An Experimental Comparison of Target and Budget Constraints in Reverse Auctions

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1 Introduction

Agri-Environmental Schemes (AES) are individual contracts in which voluntary farmers receive payments to implement specific measures to preserve or restore the environment. However, the current schemes at the European scale are often considered as not efficient enough. They indeed have a number of limitations. First, farmers involved in AES receive identical payments per hectare. This fixed payment does not reflect the diversity of farmers' opportunity costs and thus generates overcompensations (informational rents) for those with the lowest costs (Cason et al., 2003). Second, it is difficult for the decision-maker to set an efficient level for payment as he lacks information on farmers' opportunity cost (Ferraro, 2008). One option is to allocate contracts through buying auctions or reverse auctions in which the agri-environmental contracts are bought to bidding farmers through call for projects as in call for tenders in selling auctions. Those reverse auctions of agri-environmental contracts, also called conservation auctions, have been proposed by many authors in the literature (e.g. Latacz-Lohmann and Van der Hamsvoort, 1997; Cason and Gangadharan, 2004) and even implemented in some countries (e.g. Stoneham et al., 2003; Vukina et al., 2008).

Indeed, auction mechanisms are often promoted as an alternative to fixed payments in market design to reduce the asymmetry of information between the auctioneer and the bidders (Ferraro, 2008). The reason is that such mechanisms provide an incentive for bidders (farmers) to bid closer to their reserve price (cost), as they have to trade off between their margin and increasing their probability of winning the auction. Contrary to selling auctions, in reverse auctions, the buyer can announce either the target, i.e. the number of units to be purchased, or the budget he wishes to spend to buy the maximum number of units. Usually, in conservation auctions the lowest bids are accepted until the budget dedicated to the program is exhausted. This auction format is called budget-constrained auction, whereas in target-constraint auctions, the buyer accepts bids until the environmental target is reached. We are interested in these two formats of multi-unit reverse auctions. We consider here that each bidder has only one unit to sell (i.e. the farmer can enroll in a single standard agri-environmental contract). Thus, we assume that farmers are competing on prices only.

The question of how the announced constraint affects the efficiency of reverse auction results remains under studied to date. Indeed, the auction theory has widely been build up from selling auctions. Consequently, it is always the number of units that is announced in the literature on auctions. In a target auction format, an optimal bidding strategy exists based on maximising the bidders' expected surplus (Harris and Raviv, 1981; Cox et al., 1984). This result can be extended to the target reverse auction case. However, to our knowledge, no optimal bidding strategy has been identified so far when it is a budget that is announced in a reverse auction format. Therefore, we can not determine theoretically which format is the most efficient.

In this paper, we propose an experimental design to provide some answers on whether target or budget-constrained reverse auction is more efficient from the buyer's perspective. We consider a discriminatory multi-unit reverse auction, i.e. a sealed bid auction where bidders are paid their own bid. Each seller has only one unit to sell. All units are perfectly identical for the buyer, but each seller has independent and private costs.

To make the comparison possible, equivalent target and budget constraints need to be established to ensure the same degree of competition between sellers. In the target and budget cases respectively, the lower the number of units requested by the buyer or the lower the budget announced by the buyer, the greater the degree of competition between sellers. However, we can hardly predict *a priori* the level of each constraint that equalizes the level of competition between target and budget auctions. To overcome this problem, a solution is to define one of the constraints endogenously, i.e. to define one treatment's constraint using results from the other treatment (Schilizzi and Latacz-lohmann, 2007). Concretely, we propose to set the target constraint exogenously and then to define the budget constraint endogenously according to the results obtained in the target treatment to ensure some kind of equivalence. We thus calculate the budget spent in average from the target treatment. This budget, that we refer to as the average empirical budget, is then used to set the constraint in the budget treatment. Therefore if the average number of units purchased in the budget auction is higher than the number of units announced in the target auction, then the budget auction has a higher budgetary efficiency than the target auction and *vice versa*.

No theoretical or empirical (observational data) literature was found on the comparison of target and budget auctions. To the best of our knowledge, only two studies have already addressed this issue using laboratory experiments (Schilizzi and Latacz-lohmann, 2007; Boxall et al., 2017). However, these two experiments conducted in the context of conservation auctions include methodological limitations discussed in section 2.

Our experiment defers from previous ones in two main features. First, we propose a totally decontextualised experiment for a better control and to allow the results to be extended to any reverse auction. Second, we use the strategy method to obtain subjects complete bidding strategies and generate a very rich data set through simulations. In experimental auctions, the strategy method consists in asking subjects in advance for their entire bidding strategies (for all cost levels) in a single period (Mitzkewitz and Nagel, 1993). Indeed, in induced value auctions, bidders' values (here the costs) are randomly drawn for each subject and the auction outcomes depend on the drawn costs. In order to compare the different auction formats it is thus necessary to keep the same set of costs across treatments. A large number of periods is commonly run per session with different sets of costs to obtain more data. However, in this repeated auction design, there is a learning process over periods that may bias the results even if no feedback is given to the bidders after each period. In addition, there may be a wealth effect when several auctions are played and paid for successively. The strategy method overcomes those issues. We can thus simulate an auction based on the subjects' bidding strategies for any set of costs (see. section 4). In addition, the strategy method allows us to easily run an online experiment since the subjects do not need to be connected at the same time. The groups of bidders (for the calculation of the earnings) are randomly formed ex-post. We choose to use a between-subjects design where subjects are randomly assigned to a single treatment to prevent any order effect. Indeed, in a pilot lab experiment with a within design a significant order effect has been found (see. Hien et al., 2019).

In the following literature review section we discuss in more detail some elements from the experimental literature on the comparison of target and budget constrained auctions and the use of the strategy method in experimental auctions. In section 3, we present our experimental design. Then, in section 4, we explain the calculation of the average empirical budget and the various budgetary and economic performance criteria that we employ. A description of subjects and control variables is conducted in section 5, while the results are discussed in section 6.

2 Literature review

To our knowledge, only two lab experiments compare target and budget constraints in reverse auctions. First, Schilizzi and Latacz-lohmann (2007) assess the performance of these two auction formats in the context of agricultural non-point source pollution reduction. They implement a between-subject design with two treatments. The target constraint is set endogenously to the number of contracts allocated in the budget treatment. In their experiment, student subjects play the role of producers of a single unit of wheat. Each subject receive an opportunity cost of reducing pollution through pro environmental practices. In each treatment there are three auction periods with costs being reshuffled each time to capture learning effects. Costs are randomly drawn values from €5 to €264. Curiously, bidders know that costs are uniformly distributed but are not aware of the range. Participants are informed of their earnings and paid at the end of each auction period. Budgetary efficiency is assessed using the global unit price of contracts and the ratio between total payment and opportunity costs (information rents) as measures for budgetary efficiency. The economic efficiency is determined by the ratio of opportunity costs and the total number of unit purchase. Authors found that in the one-shot setting, budget and target auctions perform similarly in terms of budgetary efficiency with mixed results on information rents.

In another contextualized laboratory experiment on conservation auctions, Boxall et al. (2017) found that in one-shot target auctions outperform budget auctions in terms of budgetary efficiency. The experiment involve 12 fictive farms representative of a Canadian wetland. In each session of 15 periods, subjects are assigned to one farm with corresponding conservation costs from \$1.24 to \$4.38 experimental dollars per wetland acre restored. It is a sealed bid and private values reverse auction. In each period subjects switched farms and therefore faced different costs. Budget and target constraints are both set exogenously[1] with two levels (large and small program sizes). To carry out the comparison between the two formats, Boxall et al. (2017) use unit price and information rent rates as measures of the budgetary efficiency but does not address economic efficiency. In addition, the target format is associated in some treatments with a reserve price and an all or nothing rule, which leads to no payout if the target is not met. This rule aims to discourage overbidding by acting as a potential punishment.

Unlike Schilizzi and Latacz-lohmann (2007) and Boxall et al. (2017) we use a procedure based on the strategy method. This means that subjects must bid in advance for each cost value without knowing which cost will be used to calculate their earnings. The strategy method has already been used in experimental auctions, but never to our knowledge in the context of reverse

[1] Their results reveal that constraints are close but not equivalent in terms of quantities or budget spent.

auctions. Rapoport and Fuller (1995) studied bidding strategies in a bilateral monopoly with sealed-bid double auction setting. Both sellers and buyers are bidders who face induced costs and values respectively. Subjects had to provide their bidding strategy for all possible costs or values. Then, sellers and buyers are paired randomly within each group by the experimenter to see if an exchange is possible. Güth et al. (2002) carried an experimental comparison of first and second price payment rules in a private and independent values auction setting using the strategy method. From the results of this experiment, Güth et al. (2003) emphasized the impact of learning on bidding strategies. Subjects submit complete bidding strategies for the 11 possible induced values in 36 auctions periods. Filiz-Ozbay and Ozbay (2007) focused on anticipated regret and its implications for the equilibrium bidding strategies in first price private value auctions. This paper is specific in the auction literature using the strategy method. Indeed, each bidder had to bid for ten values that were uniformly and independently drawn between 0 and 100 and rounded to the nearest cent. Thus, bidders may not have the same set of values. Kirchkamp et al. (2009) use the strategy method to determine how the presence of an outside option affects bidding strategies, revenue and auction efficiency in first and second price auctions. Katuščák et al. (2015) studied the effect of different types of feedback given after each bidding period in one-shot first-price sealed-bid auctions with private values. Finally, all these experimental studies addresses multi-unit auctions and none of them deal with reverse auctions.

3 Experimental design

3.1 Online experiment

In an online experiment, subjects can not ask questions, therefore they must have a perfect understanding of the instructions. To this end, we produced an instructional video and a comprehension questionnaire consisting of True/False questions. After answering each question, the detailed answer appears on their screen. At any time during the experiment, the subjects could access to a text version of the instructions. Of course, participation is anonymous and the subjects cannot communicate with each other.

In this experiment, subjects can produce and sell one unit of a virtual good to a buyer (the experimenter). Each subject bears a private production cost. The distribution function of private costs is the same for all the subjects and is common knowledge. Concretely, costs are distributed uniformly by multiples of 5 from 0 to 100€, which corresponds to 21 possible costs. The uniform distribution is the simplest distribution to understand for the subjects. Subjects have to choose their selling price for each possible cost in a decision table (see Fig. 1).

The instructional video provides information to the subjects as follows. First, subjects are

Your Cost	Your selling Price
0 €	€
5 €	€
10 €	€
15 €	€
20 €	€
25 €	€
30 €	€
35 €	€
40 €	€
45 €	€
50 €	€
55 €	€
60 €	€
65 €	€
70 €	€
75 €	€
80 €	€
85 €	€
90 €	€
95 €	€
100 €	€

Figure 1: Decision table

told they are participating to an experiment in which they are anonymous sellers and can earn money depending on their decisions and the decisions of other participants. Indeed, they are randomly assigned to groups of 4 participants without being able to identify the 3 other members of their group. They are given the possibility to sell a unit of a hypothetical good to a single buyer (the experimenter) who announces a target or a budget constraint. To have a chance to sell their unit, subjects must complete a decision table (Fig. 1) containing the 21 possible production costs for their unit. For each cost, bidders have to choose a selling price rounded up to the nearest euro. In other words, they have to ask themselves «At this production cost, what is the selling price I am asking?» After completing the decision table, we elicit risk aversion in a self-assessment question as in Dohmen et al. (2011). Then we ask a follow up question to assess the difficulty respondents had in proposing selling prices. Finally subjects have to answer few socio-demographic questions. At the end of the experiment, in order to determine earnings, a production cost is drawn randomly for each participant. Then, for each subject, the bid associated to his/her randomly drawn cost is collected from his/her decision table. Finally, in each group the cheapest units are bought until the announced constraint is exhausted. In the event of a tie within a group, tied units may be divided by the buyer. In this case, the buyer buys the same fraction of a unit from each of the ties.

Subjects' gains are defined as follow. If they do not succeed in selling their unit, subjects receive only their show-off payment. If they succeed in selling all, or part of their unit, they receive in addition to their show-off payment the difference between their selling price and their production cost, weighted if their unit is not purchased in full, by the fraction of their unit they sold. Instructions for the target treatment[2] are available in Appendix C.

3.2 Treatments

In the first (target) treatment the buyer purchases the two cheapest units in each group. The average budget required to purchase the announced number of units (i.e. the winning bids) is called the average empirical budget. The latter is calculated over all auction groups (see section 4) and then is used as the budget constraint in the budget treatment. In the budget treatment, we compute the overall average number of units purchased. As mentioned before, it is this average number of units that will be compared to the exogenously announced target constraint to compare budgetary efficiency of both auction formats. A balance may remain in the budget case when the sum of all the bids in a group is lower than the budget constraint. To account for this, an average balance is computed as well at the treatment level. Features from different treatments are summarised in Table 1.

Table 1: Treatments

Treatment	Announced constraint	Calculated outcomes
Target	2 units	Average Empirical Budget
Budget	Average Empirical Budget from target	Average number of units purchased Average balance

4 Computation of the average empirical budget and performance criteria

Here we detail how from subjects' bidding strategy (decision table) obtained in the target treatment we calculate the average empirical budget that will be used as the constraint in the budget treatment. The average number of units purchased in the budget treatment is calculated in a similar way and will be compared to the 2 units announced in the target treatment. To deepen the comparison between target and budget auctions, we also calculate other performance criteria. First we define those criteria at the auction level (section 4.1), then at the group level

[2]Instructions of the budget treatment are available on request.

(section 4.2), and finally at the treatment level (section 4.3).

4.1 At the auction level

First, each group of 4 bidders associated with a given set of costs values constitutes one possible auction. In each auction, bids are ranked in order of increasing price with rank $i = 1, ..., 4$ starting from $i = 1$ for the cheapest bid to $i = 4$ for the most expensive bid.

One can then compute a series of auction performance indicators. Primarily the number of units purchased q in the budget treatment or the empirical budget spent in target such as :

$$\text{empirical budget} = \sum_{i=1}^{q} b_i \tag{1}$$

with $q = 2$ units purchased (announced constraint) within each group in the target treatment[3], b_i the price of the i^{th} unit selected.

In addition to the empirical budget we also calculate the unit cost, the share of the budget allocated to the payment of information rents and an indicator of the economic efficiency, also called allocative efficiency.

$$\text{unit cost} = \frac{\sum_{i=1}^{q} b_i}{q} \tag{2}$$

$$\text{information rents} = \frac{\sum_{i=1}^{q}(b_i - c_i)}{\sum_{i=1}^{q} b_i} \tag{3}$$

$$\text{economic efficiency} = \begin{cases} 1 & \text{if} \quad \sum_{i=1}^{q} c_i = \sum_{i=1}^{q} c_{(i)} \\ 0 & else \end{cases} \tag{4}$$

with c_i the cost associated with the i^{th} unit bought and $c_{(i)}$ the cost corresponding to the i^{th} unit in ascending order of cost[4]. These criteria are used to determine if the budget is allocated to maximise the quantities purchased and whether the participants with the lowest unit costs win the auction.

[3]Calculations are based on the same formula in the budget treatment except that $0 < q \leq 4$ and the last unit may be purchased only partially. In cases of a tie between several bids (see. section 3.1) a *prorata* is made.

[4]I.e. the lowest costs corresponding to the number of units sold in the group. Indeed, during the auction, the bids are ranked in order of increasing price and not according to their production cost. Therefore, the winning bids do not necessarily correspond to the lowest costs.

4.2 At the group level for any cost combination

So far, criteria are described at the auction level, i.e. for a given set of costs within each group. Thus, if a single set of costs was randomly drawn, any difference within treatments could be also be attributed to this specific draw. To overcome this issue, we propose to simulate, within each group, the auction results for all cost configurations. This is based on subjects' complete strategies obtained with the strategy method (Güth et al., 2002). Then, weighted averages[5] of the efficiency criteria are computed at the group level in order to provide independent observations allowing for statistical tests. To do so, each subject of the experiment appears in only one group. This has been done by forming groups randomly, so each seller has only been confronted with 3 other sellers from the treatment he took part in[6].

4.3 At the treatment level

Finally one can report a single treatment-level average value[7] for each criteria from the group-level results. The (overall) average empirical budget to be announced as a budget constraint is calculated in this last step in the target treatment.

The average number of units purchased in the budget treatment allows for a first comparison of budgetary efficiency when a budget constraint is announced relatively to the case it is a target. Indeed, if the average number of units purchased obtained in the budget treatment is greater (respectively lower) than 2 (the initial target constraint), then the budget format has a greater (respectively lower) budgetary efficiency than the target auction.

5 Data

The experiment was conducted online with 329 subjects from the FouleFactory platform. It was programmed with the o-Tree software (Chen et al., 2016). Table 2 shows our subjects are mainly workers of a wide age range. 51% of subjects had at least the French baccalaureate and 43% earned more than 1900€ per month. Finally, subjects participated to a single treatment (between-subjects).

[5]Weights are used to compute group level averages if the auction level criteria include a ratio as in unit cost or information rents. In such cases weights correspond to the denominator value from the auction level criteria (see. proof in appendix A).

[6]We performed totally exhaustive simulations as well to calculate the true average empirical budget on the basis on which the budget constraint is computed. Results were very close to those obtained from independent groups. Actually, results were the same when rounded to the nearest euro.

[7]This value has to be weighted as well in some cases (see. step 2 of proof in appendix A).

Table 2: Sample description

Sum	Mean	SD	Min	Max	N
female	0.51	0.50	0	1	329
age	40.89	13.17	17	74	329
education (graduate studies)	0.51	0.50	0	1	329
income (€1900+)	0.43	0.50	0	1	329
riskAversion	4.95	2.67	0	10	329
easyToBid	6.64	2.79	0	10	329
Comprehension Errors	0.62	0.66	0	2	329
Profession					
student	0.08	0.27	0	1	329
craftSellEntrep	0.06	0.24	0	1	329
managIntellect	0.21	0.41	0	1	329
unemployed	0.16	0.36	0	1	329
retired	0.09	0.29	0	1	329

For each treatment, to ensure that there is no bias between treatments due to sample characteristics we controlled for a range of variables (see. Appendix D). A summary of control variables can be found in Table 3. First, risk aversion and easiness to respond are self assessment questions with values comprised between 0 (highly risk averse, very difficult to bid) and 10 (highly risk-loving, absolutely no difficulties to bid). The number of incorrect answers to the 3 comprehension questions is also used to measure the well understanding of instructions. Finally, the total time is computed without the instructional video as it has not exactly the same duration in the two treatments. No significant difference was found among treatments in the control variables except in the share of unemployed people[8].

[8] Retirees and unemployed people represent a higher proportion in the target treatment while employees are over-represented in the budget treatment.

Table 3: Summary of control variables

Variable	Target[a]	Budget[a]	p-value[b]
female	0.53 (0.50)	0.49 (0.50)	0.43
age	42.04 (15.03)	40.13 (11.69)	0.20
education (graduate studies)	0.49 (0.50)	0.53 (0.50)	0.52
income (€1900+)	0.37 (0.48)	0.47 (0.50)	0.05
riskAversion	4.90 (2.61)	5.16 (2.70)	0.40
easyToBid	6.81 (2.62)	6.54 (2.89)	0.39
Comprehension Errors	0.63 (0.62)	0.62 (0.68)	0.81
Profession			
student	0.11 (0.31)	0.06 (0.23)	0.09
craftSellEntrep	0.08 (0.27)	0.06 (0.23)	0.45
managIntellect	0.18 (0.38)	0.24 (0.42)	0.18
unemployed	0.21 (0.41)	0.12 (0.33)	0.04
retired	0.15 (0.36)	0.06 (0.23)	<0.01

[a] Formats are *mean (sd)*.

[b] The p-values are computed on the basis of a student test.

6 Results

6.1 Experimental results

The target treatment results in an average empirical budget of 72.32€ (see Table 4). This is the amount the auctioneer needs on average to purchase 2 units given the bidding strategies of our 131 subjects. This amount was rounded to 72€ to serve as the budget constraint in the budget treatment.

Table 4: Empirical budget and units purchased

Treatment	N	Groups	Average quantities purchased[c]	Budget spent[c]
Target	131	32	2 (announced)	72.32€ (6.65)
Budget	198	49	2.14 (0.10)	71.84€ (0.07)

[c] Formats are *mean (sd)*.

As reported in Table 4, the budget treatment resulted in an average purchase of 2.14 units with an average balance of 0.16€[9]. This means that, according to our results, the budget format is 7% more efficient than the target format as it is significantly higher than 2 ($p < 0.01$) using a student t-test. In this case, a non-null residual budget as well as rounding the budget constraint to the nearest lower integer are two conservative assumptions in favour of the target treatment

[9]In some cases all units can be purchased for a total expenditure lower than 72€, so the budget is not entirely spent.

and therefore support our conclusion. It is also possible to calculate the overall average unit cost for each treatment that is given in Table 5. In line with the average quantity purchased approach, the average unit cost is found to be significantly lower ($p < 0.01$) in the budget treatment by on average 9%. The average rent rate is significantly higher in the target treatment than in the budget treatment ($p < 0.01$). However, the economic efficiency which is the overall average of the frequencies in each group where the winning bidders are those with the lowest costs, is not significantly different between the two treatments, and is quite high since it reaches 85 and 86%.

Table 5: Other performance criteria

Treatment	Average unit cost (€)	Average information rent (%)	Average economic efficiency
Target	36.16 (3.28)	19.69 (5.11)	0.85 (0.11)
Budget	33.68 (1.62)	14.15 (4.83)	0.84 (0.16)
t-test	$p < 0.01$	$p < 0.01$	$p = 0.86$

6.2 Discussion : perfect information case

To complete these results, we compare the performance of the two auction formats in the case of perfect information. In that case, the buyer would pay only the cost (no informational rent) as if the sellers would bid their production cost (no profit). Under this assumption, allocative efficiency would be optimal in both formats since the lowest bids would also correspond to the lowest costs. In this case, we can easily simulate all the possible outcomes for any cost combination using the same range of costs than in the experiment. To buy 2 units from 4 sellers at their production cost, the buyer needs to spend on average 58.08€[10] in the target auction. If we assume the buyer has a budget of 58.08€, he can purchase on average 2.098 units in a budget auction and he is left with an average balance of 0.10€. So in this perfect information setting, a budget auction is better (has an higher budgetary efficiency) than the target format. The intuition of this result is the following. The target constraint does not allow the buyer to adjust the number of units purchased according to the sellers' production costs. Indeed, from a budgetary efficiency point of view, it is more interesting to buy fewer units when prices are high than when they are low and *vice versa*. The flexibility on quantities of the budget format makes it more budgetary efficient on average than the target format.

This reason may partly explain our experimental results. However, nothing tells us that bidders bid the same way in both auction formats. Thus, the superiority of the budget auction may also come from different bidding strategies.

[10] This result can also be obtained analytically using the discrete cost distribution we use in the experiment.

7 Conclusion

The aim of this experiment was to compare relative performance of target and budget constraints in reverses auctions. To do so, equivalent constraints had been set up to observe the same level of competition between sellers in both treatments. It has been done by setting the budget constraint endogenously from the average budget spent in the target treatment. We used the strategy method to obtain subjects complete bidding strategies. This approach has two main advantages : (1) this gives the opportunity to make *ex post* simulations, so subjects don't need to be connected at the same time (2) it is possible to simulate all possible cost configurations within each auction group to avoid any effect from randomly induced costs. What we found, in contrast to the results from Schilizzi and Latacz-lohmann (2007) and Boxall et al. (2017), is that announcing a budget provides a higher budgetary efficiency than a target auction. On average, 7% more units are purchased in a budget auction than in a target auction.This result is confirmed by the fact that it was on average 9% cheaper to purchase one unit in the budget treatment, the average rent rate being higher in target treatment than in budget treatment.The absence of difference in terms of economic efficiency denotes that the use of one or the other auction format is on average neutral in terms of global welfare.

The perfect information case where bidders ask their costs, provides one explanation for the higher budgetary efficiency observed in budget. Indeed, in the budget format, the buyer save funds in the more expensive groups by purchasing relatively less units than in target and can get relatively more units in groups where unit prices are lower.

In the context of conservation auctions these result indicates that the buyer should announce a budget rather than a target, which is actually the case most of the time since it is usually the total budget dedicated to the program that is publicly announced. From the average information rent rate one can also deduce the share of the program funds which actually serves to compensate for the opportunity costs of farmers as it is the difference between 100% and the average rent rate. Extrapolating our results in this context, we found that on average 85.83% of program funds actually compensate for opportunity costs in the budget case while it is 80.31% if a target constraint is announced.

As extensions to this work, we could first study the bidding strategies in both auction formats to better understand the impact of the announced constraint. Second, we could propose a treatment where there is both a target and a budget constraints combined to be more consistent with the reality of constraints faced by the buyer in conservation auctions. We expect that this double constraint increases the degree of competition between sellers and thus might result in a lower unit cost and a lower average number of units purchased. Finally, considerations should also be given in upcoming works to individual bidding strategies, in order to identify potential behavioural bias that may explain our results.

A Proof that if the overall average cost is defined as in (1), the computation of the unit cost requires a weighted average

Definition : The overall average unit cost in the budget treatment (AUC^B) is define as

$$AUC^B = \frac{\sum_{g=1}^{G}\sum_{e=1}^{K}(B^T - R_{e,g})}{\sum_{g=1}^{G}\sum_{e=1}^{K} q_{e,g}} = \frac{B^T - \frac{\sum_{g=1}^{G}\sum_{e=1}^{K} R_{e,g}}{K\times G}}{\frac{\sum_{g=1}^{G}\sum_{e=1}^{K} q_{e,g}}{K\times G}} = \frac{B^T - \overline{R_B}}{\overline{q_B}} \tag{5}$$

with B^T the announced budget constraint, $\overline{q_B}$ the average number of units purchased in the budget treatment, $R_{e,g}$ the residual budget from the auction e (among K possible auctions) within the group g with $g = 1, ..., G$. Finally, $\overline{R_B}$ is the mean of the residual budget at the treatment level.

Proposal : The overall average unit cost is the 'two-stage' weighted average unit cost with respect to quantities purchased.

Stage 1

At the auction level, the unit cost (UC_e) is given by

$$UC_e = \frac{B^T - R_{e,g}}{q_{e,g}}, \tag{6}$$

$q_{e,g}$ being the amount of units purchased in the auction e of group g.

The weighted average of the unit cost in the group g ($\overline{UC_g}$) is calculated as :

$$\overline{UC_g} = \frac{\sum_{e=1}^{K} UC_e \times q_{e,g}}{\sum_{e=1}^{K} q_{e,g}} = \frac{\sum_{e=1}^{K}\left(\frac{B^T - R_{e,g}}{q_{e,g}} \times q_{e,g}\right)}{\sum_{e=1}^{K} q_{e,g}} \tag{7}$$

$$\overline{UC_g} = \frac{\sum_{e=1}^{K}(B^T - R_{e,g})}{\sum_{e=1}^{K} q_{e,g}} \tag{8}$$

Stage 2

The global weighted average unit cost $\overline{UC_B}$ is :

$$\overline{UC_B} = \frac{\sum_{g=1}^{G} \overline{UC_g} \times \overline{q_g}}{\sum_{g=1}^{G} \overline{q_g}} = \frac{\sum_{g=1}^{G}\left(\frac{\sum_{e=1}^{K}(B^T - R_{e,g})}{\sum_{e=1}^{K} q_{e,g}} \times \overline{q_g}\right)}{\sum_{g=1}^{G} \overline{q_g}} \tag{9}$$

with $\overline{q_g} = \frac{\sum_{e=1}^{K} q_{e,g}}{K}$ the mean of $q_{e,g}$ in the group g.

$$\overline{UC_B} = \frac{\sum_{g=1}^{G}\left(\frac{\sum_{e=1}^{K}(B^T - R_{e,g})}{\sum_{e=1}^{K} q_{e,g}} \times \frac{\sum_{e=1}^{K} q_{e,g}}{K}\right)}{\frac{\sum_{g=1}^{G}\sum_{e=1}^{K} q_{e,g}}{K}} = \frac{\frac{\sum_{g=1}^{G}\sum_{e=1}^{K}(B^T - R_{e,g})}{K}}{\frac{\sum_{g=1}^{G}\sum_{e=1}^{K} q_{e,g}}{K}} = AUC^B \tag{10}$$

It has been shown that the overall unit cost is the two-stage average unit cost weighted each time by the quantities purchased.

B Comprehension questions

True/False about the experiment

1. The production cost drawn at random will necessarily be the same for all 4 vendors in your group.

The answer is **"False"** because the production costs are randomly drawn independently for each vendor. It is therefore highly unlikely that the 4 costs drawn within a group are identical.

2. When you must set a bid for each row in the table, you know the cost of producing your unit. However, you do not know the cost that will be used to calculate your profit.

The answer is **"True"** because when you set a selling price this price is necessarily associated with a production cost. However, only one cost (one row in the table) will be **drawn** to calculate your win.

3. You are in competition with other sellers in your group.

The answer is **"True"** because if at least 2 other sellers in your group offer a lower price than yours you will not be able to sell your unit and your gain will be 0€. You will therefore have to make a compromise according to your preferences between asking a high price to potentially earn more or offering a lower price to increase your chances of winning (selling your unit).

C Instructional video for target treatment

Translated slides from French to English

Welcome !

This survey is launched as part of a public research project.

This is an **experiment** conducted by researchers to study decision-making.

In this experience you will have the **opportunity to earn money** in addition to the fixed participation payment.

1

This additional ***gain*** will depend on <u>your decisions</u> as well as the <u>decisions of other participants</u> who are involved in this experiment.

We ask you to pay attention to the instructions.

They should allow you to understand the experience.

2

This survey is conducted **anonymously**.

The researchers will not be able to link your identity to your decisions.

In this experiment, **groups of 4** participants will be randomly formed.

Other participants will not be able to identify you and you will not be able to identify them.

You are a <u>seller</u> and we (the researchers) a <u>buyer</u>.

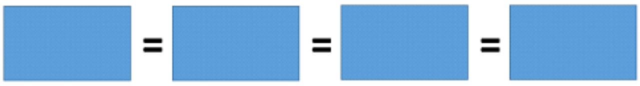
3

We are forced to use a neutral and abstract context in order not to influence your answers.

Each participant is invited to sell **one unit** of a good.

1 unit = 

The 4 units offered in each group (one unit for each seller) are perfectly identical.



4

Your task is to propose selling **prices** in euros for your unit based on its **production cost**.

To this purpose you must complete this table which contains all the possible production ***costs*** for your unit.

These ***costs*** vary by steps of 5 in the range from 0 to 100€.

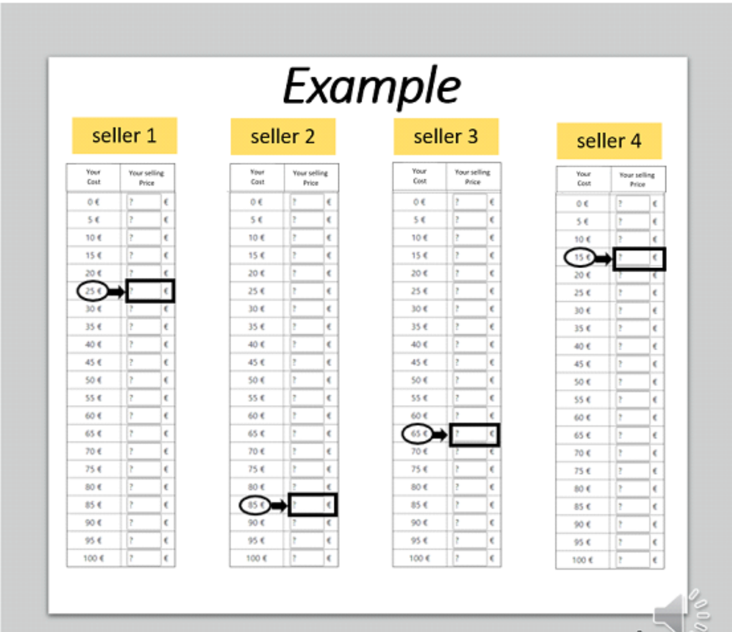
Your Cost	Your selling Price
0 €	€
5 €	€
10 €	€
15 €	€
20 €	€
25 €	€
30 €	€
35 €	€
40 €	€
45 €	€
50 €	€
55 €	€
60 €	€
65 €	€
70 €	€
75 €	€
80 €	€
85 €	€
90 €	€
95 €	€
100 €	€

5

Once all sellers have completed their tables,

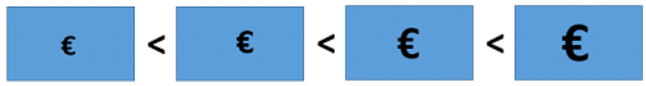
a production ***cost*** will be drawn for each seller.

Then the bid ***price*** for this ***cost*** will be researched in each seller's table.

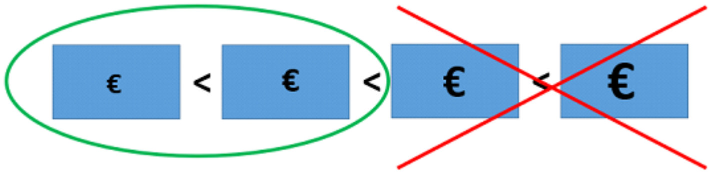


Game rules

The buyer will rank the 4 units offered in your group in ascending order of ***price*** (from lowest to highest).



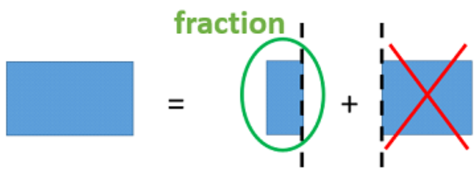
In each group, the buyer will buy the cheaper **2 units**.



9

In case of a tie

between several sales *prices* in the same group, these units will be divided by the buyer.



In this case, he will buy the same fraction of a unit from each of the ties.

10

Calculate your earnings

- If your unit is entirely purchased :

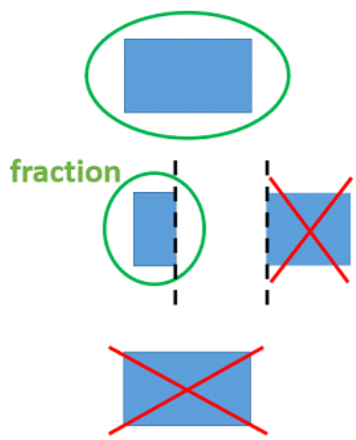
  gain = price - cost

- If a fraction of your unit is purchased :

  gain = fraction × (price - cost)

- If your unit is not purchased :

  gain = 0€



You don't need to pay the cost of producing your unit if you can't sell it.

11

Remarks

- The ***cost*** that will be drawn at the end of the experiment to calculate your earnings does not depend on the ***cost*** of the other sellers.

- Each production ***cost*** in the table has the same chance of being drawn.

12

For each possible production ***cost,*** you should ask yourself :

*« At this **cost** of production, what is the selling **price** I am asking? »*

At this point, you do not know the cost of the other 3 sellers, nor the price they will offer.

Each ***price*** should be rounded to the nearest euro and be greater than or equal to the ***cost*** of production.

Your Cost	Your selling Price	
0 €		€
5 €		€
10 €		€
15 €		€
20 €		€
25 €	?	€
30 €		€
35 €		€
40 €		€
45 €		€
50 €		€
55 €		€
60 €		€
65 €		€
70 €		€
75 €		€
80 €		€
85 €		€
90 €		€
95 €		€
100 €		€

13

Only those who succeed in selling their unit (or fraction of a unit) will receive their ***earnings***.

Before filling in the table,

please answer 3 questions in order to better understand the experiment.

Your answers to these questions will have no impact on your earnings!

After completing the table, you will be asked to answer a short final questionnaire.

During the experiment you can review the instructions by clicking on this button : See the instructions

14

D Final questions

1. Was it easy for you to choose a price for each cost? From 0: not at all (I chose randomly) to 10: yes completely (I am sure of my choices)

2. Are you a person who is generally risk-taking or do you try to avoid taking risks as much as possible? From 0: avoid taking risks as much as possible, to 10: very comfortable with the idea of taking risks

3. Age :

4. Gender:
Male
Female

5. What is your highest education level?

6. Individual monthly income before income tax:
Less than 1 100€
Between 1 100€ and 1 899€
Between 1 900€ and 2 299€
Between 2 300€ and 3 099€
Between 3 100€ and 3 999€
Between 4 000€ and 6 499€
More than 6 500€
Do not wish to answer

7. What is your socio-professional category?
Farmers
Craftsmen, Retailers, Company managers
Executives and higher intellectual professions
Employees
Students
Retired
Unemployed

References

Boxall, P. C., Perger, O., Packman, K., and Weber, M. (2017). An experimental examination of target based conservation auctions. *Land Use Policy*, 63:592–600.

Cason, T. N. and Gangadharan, L. (2004). Auction design for voluntary conservation programs. *American Journal of Agricultural Economics*, 86(5):1–18.

Cason, T. N., Gangadharan, L., and Duke, C. (2003). A Laboratory Study of Auctions for Reducing Non-point Source Pollution. *Journal of Environmental Economics and Management*, 46(3):446–471.

Chen, D. L., Schonger, M., and Wickens, C. (2016). oTree—An open-source platform for laboratory, online, and field experiments. *Journal of Behavioral and Experimental Finance*, 9:88–97.

Cox, J. C., Smith, V. L., and Walker, J. M. (1984). Theory and Behavior of Multiple Unit Discriminative Auctions. *THE JOURNAL OF FINANCE*, VOL. XXXIX(4):983–1010.

Dohmen, T., Falk, A., Huffman, D., Sunde, U., Schupp, J., and Wagner, G. G. (2011). Individual risk attitudes: Measurement, determinants, and behavioral consequences. *Journal of the European Economic Association*, 9(3):522–550.

Ferraro, P. J. (2008). Asymmetric information and contract design for payments for environmental services. *Ecological Economics*, 65(4):810–821.

Filiz-Ozbay, E. and Ozbay, E. Y. (2007). Auctions with Anticipated Regret: Theory and Experiment. *American Economic Review*, 97(4):1407–1418.

Güth, W., Ivanova-Stenzel, R., Königstein, M., and Strobel, M. (2002). Bid functions in auctions and fair divisions games: Experimental evidence. *German Economic Review*, 3(4):461–484.

Güth, W., Ivanova-Stenzel, R., Königstein, M., and Strobel, M. (2003). Learning to bid - An experimental study of bid function adjustments in auctions and fair division games. *Economic Journal*, 113(487):477–494.

Harris, M. and Raviv, A. (1981). Allocation Mechanisms and the Design of Auctions. *Econometrica*, 49(6):1477–1499.

Hien, T., Preget, R., and Tidball, M. (2019). Les enchères de contrats agroenvironnementaux : comparaison expérimentale entre contrainte d'objectif et contrainte de budget.

Katuščák, P., Michelucci, F., and Zajíček, M. (2015). Does feedback really matter in one-shot first-price auctions? *Journal of Economic Behavior and Organization*, 119:139–152.

Kirchkamp, O., Poen, E., and Reiß, J. P. (2009). Outside options: Another reason to choose the first-price auction. *European Economic Review*, 53(2):153–169.

Latacz-Lohmann, U. and Van der Hamsvoort, C. (1997). Auctioning Conservation Contracts: A Theoretical Analysis and an Application. *American Journal of Agricultural Economics*, 79(2):407–418.

Mitzkewitz, M. and Nagel, R. (1993). Experimental results on ultimatum games with incomplete information. *International Journal of Game Theory*, 22(2):171–198.

Rapoport, A. and Fuller, M. A. (1995). Bidding Strategies in a Bilateral Monopoly with Two-Sided Incomplete Information. *Journal of Mathematical Psychology*, 39(2):179–196.

Schilizzi, S. and Latacz-lohmann, U. (2007). Assessing the Performance of Conservation Auctions : An Experimental Study. *Land Economics*, 83(4):497–515.

Stoneham, G., Chaudhri, V., Ha, A., and Strappazzon, L. (2003). Auctions for conservation contracts: an empirical examination of Victoria's BushTender trial. *The Australian Journal of Agricultural and Resource Economics*, 47(4):477–500.

Vukina, T., Zheng, X., Marra, M., and Levy, A. (2008). Do farmers value the environment? Evidence from a conservation reserve program auction. *International Journal of Industrial Organization*, 26(6):1323–1332.