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Reducing non-point source pollution through auctions: Some lessons learned from a laboratory experiment

Therese Lindahl[*]

Abstract

This study compares the performance of a discriminative price auction and a uniform price auction for allocating conservation contracts to reduce non-point source pollution. In particular we evaluate (in a laboratory experiment) the influence of an environmentally based experimental design. To some extent we confirm previous results; the uniform price auction makes participants reveal their true costs. Nevertheless, the discriminative price auction is associated with higher market performance because the over-shading of bids is lower than predicted. We show that this behavior is more likely if subjects have pro-social motives and more knowledge of the problem of non-point source pollution.

Keywords: Reverse auction, price mechanism, non-point source pollution, laboratory experiments

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I Introduction

Non-point source pollution is associated with complex spatial and temporal biophysical interactions making identification of sources and regulation difficult and costly. Moreover, there are often informational asymmetries. The regulator does not have exact information about landowners' opportunity costs; the landowners know better how participation in an environmental program will influence their production plans and costs. This implies that landowners can secure rents by over stating their costs at the expense of the regulator. As a consequence, traditional policy instruments including voluntary programs, individual contracts, and education have not been sufficiently efficient at reducing non-point source pollution (Bardsley et al. 2002). To overcome such inefficiencies, market-based policy instruments are often advocated. A reverse auction for allocating contracts between landowners could for example be well suited to address the problems of informational asymmetries, by making landowners reveal their true opportunity costs (Latacz-Lohmann and Hamsvoort 1997). In such an auction landowners offer to undertake certain projects that generate environmental benefits for a specific compensation. The regulator ranks the offers based on their prices and environmental benefits and allocates a fixed budget between the competing bids. By introducing an element of competition between the landowners the reverse auction has the potential to improve the environment in a cost efficient way.

Before implementing a reverse auction program a regulator needs to decide on the best auction format (for an introduction to auction theory see Klemperer 2004). There are many aspects to consider. For example how much and what type of information should be revealed to the landowners (e.g. about other landowners, the budget), should the auction be repeated or not, should bids be made simultaneously or sequentially, should participants be allowed to revise their bids or not? One of the most important aspects however is the choice of price mechanism. Different payment formats may induce very different bidding behaviors generating substantial differences in economic performance (Latacz-Lohmann and Schilizzi 2005; Kagel et al. 1987). For a reverse auction there are essentially two price mechanisms to consider; the uniform price auction or the discriminative price auction. A discriminative price auction is one where the compensation to the landowner is equal to the requested amount, provided that the contract is granted. The uniform price is based on the highest ranked rejected bid. This implies that landowners with granted bids receive a compensation which is at least as high as their requested amount.

According to the revenue equivalence theorem (Vickrey, 1961), under certain assumptions (if bidders are risk neutral, have independent private opportunity costs, and are symmetric, if the compensation is a function of only the bid, under single unit demand (only one contract is traded) and if there are zero transaction costs), an auctioneer should be indifferent between these two mechanisms. However, for a reverse auction with the purpose to reduce non-point source pollution there are valid reasons to suspect that several of these assumptions do not hold. For one, their opportunities for production and thereby their opportunity costs differ. Secondly, the environmental effects of a specific measure could differ depending on geographical site and soil quality (Tauer, 1986, Lai et al. 2003). Moreover, for the case of conservation contracts, multiple contracts are traded (Chan et al 2003).[1]

[1] Farmers are sometimes considered to be risk averse (Binswanger, 1980). However, for the case of conservations contracts, empirical evidence suggests that they are not (Gasson and Potter 1988; Latascz-Lohmann and Schilizzi, 2005). This is also the case with our experimental subjects.

Auction theory does not offer a clear guidance about the best price rule. What can we learn from empirical evidence? There are few studies carried out with the purpose to evaluate the choice of price mechanism in reverse auctions for voluntary conservation programs. Cason and Gangadharan (2005) ran a laboratory experiment specifically designed to evaluate the choice of price mechanism in such an auction. They found that subjects were more inclined to require bids closer to costs for the uniform price treatment but that the discriminative price treatment resulted in higher achieved efficiency. In another related study Cummings et al. (2004) evaluated experimentally the choice of price mechanism in a reverse auction for allocating contracts for suspending irrigation during drought periods. They found no significant difference in bidding behavior when changing the price mechanism. Other studies (experimental and empirical) comparing the performance of the uniform price auction with the discriminative price auction also show mixed results (Kagel 1995; Smith 1982; Tenorio 1993). These ambiguous results suggest that more empirical research is needed to gain a better understanding of the underlying behavioral determinants. This becomes especially relevant considering the increasing popularity of using auctions for environmental protection.

The overall purpose of this study is to evaluate the reverse auction as a policy instrument for reducing nutrients from non-point source pollution focusing on the choice of price mechanism. For this purpose we will rely on experiments. In particular the study will evaluate the role of framed experimental instructions. There are several types of experiments. A conventional laboratory experiment is often performed in a classroom with a standard pool of subjects (university students) and with a neutral, context-free description of the problem. The subjects are often isolated and are not allowed to communicate with each other (unless communication is a treatment). A natural field experiment is another extreme; subjects (from a non-standard pool) take decisions in their natural environment without knowing that they participate in an experiment. Artefactual and framed field experiments occupy the middle ground. Compared to a conventional laboratory experiment, artefactual field experiments use a non-standard subject pools. A framed field experiment uses a non-standard subject pool and field context in the commodity, task, stakes or information to the subjects. These types of experiments sacrifice some of the controlled environment for increased realism (Harrison and List 2004) and using them is important because the context, problem knowledge and experience might influence behavior (List 2007). Regarding conservation programs for reducing non-point source pollution the commodity is a public good; each conservation contract is associated with an environmental improvement. People with pro-social preferences and knowledge of the problem may then require less economic rent (in the discriminative price auction). In fact, empirical evidence suggests that farmers besides profit motives also exhibit pro-social motives and that these pro-social motives affect how they respond to various policy instruments (Weaver 1996; Söderqvist 2003).

The experimental design used will to a large extent be based on the design used by Cason and Gangadharan (2005) but with a few critical modifications. They ran a conventional laboratory experiment with a student subject pool and with neutral experimental instructions. Subjects were told they participated in a reverse auction and the items were described as private goods. This study also uses students but with field context in the information given to the subjects in the instructions. For example, they know that the items sold are measures with the intent to improve the environment (for example increase water quality) by reducing non-point source pollution. Moreover, about one third of the subject pool belongs to an agricultural university and have more knowledge about non-point source pollution than the average university student. How will these alterations influence bidding behavior and overall results and what are the policy implications? The remained of this study attempts to answer these questions.

The next section provides a detailed description of the experimental design and implementation. Section 3 summarizes some theoretical findings and provides some hypothesis for this study. Section 4 presents the results and Section 5 concludes the paper.

2 Experimental design

The subjects were university students (recruited from Stockholm University (SU) and the Agricultural University of Ultuna (SLU). Exactly 99 students participated in the study and each subject was randomly assigned to a group of 6-8 subjects. About 42 percent of these participated in uniform price treatment auctions (6 groups) and about 30 percent (8 groups) were from SLU (with an agrarian education). Upon arrival, the subjects were given instructions to read[2], after which there was time for clarifying questions. Each subject was then placed in front of a computer and the experiment leader started the experiment. The experiment was programmed in z-tree[3] (Zurich toolbox for ready-made economic experiments) (Fischbacher, 2007). After the actual experiment the subjects were asked to fill in a shorter questionnaire, and then received their individual payment. The whole session lasted between 60-90 minutes. None of the subjects participated in more than one session and none had previous experience of this type of experiment.

The instructions were framed. The subjects were told that they each represented a landowner and that the experiment leader represented a regulator. They were also told that they would participate in a number of auctions.

[2] The instructions were in Swedish, but a translation of the instructions can be found in the appendix.

[3] The specific program used for this experiment is available upon request from the author.

"Each of you sitting in this room is a fictive landowner. The experiment leader is a fictive regulator. The experiment consists of a number of auctions. The regulator conducts these auctions to give landowners the opportunity to take certain measures for monetary compensation. The purpose of these measures is to reduce the amount of nitrogen and phosphorous loadings stemming from agriculture and thereby to improve the water quality of the sea. You (the landowners) each have three measures to other in each auction round. A measure could for example be to change the actual use of the land or production method and is thereby associated with a certain cost."

The exact information about the costs of the measures was private to the subjects but the distribution (2000-8000 EKR, where one EKR corresponds to 0,001 SEK)[4] was known to the experiment leader. The subjects were also told that each measure was associated with a certain improvement in water quality. The exact quality number for a certain measure was known both to the subject and the experiment leader, but none of the subjects had any information about the other subjects' quality numbers. The quality distribution (50-350) was unknown to the subjects. Heterogeneity was introduced through random draws of costs and quality numbers for each measure subject and auction round.[5]

For each of the three measures, the subjects were told to state the minimum amount of EKR they would require to take the measure. The bidding procedure was sealed and all bids were

[4] 1 SEK corresponds roughly to 0,125 USD.

[5] The range of cost of quality parameters were chosen to fulfill two goals. One was to approximate the parameters used by Cason and Gangadharan (2005). Their costs lie in the range (2200-10000). Their range for environmental quality lies within the range (50-200). However, we modified them a bit to better fit with estimates specific to Sweden (Gren 2008; Report 2008:31, Swedish Board of Agriculture).

anonymous. Based on one subject's bid the program calculated the number of quality units per EKR for each measure. The measure associated with the highest quality per EKR was chosen to compete against the other subjects' best bids. Each subject thus competed with one bid in each auction round.

The competing bids were ranked according to quality per requested amount, where bids with high quality per requested amount were ranked high. The bids were granted according to this ranking until the fixed budget was spent. The budget, which remained unchanged between rounds, was unknown to the subjects. If a subject's best bid was granted, the subject earned a profit equal to a specific compensation minus the cost associated with the measure. How the compensation was determined is explained below. If a subject's bid was not granted the subject earned a profit of 0 EKR that auction round. The exact number of rounds was unknown to the subjects. In order to mimic reality as much as possible we gave only limited restrictions on communication. The subjects were asked not to communicate during the actual bidding process but were told that communication was allowed between rounds. The number of auction rounds was unknown to the subjects and varied between 6 and 8 rounds.

A survey was specifically designed to collect background information about the subjects such as age, gender and educational background. We made sure that the students from the Swedish Agricultural University had studied at least two semesters, including agronomy. How do we measure pro-social motives? For the purpose of this study we want to capture motives that promote giving in the form of public good contribution. One way is of course to ask subjects a hypothetical question on their willingness to contribute to a public good of some sort (to get a measure of their respective general disposition towards giving). Such an approach often suffers from a hypothetical bias however, making subjects over-estimate their own willingness to contribute. Participating in the experiment can be seen as contribution to a public good – policy relevant research. We chose to take advantage of this. Participants were therefore asked to state their main motivation for participating in the experiment and were given three alternatives: 1) “I wanted to earn money” (for self-interested reasons), 2) “I wanted to contribute to policy relevant research (for pro-social reasons)”, and 3) “for other reasons”. This variable (although not perfect) has been used as a proxy for subjects’ pro-social motives.

3 Auction design, bidding behavior and measures for market performance

We compare and evaluate a uniform price auction with a discriminative price auction. The uniform price is determined by the highest ranked rejected bid, a so called Vickrey auction (second price sealed bid auction). This means that subjects with granted bids always receive a compensation which is at least as high (often higher) than their requested amount. For the discriminative price auction the total compensation is simply the requested amount. See Table 1 for an example, where the budget is set to 10 000 EKR and costs, compensations and profits are all in EKR.

Table 1: Illustration of the price mechanisms

Subject	Cost	Quality	Bid	Quality per EKR	Rank	Compensation		Profit	
						Uniform	Disc	Uniform	Disc
Yellow	4500	180	5000	0.036	1	7200	5000	2700	500
Red	2000	100	4000	0.025	3	0	0	0	0
Blue	1000	60	2000	0.030	2	2400	2000	1400	1000
					Sum	9600	7000	4100	1500

Regardless of price mechanism the two highest ranked bids are granted. For the discriminative price auction the sum of the granted amount is 7000 EKR with a total environmental quality of 240 units. For the uniform price auction the same environmental quality is achieved but to a higher cost (and consequently higher profits for the participants).

The example above illustrates how the two mechanisms can yield different outcomes (compensation and profit) although the bidding process is the same. However nothing is mentioned about the impact that these two mechanisms can have on actual bidding strategies. Under the discriminative price auction, the optimal bid of landowner *i*, (b_{iD}) depends on the landowners' cost (c_i) for conservation activities but also on his subjective expectation about what the highest acceptable bid will be, here referred to as *H* (which is determined ex post). The landowner will participate if the expected utility, given by the left hand side of equation (1), is satisfied, where *p* stands for probability.

$$U_i(b_{iD} - c_i) * p(b_{iD} \leq H) \geq 0 \qquad (1)$$

Landowners do not know the value of *H* but they can form expectation about it which can be characterized by a density function $f_i(b_{iD})$ and a distribution function $F_i(b_{iD})$. The probability that a bid is accepted can then be expressed as

$$p(b_{iD} \leq H) = \int_{b_{iD}}^{\overline{H}} f(b_{iD}) db_{iD} = 1 - F(b_{iD}) \qquad (2)$$

Equation (1) can then be rewritten:

$$U_i(b_{iD} - c_i) * [1 - F_i(b_{iD})] \geq 0 \qquad (3)$$

For a risk neutral landowner, the optimal bid is then the bid that maximizes the expected profit under a non-negative constraint. We obtain:

$$b_{iD}^{*} = c_i + \frac{1 - F_i(b_{iD})}{f_i(b_{iD})} \tag{4}$$

Assume now that the expectation about H is uniformly distributed with a lower and a higher bound denoted by $\underline{H}$ and $\overline{H}$ respectively. The optimal bid formula is then given by:

$$b_{iD}^{*} = \max\left[0.5\left(c + \overline{H}\right), \underline{H}\right] \quad \text{s.t. } b_{iD}^{*} \geq c \tag{5}$$

The optimal strategy is thus a strategy where participants overbid. In the discriminative price auction landowners face no uncertainty about the actual compensation, only about whether the bid will be granted or not. Thus when deciding about the offer, a landowner has to weigh the potential surplus generated by a higher price against the increased probability of being outcompeted and not getting the bid granted. The discriminative auction is thus associated with an incentive to ask for a price above the actual opportunity cost, otherwise there will be no surplus. If a person has pro-social motives that will of course reduce over-bidding, exactly how much is an empirical question.

In the uniform price auction a landowner's bid only determines the chance of getting the bid granted, not the actual compensation. All landowners with granted offers receive the same market price, which is always higher than their individual asking price. Thus, landowners have a higher incentive to reveal their true costs; asking for a higher price can only reduce the probability of getting the bid granted, it will not change the compensation. The optimal strategy is therefore to bid the opportunity cost $c_{i.}$ A higher bid would only increase the risk of being undercut and not getting the bid granted, and a lower bid can of course only result in a monetary loss. Thus,

$$b_{iU}^{*} = c_i, \tag{5}$$

irrespective if has pro-social motives or not.[6]

What can we say about market performance? The prediction of the uniform pricing rule is competitive behavior. This mechanism (if strong enough) speaks in favor of the uniform price auction. On the other hand, successful bidders will always receive compensation which is higher than their opportunity cost. The overall result will thus depend on how much landowners shade their bids under the discriminative pricing rule comparing to the uniform pricing rule. This in turn will depend on their subjective expectations and if they have pro-social preferences.

4 Results

For the statistical analysis we have used STATA 12 (StataCorp: www.stata.com). Because experiments often lead to skew distributions[7] we report the significance levels from non-parametric Mann-Whitney U tests when comparing averages. To compare proportions we use a contingency table Pearson's chi-square test (D'Agostino et al. 1988). All reported p-values are two-sided. In the regressions we let * denote significance at the 10-percent level, ** on the 5-percent level and *** on the 1-percent level. Because we can reject normality on most variables, we have bootstrapped the standard errors for all our regressions (Goncalves and White 2004).

Table 2 reports experimental results. The first observation we can make is that the randomization process worked; there are no significant structural differences between the two treatments. The average cost for implementing a measure was about 4500 EKR, the average

[6] For a risk averse landowner, the optimal bid will be lower in the discriminative price auction comparing to a risk neutral's offer because a lower bid will increase the probability of getting the bid granted (i.e. reduce risk). In the uniform price auction the optimal bid is the same for a risk averse and a risk neutral bidder.

[7] This is also the case with our data. According to a Shapiro Wilk's test we can reject normality on all continuous variables of Table 2.

environmental quality about 250 units. The average age was about 25, about 50 percent of the subjects were female, about 20 percent reported to be part of the study for pro-social reasons, and about 50 percent responded to the monetary incentives.

Table 2: Comparing averages and proportions of the two treatments.

	Discriminative	Uniform	
			Mann-Whitney U p-value
Age	24.43	25.48	0.6456
Quality	252.86	246.28	0.2413
Cost	4404.19	4621.66	0.1728
PMQ	0.7838	0.8938	0.0060
POPQ	0.6570	0.7849	0.0020
Bid over cost	1522.89	487.47	0.0000
Profit	629.708	290.459	0.7189
			Pearson’s chi-square p-value
Females	0.46	0.50	0.3710
Ultuna	0.35	0.32	0.3900
Profit motive	0.50	0.50	1.0000
Pro-social motive	0.20	0.19	0.5820

Two efficiency measures have been used in this study. For the first measure, the aim of a regulator is to maximize environmental quality given the fixed budget. But a regulator may also be interested in minimizing the price per quality for the given budget. Because a discrete number of projects is chosen each period part of the budget will typically not spent. This implies that these two efficiency measures may give different results. For each auction period we have compared all possible combinations of projects. The optimal combination of projects for each efficiency measure, based on cost draws and draws of qualities, has been identified. To be able to compare the two measures we have calculated the achieved efficiency as a percentage of the maximum possible. We refer to these as PMQ (Percentage of Maximum

Quality) and POPQ (Percentage of Optimal Price per Quality). A two-sided t-test reveals a significant difference between the two price mechanisms for both efficiency measures. Table 2 reveals that we can reject the null hypothesis of equal efficiency on a 5 percent level. The average efficiency with respect to quality (PMQ) is about 80 percent for the uniform price auction and 89 percent for the discriminative price auction. For cost efficiency (POPQ) the efficiency is somewhat lower for both test groups, about 66 percent for the uniform price auction and 78 percent for the discriminative price auction. Another indicator of efficiency is the profit made by the subjects. Lower profits means that subjects have, to a larger extent, been compensated according to their respective costs, which in turn means that more projects can be granted which could result in a higher efficiency. The profit is on average higher for the uniform price auction. However, the two-sided Mann-Whitney test indicates that we cannot reject the null hypothesis of equal averages.

We employ a tobit regression model for the efficiency measures, since by definition these efficiency measures lies between 0 and 1. We tried to use a random effects structure to capture potential within session correlation. However, the estimations did not converge. There is no specific within-group component and we had to rely on a standard tobit instead. We did however adjust the covariance matrix for potential data clustering. For the profit measure we employ a random effects linear regression model. Due to the difference in session length we only report the results for the first six sessions. In the regression analyses, beside a dummy for the treatment, we also included dummies to control for Ultuna (agrarian) students and for periods. The results are presented in Table 3.

Table 3: Regression models for efficiency measures

	PMQ Tobit St. Error	POPQ Tobit St. Error	Profit GLS St. Error
Constant	0.716*** (0.040)	0.804*** (0.045)	300.800*** (66.330)

Ultuna	0.018 (0.035)	-0.010 (0.039)	-33.344 (60.638)
Uniform	-0.081*** (0.033)	-0.104*** (0.037)	337.328*** (60.638)
Lnperiod	0.061 (0.028)	-0.004 (0.031)	-10.310 (45.316)
Sigma	0.142	0.158	242.098
Rho			0.026
Chi2	5.99	7.51	31.17
Prob > Chi2	0.112	0.057	0.000
# Observations	72	72	72

The dummy variable for Ultuna is not significant for any of the dependent variables at any significance level. Moreover, there does not seem to be much difference in market performance across periods. The only significant variable in explaining differences in market performance is the dummy variable for the uniform treatment. Table 3 thus confirms that the uniform treatment is associated with lower efficiency.

4.2 Individual bidding behavior

When analyzing the whole dataset the results are very similar to the results obtained by Cason and Gangadharan (2005) and one could be tempted to conclude that the efforts made to include more context-based instructions has been without results. However, before we draw any such conclusion we should also look at the individual bidding behavior. Figure 1 and 2 illustrate individual bids for the uniform and the discriminative price treatment respectively.

Figure 1 shows that although the cost revelation mechanism works, there is still some over bidding taking place in the uniform price treatment. The average predicted bid for the uniform treatment is 4622 EKR (equals average cost) compared to the average of actual bids 5109 EKR (two-sided p-value 0.000).

Figure 1: Individual bids for the uniform price treatment

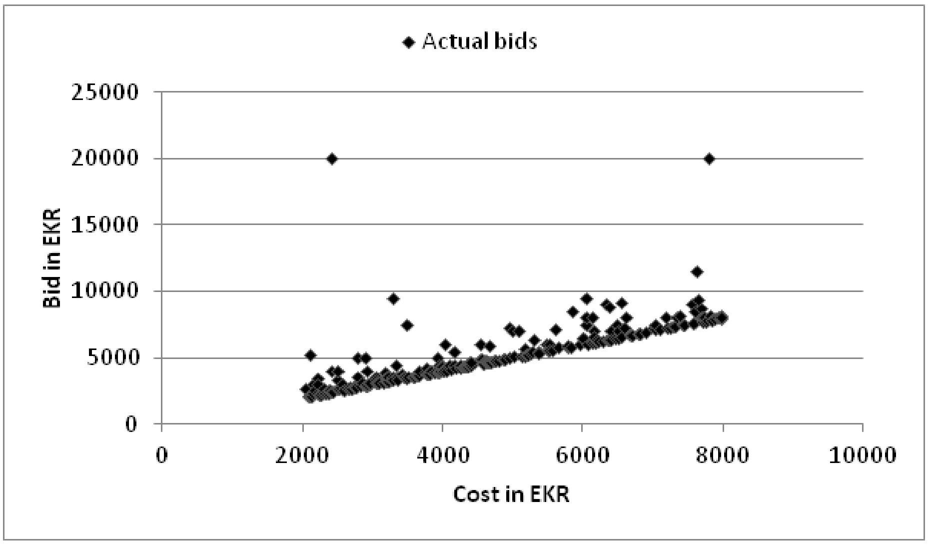
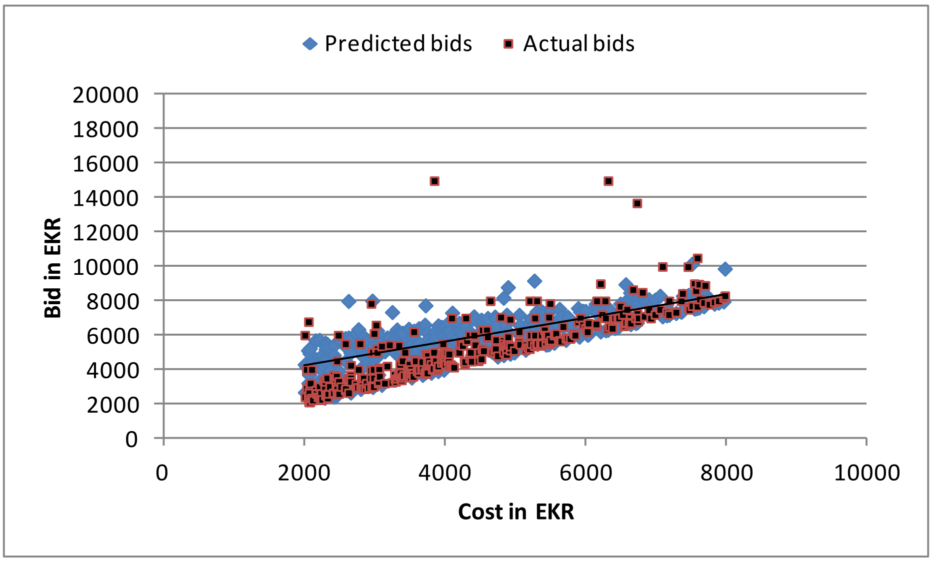


Figure 2 illustrates actual and predicted bids for the discriminative price treatment. The predicted bids are estimated based on equation (4) in section 3. From the result data we can get the exact value of the "reservation price" $\underline{H}$ (27.3 EKR per unit of environmental quality) and can then for each project calculate the predicted bid (based on risk neutral bidders)[8]. The regression line is obtained from these predicted bids.

[8] In the post-experimental survey we asked the subjects to make a choice between two lotteries, where one was more risky. The survey revealed that most subjects (0.76) were risk neutral and that only about 0.17 of the subjects were risk averse.

Figure 2: Individual bids for the discriminative price treatment



By comparing Figures 1 and 2 we see that the discriminative price treatment is associated with more over bidding. This is also confirmed statistically; the average "shading" of bids is 487 EKR for the uniform price treatment compared to 1523 for the discriminative price treatment (two-sided p-value < 0.000). However, the over-shading of bids in the discriminative price treatment is actually smaller than predicted. The average predicted over bidding is equal to 1289 EKR, which is significantly higher than the actual over bidding (two-sided p-value <0.000).

A contingency table (Table 4) for the discriminative price treatment shows that there are some structural patterns in the data. Those who provide bids which are lower than predicted are more likely to have an agrarian education (compare 0.83 with 0.67) and are more likely to state a pro-social reason for participating in the experiment (compare 0.39 with 0.15). For the uniform price treatment we do not find the same structural differences. However, we find that subjects who participated in the experiment mainly to earn money, are less likely to over bid, which is in line with rational behavior.

Table 4: Contingency tables

Discriminative

	Bids > predicted	Bids < predicted	Total Frequency	Pearson's chi-square p-value
Stockholm U	69	141	210	
Ultuna U	19	96	115	
				0.003
Profit motive	63	99	162	
Pro-social motive	25	13	163	
				0.000
Total Frequency	88	237	325	
Uniform				
	Optimal bidding b = c	Over bidding	Total Frequency	Pearson's chi-square p-value
Stockholm U	65	115	180	
Ultuna U	38	107	145	
				3.64
Profit motive	51	81	132	
Pro-social motive	52	141	193	
				4.96
Total Frequency	103	222	325	

5 Conclusions

The uniform price auction generated bids that were close to actual costs to a higher extent than the discriminative price auction; the information revelation mechanism worked. Nevertheless, the mechanism was not strong enough, the incentive to reveal the true cost was not evident to all participants in the uniform price treatment. As a consequence the discriminative price treatment was associated with a higher efficiency. From a first glance we can conclude that the overall result obtained by Cason and Gangadharan (2005) is robust to the modification; a non-neutral experimental design with an environmental terminology actually explaining the problem of non-point source pollution as well as the implications of a reverse auction program for voluntary conservation.

However, when looking more closely at bidding behavior there are some interesting patterns in the data. For the discriminative price auction, the bids are actually lower than predicted by theory) and these bids are more likely to come from bidders with an agrarian background and those who listed the social motive as the main reason for participating in the experiment. As far as this author knows, this study is the first to make this linkage.

If irrational behavior such as pro-social motives and market failures exist for some environmental good or service (for example the provision of a public good), correcting one failure (under supply) without correcting the other "failure" (deviation from the rationality assumption) could actually reduce welfare instead of improving it (Shogren and Taylor 2008). However, it has also been argued that some market based instruments, for example auctions have the potential to correct both types of failures. The argument being that by actively taking part in market exchange people can learn to be rational because the market is more rational than the individual and makes better allocation decisions concerning specialization and distribution. However, our results show some evidence supporting the opposite. We find that the auction as a market institution is not strong enough to correct irrational behavior (here pro-social behavior), even though the auction is repeated several periods. When implementing policy program for environmental protection we therefore believe it is crucial to identify and analyze not only economic circumstances and institutional designs but also the social and environmental context in which decisions are taken, because they may influence policy outcomes (also suggested by Carlsson and Johansson-Stenman 2012). For conservation auctions one should therefore consider what types of behavioral motives that are relevant, how important they are, and how they can they potentially influence behavior and consequently the overall outcome. For example, if pro-social motives exist a policy maker may want to consider exactly how the policy is presented and described even when the implementation is market based.

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Appendix

Instructions for the discrete price treatment

Thank you for participating in this experiment! This is an experiment about economic decision making. If you follow the instructions carefully and make good decisions you will earn money. The actual experiment is computer based, which means that you will be making your decisions in front of a computer screen. All earnings on your computer screen are in experimental kronor (EKR henceforth). These will be converted to SEK (Swedish kronor) towards the end of the experiment. One EKR corresponds to 0.1 SEK. So if you have earned 1000 EKR they will be converted to 100 SEK. The important thing to remember is that the more EKR you earn, the more SEK you earn as well. You will receive the show-up fee (100 SEK) plus the money you earn after the experiment.

Each of you sitting in this room plays the role of a landowner. The experiment leader plays the role of an authority. The experiment consists of a number of auctions. The authority conducts these auctions to give landowners the opportunity to take certain measures for monetary compensation. The purpose of these measures is to reduce the amount of nitrogen and phosphorous loadings stemming from agriculture and thereby to improve the water quality of the sea.

You (the landowners) each have three measures to offer in each auction round. A measure could for example be changing land use or production method and is thereby associated with a certain cost. The authority knows that these costs vary between landowners and measures and that they lie in the interval (2000 – 8000 EKR) but the exact cost of a certain measure is private to the landowner. No other landowner has exact information about your costs. Each measure is also associated with an improved water quality. The quality can vary between measures and landowners. Only the landowner and the authority have exact information about the quality associated with a certain measure. No landowner has information about the quality associated with the other landowner's measures.

For each of the three measures you as a landowner need to state the minimum amount (in EKR) you require to take the measure. These are your bids. The bidding procedure is sealed and all bids are anonymous. How the computer screen will appear in this situation is illustrated below.

Based on your bids, the authority calculates the environmental quality per EKR that each of your measures would generate. The measure with the highest environmental quality per EKR (your best bid) is chosen to compete against the other landowner's best bids. Each landowner is thus competing with one bid.

The competing bids are ranked according to environmental quality per requested amount, where the bid with the highest environmental quality per requested amount is ranked highest. The bids are granted according to this ranking until the fixed budget is spent. The budget is unknown to all of you.

If your best bid is ranked high enough and is granted your profit that period is equal to your requested amount minus the cost associated with the actual measure (profit = requested amount – cost). Note that you may make a loss if you request an amount which is lower than the cost associated with the measure. If your best bid is not granted your profit is 0 that period. In the table below we illustrate a fictive example where the budget is 10 000 EKR.

Landowner	Cost	Bid (EKR)	Quality	Quality per EKR	Rank	Granted amount (EKR)	Profit (EKR)

Yellow	**4 500**	**5000**	180	0.036	1	**5000**	**500**
Red	2 000	4000	100	0.025	3	0	0
Blue	**1 000**	**2000**	60	0.030	2	**2000**	**1000**
					Sum:	7000 EKR	1500 EKR

The experiment consists of several auction rounds. We will be taking shorter breaks of a couple of minutes every now and then. We ask you not to talk to each other during the actual rounds; however you may talk to each other during the breaks.

During the experiment you will be able to follow the auction history on the computer screen. For each round you will find information about your competing bid, the environmental quality per EKR spent for the lowest ranked accepted bid and your earnings. None of you will get information about the other landowner's bids. Before each break we ask you to fill in a user name. You do not have to state your real name. The important thing is that you fill in the same user name each time so we can keep track of your earned money and be able to identify you when paying you. After the final round we ask you to answer some additional questions.

The program then produces a payment file and the experiment leader calls each of you to her desk for individual payment.

If you have any questions during the course of the experiment raise your hand and the experiment leader will come to you.

Summary

- Earned money for a granted bid = requested amount -cost

- You have three measures to offer each round, these are associated with different costs and quality numbers. You will see your costs and quality numbers on the computer screen.
- The costs and quality numbers vary between landowners and auction rounds.
- For each of your measures you state the minimum amount you require to take the measure. The authority will grant at the most one of these measures.
- The authority grants those bids with the highest associated quality per requested amount and spends a fixed budget each auction round.

Good luck!

Instructions for the uniform treatment

Thank you for participating in this experiment! This is an experiment about economic decision making. If you follow the instructions carefully and make good decisions you will earn money. The actual experiment is computer based, which means that you will be making your decisions in front of a computer screen. All earnings on your computer screen are in experimental kronor (EKR henceforth). These will be converted to SEK (Swedish kronor) towards the end of the experiment. One EKR corresponds to 0.1 SEK. So if you have earned 1000 EKR they will be converted to 100 SEK. The important thing to remember is that the more EKR you earn, the more SEK you earn as well. You will receive the show-up fee (100 SEK) plus your earned money after the experiment.

Each of you sitting in this room plays the role of a landowner. The experiment leader plays the role of an authority. The experiment consists of a number of auctions. The authority conducts these auctions to give landowners the opportunity to take certain measures for monetary compensation. The purpose of these measures is to reduce the amount of nitrogen and phosphorous loadings stemming from agriculture and thereby to improve the water quality of the sea.

You (the landowners) each have three measures to offer in each auction round. A measure could for example be changing land use or production method and is thereby associated with a certain cost. The authority know that these costs vary between landowners and measures and lie in the interval (2000 – 8000 EKR) but the exact cost of a certain measure is private to the landowner. No other landowner has exact information about your costs. Each measure is also associated with an improved water quality. The quality can vary between measures and landowners. Only the landowner and the authority have exact information about the quality associated with a certain measure. No landowner has information about the quality associated with the other landowner's measures.

For each of the three measures you as a landowner need to state the minimum amount (in EKR) you require to take the measure. These are your bids. The bidding procedure is sealed and all bids are anonymous. How the computer screen will appear in this situation is illustrated below.

Based on your bids, the authority calculates the environmental quality per EKR that each of your measures would generate. The measure with the highest environmental quality per EKR (your best bid) is chosen to compete against the other landowner's bids. Each landowner is thus competing with one bid.

The competing bids are ranked according to environmental quality per requested amount, where the bid with the highest environmental quality per requested amount is ranked highest. The bids are granted according to this ranking until the fixed budget is spent. The budget is unknown to all of you.

If your best bid is ranked high enough and is granted your profit that period is equal to a certain compensation minus the cost associated with the actual measure (profit = compensation – cost). If your best bid is not granted your profit is 0 that period. How the compensation is determined is explained below.

All landowners with granted bids will be paid the same amount per environmental quality. The actual amount per environmental quality paid corresponds to highest ranked bid which was rejected. So if your bid is granted you will receive a compensation which is equal to or higher than your requested amount, thus make a positive profit (even if you request an amount which is equal to the cost). In the table below we illustrate a fictive example of how the compensation is determined where the budget is 10 000 EKR.

Land-owner	Cost	Bid (EKR)	Quality	Quality per EKR	Rank	EKR per quality	Granted amount (EKR)	Profit (EKR)
Yellow	**4 500**	**5000**	180	0.036	1	28	40*180 **=7200**	**2700**
Red	2 000	4000	100	0.025	3	**40**	0	0
Blue	**1 000**	**2000**	60	0.030	2	33.33	40*60 **=2400**	**1400**
						Sum:	9600 EKR	4100 EKR

As the table illustrates, the two highest ranked bids are granted. The compensation is determined by the bid which was ranked 3, corresponding to 40 EKR per quality unit. The two landowners with granted bids both make a positive profit.

The experiment consists of several auction rounds. We will be taking shorter breaks of a couple of minutes every now and then. We ask you not to talk to each other during the actual rounds; however you may talk to each other during the breaks.

During the experiment you will be able to follow the auction history on the computer screen. For each round you will find information about your competing bid, the compensation (EKR) paid for granted bids and your earnings. None of you will get information about the other landowner's bids.

Before each break we ask you to fill in a user name. You do not have to state your real name. The important thing is that you fill in the same user name each time so we can keep track of your earned money and to be able to identify you when paying you. After the final round we ask you to answer some additional questions.

The program then produces a payment file and the experiment leader calls each of you to her desk for individual payment.

If you have any questions during the course of the experiment raise your hand and the experiment leader will come to you.

Summary

- Earned money for a granted bid = compensation –cost
- You have three measures to offer each round, these are associated with different costs and quality numbers. You will see your costs and quality numbers on the computer screen.
- The costs and quality numbers vary between landowners and auction rounds.
- For each of your measures you state the minimum amount you require to take the measure. The authority will grant at the most one of these measures.

- The authority grants those bids with the highest associated quality per requested amount and spends a fixed budget each auction round.
- If your competing bid is granted your compensation corresponds to the highest ranked rejected bid. The compensation will thus be equal to or higher that your requested amount.

Good luck!