CRP_2018: Price Cap and Reference Price Auctions in a Multi-Attribute Setting

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Abstract

Intro

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Theory

The experimental environment presented here is representative of the Conservation Reserve Program but also has applications in supply chain management and other environmental auctions. Note, for example, that the results could generalize to a timber auction in which timber companies could offer to replant trees. Additional applications include development plans with environmental improvements, concessionaire procurement with variable quality, or any other auction where the bidders have an option to increase quality or mitigate damages as part of the auction design. The generalized concept is a simple case of a multi-unit, multi-attribute reverse auction, though many results should apply to forward auctions of the same type. By multi-unit, we refer to the fact that the buyer is purchasing units from multiple sellers, and in our simple example, each seller provides only one unit. By multi-attribute, we refer to the fact that the buyer cares about two attributes in this scenario, both the price of the objects and the quality of the objects. In our example, the buyer faces a quantity target (rather than a monetary budget constraint), but this is again reflective of many other auction contexts.

In this two-attribute, multi-unit environment, the buyer seeks to maximize benefits (quality) subject to the quantity target, with a secondary objective of minimizing costs. In addition, economic efficiency concerns also give rise to an objective of allocative efficiency, which may or may not be internalized by the buyer. For our application, the buyer is directly concerned about allocative efficiency, and we will stress this in our findings.

The sellers seek to maximize profits, and we assume that they have no preferences over the quality of the unit they sell. This may be an inappropriate assumption in some contexts, but it is made to simplify the setting. Similarly, potentially heterogeneous private costs for improving unit quality are ignored for simplicity.

Theoretical Predictions

Assuming this setting and these seller preferences, sellers maximize profits by choosing a pair of offer price and quality. The theoretically optimal bidding strategy depends on where a seller is located in the distribution of opportunity costs and, especially for low allowed markups, the seller's measurement error draw. For bidders who feel they can bid their price cap and win, adding quality improvements is a losing proposition, because they will spend money on quality without any expected returns. For each bidder, there is some b_{safe} such that any $b \leq b_{safe}$ could be expected to win with certainty. Under a price cap, each bidder also faces some constraint $\mathrm{b} \leq \overline{\mathrm{b}} = \mathrm{c} + \mathrm{e} + \mu$, where c is the true opportunity cost, e is the measurement error, and μ is the allowed markup over (noisily) estimated opportunity costs for all bidders. Whenever $\mathrm{b}_{\mathrm{safe}} \leq \overline{\mathrm{b}}$, the bidder has no incentive to pay for a quality improvement. In a dynamic setting of quality adjustments, $\mathrm{b}_{\mathrm{safe}}$ depends on not only the bids of other bidders but also the quality of other parcels and of the bidder's parcel.

For any $\overline{\mathrm{b}} > \mathrm{b}_{\mathrm{safe}}$, the bidder will choose to improve quality if and only if the gains in expectation exceed the cost of improving quality. Under a bid cap framework, it will also be true that some bidders will be unable to afford quality improvements that they would otherwise undertake, if the allowed markup is sufficiently small. Within our environment, this constraint and the fact that the probability of acceptance is generally decreasing in the bid mean that two bidders with the same true opportunity costs but with different noise draws will face different incentives to improve quality. Of the two bidders, the bidder with a more favorable (positive) noise draw will have a higher bid cap and therefore be able to pay for increased quality, while the bidder with a more unfavorable (negative) noise draw will have a lower bid cap and potentially be unable to afford increased quality. This should provide a very small boost to allocative efficiency.

It is worth noting that, if the costs of adding quality are concave, we would expect to see quality expenditures vary by the marginal benefit of adding quality. In the middle of the cost distribution, where the benefits of quality should be the highest, bidders may purchase all of the available quality improvements. However, at lower points in the distribution, the benefits may be smaller and fall between the marginal cost of limited improvements and the cost of all improvements.

Under a reference price mechanism, the incentives and predictions are substantially different. Unlike the price cap mechanism, even the lowest-cost bidders must be sufficiently competitive. In this setting, there may be incentives for the lowest-cost bidders to purchase quality improvements as less expensive than lowering their bid. Medium-cost bidders should again face the largest pressure to improve quality, as their choices can have large impacts on their probability of acceptance.

Experimental Design and Environment

This work expands upon Cramton et al. (2018), examining alternative auction formats within the context of an environment where bidders may compete on both price and quality.

In our experimental setting, 16 potential sellers each possess a single unit, which they aim to sell to a single buyer. The buyer will purchase the best 8 parcels, where auction ranking is decided by a one-dimensional benefits index minus cost. Potential sellers may choose whether to participate, and if they do participate, they may choose whether to increase their benefits index, at a direct cost to the seller. Potential sellers will have heterogenous, uniformly-distributed opportunity costs ranging from 10 to 100, but all parcels will have a baseline benefits index of 100. Each bidder may increase his or her benefits index to 110 by paying a lump sum of 4 [2] or to 120 by paying a lump sum of 6. This generates an incentive to improve the benefits attribute, subject to the seller's budget constraint. We also plan to explore the effects of this added dimension depending on whether the cost of quality improvement is concave (diminishing marginal returns) or convex (increasing returns to scale).

The auction follows a discriminatory, pay-as-bid implementation. Payoffs to the sellers are defined as the requested payment minus both the opportunity cost and the cost of the quality improvement. The cost (and benefits) of the quality improvement will only be assessed if the unit is purchased. The payoffs to the buyer are considered in the total benefits, total cost, and degree of allocative efficiency.

Auction Formats

The buyer observes the opportunity costs of the potential sellers with noise, which we will assume to be additive, discrete, and uniformly distributed [-5, +5]. Under bid cap designs, a potential seller cannot request more than this noisy estimate plus some allowed markup, which we evaluate at +1, +3, +5, +8, +12, and +15. For example, under an allowed markup of +5, a potential seller with an opportunity cost of 47 and a noise draw of -2 would have a bid cap of 50 = 47-2+5. Note that it will be impossible for some potential sellers to sell at a profit under the lowest allowed markup levels. In addition, low levels of allowed markup will make it impossible for some potential sellers to purchase additional benefits and still sell for a profit.

Under reference price designs, the buyer ranks all offers based on a score, which is calculated as follows:

$$Score = benefit - 50 * \frac{offer}{ref_{price}} - ref_{price}$$

For the exogenous reference price design, the reference price is the noisy measure of opportunity cost mentioned above. For the endogenous reference price design, the reference price is the average offer of the nearest 4 bidders in terms of noisily-measured opportunity cost. In other words, the buyer compares each bid to the bids of the 4 bidders that most closely resemble the bidder in question, based on its noisy measure of opportunity costs.

It may be worth also exploring how a Hellerstein and Higgins – type reference price performs.

Results

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Conclusion

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// Tables and Figures

References

Bichler (2000)

Hellerstein and Higgins (2010)

Zhang and Jin (2007)

Appendix

Instructions

Welcome to the Experimental Economics Laboratory. This study has received funding from various research foundations. Please pay careful attention to the instructions as real money is at stake.

The session is expected to last about 1.5 hours. During the study, we will use Experimental Currency Units (ECUs) and at the end of the experiment all your earnings will be converted to US Dollars. The conversion from ECU to US Dollars will be 3 ECUs to one Dollar. That is, you will receive $1 for every 3ECUs you earn during the experiment. All earnings will be paid in cash, and participants do not risk losing money. You are guaranteed a show up fee of $7.

General Procedure:

You will be participating in several rounds of auctions. In each round, you will be bidding against your fellow participants. The same set of participants will be in each auction.

In a given auction, each bidder holds an *object* and aims to sell it to the buyer (represented by a computer program). When each round starts, you will privately observe your *Cost* of the object (how much making the object would cost you).

If you sell the object to the buyer for a certain *price*, the difference between the selling *price* and your *cost* represents your profit. Each bidder's *cost* will be randomly determined. Costs can take any integer value from 10 to 100, inclusive. All numbers are drawn with equal probability and independently from other bidders' *cost* and from draws in other rounds. The other bidders participating in this auction have their own *costs* determined in the same manner and each of them will learn only his/her *cost*.

There are 16 participants in each auction, each holding a single object every round. The buyer always wants to purchase 8 objects in each auction.

You will compete in 3 different types of auctions. Each type of auction will have 20 rounds.

You will be paid based on 6 randomly selected rounds, two for each type of auction.

Throughout the instructions we will use the expression: **RAND[-5,+5]** to denote a random integer between -5 to 5, inclusive. All numbers in the set {-5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5} occur with equal chance.

Auction 1: Price Cap 1

At the beginning of each auction round, you will learn both your private *cost* and the *maximum offer* that you can submit to sell an object. Using this information, you must then decide how much to offer in the auction.

The buyer sets the *maximum offer* (or *price cap*) equal to the sum of your *cost*, a random number $RAND[-5,+5]$ and **5 ECUs**. That is:

$$Maximum\ Offer = Cost + 5 + RAND[-5,+5]$$

The random term RAND[-5,+5] is independently drawn for each bidder and for each round.

The buyer will <u>purchase from the 8 bidders with the lowest scores</u> and pay each seller the corresponding offer. All remaining offers will be rejected. If you sell your object, your profit for the round will be the difference between your offer and your cost:

$$Profit = Offer - Cost$$

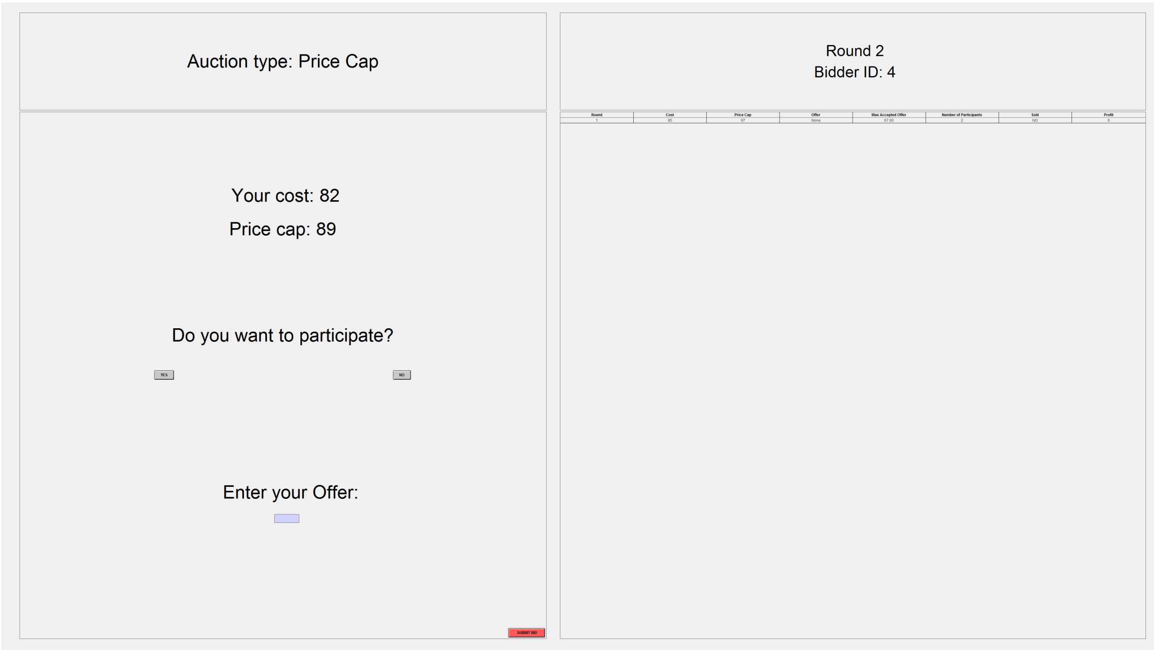
If you do not sell any object your profits for the round will be zero.

Remember that you will be given the opportunity to choose whether or not to participate each round. If 8 or fewer individuals choose to participate, all bids less than or equal to their respective price caps (maximum offers) will be accepted. To not bid, select “No” and then “Proceed without Bidding,” the red button at the bottom of the screen.

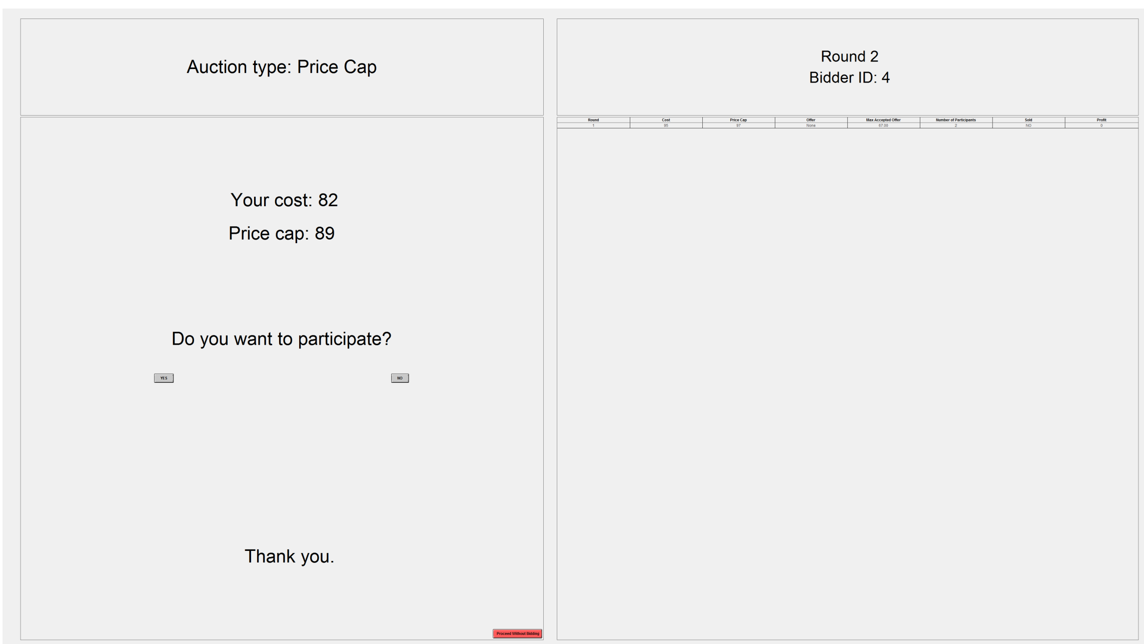
Example 1:
If your *cost* is 50 ECUs, the maximum offer that applies to you could be any integer between 50 and 60 ECUs, inclusive; all numbers equally likely. For example, it could be 54 ECUs.

Example 2:

Bidder ID	Cost	Max Offer (Cost+RAND+**5**)	Offers	Sold (8th lowest offers)	Profit (Offer – Cost)
1	78	80	None	No	0
2	40	44	43	YES	43-40 = 3
3	14	24	22	YES	22-14 = 8
4	76	81	77	No	0
5	16	17	None	No	0
6	72	74	73	YES	73-72 = 1
7	22	30	22	YES	22-22 = 0
8	51	57	56	YES	56-51 = 5
9	88	89	None	No	0
10	55	55	55	YES	55-55 = 0
12	77	83	80	No	0
13	94	102	98	No	0
14	98	100	None	No	0
15	20	29	27	YES	27-20 = 7
16	73	75	74	YES	74-73 = 1



Auction type: Price Cap
Round 2
Bidder ID: 4
Round | Cost | Price Cap | Offer | Max Accepted Offer | Number of Participants | Sold | Profit
1 | 95 | 97 | None | 67.00 | 2 | NO | 0
Your cost: 82
Price cap: 89
Do you want to participate?
YES
NO
Enter your Offer:
SUBMIT BID



Auction type: Price Cap
Round 2
Bidder ID: 4
Round | Cost | Price Cap | Offer | Max Accepted Offer | Number of Participants | Sold | Profit
1 | 95 | 97 | None | 67.00 | 2 | NO | 0
Your cost: 82
Price cap: 89
Do you want to participate?
YES
NO
Thank you.
Proceed Without Bidding

Auction 1.1: Price Cap with Participation

At the beginning of each auction round, you will learn both your private *cost* and the *maximum offer* that you can submit to sell an object. Using this information, you must then decide how much to offer in the auction.

The buyer sets the *maximum offer* (or *price cap*) equal to the sum of your *cost*, a random number $RAND[-5,+5]$ and **x ECUs**. That is:

$$Maximum\ Offer = Cost + x + RAND[-5,+5]$$

The random term RAND[-5,+5] is independently drawn for each bidder and for each round. The set of possible x's is 1, 3, 8, or 12. The possible cap calculations are as follows:

$$\begin{aligned} Maximum\ Offer &= Cost + 1 + RAND[-5,+5] \\ Maximum\ Offer &= Cost + 3 + RAND[-5,+5] \\ Maximum\ Offer &= Cost + 8 + RAND[-5,+5] \\ Maximum\ Offer &= Cost + 12 + RAND[-5,+5] \end{aligned}$$

The buyer will <u>purchase from the 8 bidders with the lowest scores</u> and pay each seller the corresponding offer. All remaining offers will be rejected. If you sell your object, your profit for the round will be the difference between your offer and your cost:

$$Profit = Offer - Cost$$

If you do not sell any object your profits for the round will be zero.

<u>*Example 1:*</u>

If your *cost* is 50 ECUs and x=3, the maximum offer that applies to you could be any integer between 48 and 58 ECUs, inclusive; all numbers equally likely. For example, it could be 53 ECUs.

Example 2:

Bidder ID	Cost	Max Offer (Cost+RAND+**3**)	Offers	Sold (8th lowest offers)	Profit (Offer – Cost)
1	78	80	79	No	0
2	40	44	43	**YES**	43-40 = 3
3	14	24	22	**YES**	22-14 = 8
4	76	81	77	No	0
5	16	17	17	**YES**	17-16 = 1
6	72	74	73	**YES**	73-72 = 1
7	22	30	22	**YES**	22-22 = 0
8	51	57	56	**YES**	56-51 = 5
9	88	89	89	No	0
10	55	55	55	**YES**	55-55 = 0
12	77	83	80	No	0
13	94	102	98	No	0
14	98	100	100	No	0
15	20	28	27	**YES**	27-20 = 7
16	73	75	74	No	0

Auction 2: Price Cap 2

At the beginning of each auction round, you will learn both your private *cost* and the *maximum offer* that you can submit to sell an object. Using this information, you must then decide how much to offer in the auction.

The buyer sets the *maximum offer* (or *price cap*) equal to the sum of your *cost*, a random number $RAND[-5,+5]$ and **15 ECUs**. That is:

$$Maximum\ Offer = Cost + 15 + RAND[-5,+5]$$

The random term RAND[-5,+5] is independently drawn for each bidder and for each round.

The buyer will <u>purchase from the 8 bidders with the lowest scores</u> and pay each seller the corresponding offer. All remaining offers will be rejected. If you sell your object, your profit for the round will be the difference between your offer and your cost:

$$Profit = Offer - Cost$$

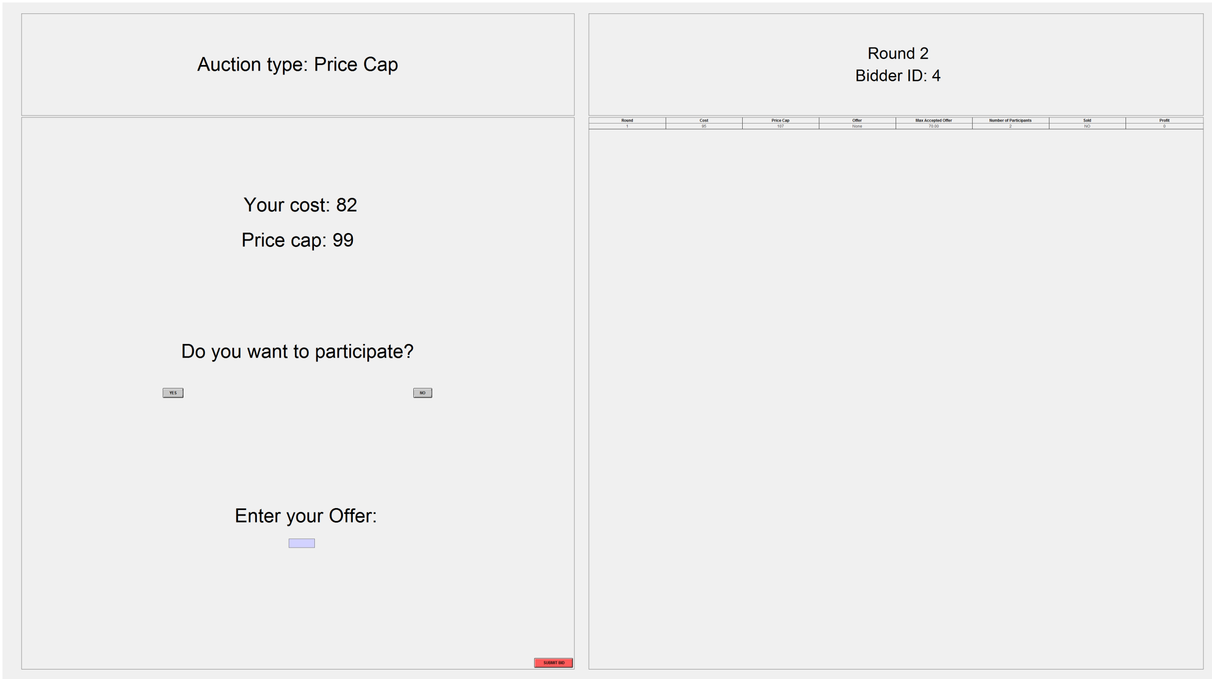
If you do not sell any object your profits for the round will be zero.

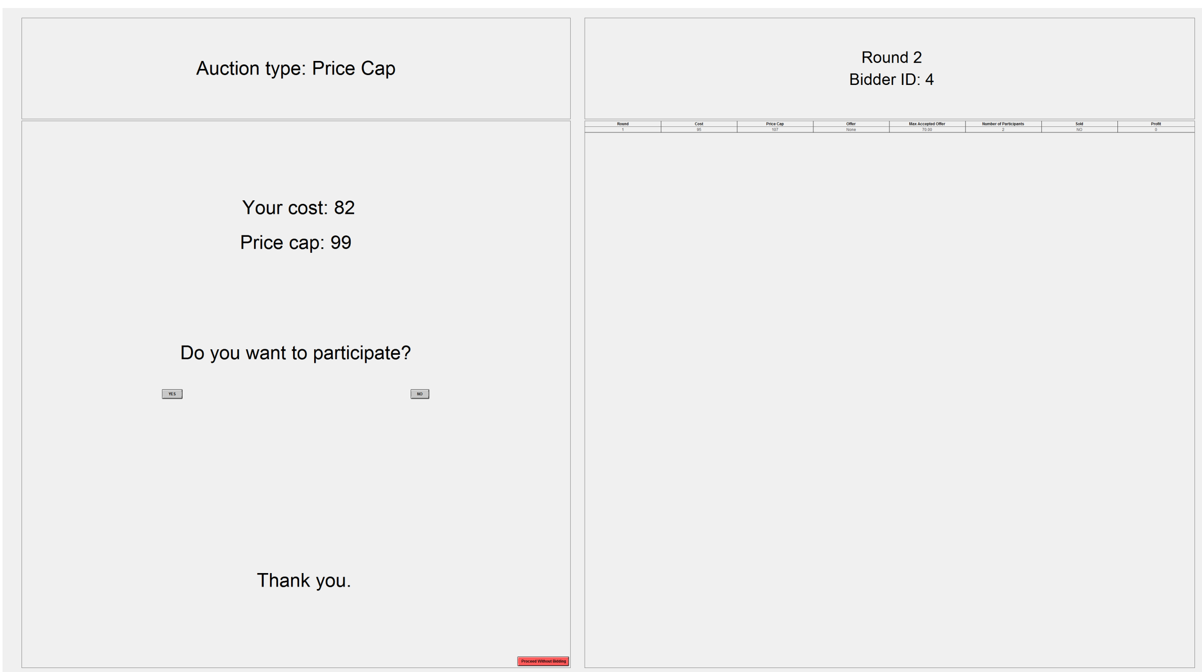
Remember that you will be given the opportunity to choose whether or not to participate each round. If 8 or fewer individuals choose to participate, all bids less than or equal to their respective price caps (maximum offers) will be accepted. To not bid, select "No" and then "Proceed without Bidding," the red button at the bottom of the screen.

<u>Example 1:</u>
Suppose in a certain round, your *cost* is 50 ECUs. The maximum offer that applies to you in that round could be any integer between 60 and 70 ECUs, inclusive; all numbers equally likely. For example, it could be 66 ECUs.

<u>Example 2</u>:

Bidder ID	Cost	Max Offer (Cost+RAND+**15**)	Offers	Sold (8th lowest offers)	Profit (Offer - Cost)
1	78	92	None	No	0
2	40	60	50	YES	50-40 = 10
3	14	29	27	YES	27-14 = 13
4	76	87	77	YES	77-76 = 1
5	16	28	None	No	0
6	72	90	79	No	0
7	22	38	29	YES	29-22 = 7
8	51	62	54	YES	54-51 = 3
9	88	98	None	No	0
10	55	70	59	YES	59-55 = 9
12	77	95	81	No	0
13	94	106	98	No	0
14	98	117	None	No	0
15	20	32	30	YES	30-20 = 10
16	73	88	78	YES	78-73 = 5


Auction type: Price Cap
Round 2
Bidder ID: 4
Round | Cost | Price Cap | Offer | Max Accepted Offer | Number of Participants | Sold | Profit
1 | 95 | 107 | None | 70.00 | 2 | NO | 0
Your cost: 82
Price cap: 99
Do you want to participate?
YES
NO
Enter your Offer:
SUBMIT BID


Auction type: Price Cap
Round 2
Bidder ID: 4
Round | Cost | Price Cap | Offer | Max Accepted Offer | Number of Participants | Sold | Profit
1 | 95 | 107 | None | 70.00 | 2 | NO | 0
Your cost: 82
Price cap: 99
Do you want to participate?
YES
NO
Thank you.
Proceed Without Bidding

Auction 3: Reference Price 1

At the beginning of each auction round, you will learn both your private *cost* and the *reference price* that applies to you. The *reference price* is the sum of your *cost* and a random number, $RAND[-5, +5]$. That is:

$$Reference\ Price = Cost + RAND[-5, +5]$$

The random term RAND[-5,+5] is independently drawn for each bidder and for each round. All integers between -5 and 5 occur with equal probability.

Using this information, you must decide your offer in the auction. The computer then calculates <u>your *score using the following rule:*</u>

$$Score = \frac{Offer}{Reference\ Price} + \frac{Reference\ Price}{50}$$

Other bidders' scores are computed in similar fashion.

The buyer will <u>purchase from the 8 bidders with the lowest scores</u> and pay each seller the corresponding offer. All remaining offers will be rejected. If you sell your object, your profit for the round will be the difference between your offer and your cost:

$$Profit = Offer - Cost$$

If you do not sell any object your profits for the round will be zero.

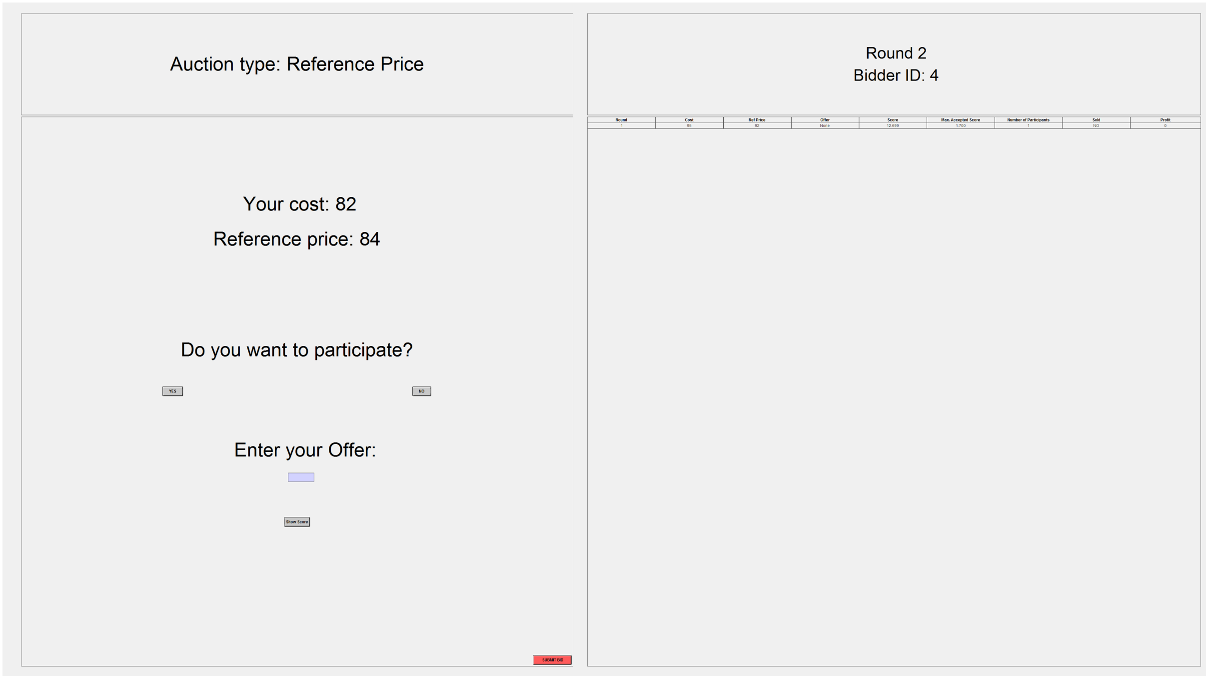
Remember that you will be given the opportunity to choose whether or not to participate each round. If 8 or fewer individuals choose to participate, all bids less than or equal to their respective price caps (maximum offers) will be accepted. To not bid, select "No" and then "Proceed without Bidding," the red button at the bottom of the screen.

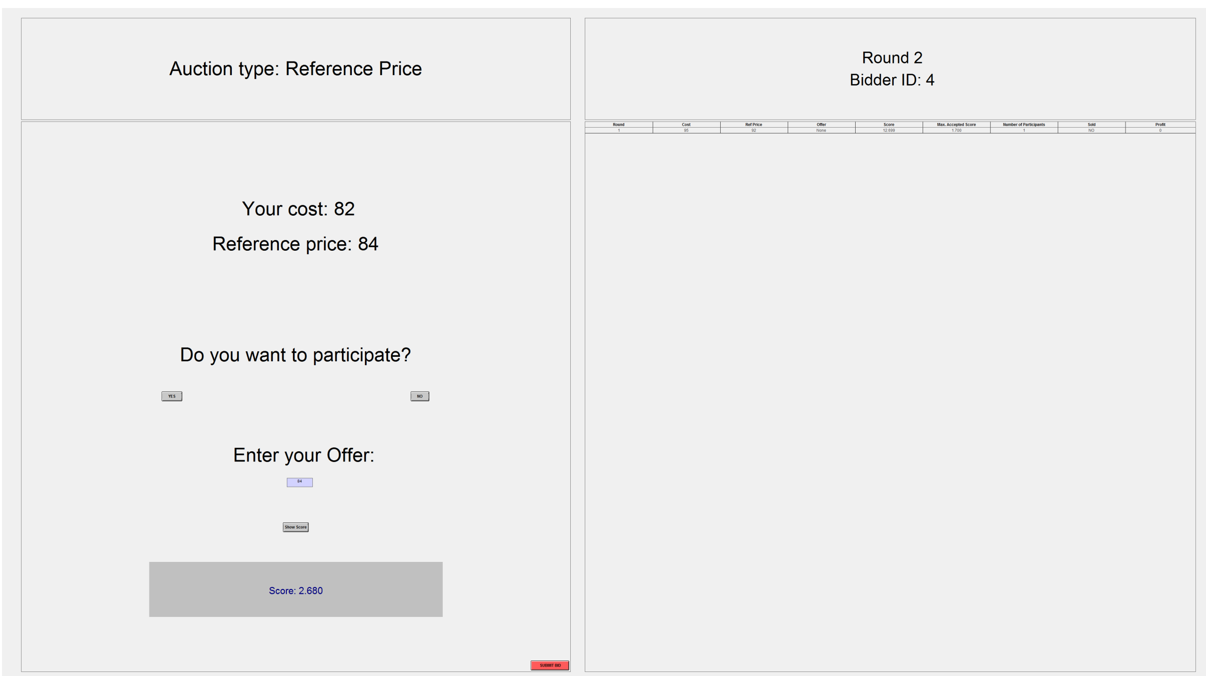
Example 1:

Suppose we are in a procurement auction for one unit of fruit, and there are apples and oranges. The *reference price* for one apple is set to \$50 and to \$75 for one orange. Suppose the apple bidder offers to sell (offers) for \$60 and the orange bidder also offers to sell for \$60. Then, the corresponding scores will be 60/50 + 50/50 = 2.2 for the apple and 60/75+75/50 = 2.3 for the orange. Since the score for the apple bidder is lower, the buyer will buy the apple.

Example 2:

Bidder ID	Cost	Ref. Price (Cost+**RAND**)	Offers	Score (Offer/ Ref + Ref/50)	Sold (8th lowest Scores)	Profit (Offer - Cost)
1	78	80	None	N/A	No	0
2	40	41	43	1.869	**YES**	43-40=3
3	14	18	18	1.36	**YES**	18-14=4
4	76	76	79	2.559	No	0
5	16	15	None	N/A	No	0
6	72	77	77	2.54	**YES**	77-72=5
7	22	22	25	1.576	**YES**	25-22=3
8	51	51	53	2.059	**YES**	53-51=2
9	88	92	None	N/A	No	0
10	55	57	58	2.158	**YES**	58-55=3
12	77	79	80	2.593	No	0
13	94	89	96	2.859	No	0
14	98	100	None	N/A	No	0
15	20	23	24	1.503	**YES**	24-20=4
16	73	69	76	2.481	**YES**	76-73=3


Auction type: Reference Price
Your cost: 82
Reference price: 84
Do you want to participate?
YES
NO
Enter your Offer:
Show Score
SUBMIT BID
Round 2
Bidder ID: 4
Round
Cost
Ref Price
Offer
Score
Max. Accepted Score
Number of Participants
Sold
Profit
1
95
92
None
12.699
1.700
1
NO
0


Auction type: Reference Price
Your cost: 82
Reference price: 84
Do you want to participate?
YES
NO
Enter your Offer:
84
Show Score
Score: 2.680
SUBMIT BID
Round 2
Bidder ID: 4
Round
Cost
Ref Price
Offer
Score
Max. Accepted Score
Number of Participants
Sold
Profit
1
95
92
None
12.699
1.700
1
NO
0

Auction 4: Reference Price 2

At the beginning of each auction round, you will learn your *cost* and your *estimated cost*. The *estimated cost* is the sum of your *cost* and a random number $RAND[-5,+5]$:

$$Estimated\ Cost = Cost + RAND[-5,+5]$$

where the random term, RAND[-5,+5], is independently drawn for each bidder and for each round.

Using this information, you must decide your offer in the auction. The computer then calculates your score using the following rule:

$$Score = \frac{Offer}{Neighbors'\ Aver.\ Offer} + \frac{Neighbors'\ Aver.\ Offer}{50}$$

where ***Neighbors' Aver. Offer*** is the average offer of the **4 participating bidders** that are closest to you in terms of Estimated Costs. Other bidders' scores are computed in similar fashion.

The buyer will purchase from the 8 bidders with the lowest scores and pay each seller the corresponding offer. All remaining offers will be rejected. If you sell your object, your profit for the round will be the difference between your offer and your cost:

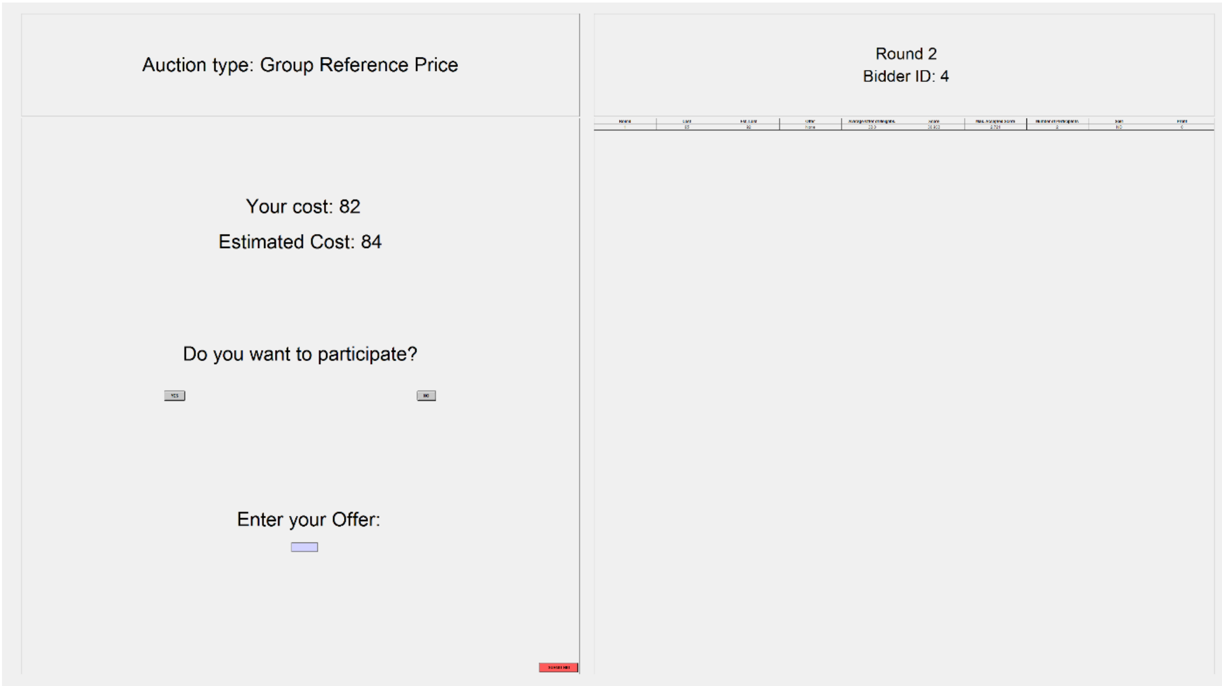
$$Profit = Offer - Cost$$

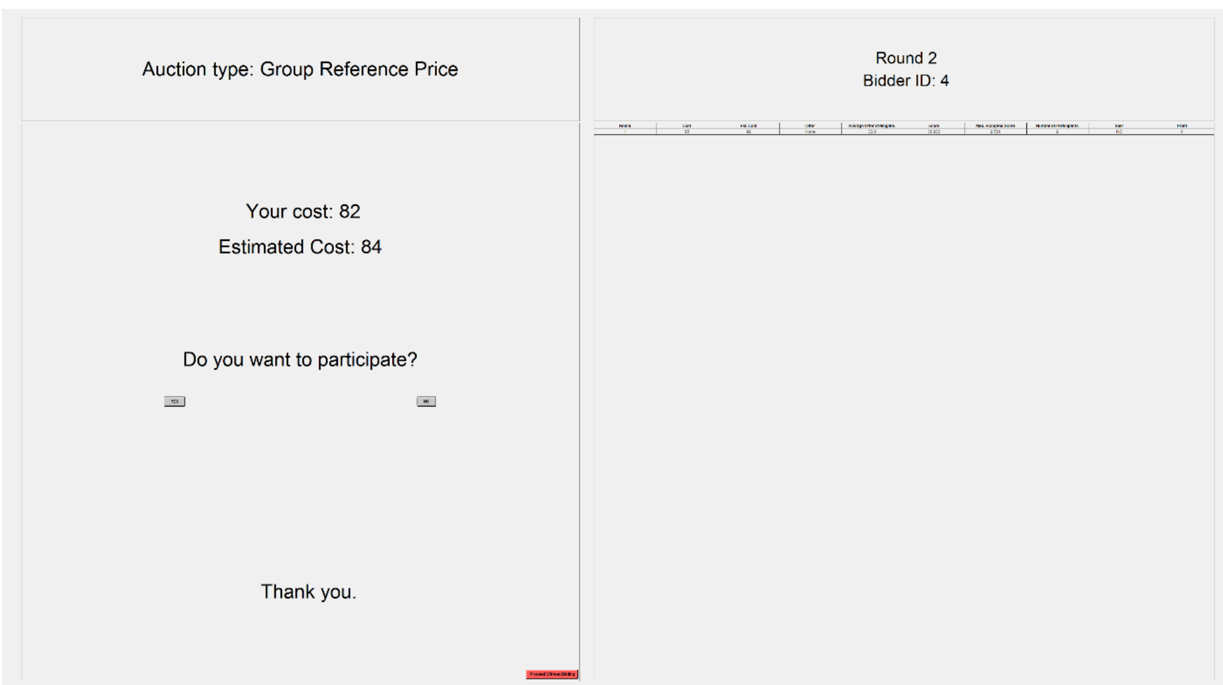
If you do not sell any object your profits for the round will be zero.

Remember that you will be given the opportunity to choose whether or not to participate each round. If 8 or fewer individuals choose to participate, all bids less than or equal to their respective price caps (maximum offers) will be accepted. To not bid, select "No" and then "Proceed without Bidding," the red button at the bottom of the screen.

Example 1:

Bidder ID	Cost	Est. Cost (Cost+RND) Sorted by	Offers	Average offer of 4 Closest Bidders	Scores	Sold (8th lowest Scores)	Profit (Offer - Cost)
5	16	15	None	N/A	N/A	No	0
3	14	18	17	37	1.199	YES	17-14=3
11	**22**	**21**	**27**	**34.5**	**1.473**	YES	27-22=5
7	22	22	**26**	34.75	1.443	YES	26-22=4
15	20	23	None	N/A	N/A	No	
2	40	41	42	41.25	1.843	YES	42-40=2
8	51	51	53	51.25	2.059	YES	53-51=2
10	55	57	59	61.75	2.190	YES	59-55=4
16	73	69	None	N/A	N/A	No	0
4	76	76	78	66.25	2.502	YES	78-76=2
6	72	77	74	78	2.509	YES	74-72=2
12	77	79	79	84.5	2.625	No	0
1	78	80	None	N/A	N/A	No	0
13	94	89	96	86	2.836	No	0
9	88	92	90	87.5	2.779	No	0
14	98	100	101	84.75	2.887	No	0


Auction type: Group Reference Price
Round 2
Bidder ID: 4
Your cost: 82
Estimated Cost: 84
Do you want to participate?
Enter your Offer:


Auction type: Group Reference Price
Round 2
Bidder ID: 4
Your cost: 82
Estimated Cost: 84
Do you want to participate?
Thank you.