USING LABORATORY EXPERIMENTS FOR POLICY MAKING: AN EXAMPLE FROM THE GEORGIA IRRIGATION REDUCTION AUCTION

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Abstract: In April 2000, the Georgia legislature passed a law requiring that the state use an unspecified "auction-like process" to pay some farmers to suspend irrigation in declared drought years. In response, we conducted a series of laboratory and field experiments to test a variety of auction procedures. This paper reports the results of these experiments, and how they were used by the policy makers who determined the auction procedures. Experimental results are compared with farmers' bidding behavior in the state-run irrigation auction conducted in March 2001.

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I. INTRODUCTION

In April, 2000, the Georgia Legislature enacted the Flint River Drought Protection Act.[1] The state was entering a third year of drought and Georgia=s primary water manager, the Environmental Protection Division (EPD), was concerned that the exercise of existing water use permits could reduce flows in the Flint River to levels that might cause serious harm to the Basin=s ecological systems in general, and to endangered species in particular. The Drought Protection Act was designed to reduce irrigated acreage (which accounts for more than 70% of consumptive water use in the Basin) during drought years. On March 1 of each year, the Director of the EPD is required to announce whether or not the upcoming summer will be characterized by severe drought conditions. If a drought is declared, the Director is then required to determine the number of acres that must be taken out of irrigation to maintain acceptable river flows. He then implements an Aauction-like≅ process wherein farmers may offer to voluntarily forego irrigation of *all*[2] lands covered by a specific water use permit for the remainder of the calendar year, in exchange for a one-time lump sum payment (determined by the auction). The Georgia Legislature set aside $10 million of funds derived from the multi-state Tobacco industry settlement for use in compensating these farmers.

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[1] O.C.G.A. 12-5-540 through 12-5-550.

[2] Reflecting issues related to enforcement, farmers were not allowed to offer partial reductions in acreage covered by a specific water use permit. Offers could be made only to take all lands covered by the permit out of irrigation for the balance of the year. If, as was often the case, a farmer held more than one permit, he/she could offer to take all lands covered by one permit out of irrigation, but continue to irrigate all lands covered by permits with offers not accepted in the auction.

After learning of the Act's auction provisions, we immediately initiated a program of research aimed at assisting the EPD in their efforts to define the substance of the "auction-like process" that they might be (and ultimately were) required to implement. An appropriate design for such an auction was not immediately obvious. The necessary characteristics were somewhat unique *vis-a-vis* received auction literature in a number of ways.[3] Unlike (as contemporary examples) the SO_2 and FCC bandwidth auctions that involve a single or multiple seller(s) facing many buyers, the water use permit (hereafter, simply "irrigation") auction involves a single, *budget-constrained*, *buyer* facing many sellers.[4] The value of irrigation to farmers in this region contains both private value and common value components. Since most farmers use irrigation for one or more of three major crops, (corn, cotton, and peanuts), we concluded that sellers have relatively good common information about the value of irrigation to other sellers, subject to some uncertainty about price and weather. In contrast, differences in permit size, soil quality, and location produced variations in per-acre productivities of irrigated land, which we modeled as "private value" differences. Finally, any effort to design an auction mechanism for this application would have to reflect obvious incentives for sellers (farmers who know one another) to attempt to collude.

The purpose of this paper is to describe our efforts to evaluate alternative auction mechanisms to implement the Act's requirements. Our goal was to design an auction that provides farmers with an incentive to reveal their true costs of foregoing irrigation, under the constraints imposed upon the auction by the law and available budget. The subjects were mostly students in laboratory settings designed to mimic likely characteristics of the actual auction, such as easy communication between sellers and large numbers of sellers. We also made use of adult subjects and farmers in field conditions. These field experiments were held at local facilities in farming communities.

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[3] For discussions of auctions for bandwidth and pollution permits, see Cramton (2000, 2002) and the experimental results in Banks, Olson, Porter, Rassenti, and Smith (2001).

[4] To provide some degree of perspective for the EPD's budget constraint of $10 million, in a severe drought year the EPD's target acreage reduction could be on the order of 100,000 acres (out of a total of some 600,000 to 800,000 irrigated acres). Achievement of the target would require that the average price/acre paid in the auction not exceed $100, which is seen by many as the lower bound on rental values for irrigated land in the Basin.

In section II, we discuss the institutional considerations that determined the basic experimental design and treatments. Modifications based on pilot experiments are reviewed in section III. Section IV presents results from laboratory experiments of various scales (from 9 to 42 participants) using various pricing, bid revision, and information provision rules. The results of two field experiments are reported in section V, one with subjects that were primarily farmers and one that was a multi-site auction with 50 people drawn from the local population at two sites in southwest Georgia, just two months prior to the actual auction. The bids in this trial run were collected using a web-based program that enabled the Director of the EPD to watch the bidding from Atlanta.[5] Section VI describes how our recommendations were implemented, and summarizes the results of the EPD auction, which involved 194 farmers at 8 Flint River basin locations. The final section concludes.

II. Implementing the Irrigation Auction in Laboratory Experiments

Because our work was motivated by a specific policy question, the experiments that we conducted included more context and fewer controls than is typical for laboratory experiments. The first part of this section provides details on the institutional context for the irrigation auction. The second part outlines our experimental implementation.

Institutional Considerations

There were many institutional details that we considered and mimicked in our experiments. First, there are many potential "sellers" (farmers) and only one "buyer" (the EPD). We use the terms buyer and seller to correspond to traditional auction theory and design, however nothing is being "bought" or "sold" in this auction. To be more precise (and legally accurate) farmers make offers to suspend irrigation for the remainder of the calendar year. These offers may be accepted or rejected by the EPD. Farmers, however, retain their land and their irrigation permit regardless of the outcome of the auction.

[5] The program, written by Krawee Ackaramongkolrotn at Georgia State University, was also used in the final auction.

Some farmers have more than one irrigation permit, and the value of the land is not homogenous across farmers. In fact, one farmer may hold irrigation permits for land that is used to grow different crops, and therefore has different values, depending on which crop he plants that year. The auction must be implemented and finalized quickly (within 25 days) after a drought declaration is made. Moreover, it must be able to accommodate a potentially large number of farmers, who are located over a broad area of southwest Georgia. Not all of these farmers have internet access, and some are not comfortable with computers. While the EPD will have a target number of acres that they wish to take out of irrigation, they also have a fixed budget constraint that is likely to be binding. The maximum budget is public knowledge, but the target acreage need not be. Finally, the institution should be "collusion-proof" given that many of those participating in the auction know one another and will have ample opportunity prior to (or during) the auction to discuss bidding strategies.

Irrigation systems in this region are not metered. Therefore it was not possible to implement a system in which a given farmer reduces irrigation to a target amount. In order to have more manageable enforcement, regulators decided that any offer to suspend irrigation required no irrigation take place on *any* of the land covered by the permit. For example, if a single irrigation permit covered three distinct fields, an offer to suspend irrigation means that no irrigation will occur on any of the three fields. However, if a farmer had more than one irrigation permit, the farmer could offer to suspend irrigation under one and still irrigate land covered by another.

An offer to suspend irrigation merely states that the farmer is willing to forego irrigating for the remainder of the calendar year in exchange for the specified (per-acre) payment. The farmer can still use the land, and in fact can still plant crops on the land. While dry-cropping (planting without irrigating) is possible, we believe it is unlikely that the land will be used for agricultural purposes. Beginning January 1 of the following year the farmer is free to irrigate once again.

There were political considerations as well. The outcome of the auction should not be considered to be either "wasteful" or "unfair." There is a large variance in the quality of land (and the crops grown), both within and across regions. Many therefore perceived that a fair pricing system would entail paying different amounts to farmers with

different values. In addition, in a uniform price auction there was the potential of negative publicity if a farmer offered to suspend irrigation for a very low amount but was paid a much higher amount determined by the uniform market clearing price. While we compared uniform and discriminative pricing in our initial experiments, described below, we narrowed our focus when it became obvious to us that a uniform-price mechanism would not be seriously considered by the EPD.

Typically one considers an auction successful if the outcome is efficient. In this context, this entails not only the "right" price resulting from the auction, but also that those farmers with the lowest land values have their offers accepted. However, the EPD's primary goal was simply to take the maximum number of acres out of irrigation within the fixed budget constraint.[6] This was particularly important given that most thought it was unlikely that they would be able to meet their target acreage within the budget they had to work with. Efficiency was a secondary concern to them.

Finally, because an auction like this had never been conducted in this region (and is expected to happen only infrequently), it is important that the rules and procedures be clear, easily understood, and also easy to implement. In particular, it was of utmost importance that all farmers understand precisely how their payment would be determined by their offer prices.

Laboratory Implementation

In the typical laboratory experiment, neutral terminology is used for goods of an unspecified nature, in order to preclude the possibility that valuations may be biased by experiment context. Moreover, subjects are often visually isolated from one another, and are not allowed to communicate (unless this communication is a treatment variable). The complexity of the auction procedures being discussed convinced us that a fair amount of context would be useful to reduce confusion, and we did not think vague beliefs about land rental rates would affect induced values that were several orders of magnitude lower. Therefore, subjects in these experiments were told:

[6] Ideally, the EPD would suspend irrigation on land with the most intensive water use; however they have no information that makes this possible.

> In this auction, each of you will be in the position of a farmer who has three "permits" to irrigate acres of land. These irrigation permits allow you to irrigate the land and earn money on crops that you grow. We (the experimenters) are in the position of a government agency charged with controlling water use. We will use an auction-like process to buy some of these permits back from you in order to reduce the amount of water being taken from river and ground water reserves in this area.

This context-specific terminology proved to be useful when we wrote instructions for the actual auction that followed a year later.

We used induced values to determine the supply function for irrigation permits. The subject was told the (per-acre) value for each permit that was held. If the permit was not sold, the subject would definitely earn this amount of money, multiplied by the number of acres covered by the permit. If the permit was sold, the subject would not earn this money, and would instead earn the negotiated per-acre price multiplied by the number of acres covered by the permit. The certain value of a held permit is a simplification of the actual situation facing farmers, since crop price is not known with certainty in advance. Roughly 75 percent of the acreage in this region is in corn and cotton, and this is also the acreage with the lowest profit margins. Farmers in this area are clearly price-takers in these crops (reducing acreage would have no effect on market prices), and therefore have a good idea of the costs and prices that they face. The remaining acreage is in peanuts. Because profit margins are higher, and also because of peanut quotas, we considered it very unlikely that any peanut acreage would be offered in the auction at prices close to those that were being accepted.

After the initial sequence of experiments, we were concerned that the laboratory environment inhibited the communication that would certainly occur among farmers in an actual irrigation auction. Therefore, we conducted the majority of our sessions in an open lobby area outside of the laboratory, or in a large meeting room, depending on the number of participants. Refreshments were provided, and subjects were encouraged to talk with one another. The auctions were conducted using a series of five-minute offer submission rounds. Subjects were told: "while you are waiting to turn in your offer submission card (or simply waiting for the end of the 5-minute period), feel free to talk with the others and to enjoy the refreshments." The experimenters were available to answer questions, but typically kept their distance (sometimes standing in another nearby

room) so that they did not inhibit any conversation. During the largest experiments and in the EPD auction, the people running the auction wore red baseball caps so that they could be easily identified in the event that there were questions or problems. For the majority of experiments, subjects were students at Georgia State University.

Even before draft rules of the auction were released by the EPD, farmers in the affected area of the state were discussing the auction. We expected them to come to the auction having discussed the auction and bidding strategies amongst themselves prior to the auction. In order to better simulate this level of experience, some subjects participated in several auction experiments. About 40 percent of our subjects participated in more than one session. Therefore our auctions involved a mix of experienced and inexperienced subjects. We did, however, shift the land values (and budget constraint) by a constant between sessions in order to change the competitive price between sessions. Also, because we expected many of the farmers to know one another, we placed no restrictions on friends or family members participating together in these experiments (this is typically avoided wherever possible in economics experiments). For example, we know of several cases where spouses, siblings, and parents participated together.

Subjects did, in fact, talk with one another during the sessions. Because communication was not a treatment *per se* (instead we were trying to parallel the naturally occurring environment) we did not monitor the conversations or keep transcripts. We did observe that subjects sometimes engaged in small talk, and at other times talked about the auction itself. Because we wanted to ensure that any auction mechanism that we recommended would be relatively collusion-proof, we were happy that bidding strategies were discussed and attempts at collusion occurred in most sessions.

Overall, 90 subjects participated in 20 auctions held during 11 sessions in April and May 2000 (some subjects participated in as many as three auctions). Most sessions lasted for two hours (the 42-person session was scheduled to last 4 hours), and earnings ranged from $36.62 to $99.88, with an average of $63.74.

III. PILOT EXPERIMENTS: PRICING RULES AND REVISIONS

In our first pilot sessions, subjects participated in more than one auction, which allowed us to test a variety of institutions quickly before narrowing our focus to one or two sets of rules.

The design and land values used in the last two pilot sessions most closely resembled those conducted subsequently. Therefore, we will report only the results from these sessions. Subjects in both participated in two sealed-offer auctions: a discriminative (own-price) and uniform-price auction. They also participated in a final (uniform-price) auction in which they were allowed to revise their offers after preliminary results were announced. In one session the uniform price was set equal to the lowest rejected offer price, and in the other session it was set equal to the highest accepted offer price. We were interested in how the average price paid, number of acres obtained in the auction, and efficiency were affected by the choice of institution and the opportunity to revise offers based on market information. In order to minimize order and information effects we first conducted the one-shot (no revision) auctions without providing any feedback on the results. Therefore when the iterative auctions were conducted, subjects had previously submitted offers, but had not observed the outcome from either one-shot auction.

A uniform price auction is typically preferred because it is incentive compatible to bid one's own value (at least when one's bid cannot determine the market-clearing uniform price). However, because subjects in our experiments (like farmers who were to be participants in the auction) had multiple permits, neither pricing rule we tested is theoretically incentive compatible (Smith, Williams, Bratton, and Vannoni, 1982; Ausubel and Cramton, 1998). To see this, think about a farmer making offers for two permits. If one offer is accepted, it is possible that his offer on the second (rejected) permit could determine the market-clearing price. In this (multi-unit) environment bidding one's value is incentive compatible only if the price is determined by the lowest rejected offer that is not one's own.[7] We did not consider such a pricing rule, however, because of the complexity of explaining and implementing it. Moreover, it wasn't clear

[7] List and Lucking-Reiley (2000) document such demand withholding behavior in field experiments when a simple uniform price auction is used.

to us that farmers would understand the incentive to bid value in such a complicated environment.

In each auction subjects knew their own land values, the range of values, the number of participants, and the fixed budget. They were told that we had a target number of acres that we wanted to take out of irrigation, and that we would accept as many offers as possible until we either reached this target or expended our budget. Subjects were not told the target number of acres. Moreover, in the auctions with revisions, subjects did not know how many revision rounds would be conducted.

In these auctions we did not observe a consistent difference between the uniform and discriminative auctions. In one session, the uniform price was below the average price paid in the discriminative auction. However, two accepted offers were substantially higher than others in the discriminative auction, pulling up the average. In the second session the average prices were identical. More evidence comparing the uniform and discriminative auctions will be presented below. Similarly, there is little difference in the uniform price auctions between a price based on the highest accepted offer and the lowest rejected offer.

The basic procedures of the auction with revisions were the same as those for the one-shot auction. After all offers had been submitted in writing, they were ranked from low to high. The lowest priced offers were then "provisionally" accepted. After the provisional winners were announced, all subjects (regardless of the status of their offer) were given the opportunity to turn in a revised offer. If no new offer was turned in, the previous offer stood. The new offers were then ranked, and new provisional winners were announced. This process continued until either no one wished to submit a revised offer or the experimenters chose to end the auction. In this case, the provisional acceptances from the most recently completed round became final acceptances. Subjects did not know in advance which would be the final offer round.

We placed no restrictions on the revisions. Therefore a subject who initially submitted a high offer price could lower their offer (provided another revision round was held). Similarly, a subject who submitted a very low offer could increase it, even if the offer was provisionally accepted. Of course, doing so involved the risk that the subject would be excluded from the market at the new offer price.

A key issue here is how to announce the provisional winners. In particular we considered whether we should simply announce which offers were accepted (identified in an anonymous manner, for example by permit ID number) or announce the cut-off offer price that determined which offers were accepted. We thought that it would be cumbersome to announce each ID number, especially in the actual auction with potentially hundreds of farmers. Therefore, we chose to announce only the cutoff price ("All offers at or below $1.20 were provisionally accepted"), however, this is a treatment that we consider below.

Across revision rounds, the average accepted offer price generally declined (from $1.11 in the first round to a low of $1.04 in round 3) in one session, and was flat in the second session (see Figure 1). In both of these auctions the uniform clearing price was *below* the competitive prediction of $1.10, obtained by intersecting the supply function (locus of ranked opportunity costs) with a demand function that is the locus of points where the price multiplied by the number of acres exactly matches the budget constraint. This sub-competitive result reflects the fact that some subjects were making offers below value, which suggests that some subjects were almost certainly confused about how their earnings were determined. We addressed this in follow-up experiments, described below.

The most important result to come out of these initial experiments is that inefficiency decreases dramatically when subjects are given preliminary results and allowed to revise offers. Our measure of inefficiency is the amount by which the opportunity cost (the value of a permit that is kept) of the accepted offers exceeds the minimum opportunity cost of the number of acres accepted in the auction. If the lowest-valued permits are obtained in the auction (regardless of the price paid for them) this measure will equal zero. When higher-opportunity cost permits are obtained instead of lower opportunity cost units, this measure will increase. Inefficiency is shown on the right axis of Figure 1, and peaks in the first or second revision round. By the final (fourth) revision round the "right" (minimum opportunity cost) offers are typically accepted.

As noted earlier, efficiency was not one of the EPD's primary goals. A one-shot sealed offer auction would be much easier to implement. Farmers could mail in their offers, which would then be sorted by policy-makers. We need a strong justification for

the additional time and expense of conducting an auction with revisions (which by necessity involves taking workers into the field). One reason is simply to insure against a bad outcome. Given that this type of auction had never been conducted before, policy-makers would like some assurance that prices would be at a "reasonable" level. If, for example, a simple sealed offer auction is conducted and the submitted offers are extremely high, very few offers would be accepted. Allowing for revisions gives farmers a chance to think about the situation and to respond to policy-makers' decisions and the bidding behavior of others. Allowing for these revisions could minimize the chance that farmers will come out of the auction wishing that they could do something differently. Given the potential political repercussions of a poor outcome, or unhappy farmers, this is a big advantage of implementing an auction with revisions. Moreover, holding other factors constant, an institution that results in more efficient outcomes (and therefore, presumably, participants who are more satisfied with the outcome) is preferable. This is a strong argument in favor using an auction mechanism that includes the opportunity to revise offers.

IV. Laboratory Experiments

This section describes the treatments that we tested in the lab, and the results from auctions using each of these treatments. We conducted a single auction in each session, varying treatments between sessions. Among the factors considered were: the tie-breaking rules, uniform versus discriminative pricing, number of participants and the information provided about cutoff offers.

Training Subjects to Understand the Institution

After observing that some subjects consistently bid below value in our pilot experiments, we were concerned that participants might be confused about how their earnings were determined in the auction. There were two potential sources of confusion: how much they earned if they retained a permit, and how their earnings were determined in the event that an offer was accepted. In a typical experiment, decisions are made over a series of rounds, and earnings are reported at the end of each round. This was not the

case in our experiment. If a subject was confused about how earnings were calculated, they received no information during the experiment that would eliminate this confusion.

Because of this we used extensive instructions (contained in the appendix) to explain the procedures and how earnings were calculated. Participants were asked to calculate their earnings for each permit that was not sold in the auction. In addition, the experimenter publicly worked through examples of how earnings would be calculated if offers on no permits or some permits were accepted. These examples used prices that were quite different than any potential prices in the market. Finally, participants worked through two practice auctions using real goods (for example, pens or post-it notes). In the first practice auction, subjects were endowed with one unit of a good (for example, a single pad of post-it notes). After the fixed budget was announced (typically several dollars), subjects submitted the price at which they would be willing to sell the good back to the experimenter. Offers were publicly recorded and ranked on a transparency and the lowest-priced offers were accepted until the budget had been expended. Those participants whose offers were accepted were paid (either the uniform or discriminative price, depending on the treatment) and the item was taken from them. It was emphasized that those participants whose offers were accepted received the money but not the value to them of the good. The others received no money but were still able to use the good. The second auction was identical to the first, except that subjects were given two possibly heterogeneous units of the good (for example, a blue pen and a black pen) to more closely correspond to the multi-unit auction design. While this did not keep all subjects from bidding below value in subsequent auctions, very few cases of this were observed.

Tie-Breaking Rules

Given a fixed budget constraint, the possibility exists that a tie could occur at the highest accepted price. For example, suppose the budget was $10 and the ranked offers in a discriminative auction were: $0.50, $1.00, $2.00, $3.00, $3.00, $3.00, $5.00, and $10.50. In this case, we could accept all offers below $3.00, but only 2 of the 3 offers at $3.00.

In one (uniform-price) session, a subject asked how we would choose which offers to accept if there was a tie such as the one described above. We responded that we

would accept all offers at this price, "even if we have to go a little above our budget." Figure 2 shows the results from this session (and a paired session, described below). The induced supply and demand arrays are shown on the left side of the graph. The supply curve is simply the permit values, ranked from low to high. The demand side of the market comes from the experimenters, and is determined by the fixed budget constraint. For example, in this market the budget constraint was $160. Therefore we could afford to buy one acre at a price of $160 per acre, 4 acres at a price of $40 per acre, or 160 acres at a price of $1 per acre. The demand curve traces out the locus of these points where the price multiplied by the number of acres exactly matches the budget constraint. In this session, the uniform competitive price was $1.10 (prices on the graph are shown in pennies). We define this price as the one at which the number of acres that would be offered in the market if all bid value (144 acres) is just what we could afford to purchase at a uniform price within our fixed ($160) budget.[8]

The right side of Figure 2 shows the time series (across revision rounds) of average accepted prices obtained in this market (shown in the "inclusive tie-breaking rule" line).[9] In the first offer round, if we had observed our $160 budget constraint, we would have accepted two of these offers (plus six offers at lower prices), for a total of 112 acres at a cost of $134.40. However, because of our announced procedure of accepting all offers at the tied level, we provisionally accepted offers for 160 acres at a total cost of $192. In the second round the highest accepted offer price fell to $1.15, and there was once again a tie. As additional revision rounds continued, almost all permits with a value below $1.15 were submitted at this level – even those with very low values in this uniform price auction. By round 6, there were 18 accepted offers. All but five of these were submitted at $1.15. We retired a total of 288 acres (double the competitive level), and spent $331.20: over double our budget. Extrapolating to the actual problem

[8] If we assume that all will bid 1-cent above value in order to avoid indifference, the price would be $1.11, and 144 acres could still be retired while staying within the fixed budget.

[9] Because the highest accepted offer is the one (uniform) price paid for all accepted offers, this is also the average price paid. For consistency with subsequent figures that show data from discriminative auctions, we label this as the average price.

faced by the EPD, this translates into spending over $20 million when the available budget is $10 million.

Later on the same day we conducted a second session (with a different group of participants). This session was identical (number of participants, parameter values, and procedures), except for an announcement that, in the event of a tie, we would randomly choose among offers at the tied level in order to stay within our budget constraint. The initial offers were quite similar to the first session (and are shown as the "random tie-breaking rule" line in Figure 2). In round 1, the highest accepted offer was at $1.15. There was a tie, and we accepted 2 of 3 offers at this level. In each subsequent round the maximum accepted offer fell. In the end, the price was 2-cents below the competitive level, and we were able to retire 144 acres.[10]

Uniform versus Discriminative Pricing

Next, we tested the effect of the pricing rule used on offers and average prices paid in these auctions. Figure 3 shows the results of several auctions run with the same budget, value arrays, and random tie-breaking rule. We observed a clear tendency for the range of offers to lie above values in both uniform and discriminative auctions, especially in early offer rounds (see the top panel of Figure 3). There was little difference in the median offer-to-value ratio among accepted offers in the two types of auctions. In each of these auctions, the offer-to-value ratio *increased* across revision rounds. In the uniform-price auction, the median ratio increased from 1.02 in Round 1 to 1.04 in Round 6. Combining the two discriminative auctions, the median ratio increased slightly: from 1.02 in Round 1 to 1.03 in Round 5.

In each of these experiments, the maximum accepted price decreased across revision rounds. In the uniform-price auction, this maximum accepted price is the one price that is paid for all accepted offers. Therefore, we can say that the average (uniform) price fell across revision rounds in the uniform-price auction. In contrast, the average price in the discriminative auction typically *increased* over revision rounds. Many

[10] The price was below the competitive level of $1.10 because one subject offered a permit at a price below value, and in fact the final price was below the value for this permit. While this sometimes occurred in these sessions, this was not typical of bidding behavior.

subjects whose offers were provisionally accepted in early rounds raised their offer price, resulting in this increase in the average price paid as more offer submission rounds were held. By the final rounds of the discriminative auction, most accepted offers were at or near the market-clearing price, effectively removing any advantage of a discriminative pricing rule (see the bottom panel of Figure 3). So, while average prices are initially lower in the discriminative auction, this difference tends to diminish or disappear as bidders are allowed to revise their offers. This is shown in Figure 4, which displays the average prices paid for these auctions.

At this point in our research it became clear to us that the uniform price auction wouldn't be seriously considered by the EPD. Therefore all remaining experiments used the discriminative auction.

Scale of the Experiment

All of our initial experiments were conducted in groups of nine participants. However, we wanted to ensure that the procedures and results were robust to changes in the scale of the experiment. Using the discriminative auction with revisions (randomly choosing among tied offers), we conducted one session with 20 participants and another session with 42 participants. None of our key results were affected by this increase in the number of participants. The highest accepted offer declined across revision rounds while the average price paid generally increased. However, average prices remained near competitive levels despite attempts to collude. Figure 5 shows the average price paid across offer revision rounds in the 20-person and 42-person discriminative auctions. The competitive price in the 20-person auction was $1.26, and 40-cents higher in the 42-person auction. This increase in values was done both to disguise the competitive price for those who had participated in a previous auction, and also to increase payoffs for this auction (which lasted almost four hours). For comparability, 40 cents was subtracted from the average price paid in the 42-person auction before constructing the graph.

Attempts at collusion in these experiments were quite explicit, but unsuccessful. Some subjects stood up to address the group, encouraging all to submit high offers. People worked together in groups, and at times a single person would turn in offer submission cards for all of those in the group.

Information About Cutoff Offers

In retrospect, the increase in average accepted price over revision rounds in our discriminative auctions made sense. Those who initially submitted very low offer prices observed the highest accepted offer, and therefore had clear information about the price others were receiving in the auction. The incentive for low-valued participants to increase their offer was clear, and they responded to this incentive. A typical pattern of behavior is shown in Figure 6, which shows the offer price submitted for 3 participants in the 42-person auction experiment. After receiving a provisional acceptance, bidders typically raise their offer price. Sometimes this increase is gradual; others increase their offer by a large amount. After being excluded in a subsequent revision round the subject then tends to decrease the offer again in order to get back into the market. Given that the maximum accepted offer typically falls across revision rounds, some subjects never again receive a provisional acceptance (as was the case for Subject 1).

Because the announcement of the highest accepted offer had this effect, we conducted additional (small-group) sessions in which we announced accepted offers (identified by permit ID number), but did not announce the highest accepted offer price. Figure 7 shows the average price paid in one of these sessions. As anticipated, we observed an initial decline in the average accepted offer price. However, we were surprised to see this average price begin to increase again (very gradually) after several offer revision rounds. Looking at the individual data, however, helps to explain this. Subjects were quite sophisticated in how they used information. Recall that each subject had three permits with heterogeneous values. Typically, a participant offered each permit at a different price. Therefore, if two offers were accepted, this gave an upper-bound on the amount by which the lower offer could be relatively safely revised upwards. If only one offer was accepted, the participant often experimented with the offer price on one or both permits to ascertain the highest accepted price. Still, given the initial decline in offer prices and the fact that some risk averse subjects did not revise provisionally

accepted offers, we concluded that this may be a more effective way to release information about which offers were accepted.[11]

V. Field Experiments

Two experiments were conducted in southwest Georgia, using somewhat different subject pools. The first utilized 22 adult subjects in Albany, Georgia. Most of these participants were farmers in the affected area. In order to simplify procedures, and expedite instructions, subjects were each given two "vouchers." Each voucher had a redemption value printed on the face of it. If the voucher was retained the subject received this redemption value in cash. If it was sold, the participant earned his or her offer price. This is equivalent to a permit that covers a single acre (so that the per-acre price received is identical to the redemption value for the voucher).

These subjects first participated in a sealed bid (no revision) discriminative auction. After turning in an offer, and before any results were announced, they next participated in a discriminative auction with revisions. No information on the highest accepted offer was released: only those permits whose offers were provisionally accepted. A fixed budget constraint was not used in this session: the lowest 15 offers were accepted without consideration of the amount of money it took to purchase these vouchers.[12] The distribution of voucher values (which was approximately uniform in this auction, as shown on the left side of Figure 8) was also different from previous auctions.

Data from these auctions are shown on the right side of Figure 8. The average accepted offer was higher in the first round of the auction with revisions than in the one-shot sealed offer auction ($21.05 compared with $19.80). Moreover, the opportunity cost of obtaining 15 vouchers was only 7.5 percent higher than the minimum opportunity cost in the one-shot compared with 12.5 percent in the first offer submission round of the auction with revisions. However, after round 1 the average accepted price was lower in each revision round than in the one-shot auction. With one exception (round 6) the

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[11] See Goeree, Holt, and Palfrey (2002) for references and new evidence relating to risk aversion in private value auctions.

[12] When the EPD released the initial auction rules for public comment it proposed either a sealed offer auction, or a sealed offer with revisions. This session was held after the release of these draft rules to educate farmers on the proposed rules, and also to obtain data that compared the two institutions. The farmers were paid for participation.

opportunity cost of obtaining these vouchers was lower in the auction with revisions. The average accepted price dropped dramatically between the first and second offer rounds (from $21.05 to $19.25). The average accepted offer was at its minimum in Round 3 ($18.71), but only increased slightly after this, remaining fairly steady just under $19.00 through the remaining five rounds. This pattern is quite like that observed in our other auctions in which the maximum accepted offer was not announced (see Figure 7, above).

By late January the EPD had approved our recommended auction rules (described in Section VI below), and it appeared likely that a drought would, in fact, be declared. We therefore conducted a multi-site experiment that field-tested the auction preparations. We had several concerns that were addressed in this field experiment. First, we wanted to determine what facilities would be needed for the EPD auction. In addition, this was our first large-scale test of the auction software. This experiment allowed us to ensure that the software could handle data entry at multiple locations, with a variety of computer systems, and expeditiously transfer information about bids and provisionally accepted offers between the auction sites in Southwest Georgia and the central processing location in Atlanta.

This field experiment was conducted at two sites in southwest Georgia, all located within the Flint basin.[13] Most of the participants were high school and college students. However, some farmers (who wanted to participate in a live demonstration of the auction procedures) also participated in the auction. A total of 50 subjects participated in the field test, with bid collection and processing done via a web-based program that enabled the EPD officials in Atlanta to follow the bidding. In fact, the director of the EPD and several others from his office were present to watch this trial auction.

The parameters and procedures were identical to the Albany field experiment, except that a budget constraint was enforced and only a single (iterative) auction was conducted. All subjects were given two vouchers at the start of the auction. Each voucher represented a single acre, and the values were approximately uniformly distributed from $15.00 to $22.50. We utilized a target of 55 vouchers, and a budget of

[13] As described below, we intended to conduct this experiment at three locations.

$975 to purchase these vouchers. As in our laboratory experiments, the budget was common information among all participants, however the voucher target was not announced. At the competitive (uniform) equilibrium, 50 vouchers could be purchased at a price between $18.50 (the value of the last four vouchers) and $19. This is just short of the target number of vouchers (55). Of course, because we were using a discriminative auction it is possible that more offers could be accepted if the average accepted offer was less than $19. After all offers were submitted at both sites, they were combined and ranked in order from lowest to highest offer price. Starting with the lowest prices, offers were provisionally accepted until either 55 vouchers were obtained or the cost of obtaining another voucher put the total cost above $975. In the case of a tie at the cutoff value, offers at this level were randomly chosen for provisional acceptance. Provisional winners were posted, using the permit ID number associated with accepted offers. No information about the cutoff value was announced.

On average, offers in this treatment started very low. In the first round, 55 offers were accepted at an average price of $17.58. However, there appeared to be some confusion among the subjects: almost 20 percent of all offers were below value (see Figure 9). Over time, however, the subjects appeared to learn about the incentives, quite possibly through conversations with other auction participants. In the final three rounds 50 offers were accepted – the competitive prediction – at an average price between $19.30 and $19.35 in each of these three rounds. The opportunity cost of these 50 vouchers was 7 percent above the minimum possible to obtain 50 vouchers. Individual behavior was very similar to that observed in our lab experiments. Across revision rounds, those subjects who submitted initial low offers increased them (see the left side of Figure 9), while those who submitted high offers reduced them (right side of Figure 9). By the final offer submission round, the distribution of offers was close to uniform.

There were some unexpected procedural difficulties during this trial auction. We intended to use three sites for this auction, but officials at one location forgot to send someone to unlock the building. We discovered problems with computer "firewalls" that inhibited communication between sites (specifically with a chat-room that was set up for site-supervisors to communicate with one another). Moreover, we expected to use cellular phones to communicate between auction sites and the central processing location

in Atlanta; however, cellular coverage was unreliable at all of the remote sites. Finally, we encountered trouble with the software that was used to print receipts (showing the final auction outcomes and payments to be received). This trial auction provided us with valuable guidance about remaining preparations that needed to be completed. However, it also convinced us that a multi-site auction with a diverse collection of computer facilities and a large number of bidders was feasible.

VI. THE FLINT RIVER DROUGHT PROTECTION ACT AUCTION

After attending our 42-person laboratory experiment and studying results from our other sessions, the EPD implemented our recommended procedures: a discriminative price auction with revisions, with no maximum accepted price announcement, and a random tie-breaking rule.

The EPD's Flint River Drought Protection Act Auction was conducted on Saturday, March 17, 2001 at eight sites in the Flint River Basin.[14] Two weeks prior to the auction, all eligible participants were sent instructions that detailed the auction procedures and directed them to the eight sites.[15] On the day before the auction, eligible permit-holders could register to participate at any one of the auction locations. A total of 576 permits (covering 98,170 acres) were certified as eligible for the auction. Of these, about two-thirds were registered to participate in the auction. A total of 194 farmers registered to make offers for 347 permits, totaling 61,806 acres. The acreage associated with these permits ranged from 4 to 1442 acres. Although we have some information about the crops (and associated prices) in this part of the state, we do not observe the values that the farmers associate with each irrigation permit. Instead, we can only observe the offers that they make on each permit. In all rounds, the per-acre offer prices ranged from \$0.01 to \$8,000. Arguably, the offers at these extremes weren't serious

[14] There was one site supervisor and two EPD representatives at each of the eight auction sites. In addition we hired a total of 58 people to work at the eight locations. These workers collected bids from farmers, entered bids on the computer, and worked with farmers as they verified that offers were entered correctly. We gratefully acknowledge the help of Maribeth Coller, who helped lead auction preparations, trained these workers, and supervised an auction site. We also thank the other site supervisors: Lisa Anderson, Paul Ferraro, Ann Gillette, Laura Taylor, and Mark Van Boening (two of the authors supervised the remaining two auction locations).

[15] These instructions are in the appendix.

offers. In fact, the person who made the 1-cent per acre offer (for a permit that covered 20 acres) stated that he was doing so as a protest.[16] The $8,000 per-acre offer was for a permit associated with a four-acre tract of land. About 85 percent of the acreage in the auction was offered at prices from $100 through $500.

Figure 10 shows the array of offers, for those offers that range up to $500 (this comprised just over 90 percent of all offers). Figure 11 shows a close-up view of these offers; the three panes divide offers into low (less than $130), medium ($130 - $210), and high ($220 - $500) offers.[17] Over the revision rounds offers typically declined (though there were some small increases at the low-end of the offer arrays, especially in the third and fourth rounds). Although the maximum accepted offer was not announced (only the permit ID numbers of those offers that were provisionally accepted), some farmers communicated both within and between the eight auction locations. For example, at the Webster County site (where approximately 20 percent of the permits and acreage were offered) some participants encouraged others to submit at an offer price of $200 per acre. Moreover, they asked one another whether their offers had been accepted, and at what price. Several had cellular phones and called people at other auction locations in order to obtain the same information. Therefore, we can conclude that they had at least some information (though not perfect) about the range of accepted offers. In the fourth round, there were 55 offers submitted at $125 per acre, but only 42 of these were accepted. Several participants apparently forgot the random tie-breaking rule that was described in the mailed instructions; participants at several sites questioned why some offers were accepted at this level, but not others. The tie-breaking rule was publicly explained at these auction locations. Therefore, it is quite likely that many participants knew that $125 was the maximum accepted price in the fourth round and that not all offers at this level were accepted. In fact, 14 of these offers were lowered in the next (and final) round. Surprisingly, these 14 offers were about evenly divided between offers that had been provisionally accepted (8 offers) and rejected (6 offers) in Round 4.

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[16] This person never cashed the resulting 20-cent check that he received. Instead, he had it framed and has been pictured with it in several news stories, while criticizing the auction.

[17] Very high offers (those greater than $500) changed very little across revision rounds.

During the auction, the EPD director made all decisions regarding the conduct of the auction. In particular, he chose the rule used to determine which offers were accepted, and how many offer submission rounds to hold. Unlike the laboratory experiments that we conducted (and over our strenuous objections), he did not use a fixed budget, acreage target, average price, or maximum accepted price during the auction. This is shown in Table 1, which lists the maximum and average accepted price, the cumulative number of acres, and the cumulative cost of all provisionally accepted offers during each round of the EPD auction. There was little change in the maximum accepted offer price in the first four offer rounds. However, the EPD director increased the average accepted offer price from $105 in the first round to $113 in Round 4, increasing the total number of acres that were provisionally accepted.

We were concerned that the round-by-round increase in the average accepted offer price would reduce competitive pressures in the market. In fact, the number of acres covered under provisionally accepted offers *decreased* between rounds 3 and 4, while the average price was essentially held constant (at $112.36 in round 3, and $113 in round 4). Anticipating the end of the auction, we encouraged the EPD Director to remain firm in the maximum accepted offer price in round 4, hoping this would encourage farmers to reduce their offers in the subsequent offer submission round. In fact (as noted above) this happened. The fifth line of Table 1 shows the result that would have been obtained had the maximum average price of $113 been enforced in round 5. Over 3,500 more acres would have been taken out of irrigation than in round 4, and the maximum accepted price would have been unchanged at $125 per acre. In reality, the EPD director chose to accept all offers through $200 an acre in the fifth (final) offer submission round (see the last line of Table 1). In the end, a total of 33,006 acres were taken out of irrigation at a total cost of almost $4.5 million (an average price of. $135.70 per acre).

Because a consistent rule was not used during the auction it is difficult to directly compare the outcome of the auction across revision rounds (or compare it to the results from our experiments). However, by fixing a rule and observing what the outcome *would have been* in each round using the fixed rule, we can approximate this analysis. Table 2 shows this for several different rules that might be used in an auction of this type – target acreage, average accepted price constraint, and a fixed budget constraint.

The top section of the table compares results that would have been attained if an acreage target had been used. For example, in the first line the target number of acres is 8,000 (just over the actual number obtained in the first round of the auction). If this had been the EPD director's goal, he could have attained 8,000 acres at an average price of $107.67 per acre in round 1, and $99.18 per acre in round 5. The number in bold (in this case, $98.90 in round 3) shows the best outcome that would have been attained in any offer submission round. The next two lines show the same comparison for higher acreage targets. The middle section of the table assumes an average price constraint was used, while the last section of the table assumes a fixed budget constraint was in effect. For all three sets of comparisons, constraints were chosen that were consistent with the actual targets used in the first, middle, and late rounds of the auction. For example, in Round 1 the average price of provisionally accepted offers was $105, in Rounds 3 and 4 the average accepted offer was close to $113, and $136 in the final offer round.

With one exception (8,000 target acreage) the best outcome that would have been attained using any of the three rules would have been achieved in Round 5. This demonstrates the benefit of allowing farmers to revise their offers. Even though the distribution of offers did not change substantially (Figures 10 and 11), those changes that did occur generally allowed the EPD to obtain a greater number of acres at a lower price. Holding the average accepted price essentially constant between Rounds 3 and 4 was helpful in lowering Round 5 offer prices. By most measures, the Round 4 outcome was worse than that observed in Round 3. However, as we note above, offer prices decreased in Round 5, which led to the improved final-round outcome (relative to any previous offer submission round).

VII. CONCLUSIONS

Auctions are commonly used for perishable commodities like fish and flowers, and they are also used in public settings where fair access is important. Auctions can be desirable relative to administrative proceedings, since the bids convey important private information about value. The use of an auction for irrigation reduction in Georgia was attractive for these reasons, and in particular because of the narrow time window between the state-mandated drought declaration date (March 1) and the March 25 deadline to

finalize the auction outcome. The auction also let farmers' bids reveal (at least indirectly) their willingness to forego irrigation on designated tracts of land for the current growing season. This avoided the anguish, inefficiency, and administrative problems of involuntary usage shutdowns using non-economic (geographic and precedence) criteria.

There are many ways to set up an "auction-like process" called for in the legislation, and we used laboratory experiments to sharpen our thinking on a number of issues: the pricing rule (uniform or discriminatory), the closing rule (with or without bid revision rounds), and how provisional results would be reported after each bid revision round. The auctions being envisioned were relatively complex environments for the bidders (student subjects and farmers), and we devoted considerable effort to coming up with a procedures and instructions that were relatively easy to understand. The laboratory experiments enabled us to make recommendations about rules (on tie breaking and information provision) that augmented competition, even in laboratory situations where socializing and collusion were facilitated.

After attending our 42-person laboratory experiment, the EPD implemented our recommended auction institution: an iterative discriminative auction. A multi-site field experiment provided a glimpse of how farmers would behave, and of what was needed to scale up the web-based procedures to handle hundreds of bidders at eight locations in Southwest Georgia. The EPD auction held on March 17, 2001 resembled the laboratory and field experiments in some (but not all) respects, and it was considered a success.

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Table 1. Results from the March 17, 2001 Irrigation Auction

Offer Round	Maximum Price	Cumulative Acres	Cumulative Cost	Average Price
1	$130	7,311	$766,771	$104.88
2	$127	12,755	$1,401,843	$109.91
3	$127	17,061	$1,917,036	$112.36
4	$125	15,854	$1,791,449	$113.00
5	$125	19,406	$2,192,789	$113.00
	$200	33,006	$4,478,842	$135.70

Table 2. Results from the March 17, 2001 Irrigation Auction
Results Under Alternative Cutoff Rules
Key: Bold figure is the best outcome from any offer round

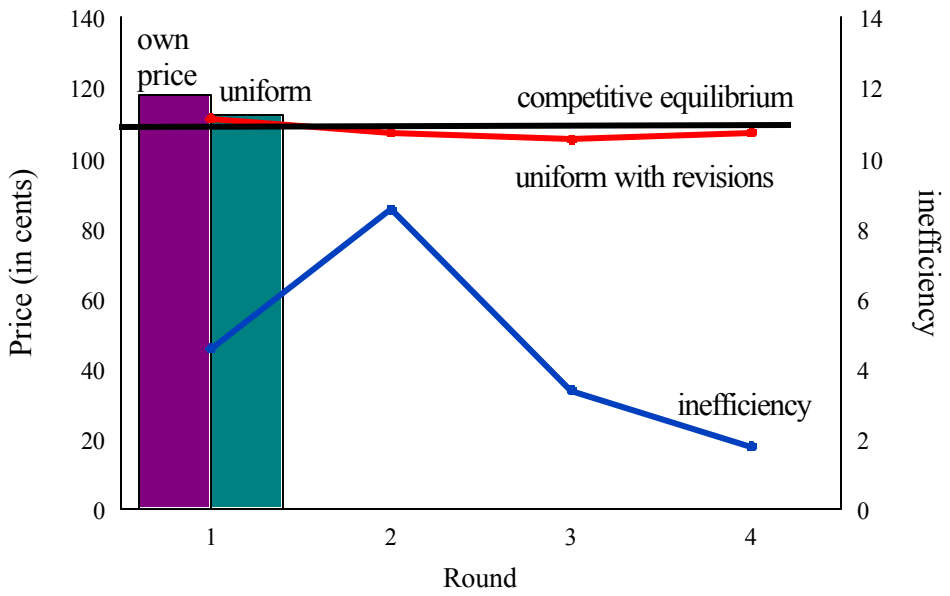
Acreage Target	Average Cost of Acquiring Target Number of Acres				
	Round 1	Round 2	Round 3	Round 4	Round 5
8,000	107.67	101.90	**98.90**	102.08	99.18
16,000	132.53	115.14	111.61	113.14	**110.59**
32,000	177.78	152.43	140.35	137.57	**113.94**

Average Price Constraint	Number of Acres That Would Be Obtained				
	Round 1	Round 2	Round 3	Round 4	Round 5
$105	7,311	9,604	10,677	9,436	**11,386**
$113	8,977	14,886	17,061	15,740	**19,406**
$136	17,110	25,130	29,912	31,081	**33,006**

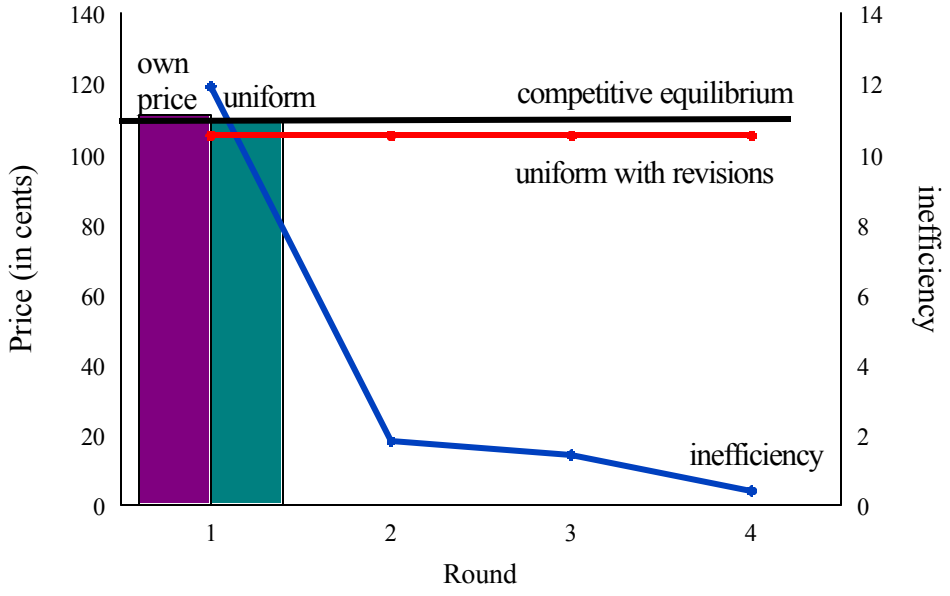
Fixed Budget	Average Cost of Acquiring Acres Obtained Within Fixed Budget				
	Round 1	Round 2	Round 3	Round 4	Round 5
$1 million	111.31	104.64	102.81	104.91	**102.42**
$2 million	130.01	116.79	112.36	114.01	**111.89**
$5 million	170.26	152.43	145.22	143.58	**141.74**

Figure 1. Comparing Uniform, Discriminative, and Uniform Auction with Revisions

(average price of accepted offers and inefficiency in each offer round)



comp. price = 110 or 111



comp. price = 110 or 111

Figure 2. The Effect of Tie-Breaking Rules in a Uniform-Price Auction
Average Price Paid in Two Auctions

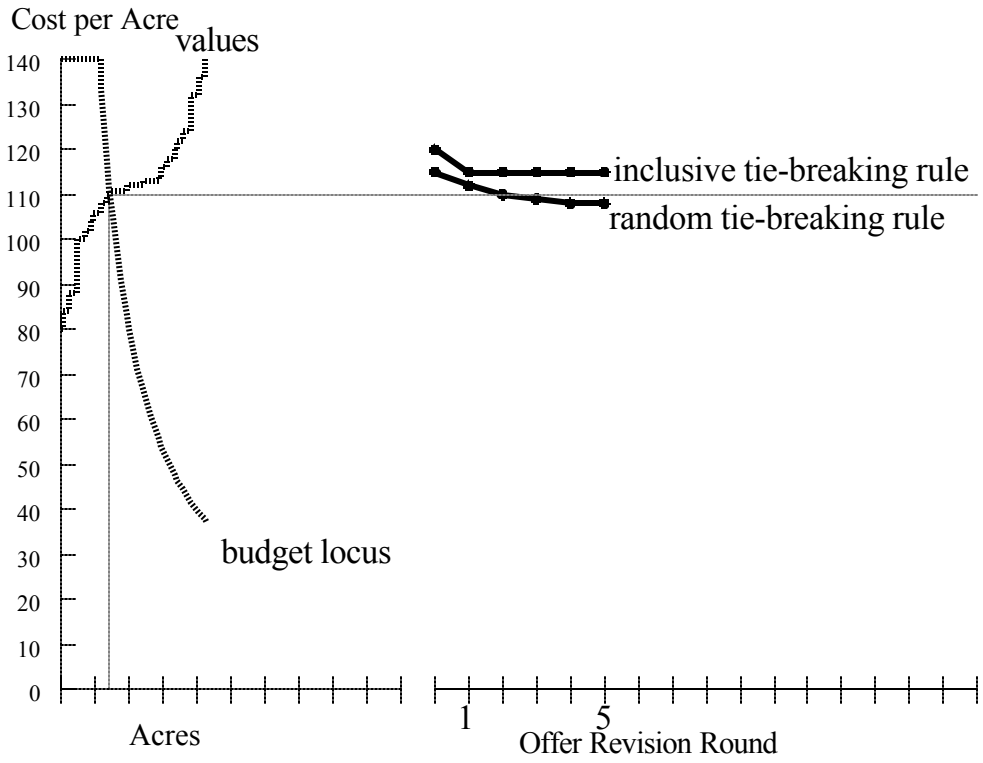
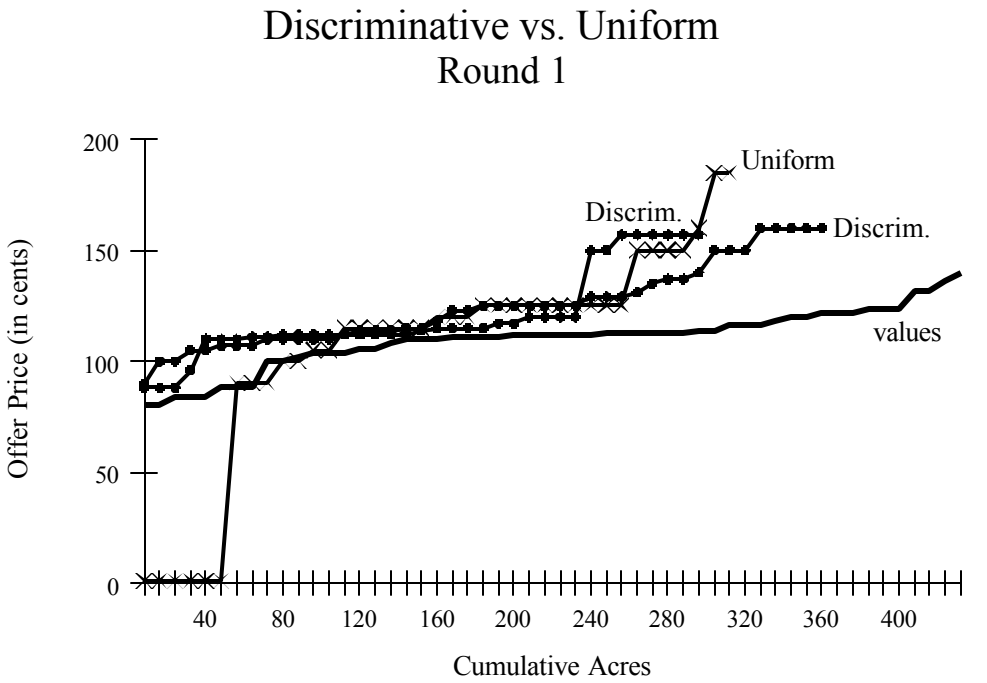


Figure 3. Distribution of Offers: Uniform and Discriminative Auctions
key: uniform (crosses); discriminative (dots)



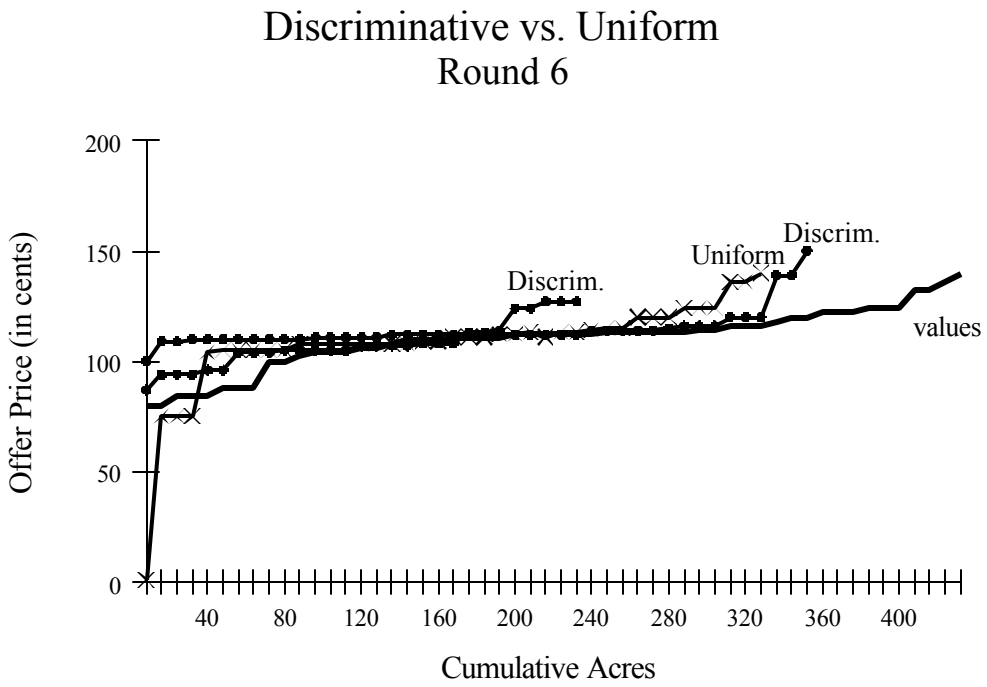


Figure 4. Average Price Paid in Uniform and Discriminative Price Auctions

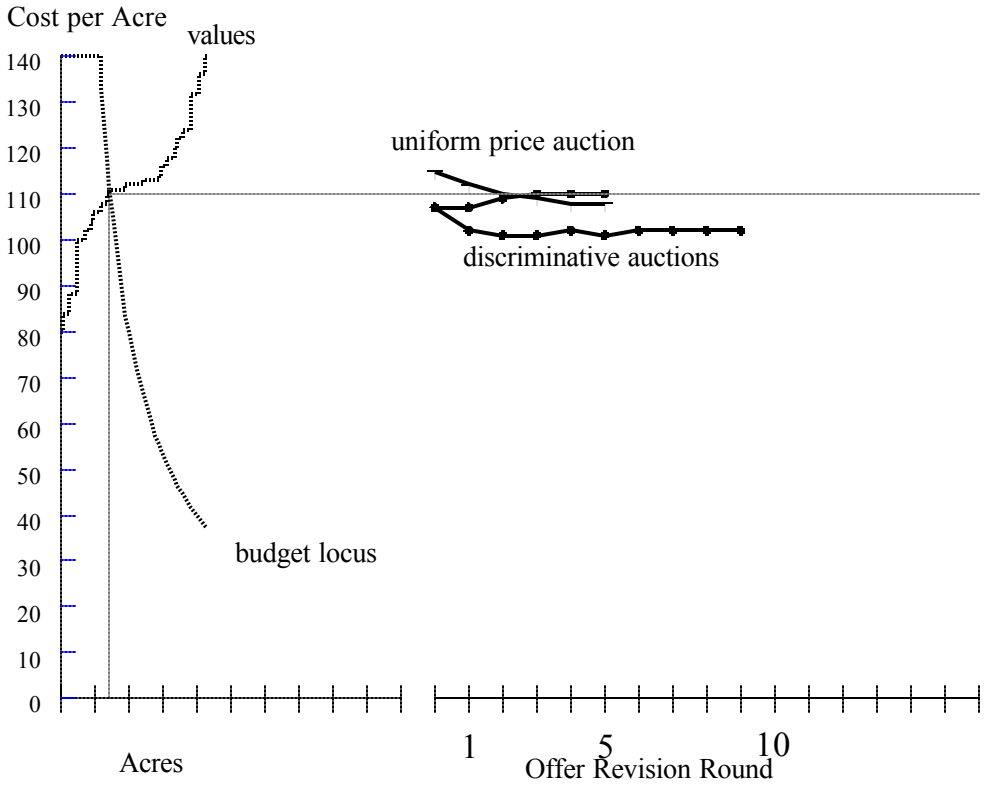


Figure 5. Average Price Paid in Discriminative Auctions: 20- and 42-subject auctions

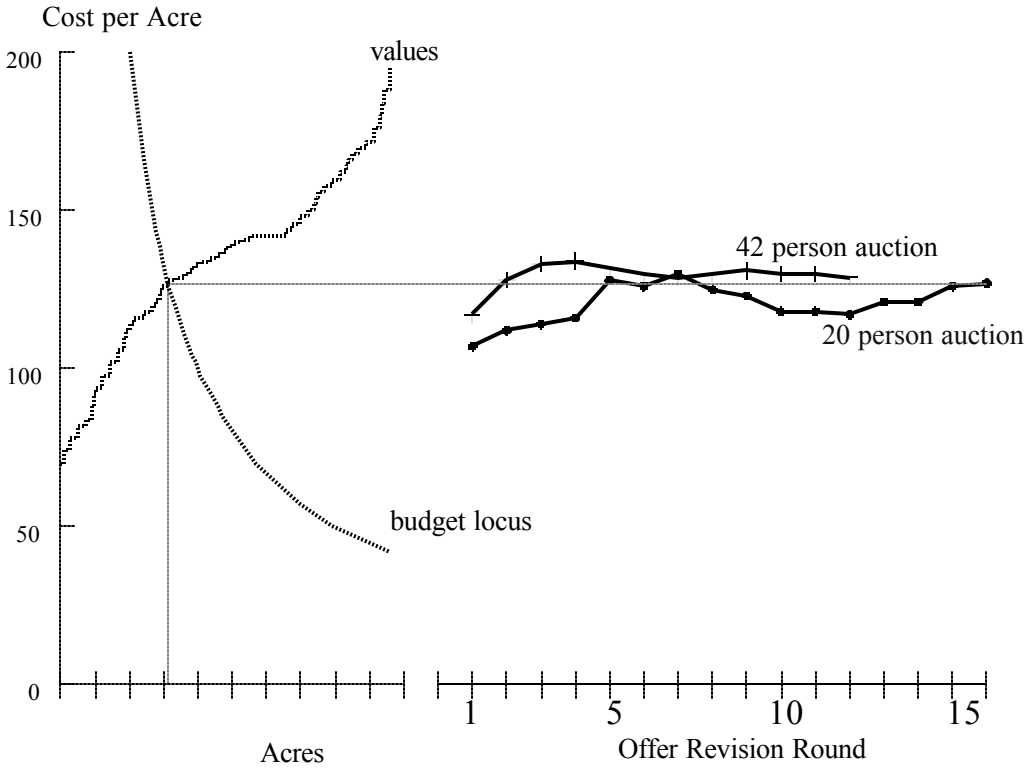
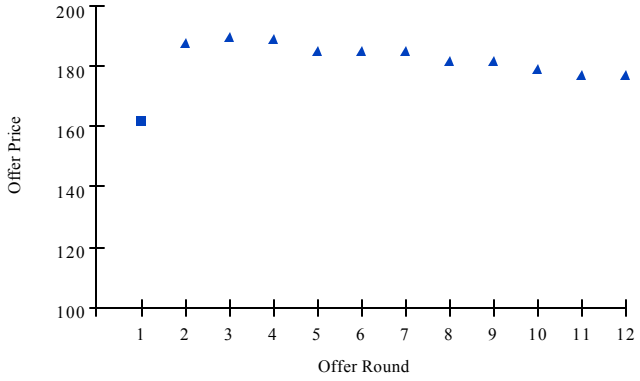
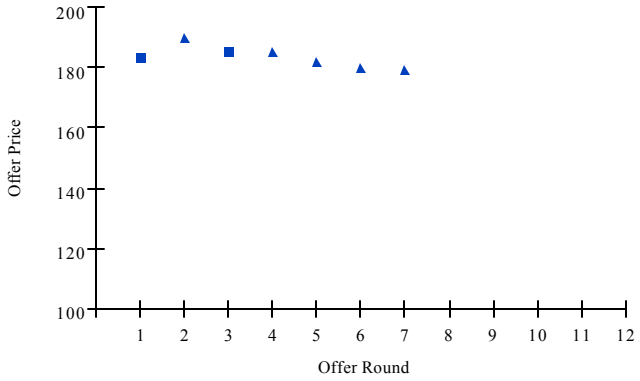


Figure 6. Time Series of Individual Offers in a Discriminative Auction
Key: Accepted Offers: Squares; Rejected Offers: Triangles

Offers: Subject 1



Offers: Subject 2



Offers: Subject 3

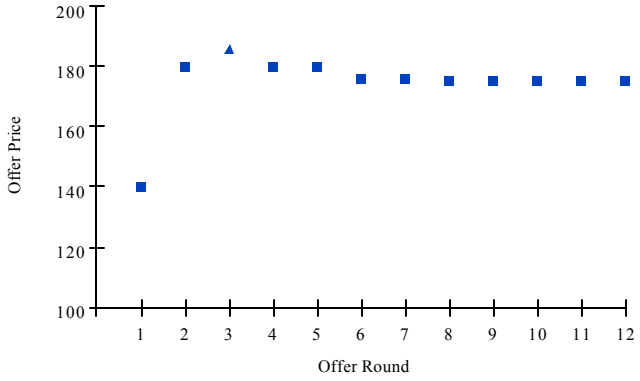


Figure 7. Average Price Paid in a Discriminative Auction: Highest Accepted Price is Not Announced

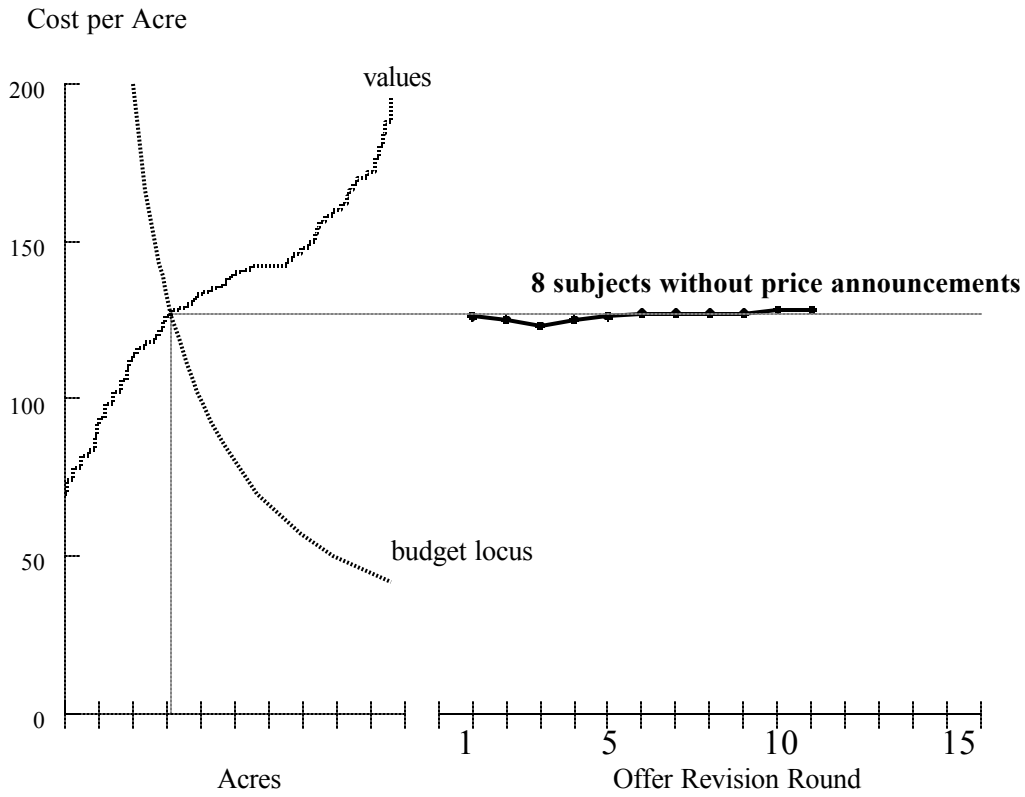


Figure 8. Comparing a One-Shot Discriminative Auction with a Discriminative Auction with Revisions

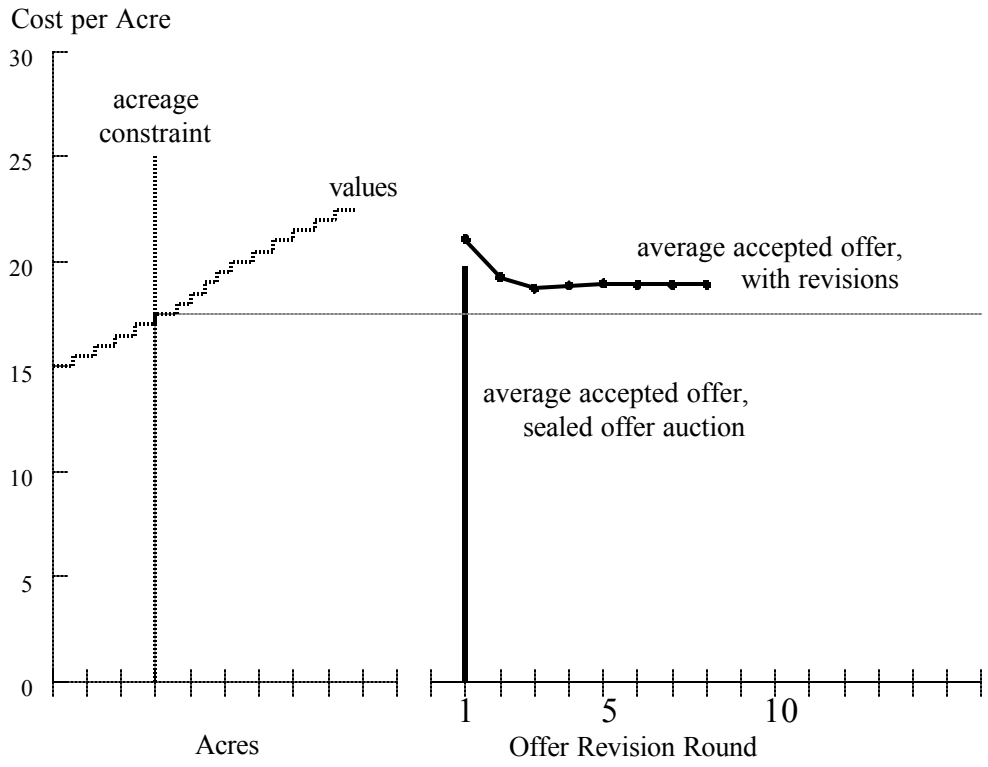


Figure 9. Offer Arrays from Field Test of Discriminative Auction Procedures

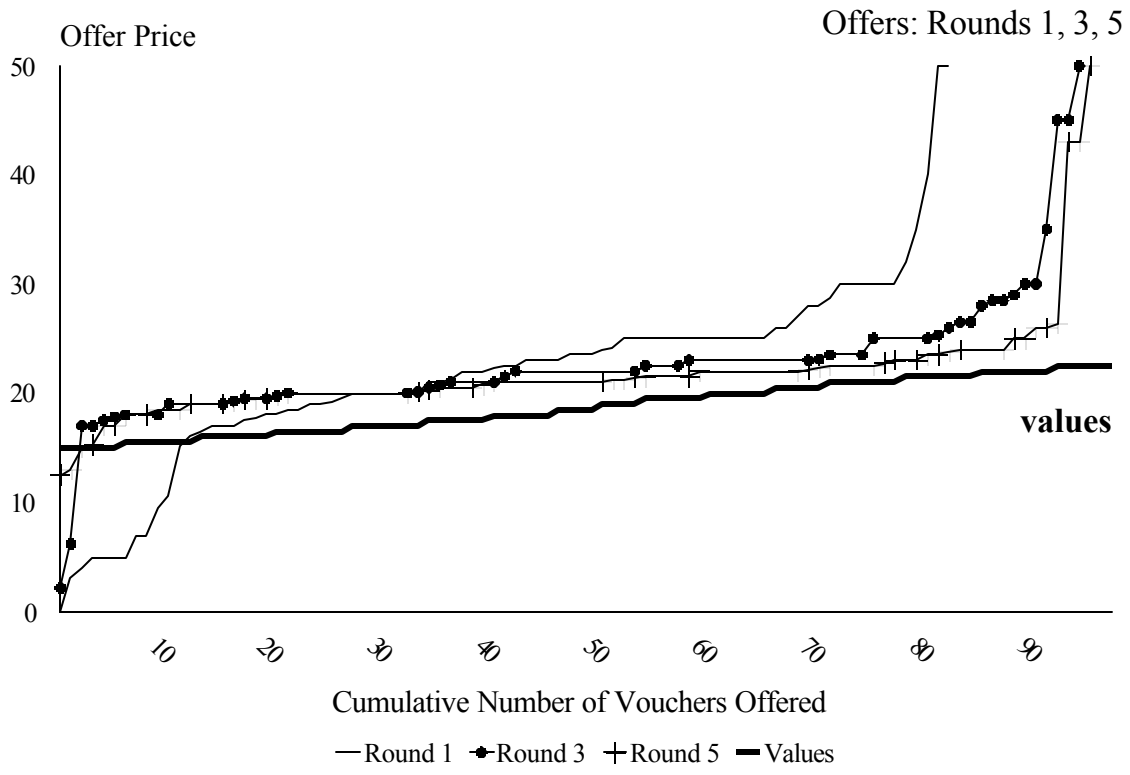


Figure 10. Offer Arrays from the EPD Irrigation Auction
Discriminative Auction Conducted on March 17, 2001

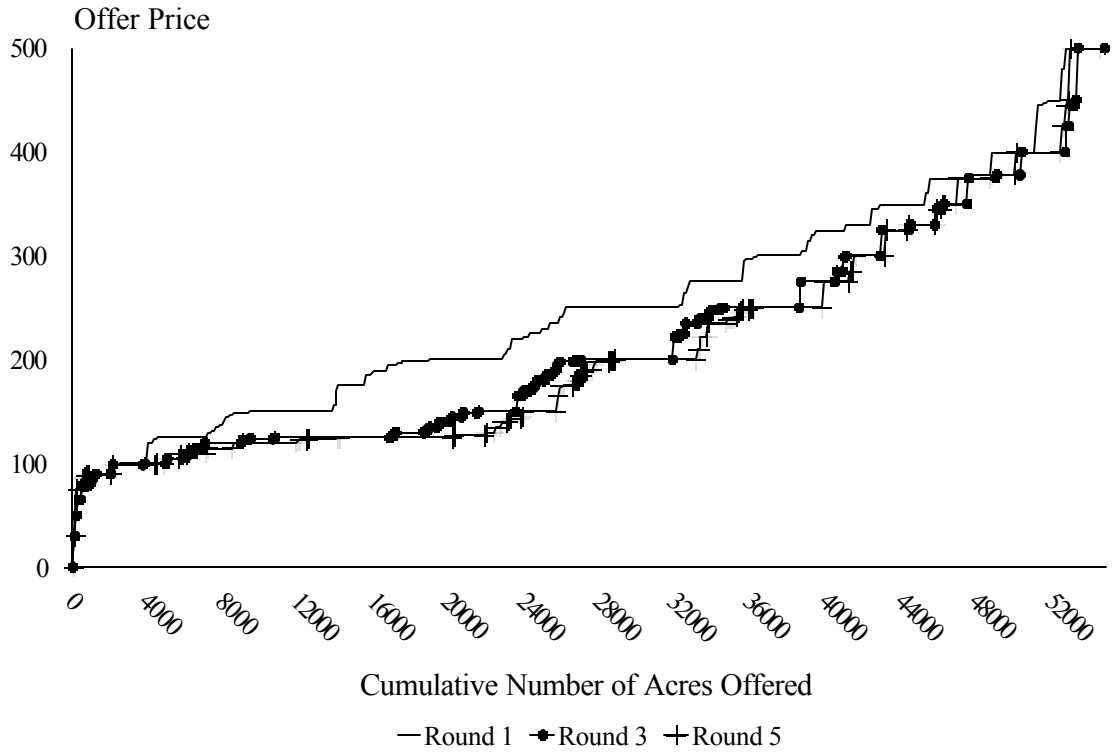
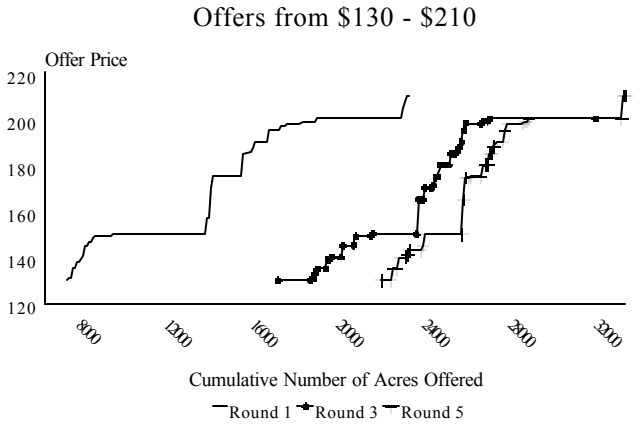
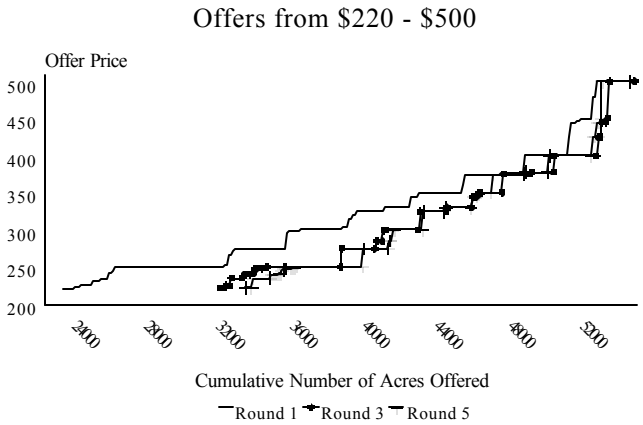


Figure 11. Offer Arrays from the EPD Irrigation Auction
Low, Medium, and High Offers





APPENDIX: INSTRUCTIONS

The experiment today will consist of an auction. We will record your earnings on the receipt form provided, and your total earnings will be paid to you in cash at the end of the experiment. The funds that we will use to pay you have been provided by various foundations, and we will use the receipt form to get reimbursed for the cash that we will pay you today. Feel free to write on these instructions if you would like to.

Some of you may have participated with us in a similar auction. We should emphasize that the rules of this auction may be different, and the value numbers that we are using today are different from those that we have used in the past.

In this auction, each of you will be in the position of a farmer who has three "permits" to irrigate acres of land. These irrigation permits allow you to irrigate the land and earn money on crops that you grow. We (the experimenters) are in the position of a government agency charged with controlling water use. We will use an auction-like process to buy some of these permits back from you in order to reduce the amount of water being taken from river and ground water reserves in this area.

We will first explain how your earnings are determined, and then we will explain the rules for the auction.

Earnings in this Experiment

Please take a minute to look at the offer cards that are located on the inside cover of your participant folder. The first card looks like the transparency that I am displaying, although the numbers on this transparency are different than those on your own offer card. We will talk about the information given to you on the left side of this card first.

Notice that you have three water permits. Each permit identification code begins with a letter (or pair of letters). We will use these letters to distinguish the offers submitted by each of you. No one else has the same identification letters that as anyone else in the room.

Each of your three permits provide irrigation for a number of acres of land. The number of acres served by each permit is written in the second column of offer card. For example, on my sample card, my first permit provides irrigation for 12 acres of land, my second permit provides irrigation for *an additional* 20 acres of land, and my third permit provides irrigation for *an additional* 16 acres of land. So my three permits together irrigate a total of 48 acres of land. Please look at your own card to see how many acres of land each of your permits will irrigate.

If you decide to irrigate the land (which occurs when you *do not* sell your permit), your **per-acre earnings** for each tract of land associated with the permit are shown in column (3). For example, on my sample offer card, if I keep my first water permit (ZZ1) and therefore irrigate this tract of land, I will earn $3.00 for each of the 12 acres served by this permit. If I keep permit ZZ2, I will earn $3.40 for each of the 20 acres served by permit S2. If I keep permit ZZ3, I will earn $3.75 for each of the 16 acres served by this permit.

Now look at the per-acre earnings numbers written in column (3) on your earnings sheet. This is your

own private information; you do not have to share it with anyone. Some of your permits may serve tracts of land with higher per-acre earnings than other permits. This reflects the fact that some land is more productive than other land. The numbers on your earnings sheet may also be different from the numbers written on others' sheets.

The per-acre earnings numbers in column (3) can only be obtained if that land is irrigated, i.e. if you do not sell the water permit that you have for that tract. In today's experiment, the per-acre earnings range from about \$0.95 to \$2.40; notice that the value numbers on my sample earnings sheet are all higher than this, and are used only to illustrate how this information will be presented to you.

If you sell the permit, your earnings for that land will be zero for this planting season. However, you will receive an amount of cash in exchange for your permit.

You may earn money in two ways: by keeping one or more of your permits (and therefore irrigating that land) or by selling one or more of your permits. We will first show you how your earnings will be calculated for those permits you keep; next we will show you how your earnings will be calculated for those permits you sell. After this, we will show you how the price at which you may sell your permits is determined in the auction.

For every permit that you do not sell, you will earn your per-acre value (shown in the third column) multiplied times the number of acres that permit serves (shown in the second column). For example, if I did not sell my first permit (and therefore irrigated these 12 acres of land), I would earn \$3.00 x 12 acres = \$36 from keeping this permit. If I did not sell my second permit, I would earn \$3.40 x 20 acres = \$68 from irrigating these 20 acres of land. If I did not sell my third permit, I would earn \$3.75 x 16 acres = \$60 from irrigating these 16 acres.

As we told you earlier, if you sell a permit you will not be able to irrigate the land covered by that permit. Therefore, you will not receive the per-acre earnings numbers written in the third column of your offer card. Instead, you will receive a per-acre price multiplied times the number of acres that your water permit irrigates.

EXAMPLE 1. Earnings Calculations with a Per-Acre Selling Price of \$6

For example, suppose that the per-acre price were \$6. (This is just an example to show you how your earnings would be calculated. Follow along with the calculations I am making on the trasparency. If you wish to take notes on this, please do so on these instructions and not on your earnings sheet). For each permit that I offer for sale, I would then receive \$6 multiplied times the number of acres the permit irrigates. I will make these calculations now on my sample earnings sheet. For example, I would receive \$6 x 12 acres = \$72 for my first permit; I would receive \$6 x 20 acres = \$120 for my second permit, and I would receive \$6 x 16 acres = \$96 for my third permit.

It is important that you understand that if you sell a permit you will not receive the per-acre value shown in column 3 (but you will receive the sales price multiplied times the number of acres covered). If you do not sell a permit you will not receive the sales price, but you will receive the per-acre value shown in column 3 (multiplied by the number of acres covered). You will receive one or the other, but you will never receive both amounts of money for the same permit. It is possible, however, that you may sell some of your permits, but

not all of them. In this case, you would receive the per-acre value of the land for those permits that you did not sell and the sales price for those permits you did sell.

For example (and still supposing the price were $6 per acre):

If I sold no permits, my earnings would be: $36 (for irrigating the land served by permit S1) + $68 (for irrigating the land served by permit S2) + $60 (for irrigating the land served by permit S3).

If I sold permit S1 at a price of $6 per acre, my earnings would be: $72 (for selling permit S1) + $68 (for irrigating the land served by permit S2) + $60 (for irrigating the land served by permit S3).

The earnings would be determined similarly if I had sold two or three permits.

Whether or not you sell a permit is determined by two things: your per-acre offer to sell your permit, and the final maximum accepted per-acre offer. These determine whether you sell a permit in the following manner:

If your (per-acre) offer to sell a permit is LESS THAN the final maximum accepted offer, you will sell your permit.

If your (per-acre) offer to sell a permit is GREATER THAN the final maximum accepted offer, you will not sell your permit.

We will explain in a moment what happens if your (per-acre) offer price is equal to the final maximum accepted offer.

Next we will explain the rules for today's auction and how this final maximum accepted offer is determined.

Instructions for Today's Auction

We have a cash reserve to purchase these irrigation permits in this auction. The amount of money in this cash reserve is: $_____. You can think of this as money set aside by the legislature for the specific purpose of buying water permits in a given season. It can only be used to purchase water permits from you. The money that you earn from growing crops (for those tracts on which you keep your water permit) comes from a different source.

This auction works as follows. You will fill out an offer submission card, which is the right half of the card we have been looking at. You have been given several copies of this offer submission card. We don't know yet how many of these offer submission cards we will use today. How this is determined will be explained shortly.

Please look once again at the top card in this stack as I display it on my transparency. On the right side of this card, we ask that you write down the **per-acre price** at which you would be willing to sell this permit. You will write this in the blank space to the right of the column showing the number of acres that can be irrigated by each permit. (You should also write this per-acre offer price on the left side of the card so that you have a record of the offer that you made.)

You may offer to sell no (zero) permits, one, two, or all three of your permits. If you want to sell your first permit, then in the space next to your first permit (on my card, this would be ZZ1) write in the per-acre price you would be willing to accept in order to sell this permit. If you want to sell your first two permits, then you would write a per-acre price next to your first permit and another price next to your second permit. If you

wish to sell all three of your permits, you would write a price amount next to all three of your permits. You may ask the same price for each permit, or you may ask different prices for each permit. If you do not wish to sell one or more of your permits, put a check-mark in the box labelled "Do Not Want to Sell" next to any of your permits that you do not want to offer for sale at any price.

When you are done filling out your offer card, please bring it to one of the designated computers.

After everyone has turned in their offer, we will use our cash reserves to buy back some of the water permits. We have a goal for the number of permits that we would like to purchase, but we cannot tell you how many this is. We may use some or all of our cash reserve (which is $_____) for this purpose. We will purchase the permits with the lowest submitted offer prices.

If we buy a permit from you, we will pay you your own per-acre offer price for each permit that you sell (multiplied by the number of acres that permit serves). Therefore, if you submitted different offer prices for each permit you sold you would receive different per-acre prices for each permit. Also, the per-acre price you receive may be different than the price another person receives. For example, if we purchased 3 permits and the per-acre offer prices on these permits were $10, $12 and $11, we would pay $10, $12, and $11, respectively, for each of these permits. This per-acre price would then be multiplied times the number of acres served by the permit to determine the farmer's total earnings from selling that permit (just as in Example 1). Anyone who submitted an offer of an amount greater than $12 (the final maximum accepted offer) would not sell their permit and would, instead, earn the per-acre amount written on the left side of your offer submission forms (multiplied by the number of acres served by that permit). If you do not sell your permit, you will earn this per-acre amount (multiplied by the number of acres that the permit serves) regardless of whether you offered that permit for sale or not.

Suppose that the per-acre offers were $10, $11, $12, and $12; for simplicity we will assume that each permit irrigates only one acre (although all of your permits irrigate more than one acre of land). If my budget was $35 (or, if my goal was to purchase 3 permits), then I could not purchase both of the permits that had offers of $12. To do so would mean purchasing 4 permits (one more than my goal) or spending ($10 + $11 + $12 + $12) = $45 ($10 more than my budget). In the event of a tie at the final maximum accepted offer we will randomly choose among the tied offers. In this example, we would randomly choose one of the permits submitted by the two people who submitted $12 offers. The person whose permit we chose would sell their permit at a price of $12 and the other person would not sell their permit.

EXAMPLE 2. An auction for post-it note pads.

For this example, I will give each of you a set of post-it note pads. I have $6.00 allocated to buy these pads back from some of you. You must decide on the price at which you would be willing to sell the pad to me. We cannot tell you how much we paid for these pads. Instead, you need to think about what these post-it notes are worth to you, and the price at which you would be willing to sell them to me.

We will hand out the pads and also a card on which you will submit your offer. Please write your name and your offer price on the index card, and then turn it in. After all offers have been submitted we will arrange the index cards in order from the lowest offer amount to the highest offer amount.

We will then determine how many pads we can buy back with the $6.00 budget, paying each person the offer amount that person submitted. We will show you how we work out how many pads to purchase (and the maximum accepted offer) as we go through the offers.

After determining how many memo pads we will purchase, we will announce those who sold their pad. We will pay each of these people the amount of their offer in exchange for their post-it note pad. Those who submitted an offer that is greater than the maximum accepted offer will not sell their pad to us.

This auction is just to illustrate how the price and number of units purchased (and therefore the maximum accepted offer) are determined. During the actual experiment you will have 3 permits to sell (and not just one), earnings will be much higher and we will not reveal what anyone offered or which individuals were able to sell their permits.

EXAMPLE 3. An auction for pens.

For this example, I will give each of you two pens: one blue pen and one black pen. I have $10.00 allocated to buy these pens back from some of you. You must decide on the price at which you would be willing to sell each pen to me. We will hand out the pens and also an index card on which you will submit your offers. Please write your name on the index card, and your offer for each for the pens. There are spaces on the index card for making offers to sell both pens. You may ask the same amount for both pens or different amounts for the two pens. After all offers have been submitted we will arrange the the prices in order from the lowest offer amount to the highest offer amount.

We will then determine how many pens we can buy back with the $10.00 budget, paying each person the offer amount that person submitted. We will show you how we work out how many pens we will purchase as we go through the offers. Even though some of you may prefer blue pens and others of you may prefer black pens, we do not care which pens we purchase. We will purchase those pens with the lowest offer prices, regardless of the color of the pen.

This auction is just to illustrate how the price and number of units purchased are determined. During the actual experiment earnings will be higher and we will not reveal what anyone offered or which individuals were able to sell their permits. Also, the offer price will be multiplied by the number of acres your permit serves.

At this point, are there any questions about how the price you receive is determined?

We have already been through several examples, but we would like to work through one more before you make your decisions in this auction today. We will only be conducting one auction, and the permits in the upcoming auction cover a lot of acres with high earnings. We are going to work through this example to be sure that you understand just how your earnings will be calculated and how your offer decisions can affect your earnings.

EXAMPLE 4. Auctioning off "permits" represented by slips of paper.

We are handing each of you a small packet with 6 slips of paper: 2 blue, 2 green, and 2 white. You

can think of each color as a "permit" and each slip of paper as an acre. So you have 3 permits, and each permit irrigates 2 acres. Written on each of these slips of paper is a number. This number tells you how much (in pennies) each acre earns if the acre is irrigated. This corresponds to the number written in the third column of your offer submission form (although the numbers written on the slips of paper are much smaller than those on your earnings sheet).

Next, we are giving you an index card that you will use to submit your offer. Please write your name on the index card, and then look at the numbers on your slips of paper. For every slip of paper you keep, you will earn the amount written on it (paid to you in pennies). For every slip of paper you sell to us, we will pay you the amount you offered. When you offer a permit for sale, you must specify the per-acre price that you would be willing to accept in exchange for this permit. If you sell the permit, we will pay you twice the per-acre price (determined by your offer price). This is the price times the two acres that were served by that "permit."

After everyone has submitted their offers, we will randomly choose 10 of these bid submissions cards. Only these 10 people will take part in this example auction (although you will not know in advance whether your offer will be one of those included in the auction). After this, we will rank the offers from lowest to highest. I have set aside $1.50 for this auction; I will buy as many "permits" as I can with this $1.50 (and choose randomly among any tied offers).

The land associated with each of your permits may earn different amounts of money if you irrigate it (that is, if you do not sell your permit). Therefore you may wish to submit different offer prices for each of your permits. However, we will purchase only those permits with the lowest per-acre offer prices; we will not consider the value of the land to you.

Remember, you will either receive the per-acre price that you offered (if you sell your "permit") OR the per-acre price that is written on each slip of paper (if you do not sell your "permit"). However, in this example auction only those 10 people that we randomly select will be paid any money. Earnings for everyone else will be hypothetical.

We suggest that you look carefully at the value numbers written on these slips of paper. If you submit an offer price that is less than your value number, it might be more likely that your offer would be accepted. However, in this event you would earn less money than if you had not sold your "permit." For example, suppose that I was told that my permit would earn 5-cents per-acre if I used it to irrigate. If I offered to sell this permit for 4-cents per acre and this offer was accepted I would have only earned 4-cents (multiplied by the two acres) in exchange for selling the permit instead of the 5-cents (multiplied by two acres) that I would have earned from keeping the permit (and therefore irrigating those two acres).

When you are ready, please write your offers on your offer card and turn it in to us; please remember to put your name on your card.

At this time are there any questions about how your earnings are determined?

In today's auction, after everyone has submitted an offer card, we will order the offers from lowest to highest and determine how many permits we will purchase (which would determine the maximum accepted

offer). When we have done this, we will announce a **"Current Maximum Accepted Offer"** What this means will be explained in just a moment.

If the per-acre offer price you submitted for any of your permits is less than this "Current Maximum Accepted Offer", then you would have sold those permits. For example, suppose current maximum accepted offer were $5.00 and I offered Permit ZZ1 for a price of $4.50 per acre, Permit ZZ2 for a price of $5.50 per acre, and Permit ZZ3 for a price of $6.00 per acre. (Remember that my offers represent the **per-acre** amounts that I wish to receive; if I sell a permit we will multiply this price times the number of acres this permit serves). In this case I would know that I would have sold Permit ZZ1, but that I would have kept Permits ZZ2 and ZZ3. In the event of a tie, we will anounce the number of tied offers, how many of these permits we would have been able to purchase (by staying within either our announced budget or the number of permits we would like to purchase), and which of these permits with tied offers would have been sold (we will announce this only by using your identification code; for example, "Permits X2 and Q3 would have been sold").

The transparency that I am displaying at the front of the room shows how this information will be presented.

These purchases will not actually go through at this time. In other words, when we announce this current maximum accepted offer you have not actually sold anything or earned any money. This is just to tell you what the outcome of the auction would have been *if the auction had ended at this point*. Instead, once this current maximum accepted offer is announced, everyone will be given 5 minutes to submit a revised offer. Please look at the second offer card in your stack to see how you will submit your second offer. This offer card looks just like your first offer card, however there is an additional column on the right side of this card (this is also shown on this transparency).

If you do not wish to revise your offer for one or more of your permits, then put a check mark in the box in the far-right column for that permit. *If you do want to revise your offer,* enter your revised offer price in the first column next to that permit or put a check mark in the box indicating that you do not wish to offer that permit for sale at any possible price. You may choose to revise your offer on some of your permits, all of your permits, or none of your permits.

While you are waiting to turn in your offer submission card (or simply waiting for the end of the 5-minute period), feel free to talk with the others and to enjoy the refreshments. We will be displaying a clock that counts down the amount of time remaining in each offer submission period. We ask that you wait for at least one minute before submitting your offer. The clock will turn red after one minute, indicating that you may submit your offer.

At the end of the 5-minute revision period, we will re-order the offers from lowest to highest, and determine how many permits we would purchase if the auction were to end. Then a new current maximum accepted offer will be announced.

We will then have another 5-minute offer submission period. This process will continue until either (a) no one submits a new (revised) offer during a 5-minute submission period; or (b) we (the experimenters) decide to end the auction. Remember, none of the results will count toward your final earnings until one of these things occur. Also, you will not know in advance which is the final offer submission period.

After one of these events occurs, the current maximum accepted offer will be named the "Final MaximumAccepted Offer." At that time, we will actually purchase those permits whose offer prices were less than the final maximum accepted offer. Everyone who submits an accepted offer will be paid their own offer price for that permit multiplied by the number of acres that permit serves. In the event of a tie, we will again randomly choose among all tied offers to determine which permits we actually buy.

We will then prepare an earnings report form for you, which confirms the number of permits you sold, your earnings from the permits sold (your per-acre offer price multiplied by the number of acres that the permit would have irrigated), and your earnings from any permits you did not sell (the per-acre earnings from those permits multiplied times the number of acres that are irrigated). Then we will pay you all of your earnings in cash. We have the cash required to pay you for all of your permits, whether you sell them to us or not.

Are there any questions?

Please take out your first offer submission card (remove it carefully so that you keep the other cards in order). Review the information contained in column 3 on the left. This tells you what your per-acre earnings will be for any permits that you do not sell in today's auction. You can submit any offer price that you wish. However, if you submit an offer price that is less than your per-acre value (shown in column 3) and your offer is accepted, then you will earn less than you would have if you had not sold that permit.

When you are ready, write in the price at which you would be willing to sell each of your permits on the right side of your offer card. (If you do not wish to offer one or more of your permits for sale at any price, place a check mark in the box labelled "do not want to sell" next to that permit.) Next, write this offer price on the left side of your offer card and keep this for your own records. Tear off the right side of your offer card and turn it in to one of the people at a designated computer.

If you have any questions, please ask one of the people wearing a red Georgia State University baseball hat. We ask that you submit your first offer card within the next five minutes.