Can Affirmative Action Be Cost Effective? An Experimental Examination of Price-Preference Auctions

By Allan Corns and Andrew Schotter*

One of the most controversial questions facing our economy and society in recent years is the question of affirmative action. The debate centers around an issue of minority representation in which the rights of the majority are depicted as being compromised by affirmative action programs set up to increase the welfare of minorities. Implicit in this discussion is the assumption that all affirmative action programs must be cost increasing. This result, it is claimed, follows trivially from economic theory since any interference into the competitive process which prevents the most capable from being chosen must be wasteful and costly.

In this paper we challenge this claim with experimental results, demonstrating that price-preference auctions, in which high-cost minority firms are given preferential treatment in the awarding of contracts in such a way that it is possible for these firms to win a contract but not have submitted the lowest bid, can be programs that both enhance minority representation and are cost effective in that they decrease the cost of government procurement. In the theoretical literature on asymmetric auctions (Eric Maskin and John Riley, 1995) and the optimal auction literature (Roger Myerson, 1981) it has been shown that in asymmetric auctions, in which firms draw their costs from different probability distributions, it is not always optimal to award the good to the lowest-cost firm. In fact, in a paper on international trade, R. Preston McAfee and John McMillan (1989) ask a question identical to the one investigated here. Our analysis follows theirs closely.

Our experiments indicate that the imposition of a price-preference rule can lead to an increase in both minority representation and cost effectiveness if the degree of price-preference is chosen correctly, but can lead to a decrease in cost effectiveness if the price-preference is too great. In our experimental auction in which a 5-percent price-preference was used, the cost of purchasing for the laboratory auctioneer decreased while at the same time the frequency with which high-cost (minority) firms won a contract increased as compared to the 0-percent preference case. For the auctions run using a 10-percent or 15-percent price-preference there was additional increase in minority representation but it came at a cost of higher purchasing prices for the laboratory auctioneer. These results are consistent with theoretical predictions however, indicating that if a government purchasing agent has some accurate prior information about the distributions from which the cost of buyers are drawn, then it is possible to choose a price-preference which will be cost effective.

In this paper we will proceed as follows. In Section I we will review the incidence of price-preference auctions among government agencies as well as the empirical work in the field. In Section II we present the theory that underlies these experiments, while in Section III we present our experimental design. In Section IV we give the results of our experiments. Finally, in Section V we offer some conclusions.

* Department of Economics, New York University, 269 Mercer Street, New York, NY 10003. The authors would like to express their thanks to Huagang Li for his computational assistance. We would also like to thank J. P. Benoit, and John Riley for sharing his BIDCOMP program with us. In addition, the research assistance of Jia Lu Yin, Gautam Barua, and Jeff Davis is gratefully acknowledged, as is the financial assistance of the C. V. Starr Center for Applied Economics at New York University. We have also benefitted from comments received from the NYU/C. V. Starr Micro Workshop and the Economic Science Association. We would also like to thank two anonymous referees for their suggestions and insight.
I. Price-Preference Auctions—Their Use in Practice

A. The Incidence of Price-Preference Auctions

Auctions in which some form of preference is given to minority bidders have been a common feature of the American economy for many years. Probably the most famous use of minority preference auctions, at least for economists, has been their use in the recent Federal Communications Commission (FCC) auction of radio spectrum licenses. In setting up this auction the government’s concern for minority representation led it to devise a preference program where minority- and women-owned firms (designated entities) were given a 40-percent bidding preference. In addition, a number of surveys have been conducted by the National Institute of Governmental Purchasing (1993) and the National Association of State Purchasing Officials (1994), whose purpose is to summarize the purchasing practices of various governmental agencies. The results indicate that 2 percent of the 402 federal, state, city, and administrative bodies responding indicated that they used minority price-preference programs in their procurement programs. In fact, of all minority preference programs existing about 8 percent are price-preference programs with the remainder split between set-aside and goal-based programs. Further, of the 50 states, 15 had some form of in-state price-preference program with percentages ranging from 2 percent to 5 percent. On the federal level there is a long history of the “Buy-American” purchasing preference program (starting with the Buy-America Act of 1933) with price-preferences ranging from 6 percent to 12 percent. On defense contracts, however, the price-preference can be as high as 50 percent. Because these price-preference programs are seen as creating substantial barriers to trade, their validity has often been challenged.

B. A Review of the Empirical Literature

Despite their common use, we are not aware of any study which investigates the procurement cost consequences of minority preference auctions except for the recent investigation by Ayres and Cramton (1996) of the FCC auction data. The reason for this lack of attention is that in all of the studies we have seen which mention minority preference programs, it has been assumed that these programs are put in place strictly for minority representation purposes with the tacit assumption that higher purchasing costs for the government will inevitably result.

While little attention has been focused on minority price-preference programs, there has been some research on the related, and theoretically identical, issue of “State-Preference” and “Buy-American” programs of state and federal purchasing authorities. When studying state and federal price-preference programs, there seems to be an implicit ad hoc methodology hinted at of simply taking all contracts awarded by an in-state preference and estimating the cost of the preference as the difference between the lowest bid and the actual price that the contract was awarded. This view of what industry seems to think of as the cost of a price-preference program is summarized by Donald E. Jordan (1978 p. 215): “The major effect of such laws is to increase the cost of government. Indeed, an obvious cost is any amount which must be paid in excess of the lowest bid from non-residents.”

This naive accounting approach, which we will call the “Naive Cost” approach, does not consider the effect of the price-preference rule on bidding behavior. For example, in computing the cost of instituting an x-percent preference auction, one must not look at the difference between the low bid and price paid within the x-percent preference auction when the preference is binding in determining the winner, but rather the difference between the price paid in the x-percent preference auction and what the price paid would have been had the auctioneer employed a 0-percent prefer-

1 In authorizing these auctions, Congress required the FCC to “ensure that . . . businesses owned by members of minority groups and women are given the opportunity to participate in the provision of spectrum-based services, and for such purposes, consider the use of tax certificates, bidding preferences, and other procedures.” [U.S.C. 309(j)(4)(D); Ian Ayres and Peter Cramton (1996).]
ence auction instead. The key ingredient in a proper cost-accounting system is to take into account the change in equilibrium behavior that would be invoked by the change in rules of the auction. This is what we do later when we discuss the "Real Cost" accounting method.

II. Some Theory

A. Price-Preference Auctions

While not optimal, it is possible that by choosing the right preference percentage a government might be able to use price-preferences to both reduce its cost of purchasing and increase the probability that higher cost, minority-owned firms win contracts. To understand why price-preferences work, consider an auction with two high-cost firms and four low-cost firms. By low cost and high cost we mean that the low-cost firms draw their costs from a uniform distribution with support $[c', c'']$, while the high-cost firms draw their costs from a uniform distribution with support $[\lambda c', \lambda c'']$, where $\lambda > 1$. We assume throughout that minority-owned firms are high-cost firms and non-minority-owned firms are low cost. This cost difference may be attributed to past discrimination, which prevented minority-owned firms from acquiring the same experience and human capital through learning by doing that non-minority-owned firms were able to gain through the winning of past contracts.

Note the asymmetry in the situation. While high-cost firms face one other high-cost firm and four low-cost firms, low-cost firms face only three low-cost firms and two high-cost firms. In other words, low-cost firms face less competition than high-cost firms. When price-preferences are instituted, it makes high-cost firms look more like low-cost firms and as a result of this increase in "effective" competition, the low-cost firms bid more aggressively, i.e., they bid closer to their cost. By analogy, high-cost firms now face less competition and hence bid less aggressively. If the preference is chosen correctly, the reduction in bids by low-cost firms (the firms which are more likely to have lower costs of production) more than compensates for the increased bids of high-cost firms.

To see this more formally, assume that there is a single contract to be awarded in a price-preference, first-price, sealed-bid auction. Let $N = \{1, \ldots, n\}$ be the set of bidders for this contract. A subset containing $k < n$ of these bidders is assumed to be of Type $A$. The rest of the bidders are of Type $B$. Each bidder privately draws an individual-specific cost, $c$, of fulfilling the contract from his own type-specific probability distribution over costs, $G_i(\cdot)$, $i = A, B$; $G_i(\cdot)$ is be assumed to be a continuous, differentiable distribution, defined over the interval $[c_i, \bar{c}_i]$, $i = A, B$, with density function $g_i(\cdot)$. It will be assumed that $c_A > c_B$ and $\bar{c}_A > \bar{c}_B$, so Type $A$ bidders will be the high-cost bidders. Each individual bidder knows his own type, how many bidders of each type are present, his own private cost draw, and the distributions of costs faced by all other bidders.

Given the assumptions on the supports of the cost draws for each type, if it is true that for any given cost, $c$, which lies jointly in both supports, $H_B(c) > H_A(c)$ where

$$ H_i(c) = \frac{g_i(c)}{1 - G_i(c)} $$

then bidders of Type $B$ have a cost advantage over bidders of Type $A$. In other words, given any cost level, $c$, contained in either interval, there is a higher probability that a bidder of Type $B$ will draw a cost lower than $c$ than of a bidder of Type $A$ drawing a cost lower than $c$.

2 Especially in the uniform distribution case, price-preference rules might be quite successful in approximating both the allocation and purchasing prices of the optimal auction.

3 Note in this specification that while the absolute values of the mean and standard deviation of the bidders' uniform distributions have increased by a factor $\lambda$ from the low-cost to high-cost firms, the coefficient of variation (standard deviation/mean) remains the same.

4 Obviously, if minority firms were also low-cost producers, then, if the auction were run fairly, there would be no need for a price-preference program to assist them.

5 We drop subscripts for simplicity.
What separates the price-preference auction from the simple asymmetric case is that bidders of Type A are given a bidding advantage in the auction for purposes of awarding the contract. After all bids are submitted, the auctioneer adjusts all Type B bids by multiplying them by one plus the amount of the preference (we will denote this sum as $\theta$) to form the comparison bids for bidders of Type B. The bids of Type A remain unchanged for purposes of comparison, so for all Type A bidders, the submitted bid and comparison bid will be identical. The bidder who submits the lowest comparison bid will be awarded the contract at a price equal to his submitted bid. Therefore, the adjustment procedure only determines the winner of the auction and does not affect the ex post payoff of the winner.

**B. Equilibrium Bid Functions**

The problem facing a bidder $i$ of Type A is to maximize expected profits given his cost draw, $c_i$. This can be written as

$$\max_b (b - c_i) \Pr(b \leq b_j \forall j \in A, j \neq i) \times \Pr(b = \theta b_m \forall m \in B).$$

We do not know the distributions of bids for the types, but we do know the distributions of costs and that the bid functions are strictly monotonic. Therefore, we can define the inverse bid functions for both types as

$$y_i(b_i) = c_i, j = A, B, i \in j.$$

We can rewrite the optimization problem facing a member of Type A as

$$\max_b (b - c) (1 - G_A(y_A(b)))^{k-1} \times \left(1 - G_B(y_B(b))\right)^{n-k}$$

given that there are $n$ total bidders, $k$ of which are of Type A. Analogously, we can define the problem faced by members of Type B as

$$\max_b (b - c) (1 - G_A(y_A(\theta b)))^{k} \times (1 - G_B(y_B(b)))^{n-k-1}.$$

Taking first-order conditions and simplifying with equation (1), we get the following system of nonlinear, first-order, differential equations:

$$\frac{1}{b - y_A(b)} = \frac{1}{c_A - y_A(b)} y_A'(b)(k - 1)$$

$$+ \frac{1}{c_B - y_B(b)} \left(\frac{b}{\theta}\right)^{(n-k)}.$$

$$\frac{1}{b - y_B(b)} = \frac{1}{c_A - y_A(\theta b)} y_A'(\theta b)(\theta k)$$

$$+ \frac{1}{c_B - y_B(b)} y_B'(b)(n - k - 1).$$

It is this system of differential equations that needs to be solved, given appropriate boundary conditions, to yield the symmetric, within-type equilibrium bid functions. The upper boundary conditions of the system for both Type A and Type B firms can be determined analytically and can serve as terminal conditions.
conditions to pin down the equilibrium bid functions. The terminal conditions depend on whether $\theta \bar{c}_B > c_A$ or $\theta \bar{c}_B < c_A$. Derivation of the system of differential equations and these terminal conditions can be found in an Appendix to Corns and Schotter (1996), available from the authors on request. It is important to note that in the case when $\theta \bar{c}_B > c_A$, Type B bidders cannot win if they draw a cost in the range $[\bar{c}_A / \theta, \bar{c}_B]$ and when $\theta \bar{c}_B < c_A$, Type A bidders cannot win if they draw costs in the range $[\theta \bar{c}_B, \bar{c}_A]$. Equilibrium behavior in these "no-win" ranges can be arbitrary but for simplicity we assume that in these regions bidders will bid their cost.

As with most systems of nonlinear differential equations, it is not possible to find a closed-form solution for the inverse bid functions, and thereby for the actual bid functions themselves. We used the algorithm of John Riley and Li Huagang (1993) to numerically solve for the equilibrium bid functions in our auction.

### III. Experimental Design

The experiments performed were a straightforward implementation of a price-preference auction. Students were recruited by announcement in undergraduate economics classes during the summer and fall of 1995. Volunteers were told to come to a classroom that was reserved for the experiment. Upon arrival six students were then randomly selected for each experimental session. Four subjects were randomly assigned to be Type B subjects and two were randomly assigned to be Type A subjects. Type B bidders independently drew their costs in all rounds of the experiment from a uniform distribution with support [100, 200]. Type A subjects drew their costs from a uniform distribution with support [110, 220]. Hence, Type A subjects were high-cost bidders while Type B subjects were low-cost bidders.

After subjects read the instructions to themselves and then had them read out loud by the experimental administrator, any questions the subjects had were answered and the experiment began. In the beginning of each round of the experiment (there were 20 rounds in all) an experimental administrator walked around the room with two bags marked A and B. In each bag was a number of chips representing uniform distributions for the integers in the supports of the two types of distributions. The bag identities were hidden from the subjects so that no one in the room knew who among them was a low- or high-cost type. If a subject was an A type (B type), the administrator would give him or her the A bag (B bag) and he or she would pull out a chip with a number written on it. This number would be the cost for the subject in that round.

After a cost was drawn, each subject would record that cost on his or her work sheet and then take out one of their 20 bid slips upon which they would write their bid. These bids were then collected by the experimental administrator and then, depending on the rules of the auction run, a winner would be determined. The experimental administrator would then write on the blackboard the number of the subject who had won, the price he or she won at, and whether that subject was an A or B type. Subjects would then record their payoffs and the next round would start in an identical manner. In each experiment the final payoff to subjects was the sum of their payoffs over the entire 20-round history of the experiment plus a $5.00 bonus for showing up. Subjects were paid at the end of the experiment and dismissed. A postexperimental questionnaire was also administered in 13 out of the 20 experimental sessions run. The results of this questionnaire are available upon request from the authors.

\[ y_a(\cdot) = \text{the upper bound to the domain of } y_a(\cdot) \text{ in the system of differential equations. Also, let } b_i, i = A, B \text{ be the maximum bid issued by both types. Then it will be true that if } \theta \bar{c}_B > c_A, \text{ then } b_A = b_i = \bar{c}_A \text{ and } b_B = \bar{c}_B / \theta, \text{ so terminal conditions are } y_A(\cdot) = \bar{c}_A \text{ and } y_B(\cdot) = \bar{c}_B / \theta. \text{ If it is the case that } \theta \bar{c}_B < c_A, \text{ then } b_A = \theta \bar{c}_B \text{ and } b_B = b_i = \bar{c}_B, \text{ so terminal conditions in this case are } y_A(\cdot) = \theta \bar{c}_B \text{ and } y_B(\cdot) = \bar{c}_B. \]

\[ \text{Equilibrium behavior in these "no-win" ranges can be arbitrary but for simplicity we assume that in these regions bidders will bid their cost.} \]

\[ \text{Here again let us take the opportunity to thank Huagang Li for all of his time and effort in helping us use this algorithm and for the actual time he took in working on this problem.} \]

\[ \text{Instructions for the 10-percent preference experiment are contained in the Appendix to this paper.} \]
Table 1 describes our design. Four treatments which differed only with respect to the preference rule used were run. The preference rules used were a 0-percent, 5-percent, 10-percent, and 15-percent preference for Type A. After all bids were submitted, the bids of the B types were increased by the appropriate percentage for the treatment before any comparison of bids was made. The lowest post-preference bid was then awarded the contract at the price of the submitted bid and the experiment proceeded to the next round. Including the $5.00 for showing up, the average payoff for the one-hour experimental session was $10.03.

Table 1—Experimental Design

<table>
<thead>
<tr>
<th>Preference experiment</th>
<th>Number of groups</th>
<th>Types</th>
<th>Costs</th>
<th>Number of subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 percent</td>
<td>5</td>
<td>2 A types</td>
<td>( c_a \in [110, 220] )</td>
<td>30</td>
</tr>
<tr>
<td>5 percent</td>
<td>5</td>
<td>4 B types</td>
<td>( c_b \in [100, 200] )</td>
<td>30</td>
</tr>
<tr>
<td>10 percent</td>
<td>5</td>
<td>2 A types</td>
<td>( c_a \in [110, 220] )</td>
<td>30</td>
</tr>
<tr>
<td>15 percent</td>
<td>5</td>
<td>4 B types</td>
<td>( c_b \in [100, 200] )</td>
<td>30</td>
</tr>
</tbody>
</table>

IV. Results

Our discussion of the experiment’s results will be broken into four sections. In the first two sections we will investigate if the imposition of a price-preference rule increased the likelihood that a high-cost firm would win an auction. We will also examine if the imposition of a price-preference rule increased cost effectiveness and which price-preference rule resulted in the lowest cost of purchasing for the auctioneer (experimental administrator). In the final two sections we will investigate how well the theory of auctions predicted the behavior of the subjects.

The descriptive results of the experiment are shown in Table 2, which we will use to discuss both the procurement cost and representation outcomes of the experiment.

In Table 2 there are two types of entries: those that are simple empirical calculations and those that are hypothetical-theoretical calculations using either equilibrium or estimated bid functions and the assumed cost distributions. The theoretical calculations are placed in bold letters to differentiate them.

A. Representation of High-Cost Firms

Lines 3–6 in Table 2 present the impact of price-preference rules on the representation of high-cost Type A firms amongst the set of winning firms. Note that as the price-preference given to high-cost firms increases, the fraction of contracts awarded to them increases. Line 5 shows, given our experimental parameters, theory predicts that the probability that Type A bidders win increases steadily from 19.1 percent in the 0-percent preference auction to 36.9 percent in the 15-percent preference auction. Our experimental results mirror this consistent increase in the frequency with which Type A bidders win, going from 12.1 percent in the 0-percent or no-price-preference auction to 43 percent in the 15-percent preference auction as shown in Line 4. More importantly, it appears that as the price-preference is increased, it becomes responsible for more and more of these wins, as it turns what would have been losing high-cost bidders under lower preference regimes into winners. For example, while 10 of 22, or 45.4 percent, of the Type A winners in the 5-percent experiment won because of the price-preference, 61.8 percent, 21 of 34, of the wins for Type A subjects in the 10-percent experiment were the result of the preference rule. The fact that the percentage falls from 61.8 percent to 53.4 percent, 23 of 43, in the 15-
### Table 2—Descriptive Results of Price-Preference Auctions

<table>
<thead>
<tr>
<th></th>
<th>Auction type</th>
<th>0 percent</th>
<th>5 percent</th>
<th>10 percent</th>
<th>15 percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Winners</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>A types</td>
<td>12(^a)</td>
<td>22</td>
<td>34</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>B types</td>
<td>87</td>
<td>78</td>
<td>62(^a)</td>
<td>57</td>
</tr>
<tr>
<td>4</td>
<td>Type A win frequency</td>
<td>0.121</td>
<td>0.220</td>
<td>0.354</td>
<td>0.430</td>
</tr>
<tr>
<td>5</td>
<td>Theoretical Type A win probability</td>
<td>0.191</td>
<td>0.249</td>
<td>0.298</td>
<td>0.369</td>
</tr>
<tr>
<td>6</td>
<td>Wins by preference</td>
<td></td>
<td>10</td>
<td>21</td>
<td>23</td>
</tr>
<tr>
<td>7</td>
<td>Winners average cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>A types</td>
<td>117.17</td>
<td>120.68</td>
<td>126.79</td>
<td>123.74</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5.68)</td>
<td>(11.85)</td>
<td>(14.45)</td>
<td>(10.14)</td>
</tr>
<tr>
<td></td>
<td>B types</td>
<td>113.82</td>
<td>111.44</td>
<td>112.81</td>
<td>112.77</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(12.25)</td>
<td>(9.29)</td>
<td>(11.55)</td>
<td>(10.38)</td>
</tr>
<tr>
<td>9</td>
<td>Winners average bid</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>A types</td>
<td>124.42</td>
<td>126.95</td>
<td>132.56</td>
<td>131.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4.79)</td>
<td>(11.85)</td>
<td>(13.92)</td>
<td>(11.01)</td>
</tr>
<tr>
<td></td>
<td>B types</td>
<td>120.80</td>
<td>117.13</td>
<td>117.52</td>
<td>119.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(10.75)</td>
<td>(9.29)</td>
<td>(11.38)</td>
<td>(9.90)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B-151</td>
<td>B-155</td>
<td>B-144</td>
<td>B-146</td>
</tr>
<tr>
<td>12</td>
<td>Average profit per unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>A types</td>
<td>7.25</td>
<td>6.27</td>
<td>5.76</td>
<td>5.47</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4.60)</td>
<td>(6.66)</td>
<td>(5.46)</td>
<td>(6.44)</td>
</tr>
<tr>
<td></td>
<td>B types</td>
<td>6.99</td>
<td>5.69</td>
<td>4.71</td>
<td>5.68</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4.75)</td>
<td>(4.11)</td>
<td>(3.61)</td>
<td>(4.80)</td>
</tr>
<tr>
<td>14</td>
<td>Average observed price</td>
<td>121.24</td>
<td>119.29</td>
<td>122.84</td>
<td>124.41</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(10.22)</td>
<td>(10.66)</td>
<td>(14.24)</td>
<td>(12.07)</td>
</tr>
<tr>
<td>15</td>
<td>Theoretical expected price</td>
<td>134.13</td>
<td>133.24</td>
<td>134.50</td>
<td>136.06</td>
</tr>
<tr>
<td>16</td>
<td>Naive cost of preference</td>
<td>0</td>
<td>0.39</td>
<td>1.06</td>
<td>2.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0)</td>
<td>(1.30)</td>
<td>(2.76)</td>
<td>(4.61)</td>
</tr>
<tr>
<td>17</td>
<td>Real cost</td>
<td>0</td>
<td>-1.91</td>
<td>-0.28</td>
<td>1.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0)</td>
<td>(4.76)</td>
<td>(6.63)</td>
<td>(6.64)</td>
</tr>
</tbody>
</table>

\(^a\) Standard errors in parentheses.
\(^b\) One Type A winner dropped due to reporting cost outside of support.
\(^c\) Four Type B winners dropped due to bid less than cost.

The percent case is likely the result of the cost realizations occurring in the 15-percent experiment where, at least in one experiment, the cost realizations for the low-cost B types were particularly high. Hence there is little dispute that, at least in our laboratory
setting, price-preference rules increase the probability that high-cost (minority) firms win contracts.

B. Procurement Price Comparisons

Looking at line 14 of Table 2 we see that the average prices paid per auction in our four experiments were 121.24, 119.29, 122.84, and 124.41 for the 0-percent, 5-percent, 10-percent, and 15-percent treatments, respectively. These figures imply that on the basis of the average price paid per auction, the 5-percent price-preference rule seems to be the best, followed by the 0-percent auction, and then the 10-percent and 15-percent auctions.

It is hard to rely on these findings as a solid demonstration that the price of purchasing is lowest when the 5-percent preference is used since these differences might not reflect a behavioral difference in bidding but rather the fact that the costs drawn in the 5-percent preference treatment were lower than those drawn in others. When this conjecture is tested using a Kolmogorov-Smirnov test we find that no difference exists between the distribution of drawn costs between any two experiments for any type. In other words, statistically the costs drawn for all experiments came from the same population.

<table>
<thead>
<tr>
<th>Kolmogorov-Smirnov Tests for Equality of Cost Distributions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment pair</td>
</tr>
<tr>
<td>--------------------------</td>
</tr>
<tr>
<td>0 percent vs. 5 percent</td>
</tr>
<tr>
<td>0 percent vs. 10 percent</td>
</tr>
<tr>
<td>0 percent vs. 15 percent</td>
</tr>
<tr>
<td>5 percent vs. 10 percent</td>
</tr>
<tr>
<td>5 percent vs. 15 percent</td>
</tr>
<tr>
<td>10 percent vs. 15 percent</td>
</tr>
</tbody>
</table>

Despite these statistical tests, however, it is still possible that the price of purchasing differences observed were at least in part due to small sample biases in the cost realizations of our four auctions. In order to control for these differences, we performed a simulation to calculate what the price of purchasing would have been in our various auctions if bidders in an auction with an x-percent (say 5-percent) rule had received the cost realizations of bidders in an auction with a y-percent (say 0-percent) rule and vice versa. To do this we estimated a bid function for each type of bidder in each auction using pooled data for bidder types in each experiment. (See Section IV, subsection D, for a full description of the estimation procedures used.) Using these bid functions we were able to simulate the bids of Type A and Type B bidders given any sample of cost realizations by simply plugging these cost realizations into our estimated bid functions and playing out the auction. These simulation results are presented in Table 3.

In Table 3 there are two types of entries: those which are derived from calculations on actual data and those which are the result of the simulations just described. The actual average purchasing prices, which are along the diagonal and are the average observed prices reported in line 14 of Table 2, are placed in bold type to distinguish them from the simulated calculations. For example, the top left diagonal element shows that the average price of purchasing in the 0-percent preference experiment was 121.24. Looking across the first row to the next cell we see that if the bidders in the 5-percent preference auctions had actually received the same cost realizations as the 0-percent preference bidders, then, using the estimated bid functions for the 5-percent preference auctions, we predict an average purchasing price of only 120.03. Going further across the first row we see that using the estimated bid functions from the 10-percent and 15-percent preference auctions, again using the 0-percent preference auction cost data, we would expect purchasing prices of 120.97 and 124.25, respectively. In other words, if we look across row 1, we find that using the cost realizations in the 0-percent auction and the estimated behavior in other auctions, the government would have had an average savings of almost 1 percent, 

\[
(120.03 - 121.24)/121.24 = -0.00998, 
\]

if it had imposed a 5-percent preference on these bidders. Likewise, it would have had a savings
of 0.22 percent had it used a 10-percent preference rule, but would have incurred an additional cost of 2.48 percent had it used a 15-percent preference rule, given the cost draws in the 0-percent treatment.

Looking across the other three rows we see that this basic pattern repeats itself. No matter what set of cost realizations is used, the 5-percent preference auction behavior is always the most cost effective. In addition, as Table 2 indicates, not only was the 5-percent rule the most cost effective, it also increased the percentage of contracts going to high-cost (minority) firms from 12.1 percent in the 0-percent preference treatment to 22.0 percent when the 5-percent preference was used. Interestingly, McAfee and McMillan (1989) estimate that with the parameters used in our experiment a 4.1-percent price-preference would have been optimal among the class of percentage price-preference rules.

The “Real Cost” accounting method discussed above and presented in line 17 of Table 2 can be derived from Table 3 as follows: Take any auction with a nonzero price-preference rule, say the 15-percent rule, and look along the diagonal in Table 3 to find the actual experimental price associated with that preference rule. In the 15-percent preference case the actual average price of procurement is 124.41, which is at the lower right-hand corner of the table. Using the 15-percent treatment cost realizations, calculate the expected procurement price associated with them when bidding behavior is characterized by the bid functions estimated in the 0-percent auction. This price is presented in the lower left-hand corner and is 123.35. This difference, \( 124.41 - 123.35 = 1.06 \), is the real cost of the preference rule.

In terms of statistical significance, it is hard for the differences we observe to pass a significance test because even equilibrium purchasing prices are not predicted to be dramatically different between the 0-percent and 5-percent price-preference auctions. Still, when using the 5-percent data and comparing purchasing costs in the 5-percent and 0-percent auctions, we find, using a Mann-Whitney U-test, that the null hypothesis of the equality of the distributions of the winning bids is rejected at the 5-percent level \( (p\text{-value } 0.032) \). However, the reverse, using the 0-percent data for comparison, was not significant at the 5-percent level. A Mann-Whitney U-test performed on the actual prices formed in the 0-percent and 5-percent auctions unconditional on cost realizations also did not show a significant difference at the 5-percent level.

If we look back again at Table 2 and compare line 14 (our experimental average purchasing prices) to line 15 (the theoretical expected prices of purchasing), we see that our experimental prices are well below the theoretically predicted prices. To test the significance of this apparent underbidding phenomenon we ran a Kolmogorov-Smirnov one-sample test in which we compared the experimental cumulative frequency distributions of bids for each type with each preference against the distributions of bids predicted by theory, given the same cost draws, with the null hypothesis that the distributions were equivalent. In each case we strongly rejected the hypothesis of equivalence at the 5-percent level. The experimental distribution was significantly below the theoretically predicted distribution with the greatest points of divergence between the distributions occurring in the lower regions of the range of bids.

C. Experimental Results and the Optimal Auction Mechanism

As we noted in Section II, subsection A, the percentage price-preference auctions we
ran are not optimal auctions. We investigate price-preference auctions because they are frequently used. Still, one might ask how much better off the government might be if it used the optimal auction form. The optimal auction for bidders who are asymmetric with respect to their cost distributions takes the following form. First, bidders submit messages representing their supposed true cost of production. The auctioneer takes these costs as truthful and constructs the following function:

\[ J_i(c_{ij}) = c_{ij} + \frac{G_i(c_{ij})}{g_i(c_{ij})} \]

where \( n_i \) is the number of firms of Type \( i \), \( i = A, B \); \( c_{ij} \) is the cost message of the \( j \)th bidder of Type \( i \); and \( G_i(\cdot) \) is the continuously differentiable cumulative cost distribution of Type \( i \) with density \( g_i(\cdot) \). The contract is awarded to that bidder with the lowest \( J_i(c_{ij}) \) at a price equal to that cost report that would equate the value of his \( J_i \) to that of the second lowest bidder (see Myerson, 1981; Jeremy Bulow and John Roberts, 1989; McAfee and McMillan, 1989).

Table 4 compares how the price-preference auctions we ran compare both theoretically and empirically to the outcomes predicted by the optimal auction mechanism. Starting with the first two rows we see that the optimal auction mechanism generates an expected procurement price of 132.19 given our assumptions on the number of bidders of each type and their corresponding cost distributions. The theoretically expected prices associated with the price-preference auction vary depending on the degree of preference, with the lowest, 133.24, being associated with the 5-percent preference and the highest, 136.06, with the 15-percent preference. Looking at the last two rows of Table 4, note that the experimental price-preference auctions performed better than the optimal auction mechanism predicts, had it been implemented using the actual cost realizations of our experimental auctions. For example, while the optimal mechanism predicts an expected procurement price of 125.53 for the cost realizations of the 5-percent price-preference groups, when the 5-percent price-preference rule was used in our experiment the average procurement price was 119.29. This "countertheoretical" result is clearly attributable to the fact that subjects in our experiments tended to bid more aggressively than the theory predicts, resulting in better than optimal purchasing prices.

D. Estimation of Bidding Behavior

Probably the best way to see how bidding behavior changes as we change the price-preference rule is to estimate bid functions using the pooled data generated by our experiment. We estimated equation (6) for each type of bidder in each preference treatment

\[ b = \beta_0 + f(c - c, DT; \beta) \]

where \( b \) is the observed bid, \( c \) is the cost draw, \( c \) is lower bound of the cost distribution, \( DT \) is a dummy variable that takes the value 0 if...
the observation comes from the first ten rounds of the experiment and 1 if from the last ten, and $f$ is a function of a vector of parameters, $\beta$, $c - \bar{c}$, and time. By making $f$ a function of $c - \bar{c}$ rather than just the cost draw we can interpret $\beta_0$ as the minimum bid for the type given the preference rule. The inclusion of a dummy variable on time allows us to see if bidders are altering their strategic behavior over time due to learning about the situation they are in.

Because we observe 20 bid-cost pairs from each subject, we cannot employ simple ordinary least squares (OLS) since that method requires independence across observations. Instead we use a random-effects specification.\textsuperscript{10} We estimated $f$ as a cubic polynomial in $c - \bar{c}$ but linear in $DT$. Table 5 reports the results of the bid-function estimations. We also ran two regressions, one for each bidder type, that pooled all observations for that bidder type over all experiments and that used a more elaborate set of dummy variables to denote treatments and included interactions with those dummy variables and the cost variables. Since the results of these regressions were not different either qualitatively or quantitatively, we opted to present these disaggregated regression results for simplicity’s sake.

The first thing of note when looking at Table 5 is that even though four of the eight regressions showed significance for quadratic and even cubic terms at the 95-percent level, all bid functions were estimated to be very close to linear. Second, if we look at the parameter estimates on the time dummy, we see that all estimates were negative and that five of the eight estimates were significantly different than 0. These results are consistent with those of Reinhart Selten and Joachim Buchta (1994) and Timothy Cason and Daniel Friedman (1995), who investigate learning in sealed-bid and single-call market institutions, respectively. They find, testing directional and error-based learning models, that over time participants bid more aggressively.

Theory predicts that as the preference is increased for the Type A bidders, their bid function should shift upward as they use the opportunity of decreasing competition to increase their bids. Thus, the 0-percent preference bid function should lie below the others, with the 5 percent next, etc. For the Type B bidders, the opposite should be true as these low-cost bidders should decrease their bids at each level of cost as preference increases since they face heightened competition due to the increase in preference.\textsuperscript{11}

From looking at Table 5, except for the intercept terms, it is hard to tell what the relationship between the estimated bid functions is. If we were to plot the bid functions for each type bidder we would see that for the Type A experimental bid functions, the 5-percent preference bid function lies below all others for most of the lower part of their cost domains. The 10-percent and 15-percent bid functions do lie above the 5-percent function as theory would predict, with the 15-percent function being above the 10-percent function for all but the lowest cost draws. Thus, the relation between these three bid functions is in close accord with the predictions of theory. However, the 0-percent bid function tends to lie above the 5-percent and the 10-percent functions for most of the lower part of the cost support, contrary to theoretical predictions.

Plotting the Type B bid functions, we would see the 0-percent bid function does lie above all others, followed by the 5-percent and 10-percent functions at least initially, as theory would predict. The 15-percent bid function lies below the 0-percent function.

\textsuperscript{10} In our analysis we dropped observations in which the bid was less than the cost draw, the cost draw reported was outside the stated cost distribution, or the submitted bid was a “throw-away” bid. Throw-away bids were extremely high bids that a few subjects issued when they drew a cost with which they associated no chance of winning. As some of these bids were one million or more, these observations had to be removed from the sample due to the influence they would have on the estimation.

\textsuperscript{11} In postexperimental surveys given subjects, 16 out of 22 B-type subjects who participated in experiments with positive preferences indicated that the existence of the price-preference rule led them to bid lower than they would have if no preference existed. For A types, three of nine subjects indicated that the preference caused them to raise their bids.
but is initially above the 5- and 10-percent functions. Eventually, though, it does fall below all other functions. Because of our treatment parameters, these bid functions cannot be expected to be dramatically different, since these parameters, theoretically, call for differences in behavior by the bidders that should not vary by a large amount from treatment to treatment.

V. Conclusions

In this paper we have demonstrated that the use of affirmative action programs need not force policy makers to have to choose between the benefits of minority representation and cost effectiveness. In certain circumstances, such as the price-preference auctions investigated here, both minority representation and cost effectiveness can be enhanced simultaneously if the proper price-preference rule is used. This result seems robust to learning on the part of bidders in the sense that after subjects have experience with bidding in such auctions, the auctions run using a 5-percent price-preference rule continue to outperform those in which no preference is given. In general, bidders bid more aggressively, closer to their cost, as the auction progresses.

Our results do raise a note of caution since, if the government fails to use the optimal price-preference rule, it could increase its average price of purchasing and fail to reap the benefits that such price-preference rules offer. Further, we can offer little in the way of guidance about how to set the optimal preference without having estimates of the parameters of the cost distributions of the bidders. McAfee and McMillan (1989) offer a rough rule of thumb to help decision makers choose the correct preference rule. This is to use one-third of the percentage difference between the means of the cost distributions of the two types of firms as the price-preference, but this rule is predicated on the assumption of uniform distributions. With our treatment parameters, their rule suggests a 3.3-percent preference, which is closest to the 5-percent rule that proved to be best among our limited set of four rules.
APPENDIX: INSTRUCTIONS FOR 10-PERCENT AUCTION

This is an experiment in the economics of market decision-making. Various research foundations and agencies have provided funds for the conduct of this research. The instructions are simple, and if you follow them carefully and make good decisions you might earn a considerable amount of money which will be paid to you after the experiment is over.

Experimental Procedures

In this experiment we are going to conduct a series of 20 independent auctions run one after the other. When you walked into the room you had the chance to choose a folder which contained these instructions along with other forms and pieces of paper. On the upper right-hand corner of your instruction sheet will be a subject number (a number from 1 to 6). Check to see that you have a work sheet and 20 bid slips each with a different round number written on it. By choosing a folder you also chose which type of bidder you are, TYPE A or TYPE B. There will be 2 TYPE A bidders and 4 TYPE B bidders. If your subject number is 1 or 2, you will be a TYPE A bidder while if it is 3, 4, 5, or 6 you will be a TYPE B. In each round of the experiment you will be asked to enter a bid for a fictitious good or service that you will provide. The cost of providing this good or service will be randomly determined separately and independently for each bidder in each round of the experiment.

The way this random cost will actually be given to you is by having, at the beginning of each round of the experiment, an experimental administrator walk around the room with one of two bags filled with chips. If you are of TYPE A you will be given the TYPE A bag. You will put your hand in the bag and pull out one and only one chip. In the bag will be a number of chips with a different number written on them, one for every number in the interval [110, 220]. The chip that is drawn in this fashion will be your cost for that round of the auction. If you are a bidder of TYPE B you will do the same from the TYPE B bag. Since we want to keep the identify of the bidder types secret, you will not notice any difference in the bags, but we will bring them to you according to your type. [We will let you inspect the contents of these bags at the beginning of the experiment so as to verify their contents and they will remain in full sight during the 20 rounds of the experiment so you will be assured that they are as we describe them.]

Your random cost for any round will be known to you and only you. Do not let anyone else see it. Once you observe your random cost in any round, write it down in Column 1 of your work sheet under the heading RANDOM COST. Knowing your cost you are now to make a bid to sell the fictitious good or service being sold. To do this, take out one of the bid slips in your folder labelled with the appropriate round. On this bid slip write down your bid for this round. In addition, record your bid in Column 2 of your work sheet under the heading BID. These slips will then be collected and brought up to the front of the room where they will be compared by the experimental administrator sitting at the desk. He will then announce both the winning bid and the type of bidder (TYPE A or TYPE B) who was the winner.

Round Payoffs

Your payoffs in any round will be determined in a very simple way. Once the bid slips for a round are brought up to the front of the
room, they will be opened and compared. This will be done as follows: First, all TYPE B bids will be increased by 10 percent. Then the experimental administrator will look over all the bids and award the contract to sell the fictitious good to that bidder of any type with the lowest bid. In short, TYPE A bidders who draw their costs from the interval $[110, 220]$ are given a preference in the bidding since, before the bid comparisons are made, their costs are not increased by 10 percent while the bids of TYPE B bidders are. For example, say that the lowest bid made by a bidder of TYPE B is 60 while the lowest bid made by a bidder of TYPE A is 63. In such a case, the bidder of TYPE A would win the auction since after the 10 percent is added on to the bid of the TYPE B bidder, their bid would be 66 and greater than the bid of the lowest TYPE A bidder. If two bidders are tied for the winning bid, a coin will be flipped to determine the winner.

The payoff to the winner of the auction is simply equal to their bid minus their cost. For example, say that a bidder receives a random cost of 55, submits a bid of 70 and wins. Then their payoff in that round of the experiment will be $\text{PAYOFF} = 70 - 55 = 15$. Note that this is the payoff to any winning bidder regardless of their type. The 10-percent increase in the bid of TYPE B bidders is done simply for comparison purposes to determine the winner. If a TYPE B bidder actually wins, they win at a price equal to the bid they entered not their bid +10 percent. If you do not win the auction, your payoff for that round is 0. Be sure in Column 3 [labeled WIN (Yes, No)] of your work sheet to record if you won or not in this round of the experiment and in Column 4 (PRICE) to record the price at which you won if you did. In Column 5 record your payoff for this round of the experiment which will be zero if you lost and will be the difference between your winning bid minus your cost if you won. Note that the only way you can lose money in this experiment is to bid below your cost. Hence, in order to avoid a loss never submit a bid below your cost. If a loss occurs, it will be subtracted from the $5.00 given to you for showing up.

Once a round of the experiment is over, the next round will start in an identical manner. First experimental administrators will walk around the room with bags generating random costs. Next you will bid, and finally you will be informed of the winning bid and the type of bidder who won. You will then your payoffs on your work sheet.

**Final Payoffs**

Your final payoff for participating in the experiment will be equal to $5.00 plus the sum of your earnings over the 20 rounds of the experiment. To determine this payoff remember to convert the fictitious francs you earn in each round into dollars at the rate of 1 franc = $0.25. This payment will be given to you at the end of the experiment.

**REFERENCES**


