

- Observe the bids and identities of losers.
- In open auction, such bids reveal bidder cost.
- Bidder identity and costs can then identify the cost distribution as in Dutch auction (Athey and Haile, 2007).

Endogeneity problem:

- Costs observed are conditional on qualification.
- Self-selection in SECI auctions: bidders with low qualification bids qualify.
- Endogenous selection threshold: Qualification bid depends on distribution of costs.

Resolving endogeneity:

- Suppose that each bidder is either strong or weak (just 2 possible distributions), i.e., $c_i \overset{i.i.d}{\sim} F(c; \theta_i)$, where $\theta_i \in \{\theta_S, \theta_W\}$ are parameters to be estimated.
- The probability density of observing an order statistic, $c^{k_1:N} = x$, conditional on observing a higher order statistic, $c^{k_2:N} = y$, is given as:

$$p^{k_1|k_2}(x|y; \theta, \mathcal{N}) = \prod_{i=1}^{k_1-1} \frac{F(x;\theta_i)}{F(y;\theta_i)} \frac{f(x;\theta_{B_{k_1}})}{F(y;\theta_{B_{k_1}})} \prod_{i=k_1}^{k_2-1} \left(1 - \frac{F(x;\theta_i)}{F(y;\theta_i)}\right) \quad (1)$$
$$= f^{k_1|k_2-1}(x, y; \theta_S, \theta_W)$$

It's independent of selection threshold.

Estimation of parameters:

- Estimate the following using MLE, where likelihood function is based on (1):

$$c_{ia} \sim \mathcal{N}(\mu_{ia}, var)$$
$$where\ \mu_{ia} = \alpha_0 + \alpha_a X_a + \alpha_S X_i$$

- Auction features: Solar or wind, Pre- or post-2018, and their interaction.
- Bidder features: Large producer or not.

Counterfactuals

Bidders assumed to respond to a mixture of distribution of large and small bidders, as they don't observe identities.

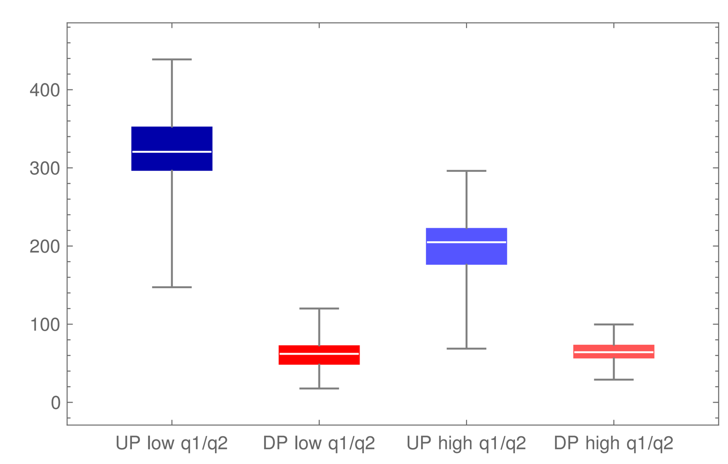

Fig. 3: Inefficiency- Uniform vs Discriminatory pricing, $M = 1200MW$

Conclusion

- Key Takeaway: Selection inefficient in current format, significant welfare improvement on switching to discriminatory pricing.
- Future tasks: Find more counterfactuals, analyse incentives in qualifier round, analyse auctioneer's incentives.

References

Athey, Susan and Philip A Haile (2007). "Nonparametric approaches to auctions". In: *Handbook of econometrics* 6, pp. 3847–3965.

Holmberg, Pär and Frank A Wolak (2018). "Comparing auction designs where suppliers have uncertain costs and uncertain pivotal status". In: *The RAND Journal of Economics* 49.4, pp. 995–1027.