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# THE EFFECT OF BID WITHDRAWAL IN A MULTI-OBJECT AUCTION

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## Abstract

The Federal Communications Commission currently utilizes a simultaneous multi-round ascending bid auction to allocate Personal Communication Services licenses. In the auction, participants are allowed to withdraw standing bids at a penalty. The penalty is equal to the difference between the price at which the bid was withdrawn and the highest bid after the withdrawal. The withdrawal rule was added to the auction design to assist bidders wishing to assemble combinations of licenses who may find themselves stranded with an assortment of licenses for which their bids sum to more than their value. This paper reports results of experiments that examine the effect of the withdrawal rule in environments in which losses can occur if packages of licenses must be assembled piecemeal. The experiments demonstrate that there is a tradeoff with using the rule: efficiency and revenue increase, but individual losses are larger. Furthermore, the increased efficiency does not outweigh the higher prices paid so that bidder surplus falls in the presence of the withdrawal rule.

# THE EFFECT OF BID WITHDRAWAL IN A MULTI-OBJECT AUCTION

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## 1.0 Introduction

Milgrom (1995) describes the auction process the Federal Communications Commission uses to allocate licenses for Personal Communication Services (PCS).[1] The PCS auction uses a simultaneous multi-round ascending bid auction to allocate the licenses. Specifically, each participant simultaneously submits sealed bids for each license they wish to bid on and the high bids become the standing bids for the next round of bidding. This basic design has many features that were considered important for the efficient allocation of licenses. In particular, the feature that all licenses in a Block[2] were offered simultaneously, i.e. all license markets closed at the same time, allows bidders to take into account interdependencies among licenses. With all markets being opened and standing bids revealed, bidders can switch among substitute licenses. Bidders who have complementary values among licenses can observe the sum of the standing bids and determine whether they should bid for several licenses. As pointed out by Milgrom, this is similar to a Walrasian adjustment process in which participants use current prices across markets to adjust their demands to find a general equilibrium outcome.

Aside from the general simultaneous multi-round design there are many important additional rules used in the PCS auction. These include stopping rules and methods to make the auction "converge quickly". The final PCS auction design imposed the following additional rules:

1. Participants have to make significant *upfront payments* which restricts their eligibility.[3] This rule forces commitment by participants and provides a strong incentive not to default since the upfront payment would be lost.[4]

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[1] For more background on the PCS auction design see McMillan (1994).

[2] The FCC identified groups of licenses, classified by geographic location and MHz offered, which were defined as a particular Block.

[3] *Eligibility* defines the total MHz times population on which a participant can tender bids. Licenses are defined by MHz and a geographic location, (which has an official population). Thus, eligibility constrains the number and type of licenses on which a participant can submit bids.

[4] There have also been special bidding credits and financing that have been extended to specific bidders (designated entities). The special financing arrangement seems to have contributed to the large premium paid in the Block C auctions (see Wilkie (1996) for details).

2. A set of rules that restricts the eligibility of bidders is used to speed-up the auction. Specifically, in order to be able to submit a bid in the round a participant must have been *active* in the previous round. To be active a participant must have submitted an acceptable bid in the previous round or have had the standing bid two rounds previous. In order for a bid to be *acceptable* in a round, it had to be at least higher than the standing bid for the item by more than a specified amount.

   The auction also uses *stages* which restricts a bidders eligibility. Specifically, stages are used to restrict the number of licenses, through individual eligibility constraints, on which a participant can bid. The *restriction* is based on a number $\lambda \geq 0$ which constrains a participant to bid for at most $(1.\lambda)$ times:[5] (1) the "number of licenses" for which the participant submitted acceptable bids in the previous round and does not currently have the standing bid plus (2) the "number of the licenses" for which the participant had the standing bid 2 rounds previous but no longer has the standing bid.[6]

3. Participants are allowed to *withdraw* any of their standing bids before a round begins. After such a withdrawal, the bid is lowered and held by the FCC and becomes the standing bid. An individual who withdrew his bid pays a *penalty* equal to the maximum of the difference between the amount of the bid he withdrew and the highest bid submitted after his withdrawal or zero.

4. The process *stops* when all bidders have no eligibility remaining. When the process stops, the items are awarded to the participants with the standing bids. Withdrawal penalties are then paid at that time.

It is the withdrawal rule that is the focus of this paper. The history of the withdrawal rule (see Milgrom (1995)) arose from bidders whose business plans called for assembling combinations of licenses. These bidders complained that the simultaneous multi-round piecemeal bidding for licenses posed a serious problem for them. If they bid <u>aggressively</u> for a combination of licenses, they might find themselves the high bidder for a subset of those licenses for which their values are low. In response, a rule change was suggested that would permit bidders to freely withdraw bids. The reasoning for this form of the rule was to allow for more <u>aggressive bidding</u> and thus higher efficiency and revenue. However, this form of withdrawal eliminates commitment in the bids and thus the monotonic aspect of auction surplus. Another early suggestion for a withdrawal rule was to allow bids to be removed at the auction close. However, if a bidder removed a bid at the close of the auction, he would have to withdraw all his bids and the items would be offered

[5] As the auction moves to a new stage the number z is reduced until it is close to zero.

[6] In addition, the participant could always bid on those items for which he currently had the standing bid.

to next highest bidders. These ideas were abandon in favor of the form described above which was offered by Preston McAfee.[7]

The effects of this withdrawal rule are hard to predict. From an individual's standpoint, the possibility of withdrawal allows a bidder to be more aggressive,[8] to try dangerous fitting strategies at lower risk, and to (maybe) avoid losses incurred "by mistake". From a strategic point of view, (i.e., when the reactions of the other players are also considered), some of these benefits may disappear. Losses occur for sure only when prices are high and the end of the auction is near, in exactly those cases in which few participants are left to bail the loser out when activity rules are present. However, it is still possible that the apparent reduction in risk will increase efficiency and revenue at the cost of increased losses. A second strategic effect is less benign. The lowering of the risk of loss could lead an opponent to try to drive the price of an item up to force you to give it up and, more importantly, because of that to release another item at a loss. This type of strategy can lower both efficiency and revenue. What will really happen remains to be studied.

## 2.0 Some Withdrawal Data From the Regional PCS Auctions

### 2.1 Regional Narrowband Auction

In the Regional Narrowband Auction 30 licenses were auctioned simultaneously. The licenses consisted of six frequency bands (two 50 kHz out-bound/return and four 50 kHz out-bound/12.5 kHz return)[9] in five regions (North East, South, Midwest, Central, and West) of the US. In addition, for one of the 50/50 licenses for each region and one 50/12.5 for each region, preferences were given to small businesses, and women- and minority-owned bidders. These bidders received 40% discounts on those licenses. There were only two withdrawals in the entire auction. The auction lasted for 104 rounds and the withdrawals occurred in round 78 for the 50/12.5 West region license for which the 40% discount applied and round 83 for a 50/12.5 South region license. Figure 1 shows the final bids and withdrawn bids for the South and West regions. The main item that stands out is the 2.1 million dollar penalty paid by Pagemart for a license it did not receive. The data from this auction shows that several bidders were trying to assemble nationwide coverage by bidding on similar licenses across all five regions. This license aggregation bidding behavior suggests that a synergy value (superadditive values for combinations of licenses, specifically nationwide coverage) existed for these licenses. Milgrom (1995) argues that the withdrawal behavior and

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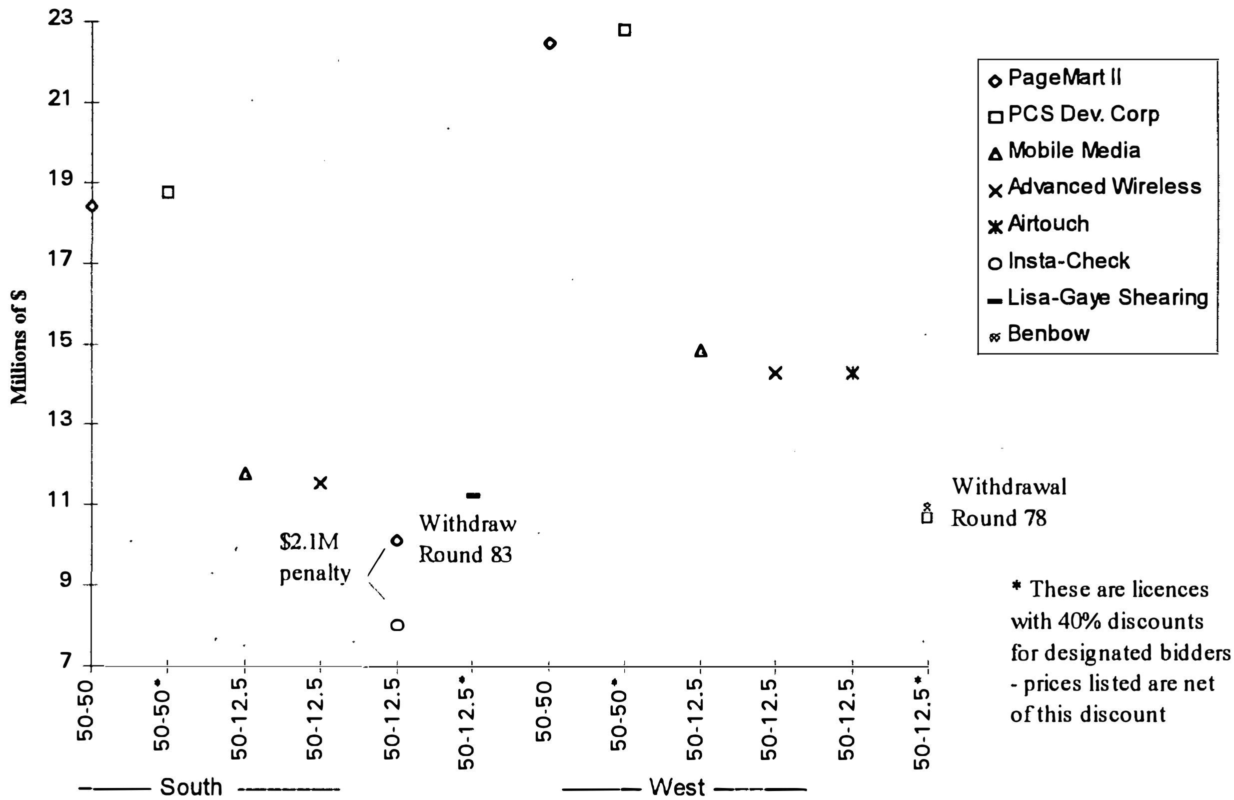
[7] Notice that there is a continuum of withdrawal penalties that may "do the trick" with less exposure to the individual withdrawing. Specifically, the penalty could be $\alpha(W)$ where $0 \leq \alpha \leq 1$ and W is the penalty described in 3. Thus, when $\alpha = 1$ we get the McAfee penalty and when $\alpha = 0$ we get the original withdrawal "penalty" proposal.

[8] It lowers the <u>expected</u> cost of not acquiring a piece of a package in a simultaneous auction.

[9] The 50/50 licenses allow for two-way paging.

subsequent penalty resulted from a strategic play by a bidder rather than a bidder being "stuck" by not obtaining their desired aggregation of licenses. The strategic behavior described by Milgrom resulted from a bidder parking himself in an unwanted license in order to main his eligibility without getting into a bidding war for the license he did desire. While waiting for the "smoke to clear" and hiding his true demand in an unwanted license the bidder ended-up needing to withdraw in order to bid for his desired license. It is not clear whether this strategy was prudent given the penalty paid.[10] The one bit of analysis that cannot be made is whether the existence of a withdrawal rule exacerbated this outcome by reducing the cost of hiding, i.e., allowing a bidder to "unload" from a miscalculation.

**Figure 1:**
**Regional Narrowband Withdrawal Data**



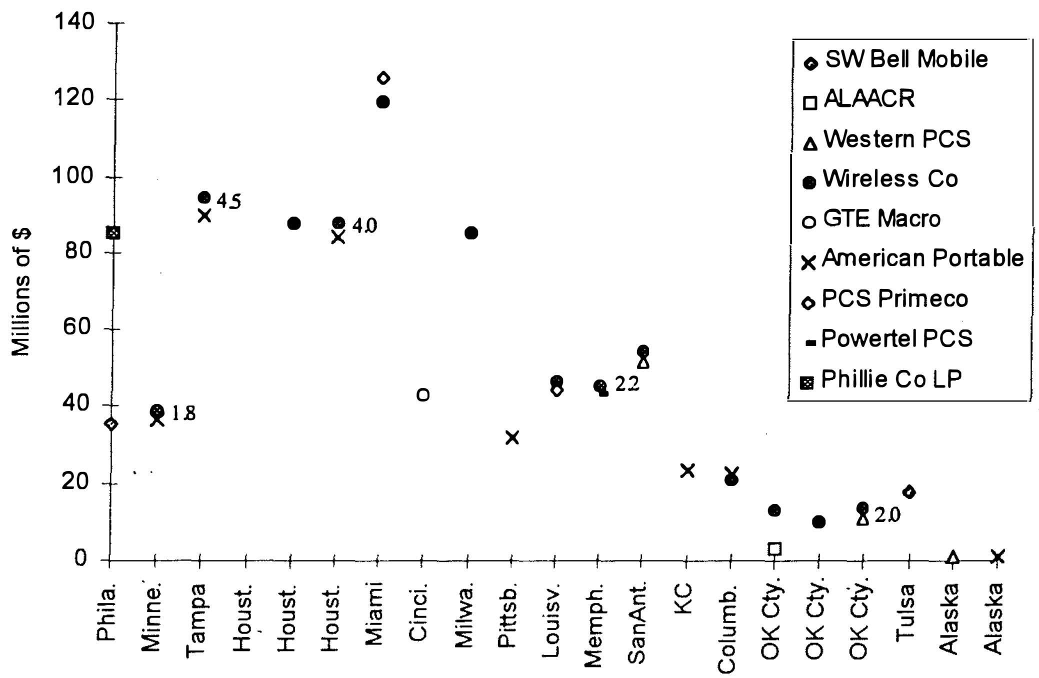

## 2.2 MTA Broadband Auction

The FCC conducted a much larger auction in which 2 identical (identified as Blocks A and B) broadband frequencies were offered in 51 Major Trading Areas (MTAs) as defined by Rand-McNally Commercial Atlas. Bidders could only obtain one of the two licenses per MTA. The auction lasted for 112 rounds and unlike the

[10] McAfee and McMillan(1995) provide an aggregate analysis of this auction.

narrowband auction withdrawals occurred "often" (a total of 21 withdrawals were tendered in rounds 18, 27, 66, 81, 82, 87, 97, 98, 102, 104, 108 and 109). Figure 2 shows the pattern of withdrawal across the licenses for which withdrawals were tendered. The figure shows the withdrawn and winning bids for each auction. Many times the bidder who withdrew his bid ended up with the winning bid for the item at the price he withdrew (see Cincinnati, Milwaukee, Pittsburgh, Kansas City, and Alaska). For six licenses (Philadelphia, Miami, Louisville, San Antonio, Columbus, and Tulsa) the final bid was above the withdrawn bid. For five licenses (Minneapolis, Tampa, Houston, Memphis, and Oklahoma City) Wireless Co. paid a withdrawal penalty on each, for a total of over $14 million in withdrawal penalties. It is also interesting to note that multiple withdrawals were tendered on the same licenses (see Houston, Oklahoma City and Alaska).

Figure 2:
MTA Broadband Withdrawal Data




Salant (1995), supplies an analysis of this auction from a bidder's perspective in his experience with GTE. He suggests that the withdrawals and penalties stem from a budget constraint problem faced by Wireless. Salant does not elaborate on the nature of the budget constraint problem faced by Wireless Co. Salant also admits that he was confused by the pattern of bidding from Wireless who, among other strategies, bid on both A and B licenses, as did others, in the same MTA.

Ausubel et al. (1996) estimate an econometric model from the final bids in the auction with several variables to account for value synergies. They find no significant synergies from the estimates of their model. This suggests that the withdrawals were related to strategic behavior such as hiding, signaling to reduce demand, etc. or bidding errors.

Which strategies are used in the face a withdrawal policy are unclear. In addition, the effect of the withdrawal rule on bidder losses is uncertain since no comparative data is available without the withdrawal rule. The only definitive way in which to get a handle on these issues is through controlled experiments. This is what we turn to next.

## 3.0 Economic Environments and Experimental Design Issues

This section describes the economic environments that confronted the subjects in the experiments. Several issues that were encountered in the design of the experiments due to the complexity of the auction mechanism and the potential loses that could be suffered by subjects will also be presented.

### 3.1 Base Economic Environments Covered

All of the environments reported in this paper are derived from the following generic setup. A set of n objects, labeled $x_1,\ldots,x_n$ are to be allocated to m agents. Agent i's profit function is $V_i\,(x_{1i},\ldots,x_{ni})$ where $x_{ki}=1$ if and only if agent i is awarded item k. Thus, an agent knows what they will be paid if they successfully acquire any particular subset of the items. In some cases below, subjects are supplied common information about aspects of others' values. In other cases agents will know nothing a priori except their own valuations.

In this class of environments the most efficient allocation solves the problem:

$$\max_{x} \quad \sum_{i} V_i(x_{1i},\ldots,x_{ni})$$

$$\text{subject to}$$

$$x_{ji} = 0 \ \ or \ \ 1; \ \text{and}$$

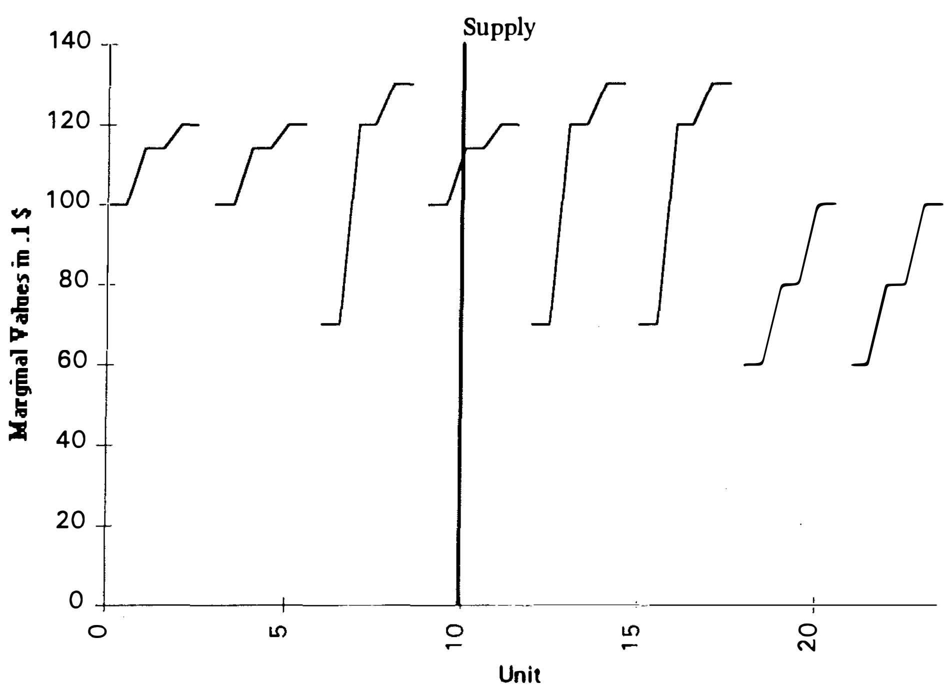
$$\sum_{j} x_{ji} = 1 \quad \text{for each } i$$

Two classes of environments are examined. The first class examines superadditive values for multiple units of a homogenous good. The second class looks at an environment in which preferences are spatial, i.e., subjects have superadditive values for specific combinations of objects.

### 3.1.1 Homogenous Goods with Superadditive Values

Items in this environment are <u>homogenous</u>, i.e., $V_i(x_{1i},\ldots,x_{ni}) = V_i(\sum_j x_{ij})$. The demand for these items are assumed to be superadditive for some participants, i.e., $V_i'(\sum_j x_{ji}) \geq 0$. An example is given in Figure 3 below.[11] There are eight participants. In the figure, each step represents a participant's marginal return function for the first three units. The marginal return for more than 3 units is zero. Notice that in this environment there is no single price equilibrium. As soon as bids go over 100, losses must occur. When price is above 100, bidder 5 for example, might then withdraw his bid and accept any price above 70. This result occurs because the mechanism does not allow nonlinear pricing. Thus, either the outcome must result in losses or at least one bidder must forgo the pursuit of potentially profitable opportunities.

**Figure 3:**
**Superadditive Environment for Auction 1**




[11] In many of the superadditive environments several of the subject did not have superadditive values. This was done to examine the bidding behavior of non-synergy bidders. See Appendix B for the actual environments.

In the experiments, subjects were provided with the following common information about their environment: the number of units being auctioned, the number of participants and who had the standing bid on which items. The subjects did not know the distribution over which the values were drawn or even if a single price could clear the market.

### 3.1.2 Spatial Fitting Environments

The spatial fitting environment has the property that for some $J^* \subseteq \{x_1, x_2, .., x_n\}$:

$$\sum_{x_j \in J^*} V_i(x_j) < V(J^*)$$

Specifically, the following method was used to determine individual values. There are 6 heterogeneous items (which are label as a,b,c,d,e, and f) to be allocated among 5 participants. The values over the items were established by:

i. The single item packages labeled a,b,c,d,e and f have their integer values drawn independently from the uniform distribution with support [0,10].

ii. The two-item packages {a,b}, {a,c}, ........,{e,f} have their integer values drawn independently from the uniform distribution with support [20,40].

iii. The three-item packages {a,b,c},.......,{d,e,f} have their integer values drawn independently from the uniform distribution with support [110,140].

iv. A single value for the six-item package {a,b,c,d,e,f} is drawn from [140,180].

A total of 25 unique packages, from the total possible, are generated from i-iv above and are given to participants. The main point to note is that two three item packages clearly form the largest aggregate value. However, this optimal package configuration is likely to be overlapped by many other competing packages. The task of the mechanism is to guide the owners of the components of the optimal allocation to find each other. In Table 1 below the values for one particular draw from the experiment are shown. Notice that bidders 5 and 2 have the optimal fitting packages.

**Table 1:**
**Values for Auction 1**

| | | | | | | |
|---|---|---|---|---|---|---|
| *Bidder 1* | *Packages*: | f | cd | bcf | bde | abe |
| | *Values* | 9 | 22 | 128 | 130 | 120 |
| *Bidder 2* | *Packages*: | b | df | ae | af | abd |
| | *Values* | 8 | 28 | 24 | 27 | 130 |
| *Bidder 3* | *Packages*: | c | a | d | bd | abf |
| | *Values* | 2 | 3 | 8 | 20 | 119 |
| *Bidder 4* | *Packages*: | e | abc | adf | bdf | aef |
| | *Values* | 10 | 117 | 112 | 128 | 125 |
| *Bidder 5* | *Packages*: | cf | de | cef | bef | abcdef |
| | *Values* | 29 | 25 | 117 | 125 | 142 |

Optimal Fit

Subjects were given common information concerning how the values were drawn along with the number of participants and who had the standing bid on which item.

## 3.2 Experimental Design Issues

There are two major issues to confront in the implementation of theses experiments. First, the actual process used by the FCC is very complex and it is subjective when to move to new stages of the auction. A simplified version of the mechanism was chosen so that the effect of withdrawal could be examined without peripheral issues. Second, since losses are possible, measures are required to ensure that control is not lost when losses grow for an individual and there is no credible means to enforce payment.

### 3.2.1 The Auction Mechanism

The auction process used by the FCC is very complicated. In Ledyard et al. (1996a) experiments using the FCC rules required extensive training on the part of subjects to become familiar with the rules. In addition, the process took significant time to conduct. Fortunately, Ledyard et al. (1996a) also conducted continuous versions of the FCC auction. That form of the auction was easier to manage and also resulted in better efficiency in their experiments relative to the FCC batch design. One can think of the continuous case as a limit to the batch case when there are no activity rules.

The auction used in the experiments allows participants to submit bids on any of the items at any time the auction is open. Only the highest bid on each item is posted. A standing bid may not be withdrawn without penalty. A new bid must better the standing bid in order to replace it. Thus, it is a standard English auction process but with all markets open at the same time. Bid withdrawal was allowed in this auction using the following penalty rule:

> Participants were allowed to delete any of their standing bids. After such a withdrawal, the price of that item was dropped to zero and that bid became the standing bid of the experimenter. An individual who withdrew his bid paid a *penalty* equal to the maximum of the difference between the amount of the bid he withdrew and the highest bid submitted after his withdrawal or zero.

All of the markets closed simultaneously when no new bid was placed in any of the markets after 15 seconds.

This auction form has no subjective issues relating to moving to new stages.[12] In addition, unlike the batch process with activity rules, everyone is active as long as the market is open. Thus, when a withdrawal occurs there is a full market to accept the withdrawal. With activity rules, there is a strong possibility, in this design, that when a participant withdraws a bid those that could use the unit would be inactive. Thus, this auction form has the best chance of enhancing efficiency. The tradeoff is of course is that cycling may occur in the continuous case since withdrawal is not a costly act in terms of eligibility. Since Ledyard et al. (1996a) did not see this cycling occur often, it is a tradeoff that is accepted here.

#### 3.2.2 Bankruptcy

It is easy to see that the potential for losses is a strong possibility in the design. To reduce the possibility of bankruptcy and its effects, two direct sources of earnings to offset losses were added. First, everyone was given 5 dollars of working capital at the start the experiment and had two dollars added to their working capital account at the end of each auction. In addition, in the spatial environment, four more goods were added into the environment whose values were completely additive. That is, for these items, individual values were such that $V_i(x_k, x_j) = V_i(x_k) + V_i(x_j)$. Subjects knew that these markets were not related at all to the spatial markets. These additional markets allow us to provide more earnings to subjects to offset losses and allow us to see if the mechanism works as advertised in these simple markets without any strategic spillover from the spatial markets.

[12] Cull and Bykowsky (1996) provide some analysis that suggests that the FCC stage III activity rule was too restrictive in the MTA auction and biased the prices paid by bidders.

### 3.3 Design Summary and Procedures

All of the experiments were conducted at the California Institute of Technology using the student population as the subject pool. Instructions for the experiments can be found in Appendix A. The continuous market was computerized[13] and withdrawals were listed on a board for all to see. All of the subjects had been in previous unrelated economics experiments and were familiar with the general software. In addition, a full practice period was used to let everyone become familiar with the market and related accounting procedures. Each experiment consisted of 5 auctions. Subjects confronted the same auction institution and rules for each period but their values were redrawn for each auction period. Subjects were recruited for 2 hours and did not know that only 5 auctions would be conducted. Each experiment lasted less than 1 hour and 45 minutes. The table below summarizes our 2x2 experimental design of environments and auction withdrawal rules.

**Table 2**
**2x2 Experimental Design**

| | *Homogenous Superadditive Values Environment* | *Superadditive Spatial Environment* |
|---|---|---|
| *Auction with Bid Withdrawal* | 15 Auctions* | 20 Auctions |
| *Auction without Bid Withdrawal* | 15 Auctions | 20 Auctions |

* An auction is one realization from an experiment sequence of 5 auctions. Thus, in the homogeneous environment 3 experiments per treatment were conducted and for the spatial environment 4 experiments were conducted (for a total of 14 experimental sessions).

## 4.0 Experimental Results

In this section two major aspects of the performance of the mechanisms are examined: economic efficiency and individual losses. An examination of withdrawal behavior and bid dynamics is also performed.

### 4.1 Efficiency Loss Tradeoff

Since we are working in environments where value is measured in terms of profit, efficiency is defined as the aggregate value achieved by the mechanism as a

[13] The Multiple Unit Double Auction software (see Johnson et al. (1989)) was used with subjects restricted as buyer only.

percentage of the maximum possible. Since only relative performance is considered in our design, no time will be spent discussing the parameter scales in individual values. Losses are simply defined as the negative earnings, in dollars, made by subjects at the end of an auction.

### 4.1.1 Homogenous Superadditive Case

The table below shows the descriptive statistics for efficiency and losses across each treatment.

**Efficiency and Loss Statistics**

| Treatment | Mean (Efficiency, Loss) | Standard Deviation (Efficiency, Loss) |
|---|---|---|
| *Auction with Bid Withdrawal* | (98.72, 1.62) | (1.64, 1.34) |
| *Auction without Bid Withdrawal* | (97.53, 1.38) | (1.85, 1.42) |

Observation 1: The withdrawal rule results in higher efficiency.

Support: The table below shows the results of two non-parametric tests to see if the efficiency distributions are the same for each treatment.

**Test of Equality of Distributions of Efficiency**

| Test | Statistic | P-Value |
|---|---|---|
| *Kolmogorov Smirnov* | D=.467 | .0991 |
| *Mann-Whitney* | z=1.97021 | .0488 |

Observation 2: Efficiency outcomes are slightly more volatile without withdrawal but the difference is not significant.

Support: Differences in the variance of each of the treatments were tested and an F statistic = 1.274 was obtained, which is not significant at the 10% level.

Observation 3: The withdrawal rule results in higher losses, but the difference is not always significant.

Support: The table below shows the results of two non-parametric tests to see if the loss distributions are the same for each treatment.

**Test of Equality of Distributions of Losses**

| Test | Statistic | P-Value |
|---|---|---|
| *Kolmogorov Smirnov* | D=.2667 | .2512 |
| *Mann-Whitney* | z=.7519 | .4520 |

Observation 4: Losses are slightly more volatile without withdrawal but the difference is not significant.

Support: Differences in the variance of each of the treatments were tested and an F statistic = 1.117 was obtained, which is not significant at the 10% level.

Next to see if there is a "learning" influence, behavior across auctions within an experimental session is examined. Figures 4a - 4d below show the time series for each experimental session. From these figures we see:

- Each sessions looks distinct. Each group has its own character.
- When there is no withdrawal rule, losses are lower in the later auctions which suggests that bidders are less aggressive after losses.

**Figure 4a:**
**Time Series of Efficiency:**
**Superadditive Environment no Withdrawal**

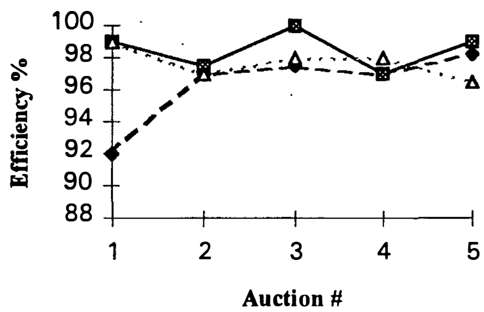



**Figure 4b:**
**Time Series of Losses:**
**Superadditive Environment no Withdrawal**

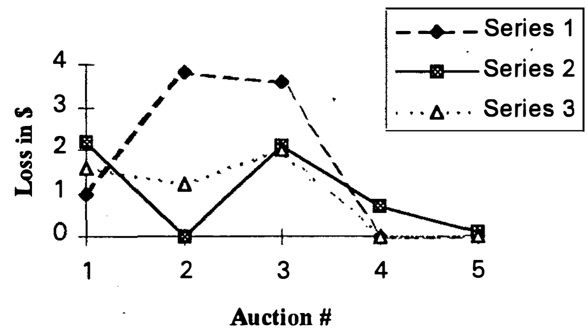



**Figure 4c:**
**Time Series of Efficiency:**
**Superadditive Environment Withdrawal**

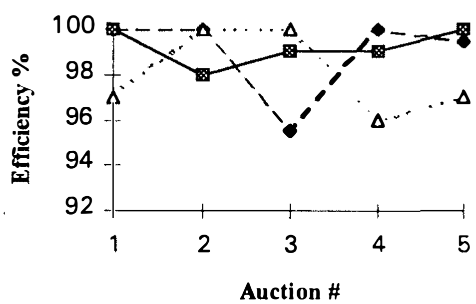



**Figure 4d:**
**Time Series of Losses:**
**Superadditive Environment Withdrawal**

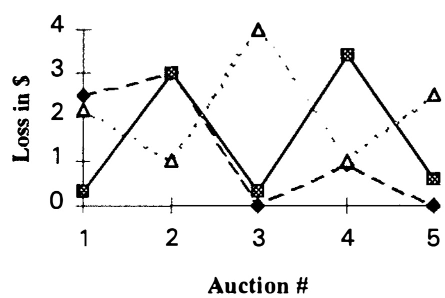
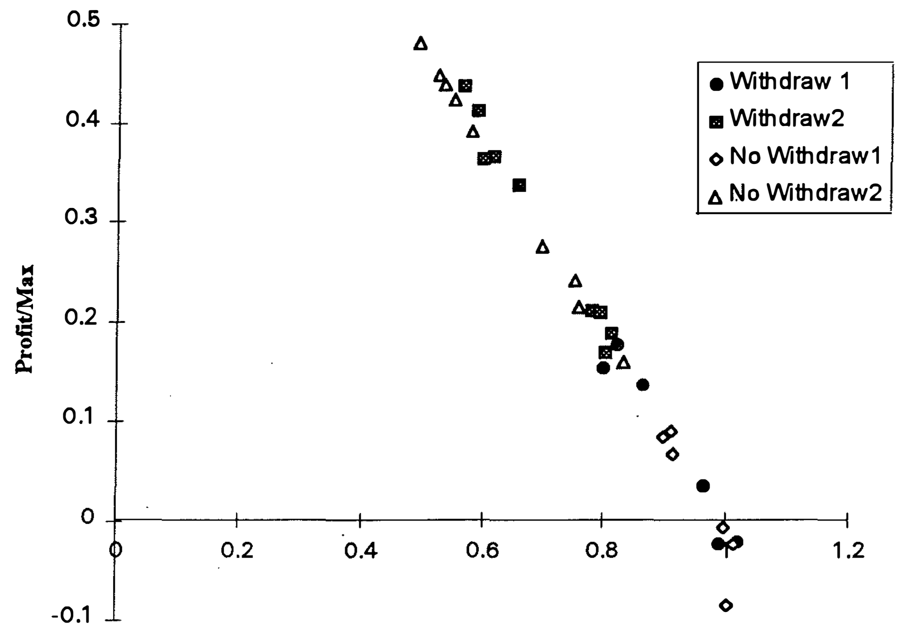



Figure 5 shows the revenue and bidder surplus for various auctions (auctions 1 and 3 and auctions 2 4 and 5 are grouped together since they have similar environment parameters). From this graph we make the following observation:

**Figure 5:**
**Surplus and Revenue Superadditive Environment**




Observation 5: The gain in efficiency isn't always large enough to overtake the losses and thus bidder surplus is reduced. Thus, the seller is made better off since revenues are higher but this is at the expense of bidder surplus in many cases.

### 4.1.2 Spatial Environment

The table below shows the descriptive statistics for efficiency and losses across each treatment. The bivariate distribution of loss and efficiency shows a bimodal distribution with (efficiency, loss) outcomes located at (100%, $0.50) and (60%, $10.00). This is similar to results found in Banks et al. (1986) in which coordination failures for the funding of a public good resulted in no provision or optimal provision when unanimity was required.

**Efficiency and Loss Statistics**

| **Treatment** | **Mean (Efficiency, Loss)** | **Standard Deviation (Efficiency, Loss)** |
|---|---|---|
| *Auction with Bid Withdrawal* | (72.5, 9.16) | (21.27, 7.44) |
| *Auction without Bid Withdrawal* | (62.6, 6.55) | (16.52, 3.90) |

Observation 6: The withdrawal rule results in higher efficiency.

Support: The table below shows the results of two non-parametric tests to see if the distributions are the same for each treatment.

**Test of Equality of Distributions of Efficiency**

| **Test** | **Statistic** | **P-Value** |
|---|---|---|
| ***Kolmogorov Smirnov*** | D=.3000 | .1301 |
| ***Mann-Whitney*** | z=1.4877 | .1368 |

Observation 7: Efficiency outcomes are slightly more volatile with withdrawal than without withdrawal, but not significantly.

Support: Differences in the variance of each of the treatments were tested and an F statistic = 1.65 was obtained, which is not significant at the 10% level.

Observation 8: The withdrawal rule results in higher losses than when it is not used.

Support: The table below shows the results of two non-parametric tests to see if the distributions are the same for each treatment.

**Test of Equality of Distributions of Losses**

| **Test** | Statistic | **P-Value** |
|---|---|---|
| ***Kolmogorov Smirnov*** | D=.3500 | .1010 |
| ***Mann-Whitney*** | z=1.231 | .2180 |

Observation 9: Losses are more volatile with withdrawal. This suggests that losses are likely to be higher for a group that cannot coordinate when the withdrawal rule is present.

Support: Differences in the variance of each of the treatments were tested and an F statistic = 3.645 was obtained, which is significant at the 5% level.

The time series of each experiment can be found in the figures below. The data shows:

- Each group seems to have its own character.
- The Auction 3 parameters result in high efficiency and low losses across both treatments.

**Figure 6a:**
**Time Series of Efficiency: Spatial Environment No Withdrawal**

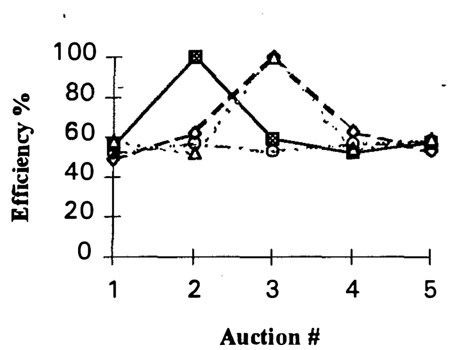



**Figure 6b:**
**Time Series of Losses: Spatial Environment No Withdrawal**

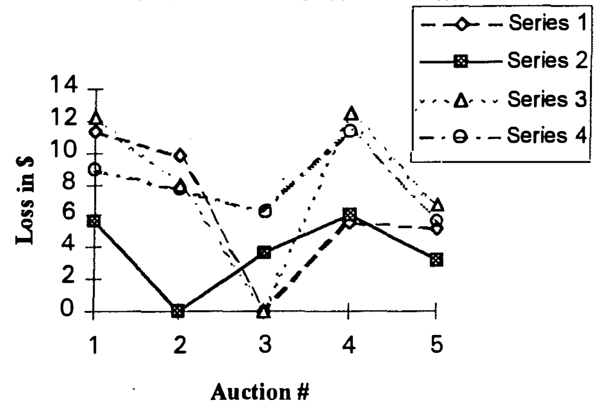



**Figure 6c:**
**Time Series of Efficiency: Spatial Environment Withdrawal**

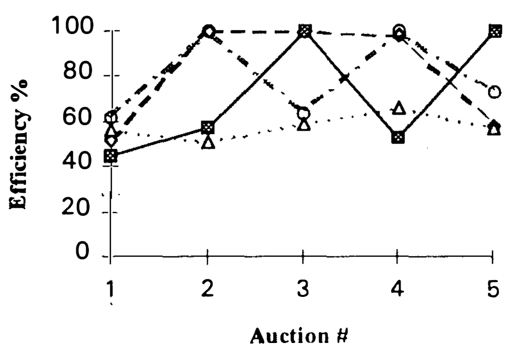
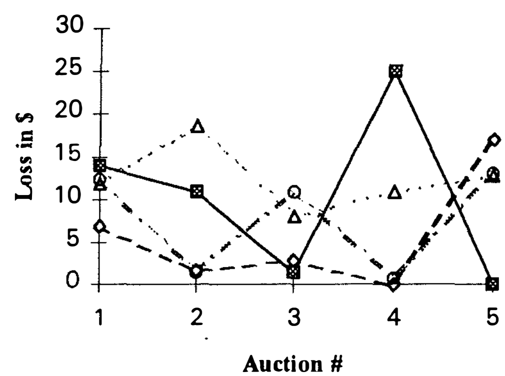
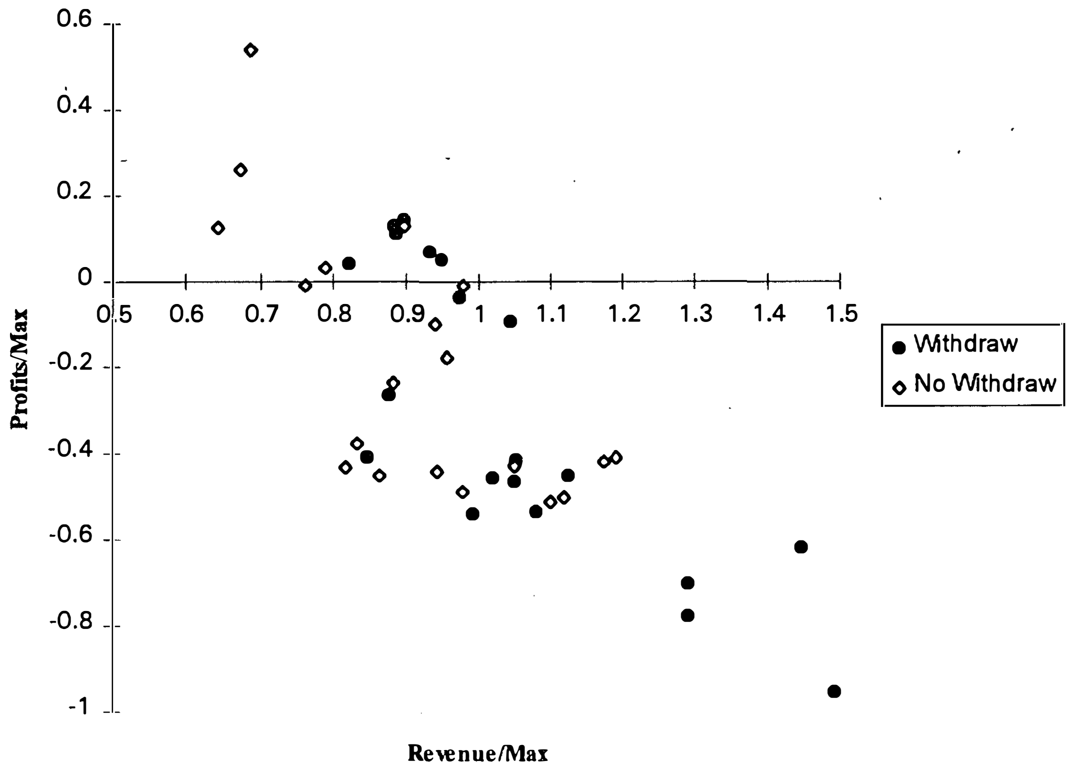



**Figure 6d:**
**Time Series of Losses: Spatial Environment Withdrawal**




In this environment the results are stark. When a group cannot coordinate, i.e., fitting bidders cannot find each other quickly, then major losses and low efficiency can occur with the withdrawal rule. Figure 7 shows the revenue and bidder surplus for each auction.

**Figure 7:**
**Consumer Surplus and Revenue: Spatial Environment**




From this graph following observation is made:

Observation 10: The gain in efficiency isn't large enough to overtake the losses and thus bidder surplus is reduced. The seller is made better off since revenues are higher but mainly at the expense of bidder surplus.

## 4.2 Withdrawal Behavior

### 4.2.1 Withdrawals, Efficiency and Losses

Figure 8 shows the relationship between efficiency and the number of withdrawals tendered in each auction. In the spatial environment, there is a negative relationship between withdrawals and efficiency, i.e. more withdrawals signals low efficiency.

**Figure 8:**
**Withdrawals versus Efficiency**

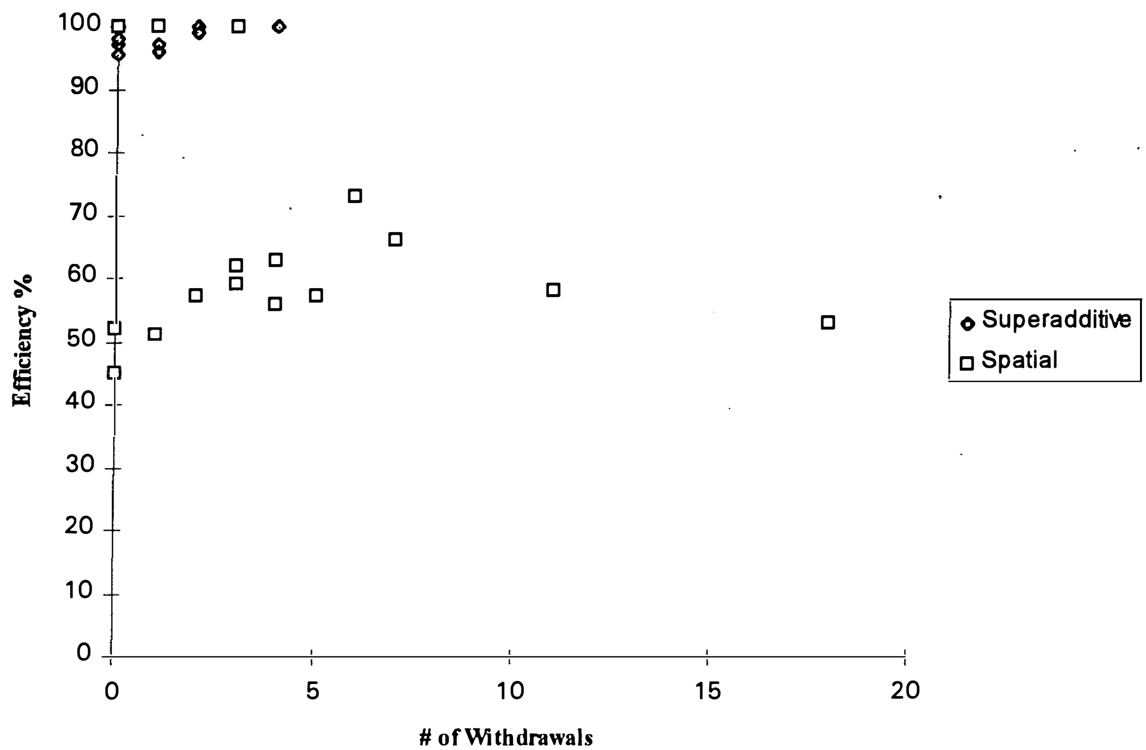
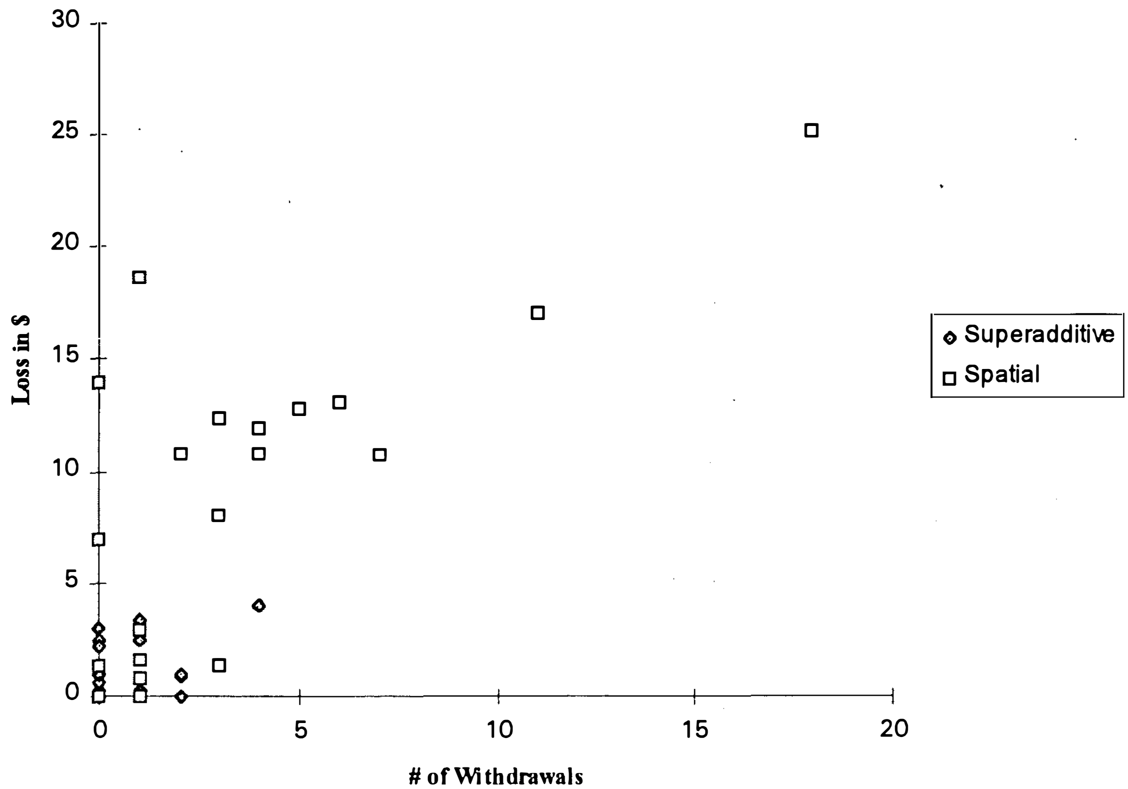



Figure 9 shows the relationship between the number of withdrawals tendered and losses for each auction. In the spatial environment there is a positive relationship between the number of withdrawals and the eventual losses. This suggests that many withdrawals signals poor coordination and thus looming losses when fitting is an issue.

**Figure 9:**
**Withdrawals versus Losses**




### 4.2.2 Synergies and Coordination

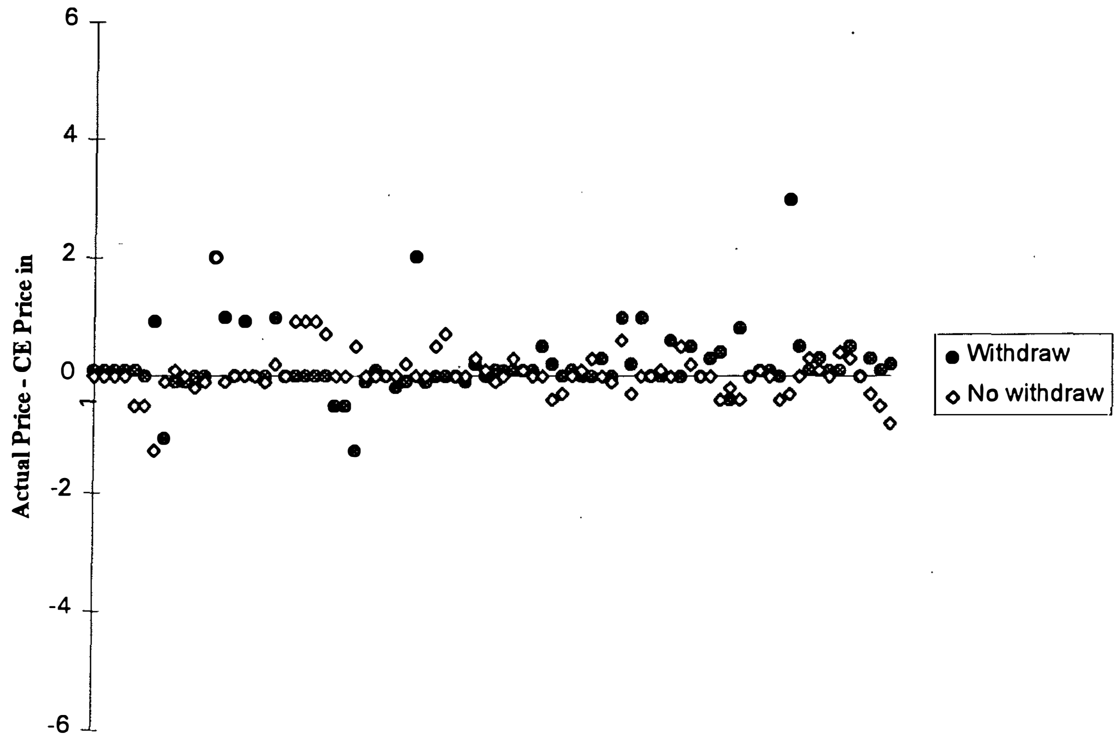
#### 4.2.2.1 Homogenous Superadditive Environment

Recall that in some of the auctions (2, 4 and 5) several bidders did not have superadditive values. In each of these auctions, those bidders never withdrew a bid or made a loss. Thus, if one sees withdrawals in these experiments it is entirely due to superadditivity.

#### 4.2.2.2 Spatial Environment

In the spatial environment, four markets were created in which values were strictly additive. These markets should pose no problem for most mechanisms. In fact we would expect that prices should be at the second highest value (the competitive equilibrium). In these non-spatial markets the deviation from the competitive equilibrium prices is charted in Figure 10. It should be noted that in these markets 100 % efficiency was obtained in 38 out of 40 auctions and there was never a withdrawal tendered in these markets. The mechanism worked as one would expect and no strategic retaliation was noticed that filtered into these markets from the spatial markets.

**Figure 10:**
**CE Price Deviation in Non-Spatial Markets**



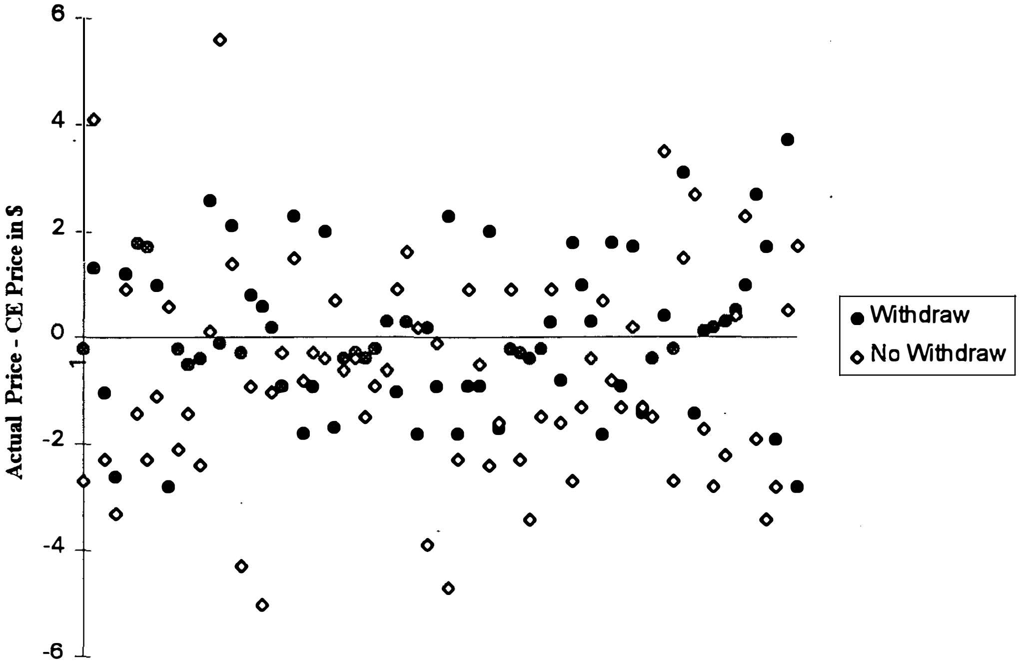

While the competitive equilibrium (CE) outcome is a good predictor of outcomes in the simple markets it does not do so well in the spatial market. In some of the auctions (1,3 and 5) it happens that there is a set of prices that can clear the markets. That is, one can solve the following set of equations for $p_j$:

$V_i(\mathbf{x}_{ji}^*) - \Sigma_J\, p_j \geq 0$ for each i and for $J \subseteq N$ where $\mathbf{x}_{ji}^*$ is the optimal allocation, and

$V_i(\mathbf{x}_{ji}) - \Sigma_J p_j \leq 0$ for all $J \subseteq N$ and i where $\mathbf{x}_{ji} = \mathbf{x}_{ji}^*$

Figure 11 shows the CE price deviations for these cases. It is clear that this is not a good predictor of the outcome in these auctions.

**Figure 11:**
**CE Price Deivation in Spatial Markets**

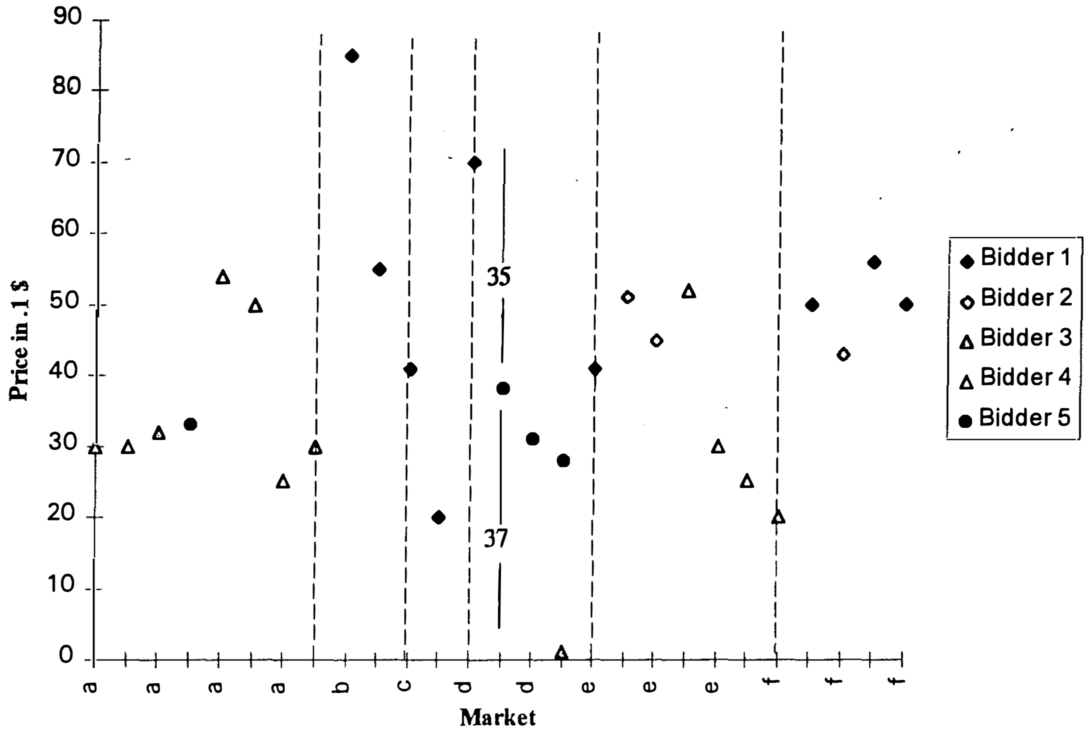



### 4.2.2.3 Path Dependent Losses

Too see how biding and withdrawal can go awry, two specific auctions are illuminating. In Series 1 Auction 5 a large loss ($17) was observed. In the previous auctions in that series the losses were low and efficiency was high. What occurred is that bidder 4 decided, after the first auction, not to bid in the spatial markets. In all the auctions except Auction 5, this bidder was not part of the optimum. Thus he did not provide any noise in the bids and the optimal packages could find each other (only 2 withdrawals were used in Auction 1 through 4). However, in Auction 5 that bidder was part of the optimal allocation. His failure to participate resulted in the large loss and 7 withdrawals were tendered in that auction.

Figure 12 charts the withdrawals in Auction 4 Series 2, the auction which sustained the highest losses. Each bidder withdrew at least once and each item had at least 1 withdrawal. For items a,b,c e and f, the item ended up with the bidder who withdrew at the highest price. Thus, no penalty was paid on those items, but two penalties were paid on item d ($3.50 and $3.70). One interesting bit of information came from bidder 4 who obtained items a and e. These items had no value to him without item b (he sustained a $10 loss); next to auction 4 on his accounting sheet he wrote: "Played wrong. Should have bid for b, no matter how high!"

**Figure 12:**
**Withdrawal Behavior in Auction 4 Series 2**




## 5.0 Conclusions

The main result is that there is a tradeoff when using the withdrawal rule. Allocative efficiency may increase but individual losses increase and total bidder surplus is reduced. In environments where fitting and coordination are <u>not</u> paramount, such as the homogenous case with superadditive preferences, the mechanism seems to work well. When preferences are such that fitting and coordination are crucial, the mechanism does not perform well.

In these experiments, participants who submitted bids on withdrawn items were typically "inactive", i.e. they had not submitted a bid for a over a minute prior to the withdrawal. Several times, these inactive bidders won the withdrawn items and added to total surplus. Thus, if one wants to use a simultaneous multi-round ascending bid auction with withdrawal and <u>activity rules</u> to allocate items, then to increase efficiency, when a bidder withdraws a bid, everyone should be able to bid on the item regardless of their eligibility status. That is, when a withdrawal occurs, bidding is open for that item.

Beyond this simple fix however, it seems that when preferences have spatial properties a better mechanism needs to be designed. Mechanisms that allow for combinatorial bidding may be the best option. Banks, Ledyard and Porter (1989) describe one particular mechanism that seems to do well. This mechanism has been investigated further in Ledyard et al. (1996ab). Ausubel (1996) suggests an ascending bid extension of the now famous Vickrey (1961) auction.[14] His suggestion of the extension to Vickrey's auction is incredibly complex and difficult to implement even in a very simple testbed. Rothkopf et al. (1995) suggest a method that reduces the combinatorial complexity while attempting to maintain the efficiency properties of a full combinatorial auction. How it is implemented is an open question.

[14] Rassenti, Smith, Bulfin (1982), provide an extension of the Vickrey auction with combinatorial preferences, but they only consider only a one-shot sealed-bid version of the mechanism.

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## Appendix A

## Instructions

You are about to participate in an economics experiment. The decisions you make in the experiment will result in earnings in U.S. currency which will be yours to keep. In this experiment all transactions will be stated in francs. You can convert your franc earnings into U.S. dollars at a rate of    francs to 1 dollar at the end of the experiment.

The experiment will be broken-up into a series of **periods.** At the beginning of each period you will be given a **Redemption Value Sheet.** This sheet describes the value to you of decisions you might make. *Do not reveal this information to anyone.*

### How To Read Your Redemption Value Sheet

A Redemption Value Sheet is a list of **packages of items** (the items are labeled as A, B C and so forth) and its value to you in francs. Below you will find a generic Redemption Value Sheet with four packages listed.

**Table 1: REDEMPTION VALUE SHEET**

| ITEMS in PACKAGE | VALUE in FRANCS |
|---|---|
| A | 100 |
| B | 67 |
| D | 35 |
| BD | 210 |

Thus, if you were allocated Item A you would get 100 francs in Value. If you obtained items A, B and D your total value would be 310 (100 + 210) in this example. The amount you get to keep will be the difference between the Value you obtain from items allocated to you and the cost of obtaining those items.

YOUR PROFIT = Value of Items Redeemed - Cost of Items Obtained

## How the Redemption Values are Determined

You will be one of 5 participants in this market. At the beginning of a period each participant will be given a set of packages and associated redemption values for the packages. The set of packages and values, from which yours will be selected, are determined as follows:

1. Each of the single-item packages (a, b, c, d, e, f ) will have their values taken independently from the interval [0,10]. Each value in this interval will be equally likely to be selected.

Example: Package a gets the value 4 Package b get the value 7.

2. The experimenter will select 7 of the 15 two-item packages (ab, ac, ad,.... ,ef) which have their values taken independently from the interval [20,30]. Each value in this interval will be equally likely to be selected.

Example: Package ce gets the value 27, Package de gets the value 21.

3. 11 of the 20 three-item packages will be selected and their values will be drawn independently from the interval [110,130] all of which are equally likely.

Example: Package abc gets the value 111, Package cde gets the value 125.

4. The package abcdef will have its value drawn from the interval [140,180] all of which are equally likely.

*Summary to this Point*

- There will be a total of 25 packages (6 single-item packages, 7 two-item packages, 11 three-item packages and 1 six-item package) generated each period to be distributed among the six participants each period.
- Each participant will be assigned 5 of the packages. Thus, no one has duplicate packages.
- The values for the packages were determine as follows:

Single-item package values are selected from the interval [0,10] -
Two-item package values are selected from the interval [20,30] -
Three-item package values are selected from the interval [110,130] -
Six-item package value is selected from the interval [140,180]

## The Allocation Process

Items will be allocated through a market process in which you can submit bids (in francs) for items you want. The process starts when the market is *opened.* You are then allowed to submit bids for any of the items. Only the highest bid for each item is posted, which we call the *standing bid.* The only way for your bid to be registered for an item is to submit a bid for that item that is higher than the standing bid. The market for the items will *close* if no new standing bid for any item is registered within ____ seconds.

In addition to bidding in the market, if you have a standing bid for an item you will be able to *withdraw* your bid for a potential *penalty.* When a bid is withdrawn its price is set to zero and can be bid for by participants in the market. The individual who withdraws a bid will pay a penalty equal to:

The Maximum of {0 or
The difference between the bid withdrawn and the highest bid for that item after the withdrawal

Example 1:

| | Bid | | |
|---|---|---|---|
| Item F | 345 | → | Bid Withdrawn |
| | 0 | | |
| | 200 | | |
| | 245 | | |
| | Close | → | Penalty = 345 - 245 = 100 |

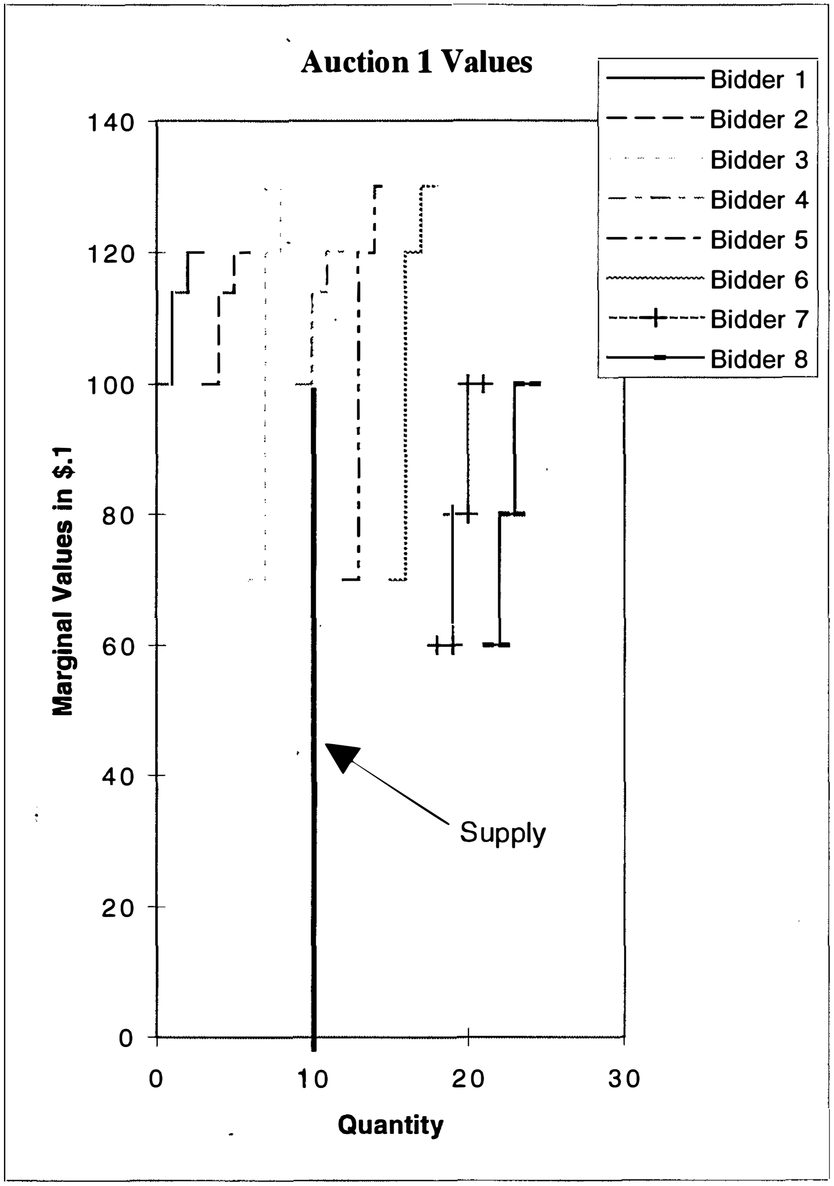
Example 2:

| | Bid | | |
|---|---|---|---|
| Item F | 345 | → | Bid Withdrawn |
| | 0 | | |
| | 200 | | |
| | 245 | | |
| | Close | → | Penalty = 0 |

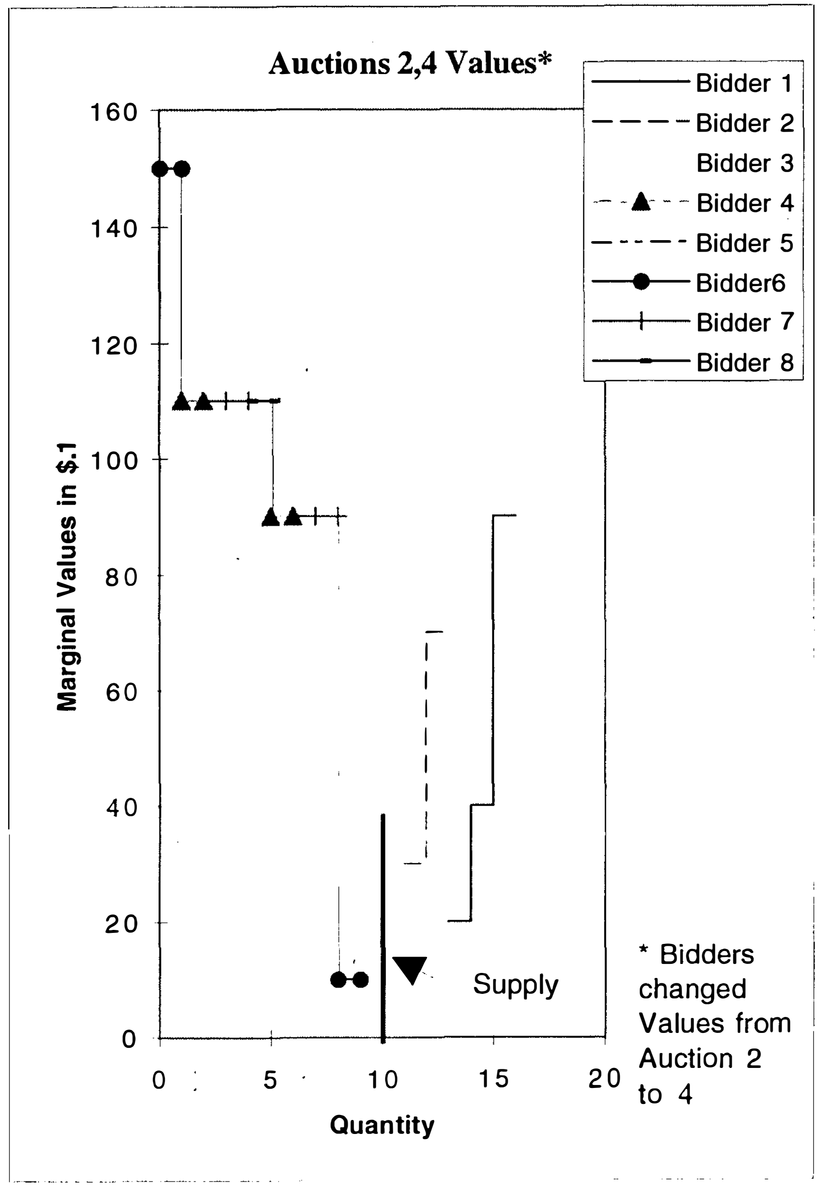
When the market closes those holding the standing bid will be assigned those items and will pay their bid for the item. In addition, participants will pay any withdrawal penalties at that time.

Profit = Value of Items Redeemed - Standing Bids - Withdrawal Penalties

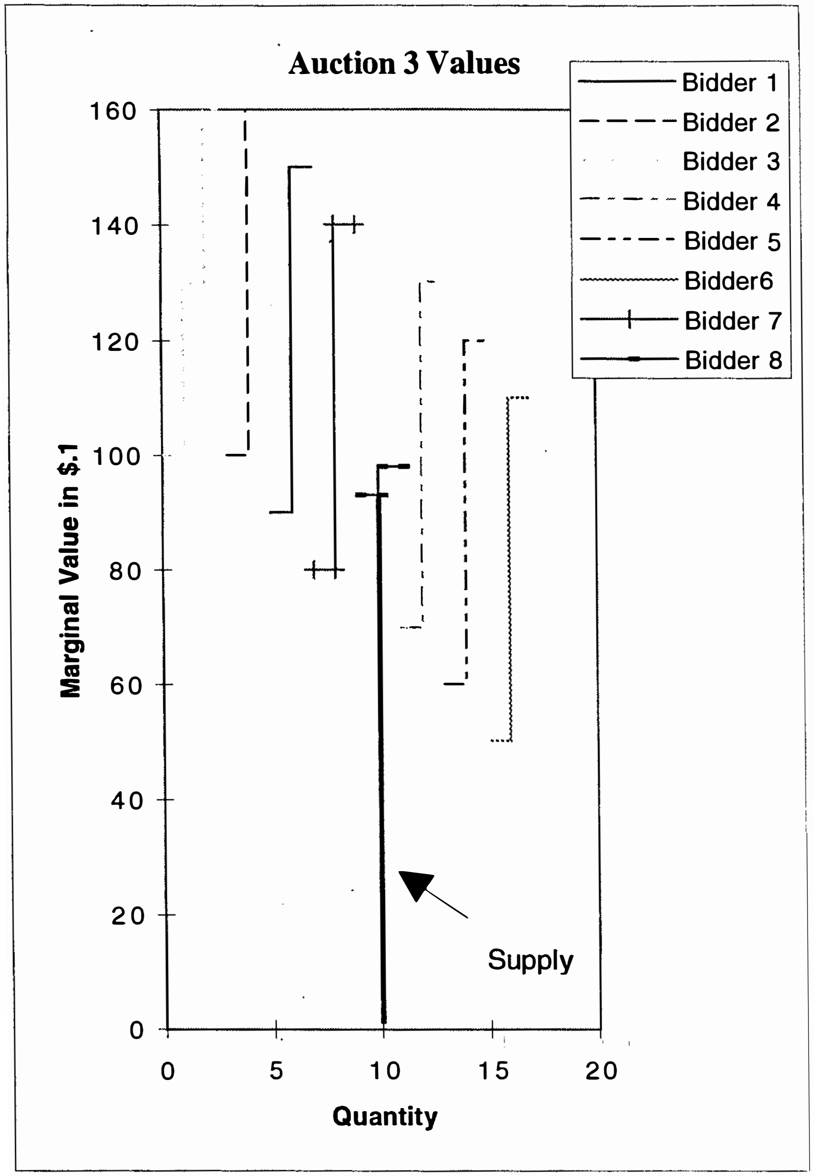
# Appendix B

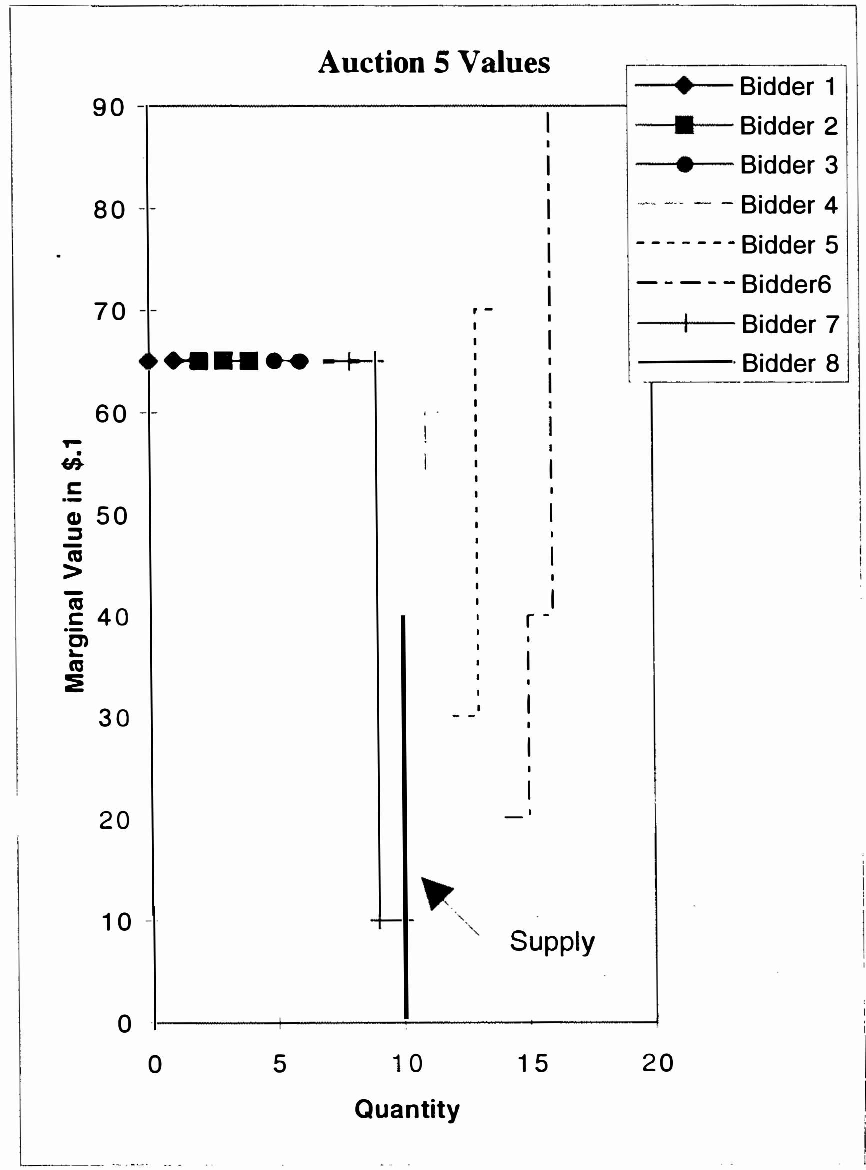


Auction 1 Values
Bidder 1
Bidder 2
Bidder 3
Bidder 4
Bidder 5
Bidder 6
Bidder 7
Bidder 8
140
120
100
80
60
40
20
0
Marginal Values in $.1
Supply
0
10
20
30
Quantity

Auctions 2,4 Values*
Bidder 1
Bidder 2
Bidder 3
Bidder 4
Bidder 5
Bidder6
Bidder 7
Bidder 8
160
140
120
100
80
60
40
20
0
Marginal Values in $.1
Supply
0
5
10
15
20
Quantity
* Bidders changed Values from Auction 2 to 4


Auction 3 Values
160
140
120
100
80
60
40
20
0
0
5
10
15
20
Marginal Value in $.1
Quantity
Supply
Bidder 1
Bidder 2
Bidder 3
Bidder 4
Bidder 5
Bidder6
Bidder 7
Bidder 8


Auction 5 Values
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
Marginal Value in $.1
Quantity
Supply
Bidder 1
Bidder 2
Bidder 3
Bidder 4
Bidder 5
Bidder6
Bidder 7
Bidder 8