Reverse Auctions to Procure Negative Emissions at Industrial Scale

NBER WORKSHOP ON
THE ECONOMICS OF DECARBONIZING INDUSTRIAL PRODUCTION

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RESOURCES for the FUTURE

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The Assignment

How should Sweden procure BECCS?

A LIMITED BUDGET FOR PROCURING CCS FROM THE WOOD PRODUCTS INDUSTRY

- Fixed budget (3.3 billion euro) for a procurement to meet international obligations
- Small number of firms, each with a fixed maximum capacity
- Concave costs (high fixed costs, low variable costs)
- High uncertainty about technology costs
- Unclear policy on potential default by winning bidders

Policy Goals

- Meet international emission reduction obligations (national emission reductions)
- Induce technological change but at low cost
- Support development of a market for sequestered carbon
- Policy risk due to high price, low procurement, and performance default by winning bidders

Procurement of Carbon Capture for Net Zero

RESIDUAL INDUSTRIAL FOSSIL USE WILL EXTEND WELL BEYOND 2050

- The Swedish BECCS case is the first of many
- How will governments and firms procure carbon capture services?
- Retrofits on existing capital stock
- This means concave costs and firm-level capacity constraints
- High risk investment: mix of firm-specific and systematic risk
- While risky, the investment produces learning and cost reductions

Research Motivation

- Auction performance is sensitive to institutional context (Kremer and Nyborg, 2004)
- Experimental evaluation and refinement can help identify formats that will likely work well in a given context (Cummings et al. 2003)
- We hope to identify auction features that can produce good outcomes in procurement of industrial CCS and carbon removal generally

Specific design goals

- Induce high CO_2 reductions for a fixed budget
- Spend most of (but not more than) the available budget
- Reduce the likelihood of collusion
- Allocate procurement efficiently across firms
- Reduce the influence of the winner's curse on firm bids
- Auction design should increase participation and acceptance
- Public perceptions of transparency and fairness are important

Important context elements

- CCS installations have concave costs
- A small number of potential bidders
- Correlated common-value risks
- A fixed (capped) budget with a variable quantity to purchase
- A high cost to the agency in the event of a performance default

The Puzzle: What auction format to use?

AUCTION OUTCOMES CAN BE VERY SENSITIVE TO CONTEXT

Procurement Auctions in Practice

- Dynamic auctions are often used for sales but rarely for procurement
- Choice influenced by bidder risk aversion and market characteristics (Burtraw et al., 2009; Holt, 1980).
- First-price sealed bid auctions encourage aggressive bidding, potentially lowering procurement costs.
- Open auctions may disadvantage weaker bidders and raise prices (Aloysius et al., 2016; Katok, 2013; Decarolis, 2014, 2018).
- But open auctions are advocated for reducing winner's curse (Ausubel & Cramton, 2006)

Procurement Auctions in Practice

- The available evidence is still unsettled.
- With potential costly default, the sealed-bid, first-price auction may minimize total expected costs of procurement and default (Birulin 2006)
- But procurement reforms that lower bids can increase costly default risk (Decarolis 2013)
- Private (seller determined) auctions often add post-bid evaluation step
- Public agencies generally avoid post-bid evaluation to avoid potential corruption

Concave Costs

WHERE BIDDERS OFFER TO SELL MANY UNITS

- If the buyer needs a fixed number of units or has a fixed budget, then concave costs pose a difficulty
- Unit costs are minimized when all sellers operate at full capacity
- But with few large bidders, one bidder dropping out may leave a gap in either the quantity obtained or the budget used
- There may be a policy benefit to buying some additional units but from a producer not operating at full capacity (higher unit costs)

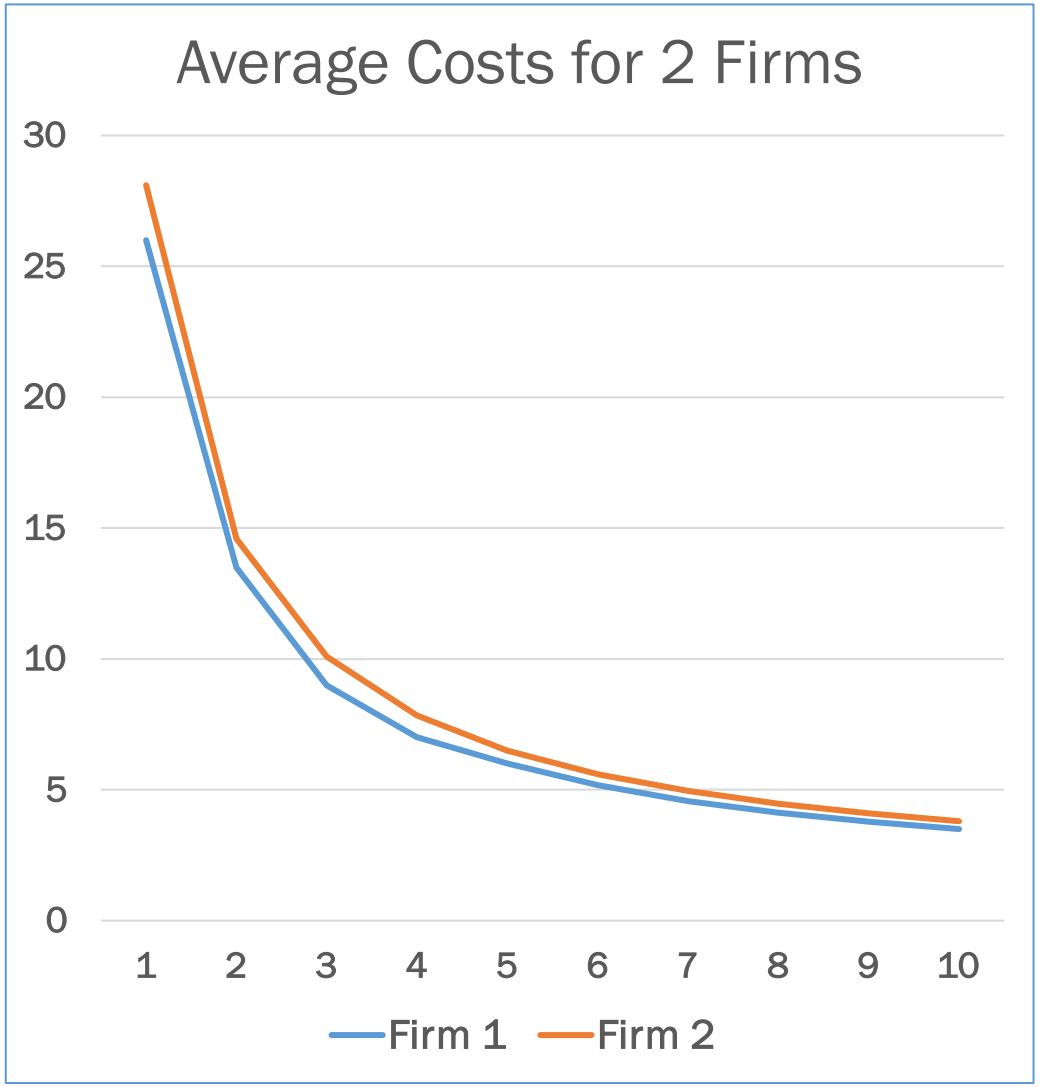
Spending the Budget

YOU MAY NOT TAKE THE LOWEST BID

If you have $66 to spend, choose F2 to produce 10 and F1 to produce 3.

We need to know more than just the price at maximum capacity

We need a new auction design to accomplish this



The Descending Clock as an Option

- Baranov et al. (2017) explore vaccine procurement in a similar case
- Buyer requires a fixed number of doses from few large producers
- To minimize costs, most bidders should operate at capacity but a marginal bidder may operate at a lower capacity (higher unit cost)
- They suggest a descending clock auction where bidders offer an output range: any amount above a minimum quantity
- The auctioneer has information to choose the marginal bidder

We use Experiments to Explore Auction Performance

- Test auction designs for procuring from firms with concave costs
- Theoretical results on auction often apply to a specific strategic environment
- In more general cases, refinements in auction design must be tested experimentally
- We will use laboratory experiments to test auction designs for a case that resembles the current case of interest: procuring CCS
- Balancing maximum sequestration and efficient budget utilization.
- Managing limited supplier numbers and single auction constraints (LiCalzi & Pavan, 2005; McAdams, 2007; Kremer & Nyborg, 2004)

The Experiments

Testing Procurement Auctions where Costs are Concave

- We wish to investigate auction designs that will give information about costs to firms of operating at less than full capacity
- This will allow the buyer to choose all but one bidder to operate at full capacity and one bidder to operate at partial capacity
- Since theory does not give clear guidance, on format, we will test both sealed bid, first price auctions and declining clock auctions
- The auction must work well in the small-numbers case

Treatments

- Sealed bid versus sequential (declining clock)
  - Each auction type will be modified to allow bids for operating facilities at any level from half capacity to full capacity
- The two auction types will be tested with both 6 and 3 competitors to test the effect of very small numbers of bidders
- Common value information design: $6 known fixed cost with a noisy signal on variable costs
- Each bidder gets a signal on [3,4,5] about variable costs. Actual costs are the average of the signals of all bidders.

The Lab Setup

- Our participants are recruited from the UVA student body
- We use the VEconLab experimental software
- Students are paid $10 to show
- Each session involves a practice round (data not used) and then 6 repetitions of the treatment auction
- They earn money for both practice and treatment rounds
- Average earning are around $30 for about a one hour session

Specifics of Auction Design: Sealed bid

- Sealed bid
  - Bidders enter two bids, one for operating at full capacity and one for operating at half capacity
  - Bids are available in $0.50 increments, max bid is $8
  - Full capacity bids are selected until no additional full capacity bids can be accepted without exceeding the budget
  - Then secondary, low capacity bids are filled from low to high until no more bids can be accepted without exceeding the budget

Specifics of Auction Design: Declining clock

- Declining clock
  - Clock starts at $8 and declines by $0.50 for each round
  - Bidders offer to sell 0 units (withdraw) or full capacity (6 units) at the current clock price
    - 0 means drop out of this auction (subject to lookback)
    - 6 means offer to operate at full capacity at the current clock price
  - Bidders also enter the minimum quantity they would be willing to offer at the current clock price
  - Clock falls until the sum of the full capacity bids falls below the budget
  - Full capacity bids are filled at the closing clock price
  - Lookback checks whether anyone dropping out in previous round can have at least their minimum quantity filled at the previous clock price without exceeding budget

Novel Auction Design

- The novel features of this auction design are:
  - Sealed bid: The secondary, low capacity price bid
  - Clock: The lookback procedure
- These features are a way to harvest some additional cost function information from bidders
- Each bidder reveals additional information about their costs to the auctioneer

Preliminary Results

Lab Sessions

- We have two groups of sessions so far:
  - 6 sessions each of 6 bidder sealed bid and clock auctions
  - 3 sessions each of 3 bidder sealed bid and clock auctions
- 6 bidder sessions had a procurement budget of $168
- 3 bidder sessions had a procurement budget of $84
- We use a stratified two-tailed permutation test to assess possible differences between the clock and sealed bid auctions

Session Results So Far

	Avg. Bidder Earnings		Units Procured		Avg. Expenditure		Avg. Cost per unit		Negative Profits
Sealed bid 6 bidder avg.	3.2		29.3		164.7		5.6		17.0
Clock 6 bidder avg.	2.0		30.0		160.3		5.3		14.0
Sealed bid 3 bidder avg.	1.2		14.2		75.8		5.4		4.3
Clock 3 bidder avg.	-1.2		16.0		77.0		4.8		9.3
2-tail permutation test p value:	**0.005**		**0.029**		**0.162**		**0.004**		**0.433**
	***		**		**not significant**		***		**not significant**

Interpretation

- We find lower procurement costs with the clock but no difference in the fraction of the budget used
- The number of units procured is larger with the clock (although this result is only marginally significant)
- Much of the literature suggests that sealed bid first price auctions will result in "overly aggressive" bidding
- Bidder earnings are lower with the clock but negative earnings are not more frequent

Observations

- The clock induced more aggressive bidding
- We do not see significantly more cases of losing money, so we cannot attribute this to winner's curse
- The second bid and lookback mechanisms worked to increase the number of units procured
  - 11 units per session in the sealed bid case based on the second bid
  - 240 units per session in the clock case based on the lookback procedure

More Observations

- There was no evidence of collusion in the 3 bidder sessions.
  - If anything, competition seemed more intense in the 3 bidder clock auction
- We do not offer an option of defaulting by the winning bidders
- So, based on our current results, we cannot draw conclusions about whether lower earnings increase default risk
  - Recent defaults on New Jersey wind auctions make this an important issue to address in the future

Importance

- Auctions promote price discovery
- This result is critically important as we try to draw firms into large investments in new, untried technologies for industrial decarbonization
- We have shown that, with concave costs, the auctioneer can learn about production costs at less than full capacity
- This can boost CCS procurement at reasonable cost

Extensions

- Explore in more detail the reasons for the aggressive bidding in the clock auction
- Determine how the existence of the outside option of a global market for carbon sequestration might change the auction
- Use firms with different costs to investigate efficiency questions
- Inquire about mechanisms for managing default risk

Thank you

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