Are Bid Preferences Benign? The Effect of Small Business Subsidies in Highway Procurement Auctions

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November 15, 2004

Abstract

Government purchases of goods and services represent approximately 10 percent of the U.S. economy, and policy is commonly used to direct some of those purchases toward specific groups. Bid preferences in procurement auctions, which allow firms from an identifiable group an advantage in bidding against unfavored firms, are one tool commonly used to achieve a particular allocation. While economic efficiency is expected to fall as a result of bid preferences, government procurement costs may either increase or decrease depending on the competitive response of favored and unfavored firms.

Using data from California auctions for road construction contracts, where small businesses receive a five percent bid preference in auctions for projects using only state funds and no preferential treatment on projects using federal aid, I show that procurement costs are 3.5 percent higher on auctions using preferences. This increase cannot be explained by the bidding behavior of firms. Large firms bid 1.4 percent lower on auctions using bid preferences, while the lowest cost small firms increase their bid on preference auctions by 1.4 percent. The higher procurement cost in preference auctions is instead attributed to reduced participation by lower cost large firms.

Structural estimates of latent firm costs are then used to evaluate how efficiency and the division of surplus between firms and the government is impacted by the use of preferences. Firm profits are 9.8 percent lower on preference auctions, implying significant losses in economic efficiency. The efficiency loss associated with changing some auction winners from large firms to small firms is estimated to represent less than 0.3 percent of overall procurement costs; however, including the adverse effect of preferences on the participation of large firms increases the estimated efficiency loss to 6.5 percent.

*I would like to thank the members of my thesis committee, Marianne Bertrand, Jonathan Guryan, Ali Hortacsu, and Steve Levitt for their guidance and support. I also appreciate the helpful comments of Jeremy Fox, Matthew Gentzkow, Jagadeesh Sivadasan, Chad Syverson, and seminar participants at Chicago GSB, Clemson, Cornell, Harvard KSG, Illinois-Chicago, Kentucky Martin School, Missouri-Columbia, Queen's University, UC-Santa Cruz, and the University at Buffalo. Address: Department of Economics, UC-Santa Cruz, 401 Engineering 2, Santa Cruz, CA 95064. E-mail: marion@ucsc.edu.

1 Introduction

The tradeoff between redistribution and efficiency is a central topic in public finance. Public procurement of goods and services is a significant and commonly used means to reallocate resources across economic agents. Through various preference programs, the federal government in 2001 awarded $21.3 billion of procurement contracts to small firms, minority and women owned businesses, companies located in economically disadvantaged areas, and veteran-owned businesses. This represents nearly 10 percent of the $216 billion federal procurement market. In addition, favored status is afforded to domestic producers in federal procurement, and a multitude of similar programs have been implemented at the state and local level. Reallocation through asymmetric treatment in procurement is generally thought to result in a loss in efficiency, either by forcing prime contractors to alter the mix of inputs used or by increasing government purchases of goods from less efficient suppliers.

Bid preferences are one tool commonly used in procurement auctions to favor particular sellers.[1] A typical bid preference program awards a procurement contract to the lowest favored bidder if its bid is within a certain percentage of the low bid from the unfavored group. Since they achieve redistribution by transferring contracts from unfavored firms to higher cost favored firms, bid preferences directly result in a loss of productive efficiency.

However, several theoretical results suggest that while bid preferences lower efficiency, they may also act to lower a government's procurement cost. Maskin and Riley (2000) and Myerson (1981) show that in asymmetric auctions only in specific cases does the optimal auction design always award the contract to the low cost firm. McAfee and McMillan (1989) in particular show that bid preferences can reduce the government's procurement cost through their effect on the competitive interaction between favored and unfavored firms.[2] As a result, direct losses in efficiency are potentially mitigated since government expenditure is in practice financed through distortionary taxation.

Instituting bid preferences can be optimal for the government if there are identifiable groups with different costs. Without preferences, low cost firms face weaker competition and earn higher

[1] In 2001 $137 million of federal procurement contracts were awarded through bid preferences to small disadvantaged businesses and firms located in economically disadvantaged areas. Currently 17 states favor in-state bidders, the federal government awards a 6 percent bid credit to domestic firms through the Buy America Act and a 10 percent bid credit to small disadvantaged businesses. Furthermore, many states and localities use bid preferences to award contracts to minority and women owned firms.

[2] Rezende (2004a) has also considered the case where the product to be provided by the stronger and weaker supplier also differs on an unobserved dimension. The government biases the procurement auction toward the favored seller balancing the competing objectives of achieving an efficient allocation and encouraging competition.

rents than high cost firms. For instance, in an auction with two low cost firms and two high cost firms, each low cost firm faces competition from only one other low cost firm. If bid preferences are instituted that favor the high cost firms, then the effective competition faced by the low cost firms increases. These firms are then forced to bid closer to costs.

Three factors could act to increase procurement costs. First, preferences may allow favored firms to increase their bid. Second, preferences transfer some contracts from low cost to high cost firms. Finally, the participation of large firms could be adversely affected, leading to higher cost participants or less competition.

This paper will examine the program of the California Department of Transportation (CDOT), which provides bid preferences for small businesses in auctions for road construction contracts, to address two questions. First, do bid preferences affect the bidding behavior of favored and unfavored firms as predicted? Second, what is the impact of the preference program on procurement costs and efficiency?

Bid preferences in this program are applied to auctions for contracts using only state funds and are not applied to auctions for contracts using federal funds. In the first portion of the paper, I will exploit this distinction to identify the impact of preferences on bidding behavior and procurement costs. I find that large firms bid 1.4 percent lower on preference auctions than on similar non-preference auctions. The more aggressive bidding by large firms is offset by less aggressive bidding on the part of small firms, as the lowest cost small firms are able to bid 1.4 percent higher on preference auctions.

The average winning bid on preference projects is found to be 3.5 percent higher than for similar non-preference projects. Some of this increase is explained by reduced participation of large firms on preference auctions. When controls for the number of small and large bidders are included the estimated impact of preference auctions falls to 1.8 percent. The remaining increase is explained by the different composition of auction winners under preferences, which results from higher cost participants as well as shifting some contracts to higher cost firms. After controlling for firm effects the estimated impact of preferences on procurement costs falls to -0.5 percent.

The reduced form model of procurement costs informs how preferences affect the average winning bid, however it is unable to distinguish between a loss of surplus and a shift in surplus between the government and firms. The second half of the paper uses a structural model to investigate the loss in efficiency resulting from the use of preferences and apportions this loss between the effect of preferences altering the winning bidder and the effect of firm participation patterns. I employ the nonparametric techniques of Guerre, Perrigne, and Vuong (2000) to obtain structural estimates of latent firm costs on both preference and non-preference auctions. The profits of the winning bidder are found to decline by 10.5 percent. This combined with the result that preferences increase procurement cost implies that productive efficiency must be adversely impacted. I find that by awarding fewer contracts to the low cost firm, preferences increased construction costs by 0.28 percent. Two sets of preference auctions are then simulated to estimate the effect of participation patterns on the construction cost of the winning firm. One simulation uses the distribution of participants on preference auctions, while the other uses the counterfactual distribution of participants observed on auctions not using preferences. Participation patterns are found to be responsible for an 6.5 percent increase in the cost of the winning firm.

This paper represents the first systematic empirical evaluation of a bid preference program taking into account the strategic response of firms. Older estimates of the effect of bid preferences on procurement cost, such as Lowinger (1976), ignore the competitive response of favored and unfavored firms. Ayres and Cramton (1996) provide a case study of the FCC auctions for the regional narrowband spectrum. For ten of the thirty auctions, minority and women owned enterprises were given bid preferences. On an additional ten auctions these firms were given more favorable payment terms. The authors provide evidence suggesting that non-favored firms bid more aggressively in the auctions for which preferences were employed, leading to higher revenues in those auctions. Consistent with participation concerns playing an important role, they find that bid preferences were set high enough in some auctions to discourage the entry of unfavored firms. Corns and Schotter (1999) provide evidence from a laboratory experiment using college students who were given varying bid preferences in hypothetical procurement auctions. They find that bid preferences lower the bids of non-preferred subjects while raising the bid of preferred subjects. Overall, procurement costs were lower under bid preferences.

Bid preferences, when used to favor minority and women owned firms, are often viewed as an alternative to other forms of affirmative action in contracting due to their potential to reduce procurement costs. Unfortunately, only a small literature has considered how redistribution in contracting affects procurement costs and efficiency, leaving little for comparison. Marion (2004) studies subcontractor utilization requirements for women and minority owned enterprises, finding significant reductions in government procurement costs due to California's Proposition 209, which eliminates these requirements for some contracts. Denes (1997) examines contract set-asides, finding that restricting the bidding for federal dredging contracts to small businesses has little impact on the winning bid. Government contracting is also used to impose hiring restrictions on federal contractors. Griffin (1992) finds that employment quotas restrict firms' ability to adjust labor demand, reducing productivity.

This paper makes two contributions to the auction literature. First, it contributes to the literature showing the importance of the participation margin in evaluating the procurement cost effect of different auction mechanisms. In a related paper, Athey, Levin, and Seira (2004) study the revenue effects of sealed versus open bidding in timber auctions when potential bidders are asymmetric and choose whether to participate in an auction based on the auction entry cost and the expected profit for own-type firms. Sealed bidding is more attractive to firms with lower valuations, and they find that the participation of these firms and the winning price is higher in sealed bid auctions. Furthermore, this paper also closely relates to the literature using reduced form techniques to test the behavioral predictions of the auction model characterized by a Bayesian-Nash equilibrium (see for instance Hendricks and Porter,1988,1993).

The paper proceeds as follows. Section 2 describes the preference program used by CDOT and the data that will be used. The basic reduced form empirical results are presented in Section 3. Section 4 presents the model and the structural estimates of firm costs that are used to estimate efficiency loss. Section 5 concludes.

2 Data and Background

2.1 Bidding on California Highway Auctions

The California Department of Transportation (CDOT) awards contracts through a sealed-bid, lowest price auction system. Potential bidders are solicited through a newsletter that details the bid letting date and the details of the project. A firm can bid on any project for which it has been prequalified to do the specified category of work; this prequalification is based on the firm's equipment, training, licensing, and past work history. A firm specifies in its bid which subcontractors it will use and a unit price of each item the engineer has specified.

Small businesses are given a bid preference on all contracts not using federal funds. If a small bidder bids within a certain dollar amount of the lowest regular bidder, the small business is awarded the contract. The preference amount is either 5 percent of the lowest large firm bid or $50,000, whichever is less.

A firm must meet several criteria to qualify as a small business. The firm must be independently owned and operated, so that larger firms are not able to form smaller subsidiaries to take advantage of the program. The firm must be located in California, have less than 100 employees, and earned less than $10 million in average annual revenue in the past three years.

Preferences are also given to firms of any size located in the state of California when bidding against out-of-state firms. The program is reciprocal in that preferences are only considered when the California firm is competing against a firm originating from a state with a local preference program. In that case, the preference given to the California firm is equal to the preference that would be given to the competing firm in its own home state. Aside from California, only sixteen states operate some sort of preference program for local firms. Of these sixteen states, ten are reciprocal programs like California, and only six states set a preference parameter. In the data for California roadway auctions, no bids are observed by firms with home offices in one of those six states.

2.2 Federal aid for highway projects

The U.S. Department of Transportation provides funds to states for the maintenance and construction of interstate and national highways, bridge projects, air quality and congestion management efforts, and other local projects. Federal aid for highway projects is funded through user related taxes such as gasoline taxes and truck-related taxes. A state's share of the federal funds through this program is related to a state's contributions to the Highway Trust Fund.[3]

A federal apportionment formula determines the grant to be given to the state under each federal aid program in a given year. While there is a fair amount of discretion as to what projects qualify for aid, there are specific formulas determining the percentage of a project's costs that are used for federal aid. For instance, for a project using funds under the national highway system program, federal funds account for 90 percent of the project's costs. Therefore, it is not possible for the state to apply a small amount of federal aid to all projects.

2.3 Data

The data in this study consist of information for 4,272 highway construction contracts awarded by CDOT between May 1996 and December 2002. For each awarded contract, a set of information describing the project is given, including the road and county where the work will take place; a short description of the nature of work to be completed; and the estimated number of working days to complete the project. The federal-aid status of the contract is given as well as the DBE

[3]Prior to 2000, a state's disbursements was determined by long range estimates of its contributions to the Highway Trust Fund. After 1999, there was a substantial increase in the amount of federal funding allocated to California as a result of the Revenue Aligned Budget Authority. The RABA tied disbursements to actual tax revenue, which increased dramatically during the expansion years. As a result of this increase, the average federal-aid project increased dramatically in size. The results obtained later in the paper are robust to the exclusion of post-1999 contracts.

participation goal that applies to that project. Bids are observed for every general contractor submitting a bid as well as the firm's location and a list of subcontractors to be used.

CDOT specifies each item that will be required to complete a project and the quantity of that item to be used. The bidder places a unit price for each item, and the sum of the unit prices multiplied by their quantities gives the total bid: $\sum_j p_{ij} q_{ij} = B_i$. The unit prices are used in the event that more of a particular item is required to complete the project, in which case the contractor is allowed extra compensation given by the unit price multiplied by the unexpected quantity. Also, the engineer's office uses the item prices to generate highway construction cost indices for common categories of items. These cost indices, along with project specific factors, are used to form an engineer's estimate of the cost of completing each project. This estimate is also observed in the data. The data is somewhat limited in identifying firms that qualify as small business bidders. Data describing revenue and employees, the two main criteria by which small business status is evaluated, are unavailable. As a result, small business status must be inferred from whether a firm claims the small business preference when bidding on state funded (preference) auctions. One complication is that the same firm does not always bid as a small business. The 421 firms that bid at least once as a small business do so 67.3 percent of the time on preference auctions.

A likely explanation is that some smaller firms temporarily fail to meet either the revenue requirement, the number of employees requirement, or both.[4] A firm engaged in other work may increase its workforce above the 100 employee limit. Also, the government typically makes progress payments to contractors while projects are underway, which could increase a firm's average revenue above the $10 million threshold. Jofre-Bonet and Pesendorfer (2003) find that capacity constraints are important in the road construction industry, suggesting that a given firm could face different marginal costs when bidding as a small business than when bidding as a large business.

The possibility that capacity constraints are correlated with small business status is supported by the relationship between past contract volume and the propensity of firms to claim small business status. Consider firms that bid as a small bidder at least once. Summing the volume of contracts a firm has won over the previous three years yields a measure that should be correlated with total firm revenues as long as firms do not excessively substitute away from non-CDOT road projects when a CDOT contract is won. Due to the highly nonlinear revenue criteria, for small levels of past volume the gradient between small business propensity and volume should be close to zero.

[4]Another candidate is that firms are graduating from the small business program. The data, however, indicate this is unlikely. There are 227 firms that only sometimes bid as a small bidder. These firms bid as a small bidder 60 percent of the time on the final auction that they bid on in the data, which is not significantly different from the rate for all auctions.

As past revenue increases it becomes more likely that a firm fails the revenue condition. In Figure 1, the propensity of firms to bid as a small business is plotted by total contract volume in the past three years. Among firms that ever bid as a small business, the propensity to claim small business status is greater than 70 percent when total past volume is less than $10 million and between $10 and $20 million. When past volume is greater than $20 million, firms bid as small bidders less than 25 percent of the time.[5]

A potentially strong relationship between claimed small business status and firm costs could therefore exist. This is particularly problematic since small business status is not known on non-preference auctions. The empirical work will define a firm as a small business if it ever bid as one on a preference auctions. While this measure will avoid bias associated with endogenous small business status, it will potentially understate the effect of bid preferences on the bids of small firms since it is an imperfect measure of small business status.

SUMMARY STATISTICS

Table 1 presents the summary statistics of the data. Panel A shows means for all projects, while Panel B shows only projects where the engineer's estimate is less than $1 million. Projects using federal aid tend to be larger in size. The median engineer's estimate on federal aid projects is $1.33 million, nearly four times the median engineer's estimate of $0.36 million. Small firms make up a greater proportion of the bidders on state funded contracts, and much of this difference is due to differences in size between the two types of projects.

Small firms are more likely to win preference auctions. On federal aid projects under $1 million small firms represent 39 percent of the bidders but only 34 percent of the auction winners. On preference auctions under $1 million small firms represent 45 percent of the bidders and 44 percent of the auction winners, indicating that small firms are as likely to win preference auctions as large firms. Some of this improvement seems to be accounted for by the use of preferences, which were invoked on 7 percent of the eligible auctions. It is important to note that due to the competitive response of small and large firms, it is not necessarily true that in each of these cases the winner would have been different had the auction been conducted without preferences.

Despite differing in size, state funded and federal aid contracts are similar in other dimensions. Work takes place on state highways for 58 percent of the state funded projects compared with 65 percent of the federal aid contracts. Interstates account for 30 percent of the state funded contracts

[5]This pattern need not arise when the small business propensity of all firms is considered. Participation of large firms, as well as their probability of winning, increases as project size increases. This will introduce a relationship between past volume and small business propensity that is unrelated to the revenue criteria. Consistent with this observation, when all firms are considered small business propensity declines monotonically in past volume.

compared with 25 percent of federal aid projects. The proportions are also similar for U.S. highways and other types of roads as well. The types of projects are also similar across the two types of auctions. By far, the most common type of project involves road construction and repair. For smaller projects, 52 percent of state funded contracts primarily involve road construction or repair compared with 53 percent for federal aid contracts. There are several other types of projects, including bridge construction and repair, landscaping, and drainage. Often these are elements of larger road construction projects, but occasionally they are the primary focus. There are no noticeable differences between state funded and federal aid contracts in the composition of these projects either.

3 Reduced form results

This section will begin by presenting a reduced form empirical model of the effect of bid preferences on the winning bid. It then proceeds by evaluating how firms' bidding behavior and participation decision contribute to this effect.

3.1 Procurement Cost Effect

The first goal is to establish the impact of bid preferences on government procurement costs. This section describes a simple empirical approach that uses the distinction between state funded and federal aid projects to identify this effect. In particular, suppose the log of the winning bid, $ln(B)$ on auction k is a function of the preference format used and a set of project specific characteristics:[6]

$$ln(B_k) = \alpha * PREFAUCTION_k + \beta' X_k + \epsilon_k. \tag{1}$$

The sample considered are those projects where the engineer's estimate is less than \$1 million. Bid preferences are proportionally the same for these projects, since the bid preference is capped at \$50,000.[7] For larger projects the importance of preferences depends on the scale of the project, which is likely correlated in an unknown way with the distribution of small firm costs.[8]

Two other key aspects of this model must be noted. First, the equation (1) will be estimated with and without including the number of bidders in the vector X_k. Excluding the number of

[6] If the relative cost of small and large firms differs by project size, then the effect of preferences could be correlated with project size as well. Estimating a model of the log bid could be misleading since it gives proportionally greater weight to smaller values of the dependent variable. However, estimating similar specifications in levels rather than yields similar results.

[7] The engineer's estimate is used as the cutoff rather than the lowest firm bid since this is a choice variable of the firm, which would make the cutoff correlated with the preference regime.

[8] In addition to this problem, as project size gets larger, the number of observed state funded (preference) auctions declines dramatically. This makes inference difficult as the estimated effects are dramatically imprecise.

bidders allows the coefficient α to incorporate the correlation between the preference format used and firm participation. Second, this model only identifies α if there are no unobserved components of X_k correlated with $PREFAUCTION$. Included in X_k will be the engineer's estimate, number of workdays, number of items to be provided, the minority subcontractor participation goal, indicators for broad work categories, as well as road, county, year, and month effects.[9,10]

The results of this specification are shown in Table 2. Column (1) displays the results from estimating (1) without controlling the number of small and large bidders. The winning bid is found to be 3.5 percent higher on preference auctions than on similar non-preference auctions. The specification shown in column (2) controls nonparameterically for the number of bidders by including variables indicating the number of small and large bidders. Including these controls reduces the coefficient on the preference auction dummy to 0.018, suggesting that approximately half of the procurement cost effect of preferences is due to fewer bidders participating on preference auctions.

Finally, column (3) displays results controlling for firm fixed effects, which is meant to control for the composition of winners on preference versus non-preference auctions. Including firm effects reduces the coefficient on the preference auction variable to -0.005 and is indistinguishable from zero. Two explanations could account for the weaker composition of winners. First, preferences sometimes shift the project from the low bidder to a higher bidding small firm. However, preferences are invoked on only 7 percent of the preference auctions, so the most this could increase the winning bid is 0.3 percent – 7 percent multiplied by 5 percent, the highest possible value of the bid preference. A second explanation could be that the set of auction participants have higher costs on average. Section 3.3 will consider this possibility in more detail.

3.2 Bidding behavior

Conditional on auction participation, to what extent are firms responding to the use of bid preferences? Bid preferences can only lead to a fall in procurement costs if they lead large firms to bid more aggressively. Even if large firms bid more aggressively, if small firms respond by bidding more passively then the net effect of preferences on government costs could be positive.

[9]Marion(2004) shows that the minority participation requirement could impact firm costs. This requirement was lifted on state funded contracts as a result of Proposition 209 in March 1998. Controlling for the requirement percentage is meant to account for the differential effect of Prop. 209 on state funded contracts.

[10]Athey, Levin, and Seira (2004) employ two methods for controlling for observable heterogeneity. They run a logit of auction form on covariates, and then drop observations with particularly high or low propensity scores. They also use a matching estimator. Both of these methods yield qualitatively similar results to those presented in this paper.

This section models the log of the firm's bid as a linear function of a small business indicator, a preference auction indicator, and an interaction between these two. Again, a set of auction specific covariates are employed to control for factors that shift costs across projects, and only projects where $ENGEST < \$1$ million are considered. The equation to be estimated is as follows:

$$ln(b_{ik}) = \beta_0 + \beta_1 SB_i * PREF_k + \beta_2 SB_i + \beta_3 PREF_k + B'X_k + \eta_i + \epsilon_{ik} \quad (2)$$

where SB_i is a small business indicator variable and $PREF_k$ is an indicator for whether auction k uses preferences. Each specification will include in X_k the log of the engineer's estimate, $ln(ENGEST)$, and dummy variables for each interaction of the number of small and large bidders.

Together, the estimates of β_1 and β_3 can be used to infer the effect of preferences on the behavior of small and large firms. For large firms (where $SB = 0$), the coefficient β_3 represents the extent to which large firms lower their bid in response to preferences. For small firms (where $SB = 1$), the coefficient on the preference auction dummy is $\beta_1 + \beta_3$.

Some specifications will control for firm effects, η_i, which account for the different participation patterns observed by small and large firms. If relatively strong large firms participate less often when preferences are used, then the coefficient β_3 will be biased upward. If some firms tend to be consistently weak or strong across auctions, then controlling for firm fixed effects will account for changes in the composition of auction participants.

Finally, even for projects where the engineer's estimate is less than \$1 million, the average preference auction is smaller than the average non-preference auction. Included in X_k will be a control for an interaction between the small business indicator and the engineer's estimate normalized by its mean, $ln(\widetilde{ENGEST_k})$, to account for the effect of project scale on small firm costs.

Table 3 displays the estimates of (2). The first two columns present results for a sample including all bids submitted on the set of contracts where the engineer's estimate is less than \$1 million. A necessary condition for preferences to reduce procurement costs is that unfavored firms be cost advantaged relative to small firms. The coefficient on the small business indicator variable is 0.014 and statistically significant. This suggests that while small and large firms are not drastically different, large firms do have a small advantage in costs. It is worth noting that low cost firms markup bids over costs more than high cost firms, indicating that the estimate of 0.014 represents a lower bound of the difference in costs between the average small and large firm.

For the full set of bidders, the impact of preferences on bids is estimated to be quite small. The average large firm bids 0.4 percent lower on preference auctions, while the average small firm bids 0.6 percent higher, neither of which are statistically significant.

The results presented in column (2) include controls for firm effects and suggest that the small difference in large firm bids between the two auction regimes are because the average large participant has higher costs in preference auctions. The results suggest that a given large firms bid 1.4 percent lower on preference auctions, and the difference between the bids of small and large firms on preference auctions is a statistically significant 1.6 percent. Combining these two coefficients again leads to the conclusion that the average small firm bids similarly on the two types of auctions. [11]

A logical extension to the specification given by (2) would be to include contract dummies. The principal advantage of contract dummies is that they can account for any cost shifters that affect all firms equally. However, this approach can only identify the relative impact of preferences on the bids of small and large firms and not the effect on the level of bids. Similar results obtain for the coefficient on the $SB * PREF$ variable when contract effects are included.

ONLY TOP BIDDERS

By considering all bids, the specifications displayed in columns (1) and (2) assume that the effect of preferences is constant throughout the cost distribution. However, firms receiving a high cost draw are already likely to be bidding close to costs, and introducing preferences is likely to have only a small impact. Therefore, if preferences are impacting bidding behavior, the effect should be largest in the lowest cost firms. Furthermore, the equilibrium winning bid is not highly sensitive to the bids of firms higher in the cost distribution. To assess the role of firms' bidding response to preferences in procurement costs, the behavior of the lowest cost firms will be most relevant.

The specifications shown in Columns (3) and (4) of Table 3 only consider the bids of the top small and large bidders. According to auction theory, the equilibrium bid function is monotonically increasing in cost. These firms should therefore have the lowest within-type cost on a particular auction. Preferences seem to affect the bid of the large firm similarly regardless of where in the cost distribution the firm lies. In the full specification, the low cost large firms bids 1.4 percent lower on preference auctions compared with 1.3 percent lower in the specification considering all bids.

The lowest cost small firms, however, are more able to increase their bid above cost than the small firms higher in the cost distribution. Relative to large firms, small firms bid 3.2 percent higher under bid preferences. This increase in the difference between small and large firms on preference auctions remains after controlling for firm effects. The estimated coefficient on the $SB * PREF$

[11] The effect of preferences on small firms may be understated due to the use of a proxy variable for small business status. Since the variable employed describes firms that ever bid as a small business, it will sometimes take on a value of one when the true value is zero but never take on a value of zero when the true value is one.

variable, controlling for firm effects, is 0.027, similar to the estimate of 0.032 in the specification without firm effects. Together with the estimate that low-cost large firms bid 1.3 percent lower on preference auctions, these results indicate that the lowest cost small firms bid 1.4 percent higher on preference auctions than auctions not using preferences.

While large firms are bidding somewhat more aggressively on preference auctions (subject to the caveat that the point estimates of β_1 are not statistically significant), this effect is offset by less aggressive bidding by the lowest cost small firms. One explanation is that the estimated difference between small and large firms may be too small relative to the bid preference percentage. If the difference were greater, a small firm may have less room to increase its bid over costs

3.3 Participation

Participation patterns could lead to a higher equilibrium winning bid if fewer firms participate in preference auctions, or if the set of participants have higher costs. This section examines the participation margin more closely, finding a consistent pattern of weaker large firm participation on preference auctions.[12]

The first goal of this section is to establish the effect of preferences on the number of bidders. Table 4 presents results from regressing the number of small and large bidders on a bid preference dummy. Without controlling for any auction characteristics, the mean number of small bidders on preference and non-preference auctions is nearly identical. The coefficient on the preference indicator is 0.07. Similarly, after controlling for observable auction characteristics, the coefficient is -0.02 and statistically insignificant. On the other hand, the number of large bidders is significantly affected by bid preferences. Preference auctions see .64 fewer large bidders than non-preference auctions. Some of this difference is accounted for by the characteristics of preference auctions. Since preference auctions tend to be smaller, they may attract fewer large firms. Even after accounting for auction covariates, the estimated effect of bid preferences is a reduction of 0.48 large firms.

How does this pattern affect the average quality of bidders? Recall from section 3.2 that including firm effects when estimating (2) has a notable effect on the estimated impact of preferences on bidding behavior. The coefficient on the preference auction variable approximately triples from -0.004 to -0.014 when firm fixed effects are included. Changes in the participation patterns of firms from different locations in the cost distribution could be one explanation.

[12]Reservation prices could be one source of variation in participation across auctions. In highway construction markets, these are typically set relative to the engineer's estimate, however they need not be binding. Often bids are observed well in excess of the engineer's estimate, suggesting that firms often expect that the reservation price will be waived.

Consider the estimates of the firm fixed effects, η_i in equation (2). Define a low cost small firm as one whose η_i is below the small firm median and define a low cost large firm similarly. Preference auctions effect the participation of low cost large firms the most. The average preference auction has 1.41 low cost large bidders compared with 1.87 for the typical non-preference auction. High cost large firms are also affected, but to a smaller degree. There are 0.18 fewer high cost large firms on preference auctions. The participation of small firms is affected to a much smaller degree. Preference auctions see 0.05 more low cost small firms than non-preference auctions, compared with 0.02 more high cost small firms.

These results are significant since existing theoretical results regarding the impact of bid preferences take participation to be an exogenously given variable. This assumption here seems to be a costly one, as any effect of preferences on bidding behavior is swamped by a fairly substantial response on the participation margin.[13]

4 Structural Estimation and Efficiency

Taken together, the results of section 3 form a fairly coherent picture of the impact of bid preferences on procurement costs and the behavior of firms. Small firms bid less aggressively in preference auctions, while large firms bid more aggressively but show up less often. The net effect of these forces is an increase in procurement costs of 3.5 percent.

Underlying the changes in procurement cost is a shift in economic efficiency. Preferences clearly involve a transfer of economic surplus among small firms, large firms, and the government. From a policy evaluation standpoint it is also important to understand how the size of the surplus to be divided is impacted by preferences. If all firms simply bid their cost, then a regression specification with the winning bid as the dependent variable would provide an estimate of the efficiency loss associated with the use of preferences. Yet preferences affect both markup over cost as well the cost of the winning bidder. For that reason, the reduced form approach is unable to uncover the efficiency loss associated with preferences. [14]

To remedy this shortcoming, this section employs a structural model to study how efficiency, defined as the construction cost of the winning firm, is affected by the use of preferences. In the

[13]The participation margin has been found to be an important consideration in other auction settings as well, however its impact on the outcomes of different auction regimes has been sparsely studied. Athey, Levin, and Seira (2004) for instance note the importance of participation effects when choosing between sealed and open bid auction regimes.

[14]Rezende (2004b) shows how OLS regressions similar to that presented in table 2 can be used to estimate the impact of covariates on firm valuations. However this methodology is potentially less powerful in settings with asymmetric auctions, where it will not uncover the distribution of valuations of the different classes of firms.

auction literature, efficiency loss is typically described by the difference between the lowest cost of the auction participants and the cost of the winning bidder. Extending this definition to include the effect of participation on the construction cost of the winning firm is appropriate if bid preferences alter expected profits and not the distribution of participation costs. If participation effects lead to fewer or higher cost bidders, then the expected cost of the winning bidder rises. If variation in participation across preference and non-preference auctions is driven by differences in participation costs, then fewer bidders – and consequently higher expected construction cost – represents an efficient outcome. On the other hand, if bid preferences distort the entry decision for a firm with a given cost by reducing expected profits, then a loss in efficiency occurs.

Two other strong assumptions of the expanded definition of efficiency are also worth noting. First, this definition assumes that the participation decision of a firm on one auction does not impact its participation decision on other auctions. However, if preferences lead a large firm to participate not only in fewer preference auctions but also in more non-preference auctions, then the higher expected construction cost in one is offset by lower expected costs in the other. In other words, the outcomes on zero preference auctions may not resemble the equilibrium outcomes in an economy without bid preferences. The definition of efficiency loss used in this paper may therefore overstate the efficiency loss due to participation. Finally, the efficiency loss can only be summarized by the change in construction cost if demand for road improvements is inelastic. Ignoring the elasticity of demand will also tend to overstate the efficiency loss.

Evaluating changes in construction costs associated with bid preferences requires estimates of unobserved firm costs. This section will describe a model of bid preferences in a first price sealed bid auction setting, and the model will be estimated using the nonparameteric techniques of Guerre, Perrigne, and Vuong (2000) to obtain the latent costs of firms. These costs can be used to calculate firm profits, as well as the construction cost of the winning bidder on preference and non-preference auctions. Furthermore, the distribution of costs of participants on nonpreference auctions can be used to simulate a counterfactual set of preference auctions holding participation fixed. Therefore, the effect of preferences on the construction cost of the winning bidder can be assessed, and this effect can be divided between the direct effect of preferences (altering the winning bidder given a set of participants) and the indirect effect working through participation.

4.1 A Model of Bid Preferences

Suppose the government wishes to purchase a road construction project through a first price sealed bid auction. Let there be two groups of bidders, small and large. On each auction, there are n_s ex ante identical small businesses and n_l ex ante identical large businesses, where n_s and n_l are exogenously given.

Prior to bidding, each firm learns its cost c, for auction k, which is drawn from from a type and auction specific distribution $F_{ik}(c)$. The cost draws are independent within bidder type and are private information; however, each bidder knows the distributions from which costs are drawn as well as the number of small and large bidders.

When comparing the bids of small and large firms the bids of the large firms are adjusted to form the comparison amount $z(b)$. Small firms are preferred if $z(b) > b$. Denote the low small and large firms' bids by $\underline{b_s}$ and $\underline{b_l}$ respectively. If $z(\underline{b_l}) > \underline{b_s}$, then the contract is awarded to the small firm at the value of its bid, $\underline{b_s}$. Similarly, if $z(\underline{b_l}) < \underline{b_s}$, then the contract is awarded to the large firm at the value of its bid, $\underline{b_l}$. While potentially suboptimal, the common form of the bid preference schedule adjusts the unfavored bids upward by a fixed percentage such that $z(b) = \theta b$.

Firms are risk neutral, and each firm chooses its bid, b, to maximize expected profits:

$$(b - c)Prob(win|b) \tag{3}$$

Let each firm's optimal bid be determined by a monotonic function of its costs, $b = \phi_{ik}(c)$, which is symmetric within bidder type and differs depending on the level of preference θ, the number of small and large bidders, and other characteristics of the auction k. Denote the equilibrium inverse bid function $c = y_{ik}(b)$. The small business objective function becomes

$$(b - c)(1 - F_{sk}(y_{sk}(b)))^{n_s - 1}(1 - F_{lk}(y_{lk}(b/\theta)))^{n_l} \tag{4}$$

The first term, $(b-c)$, represents the firm's profits should it win the auction. The second and third terms in parentheses represent the probability that the firm's bid is lower than all other bidders given that they are bidding optimally. The large firm's objective function can similarly be written

$$(b - c)(1 - F_{sk}(y_{sk}(\theta b)))^{n_s}(1 - F_{lk}(y_{lk}(b)))^{n_l - 1}. \tag{5}$$

The first order condition of (4) with respect to b reduces to

$$c = b - \left((n_s - 1)\frac{f_{sk}(y_{sk}(b))y_{sk}^{'}(b)}{1 - F_{sk}(y_{sk}(b))} + n_l \frac{f_{lk}(y_{lk}(b/\theta))y_{lk}^{'}(b/\theta)/\theta}{1 - F_{lk}(y_{lk}(b/\theta))} \right)^{-1} \tag{6}$$

with a similar first-order condition for the large firm:

$$c = b - \left(n_s \frac{\theta f_{sk}(y_{sk}(\theta b)) y'_{sk}(\theta b)}{1 - F_{sk}(y_{sk}(\theta b))} + (n_l - 1) \frac{f_{lk}(y_{lk}(b)) y'_{lk}(b)}{1 - F_{lk}(y_{lk}(b))} \right)^{-1} \tag{7}$$

Ideally one would like to obtain for auctions with and without preferences the function $c = y_{ik}(b)$ determining the mapping between costs and bids; however, an analytical solution to the system of differential equations described by (6) and (7) is not generally possible. This section will proceed by avoiding estimating this function directly by using the nonparametric methods of Guerre et al (2000).

4.2 Structural Estimation of Private Costs

Structural estimation uncovers the set of firm costs that rationalizes the set of observed bids, assuming that the observed bids represent the outcome of a Bayes Nash equilibrium. Under this assumption, the firm's latent costs can be inferred using the firm's first-order conditions from (6) and (7). Since b, n_s, n_l, θ and k are known, structural estimation proceeds by obtaining estimates of the other unknown elements of (6) and (9). Let $G_{ik}(b)$ be the distribution of bids for firms of type i, and let $g_{ik}(b)$ be its associated density. The monotonicity of $y_{ik}(b)$ implies that $G_{ik}(b) = F_{ik}(y_{ik}(b))$ and $g_{ik}(b) = f_{ik}(y_{ik}(b)) y'_{ik}(b)$. Therefore, given suitable estimates of g_{ik} and G_{ik}, $\widehat{g_{ik}}(b)$ and $\widehat{G_{ik}}(b)$, each small bidder's latent costs from (6) can be estimated from

$$c = b - \left((n_s - 1) \frac{\widehat{g_{sk}}(b)}{1 - \widehat{G_{sk}}(b)} + n_l \frac{\widehat{g_l}(b/\theta) \frac{1}{\theta}}{1 - \widehat{G_l}(b/\theta)} \right)^{-1} \tag{8}$$

and the latent costs of large firms from

$$c = b - \left(n_s \frac{\theta \widehat{g_{sk}}(\theta b)}{1 - \widehat{G_{sk}}(\theta b)} + (n_l - 1) \frac{\widehat{g_l}(b)}{1 - \widehat{G_l}(b)} \right)^{-1}. \tag{9}$$

Since bids submitted under one combination of small and large bidders are not comparable with bids submitted under another (n_s, n_l) combination, nor are bids submitted under auctions with preferences comparable with bids submitted under auctions without preferences, then $G_{ik}(b)$ and $g_{ik}(b)$ must be estimated separately for each (n_s, n_l) and for each θ.

Table 6 shows the number of bid observations at each (n_s, n_l) combination for preference (θ=1.05) and non-preference (θ=1.0) auctions. At many points in this matrix, there are very few observations with which to estimate the relevant distributions. Haile et al (2003) estimate those auctions for which they have greater than approximately 70 observations. Here, I will estimate the model for auctions with between two and five large bidders and between one and four small bidders. This allows both a rich set of bids as well as a rich set of auctions. Only three of these combinations have fewer than 100 observations. The results are qualitatively similar when this is expanded to include more auctions.

This estimation method assumes that the number of bidders is exogenously given, which in this setting will lead to a biased estimate of the underlying distribution from which costs are drawn. This method is able to identify only the distribution of auction participants. This significantly limits the counterfactual exercises that can be considered, since participation is not modelled explicitly and estimates of the distribution of all potential bidders are not derived.

Existing models of participation do not fit well with the patterns of participation observed in this market. Athey, Levin, and Seira (2004) estimate a model of participation with asymmetric bidders. Their approach, however, relies on two assumptions. First, firms pay an entry cost before learning their cost draw, which should lead to the participation decision being uncorrelated with the firm's *ex post* location in the value distribution. Second, entry costs are assumed to be concentrated, so that firms drawing from the relatively strong distribution always enter, while the weak firms are the marginal participants. Both of these assumptions are rejected here. First, the entry decision of large firms is sensitive to the preference regime, suggesting that in this market both firms should be considered marginal participants. Second, large participants tend to be stronger on non-preference auctions. This makes the cost distribution of participants sensitive to auction regime, which is not consistent with the assumption that firms learn their cost only after deciding whether to enter.

4.2.1 Project heterogeneity

Structural estimates of costs will be biased without controlling for project specific cost shifters. The bias enters through two channels. First, estimated costs will be biased downward on less complex projects and biased upwards on more complex projects. Since project size is correlated with the federal-aid status of the project, profits will be overstated for state funded projects. Second, unobserved heterogeneity spreads out the distribution of bids. This biases downward the estimate of the density $g(b)$ for a given bid, which leads to a downward bias in estimated firm costs.

While the first bias is obviously a problem when comparing preference and non-preference auctions, the second bias could be important as well. The impact of bid preferences on procurement costs works through the tradeoff between reducing the profits of large firms and awarding more contracts to higher cost firms. The evaluation of this tradeoff could be particularly sensitive to biases in the estimation of firm costs.

The auction literature has suggested several methods of incorporating project heterogeneity. Haile, Hong, and Shum (2003) suggest a method of controlling for auction characteristics by generating a pseudo bid that is conditional on covariates. They show that if there is a vector of characteristics, $\mathbf{y}$, that enters into firm costs linearly, such that $c_{ik}(\mathbf{y_k}) = c_{ik} + \Gamma(\mathbf{y_k})$, where c_{ik} is a firm's idiosyncratic cost draw, then the equilibrium bidding strategy will be linear in $\Gamma(\mathbf{y_k})$ as well. A firm's bid conditional on auction characteristics is obtained by regressing bids on a vector of auction characteristics and a dummy variables for each (n_s, n_l) combination. The sum of each residual and the (n_s, n_l) intercept yields the firm's bids on a generic (n_s, n_l) auction.

The assumption that firm costs are linear in the common and individual components is a strong one. One implication of this assumption is that the variance of bids on a particular contract is independent of the size of the project. This is rejected in the data. Denote the deviation of the bid from the contract mean by $b'_{kj} = b_{kj} - \overline{b_k}$. If bids are linear in the cost factor $\mathbf{y}$, then $var_i(b'_{kj}) \perp \Gamma_1(\mathbf{y})$. This can be tested by regressing $var_i(b'_{kj})$ on $\overline{b_k}$. The result of this regression indicates that every \$1 increase in the mean of the bids on an auction is associated with a .09 increase in the standard deviation of b'_{kj}.

An alternative approach is proposed by Krasnokutskaya (2003), who assumes that the firm's cost on a project is the product of a common component and a firm specific idiosyncratic component. Her approach then separately identifies the distributions from which the common and individual components are drawn. This approach performs markedly better than both independent private values and affiliated private values models, which tend to understate firm costs and overstate markups over costs. While the multiplicative form that permits identification also has the advantage of allowing the variance of bids to depend on the scale of the auction, this model requires that scale is independent of the distribution of the idiosyncratic component. This assumption will be violated if, for instance, small firms tend to have relatively higher costs as the size of the project grows.

This paper instead uses the approach taken by Flambard and Perrigne (2001) and Elyakime et al (1994) who allow the distribution $F_{ki}(c)$ to depend on auction characteristics, z_k, such that $F_{ki}(c) = F_i(c|z_k)$. Due to data requirements, z_k is typically measured as a single variable. Elyakime et al (1994) for instance study auctions of timber lots and use the estimated percentage of saw timber of the lot. The approach taken here will condition on the engineer's estimate.

The conditional distribution method has several advantages in the context of estimation of auctions with bid preferences. First, it does not require the value of bids to be adjusted as in Haile, Hong, and Shum (2003). In that case, the value of the bid preference applied to the conditional bid does not match the value applied on the original auction since the bid preferences in the California program are stated as a percentage of the bid.

Second, the distribution of costs of small and large firms is allowed to vary in an arbitrary way depending on the scale of the auction. This is important since large firms may bid less aggressively on larger projects knowing they face less competition from smaller firms. The effect of bid preferences on the expected profits of small and large firms could vary by the size of the auction as a result, which the conditional distribution approach would pick up.

Finally, this approach can yield consistent estimates of firm costs even if the engineer's estimate endogenizes the effect of the preference regime. Suppose that on preference auctions the observed engineer's estimate is a function of the "true" engineer's estimate, z': $z = \phi(z')$. Conditioning on the observed estimate will be equivalent to conditioning on the true estimate since $F(c|\phi(z')) = F(c|z')$ so long as $\phi(z')$ is monotonic.

4.3 Estimation method and results

The estimation of the elements of (8), $\widehat{g_i}(b|z)$ and $\widehat{G_i}(b|z)$, are obtained from observed bids using standard kernel techniques. Note that the conditional distributions are related to the joint distribution of b and z through $\widehat{g_i}(b|z) = \widehat{g_i}(b,z)/f_z(z)$ and $\widehat{G_i}(b|z) = \widehat{G_i}(b,z)/f_z(z)$, where $\widehat{f_z}(z)$ is the density of the engineer's estimate. The following nonparametric estimators are used to obtain the joint distributions of b and z, and density of z:

$$\widehat{g_i}(b,z) = \frac{1}{Kh_g^2}\sum_{k=1}^{K}\frac{1}{n_{ik}}\sum_{p=1}^{n_{ik}} K_g\left(\frac{b-b_{ipk}}{h_g}, \frac{z-z_k}{h_g}\right) \tag{10}$$

$$\widehat{G_i}(b,z) = \frac{1}{Kh_G}\sum_{k=1}^{K}\frac{1}{n_{ik}}\sum_{p=1}^{n_{ik}} 1I(b_{ipk} \leq b) K_G\left(\frac{z-z_k}{h_g}\right) \tag{11}$$

$$\widehat{f_z}(z) = \frac{1}{h_z K}\sum_{k=1}^{K} K_z\left(\frac{z-z_k}{h_z}\right). \tag{12}$$

According to the conditions provided by Guerre et al., the chosen kernel must have compact support and be continuously differentiable on its support, including the boundaries. Following Li, Perrigne, and Vuong (2000), I will use the triweight kernel

$$K(u) = \frac{35}{32}(1-u^2)^3 1(|u| \leq 1). \tag{13}$$

The kernel for the estimation of the joint density $\widehat{g_i}(b,z)$, K_g, is the product of two triweight kernels. The choice of kernel does not have a quantitatively important impact on the results. The use of the biweight kernel for instance yields similar estimated distributions. However, the results are somewhat sensitive to the choice of bandwidth. It is common practice to use the rule of thumb suggested by Hardle (1991), which sets the bandwidth according to $h_g = c_g * 1.06 * \hat{\sigma}(nL)^{-1/6}$, where c_g is a constant and $\hat{\sigma}$ is the standard deviation of the underlying data. As Hardle notes, however, the rule of thumb bandwidth is optimal only if the kernel resembles the true distribution of underlying data. Observed bids tend to be skewed significantly to the right, while commonly used kernels tend to be symmetric. Since the rule of thumb is calculated from the standard deviation, significantly skewed data will lead to an overstatement of the bandwidth. The constants c_g, c_G, and c_z will be set to 1.0, rather than 2.978 as suggested by the rule of thumb for the triweight kernel.[15]

Estimation of the components of (8) must be performed separately for preference and non-preference auctions, and for each combination of the number of small and large bidders. The reason is that the inverse equilibrium strategy is conditional on the preference parameter and the number of bidders. If all bids were considered, then for two bids b and b' on separate auctions, the relationship $G(b) > G(b')$ does not necessarily imply that $c > c'$.

Figures 2 and 3 display kernel estimates of the cost distributions for small and large participants on non-preference and preference auctions, evaluated at the median of the engineer's estimate. In auctions without preferences, the distribution of large firms dominates that of the small firms. For auctions with preferences, however, the estimated cost distribution of small and large participants are very similar except for very low cost values. This is a very striking pattern of participation. Consistent with the reduced form results, the reduced participation of stronger large firms on preference auctions is largely responsible.

How do the costs of the typical small and large firms vary with project size? Figure 4 plots the estimated median cost of small and large firms by the size of the project, as measured by the engineer's estimate. Except for projects where the estimate is between \$600,000 and \$700,000, the median cost of the small firm is higher than that of the large firm. Furthermore, the difference in median cost between small and large firm rises with project size. On smaller projects, the two types of firms are nearly identical, while on the largest projects the median cost of small firms is 9.2 percent larger than the median cost of the large firms.

BID PREFERENCES AND FIRM PROFITS

[15] The median markup estimated using the rule of thumb bandwidth is 14.8 percent. The markup for the bandwidth where c_g and c_G is set to 1.06 is 8.5 percent, which is closer to the 6.3 percent markup estimated in Krasnokutskaya (2002) from auctions for Michigan highway construction contracts.

To what extent do bid preferences affect the distribution of surplus between the government and firms? If firm costs are unchanged across auctions, then a specification like that in Table 2, where the winning bid is regressed on a preference auction dummy and a set of cost shifters, will yield an estimate that will place a sign on the effect of preferences on firm profits. Average firm costs are not necessarily the same in the two types of auctions though. The cost of the winning firm will be higher in preference auctions due to preferences changing the winner and due to the weaker set of large firm participants. Therefore, to assess preference's impact on the distribution of surplus, it is necessary to evaluate profits directly.

A pseudo sample of firm profits can be formed from the estimates of unobserved costs, which can be used to study the effect of bid preferences on the profits of small and large firms. Table 7 displays the results from a regression specification where the log of estimated profits is regressed on a small business dummy variable, a preference auction indicator, and an interaction term between small businesses and preference auctions. Controls include the engineer's estimate and dummy variables for each combination of small and large bidders.

The first column of Table 7 considers the profits of all bidders, regressing log profits on a small business dummy variable, a preference auction indicator, and an interaction term between small businesses and preference auctions. Controls include the engineer's estimate and dummy variables for each combination of small and large bidders. Small firms have less leeway to mark up bids over costs. Profits for these firms are 9.8 percent lower than those of large firms. Large firms are affected significantly by preferences. Large firm profits are on average 22.8 percent lower on preference auctions than non-preference auctions. Combining the preference coefficient and the small firm*preference interaction term suggests that profits of the average small firm are unchanged on preference auctions.

The second column of Table 7 considers only the low bidder on each auction. Consistent with the specification of bidding behavior described in section 3, the impact of preferences on the profits of the lowest cost large firm is largely unchanged. Profits for these firms are 23.9 percent lower on preference auctions.

Finally, the third column of Table 7 considers the effect of preferences on the profit of the winning bidder. The profits of the average winning firm are 10.5 percent lower than on non-preference auctions. While firms on average lose surplus on preference auctions, the government also pays more for similar procurement auctions. These two results suggest that bid preferences result in a significant loss in productive efficiency.

BID PREFERENCES AND CONSTRUCTION COSTS

When bid preferences are invoked and the higher bidding small firm is awarded a procurement contract, the winning small firm often has a higher cost than the lower bidding large firm. To what extent does this contribute to the lower efficiency on preference auctions? To answer this question, it is necessary to compare the cost of the winning firm with the cost of the firm who would have won in the absence of preferences, holding participation fixed. This is complicated for two reasons. First, since preferences have the effect of lowering the equilibrium bid of the large firm, some large firms now will submit the low bid who would not have otherwise. On the 800 preference auctions used in estimation, preferences were invoked 91 times. However, a significant fraction may not have altered the identity of the winning bidder and only the identity of the low bidder. Comparing the cost of the low bidder with the cost of the winning bidder will lead to an underestimate of the efficiency loss.

Second, unlike in the case of symmetric auctions, Maskin and Riley (2000) show that in an asymmetric auction the low cost firm is not necessarily the auction winner. As a result, comparing the cost of the auction winner with the lowest cost could prove misleading as well. In the auctions where preferences are invoked, this comparison leads to an overstatement of the efficiency loss. However, the sign of the bias in this comparison is not clear. When preferences are not invoked, the response of bidders to preferences could make the likelihood of the low cost firm losing either more or less likely.

The approach taken in this section will take the average difference between the winning cost and the lowest cost on preference auctions, and compare this with the the similar difference on non-preference auctions. Comparing these differences will account for both of the potential biases mentioned above. Table 8 shows this comparison. Of 800 preference auctions, the low cost firm loses 44 times compared with twice on the 399 non-preference auctions. The average efficiency loss is $823 per preference contract and $29.45 per non-preference contract. If preference auctions had a similar expected efficiency loss, then construction costs would on average be $793.7 lower. This represents 0.28 percent of the total construction cost on preference contracts. This suggests that the use of preferences results in a relatively small loss in efficiency.

4.4 Simulation

The correlation of participation and the distribution of costs with the preference regime suggests that the entry decisions of firms from different parts of the cost distribution is an important component of the impact of preferences. The reduced form results suggest that participation effects are responsible for most of the increase in procurement costs on state funded contracts.

This section considers what the preference auctions would have looked like had the participation patterns of firms been unchanged from that observed in non-preference auctions. From this counterfactual, the difference in the winning bid and construction cost on preference and non-preference auctions can be decomposed into the effect of participation and the direct effect of the invocation of preferences. To accomplish this, numerical methods are used to obtain the inverse bid functions of small and large firms for preference auctions under the counterfactual assumption that the distribution and expected number of participants is the same as that observed on *non-preference* auctions. The inverse bid functions are also obtained for preference and non-preference auctions using the actual participation patterns observed for those auction regimes. From these computed bid functions, a set of auctions can be simulated for three scenarios – non-preference auctions with actual participation, preference auctions with the counterfactual non-preference participation, and preference auctions with actual preference participation.

As noted, the system of differential equations defined by the firms' first-order conditions does not have an analytical solution in the case of asymmetric bidders. It is therefore necessary to use numerical methods to solve for the equilibrium bid function. Bajari (2001) suggests parameterizing the bid function as a fifth-order polynomial, and then minimizing the squared deviation between the firm first-order condition over the set of parameters characterizing the bid function of small and large firms. Here I will describe the method first without considering bid preferences, and then describe how bid preferences enter.

Let all firms draw from a cost distribution with support on $[\underline{c}, \overline{c}]$. According to Maskin and Riley (1996), the unique equilibrium is characterized by three conditions.

(i) For each firm, $y_i(\overline{c}) = \overline{c}$

(ii) At the lowest cost, all firms bid β*:* $y_i(\beta) = \underline{c}$

(iii) Each firm's first-order condition holds for all b.

Conditions (i) and (ii) describe boundary conditions for each auction participant. These constrain the bid functions to be identical for small and large participants at the endpoints of the cost distribution.

Let the bid function take the form

$$y_i(b; \underline{b}, \alpha) = \underline{b} + \widetilde{y}_i(b; \alpha) \tag{14}$$

where

$$\widetilde{y}_i(b; \alpha) = \sum_{k=0}^{5} \alpha_{i,k}(b - \underline{b})^k. \tag{15}$$

Let $G_i(b; \underline{b}, \alpha) = 0$ denote the first-order condition of firm i. Bajari's method evaluates the first-order conditions on a grid of k uniformly spaced points between $\underline{b}$ and $\bar{b}$. The first-order conditions for each firm at each point in the grid, along with the $2N$ boundary conditions are used to define a least-squares objective function:

$$H(b, \alpha) = \sum_i \sum_k G_i(bgrid_k, \underline{b}, \alpha)^2 + \sum_i (\underline{c} - y_i(\underline{b}; \underline{b}, \alpha))^2 + \sum_i (\bar{c} - y_i(\bar{c}; \underline{b}, \alpha))^2. \tag{16}$$

Preferences can be included in this model by modifying the boundary condition (ii). Without preferences, the bid at the lowest cost must be the same for the two firms since the marginal competition faced by each at this cost is identical. This relationship is broken with preferences, as the optimal bid for large firms at the lowest cost will now be lower than the optimal bid for small firms. With preferences, therefore, condition (ii) is altered to allow $\underline{b}$ to vary depending on the firm type.

To implement this method, the cost distribution estimated in section 4.3 is parameterized using a Weibull distribution:

$$f_i(c|\theta, z_0) = \alpha_i(\theta)\beta_i(\theta)c^{(\alpha_i(\theta)-1)}e^{-(c/\beta_i(\theta))^{\alpha_i(\theta)}} \tag{17}$$

where $\alpha_i(\theta)$ and $\beta_i(\theta)$ are type-specific parameters that depend on the preference regime, and z_0 represents the engineer's estimate. This distribution has support over positive values of c, and allows for a non-symmetric cost distribution. The parameters of $f_i(c|\theta, z_0)$ are estimated for $z_0 = med(z)$ by minimizing the squared distance between the Weibull density and kernel density estimates evaluated at the median of the engineer's estimate.

Using the above methodology, the bid function for preference and non-preference auctions will be computed for three cases – non-preference auctions with observed non-preference participation patterns, preference auctions with participation patterns observed on non-preference auctions, and finally preference auctions with observed preference participation patterns. For each of these three cases, the number of small and large participants will be drawn with probability $p(n_i|\theta)$, which is obtained from the observed likelihood of an auction with preference level θ having n_i bidders. For each of these participants, a cost will be drawn from the estimated Weibull distribution $f_i(c|\theta, z_0)$. Finally, a bid for each firm is generated from the inverse bid function $y_i(b|\theta, n_s, n_l, f_i(c|\theta, z_0))$. This allows the effect of preferences to be evaluated under actual participation patterns as well as the counterfactual participation patterns observed in non-preference auctions.

RESULTS

Figures 5 and 6 display the computed bid functions for small and large firms when $n_s = 2$ and $n_l = 3$. This number of small and large firms is near the average number of participants observed in the data. The effect of preferences on the computed bid function is small but fits closely with expectations. At a given cost bid preferences lower the equilibrium large firm bid. The effect of preference auctions is dampened by the participation effect. Having higher cost participants shifts the bid function up for the case with actual participation in preference auctions relative to the counterfactual case using non-preference participation. A similar pattern emerges from the small firm bid functions. Holding participation constant, bid preferences shift up the bid function for small firms. Allowing the participation to differ shifts the small firm bid function up even further since in preference auctions each small firm faces higher cost competitors. For both small and large firms the bids of the lowest cost firms are affected the most, and this effect is most pronounced among small firms.

Table 9 displays the simulation results. In column (1), the average outcomes for small and large bidders is described for non-preference auctions. Large firms tend to have lower cost, and this cost difference is amplified by the fact that there are more large firms. Consistent with having lower average costs, large firms have a slightly higher mark-up of bids over costs.

In Column (2), preferences are added to the model holding fixed participation patterns. Consistent with this, the average number of small and large firms is virtually identical with those in the simulation of column(1). Small firms seem to benefit from the introduction of preferences, while large firms earn lower profits. The average large firm reduces its bid by \$4037, while the average small firm increases its bid by \$478. This is also reflected in average markups, which are now higher for small firms and lower for large firms. The lower profits earned by large firms translates into a winning bid that is \$4784 lower in preference auctions. This suggests that had the participation of large firms remained constant across preference and non-preference auctions, procurement costs would have fallen as suggested by theory. Surprisingly, the winning cost is also reduced slightly.

Finally, column (3) describes the results from simulated preference auctions where the number and distribution of firms matches that observe in actual preference auctions. The higher cost set of participants has two conflicting effects on the bids of firms. Each firm faces weaker competition, which tends to increase bids. However, the average firm has higher costs, leading to a lower ability to markup bids over costs. The first effect seems stronger, as the markups of small and large firms are higher when competition is weaker. Finally, the weaker set of participants results in a higher average winning construction cost. The cost of the average winning firm is \$211,042, 6.5 percent higher than for non-preference auctions. This increase in construction costs is due entirely to the effect of participation, which apparently swamps the impact of preferences occasionally switching to higher cost firms.

5 Conclusion

Public procurement of goods and services is a significant means of redistribution across economic agents. Bid preferences have the potential to achieve redistribution while at the same time lowering procurement costs to the government. This paper shows that preferences may lower procurement costs holding the participation of firms constant at little cost to efficiency. However, entry is endogenous to the preference regime used. The effects of participation on procurement costs and economic efficiency swamp the effects of preferences on bidding behavior and altering the auction winner. This suggests that participation is a primary concern when considering procurement policies that treat firms asymmetrically.

The fact that procurement costs tend to rise is not itself evidence that the bid preference schedule is suboptimal. McAfee and McMillan (1989) show that if the favored group's profits enter positively into the social welfare function, then the optimal bid preference is always positive. While weaker in their conclusions, Naegelen and Mougeot (1998) and Branco (1994) also show that favoritism could lead to positive optimal bid preferences even if an increase in procurement costs results. Even still, there is reason to believe that California is not setting the preference schedule in an optimal manner. Since the preference amount is capped at $50,000, the size of the preference declines relative to a firm's bid for bids greater than $1 million. This means that for larger projects, as the project size increases the preference percentage declines. However, as project size increases, the costs of small firms increase more than proportionally. Consequently, it is possible that the preference percentage should be increasing rather than decreasing as projects get larger, depending on how the participation patterns of firms are altered.

Evaluating the optimal bid preference schedule, or investigating the effects of bid preferences for counterfactual groups, requires a more complete model of participation.[16] Without such a model, evaluating counterfactuals far from what is observed is difficult. For instance, firms located in economically disadvantaged areas are given favorable treatment in many federal procurement auctions. Since firm location is observed in the California road construction data, it would be possible to derive an estimate of the impact of bid preferences for these firms. However, since preference auctions for these firms are not observed, the data provides no guidance for how the participation of firms might respond. With a model of participation, it would be possible to incorporate the entry response of firms from disadvantaged and non-disadvantaged areas.

[16]Examples might include preferences for firms located in economically disadvantaged areas or minority and women owned firms.

A further limitation of this paper is that it does not consider how the equilibrium market structure is impacted by bid preferences. The comparison this paper makes is between preference and non-preference auctions, however non-preference auctions may be a poor benchmark for the patterns one would see in an economy without a bid preference program at all. First, bid preferences might act to distort firm investment incentives. Since the criteria for program eligibility is based on firm revenues and number of employees, bid preferences could impact the optimal firm size. If there are scale effects, for example through learning by doing, then the preference program could induce some firms to choose a firm size that is inefficient.[17] The true efficiency loss of the bid preference program may be understated as a result. Conversely, if the bid preference program leads to higher survival rates for small firms, then the number of firms in the market will increase leading to more competition in the market. The existing evidence regarding the impact of procurement policies on the number and size of firms is limited and suggests future research.[18]

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Figure 1: Propensity to Claim Small Business Status Among Firms that Ever Did

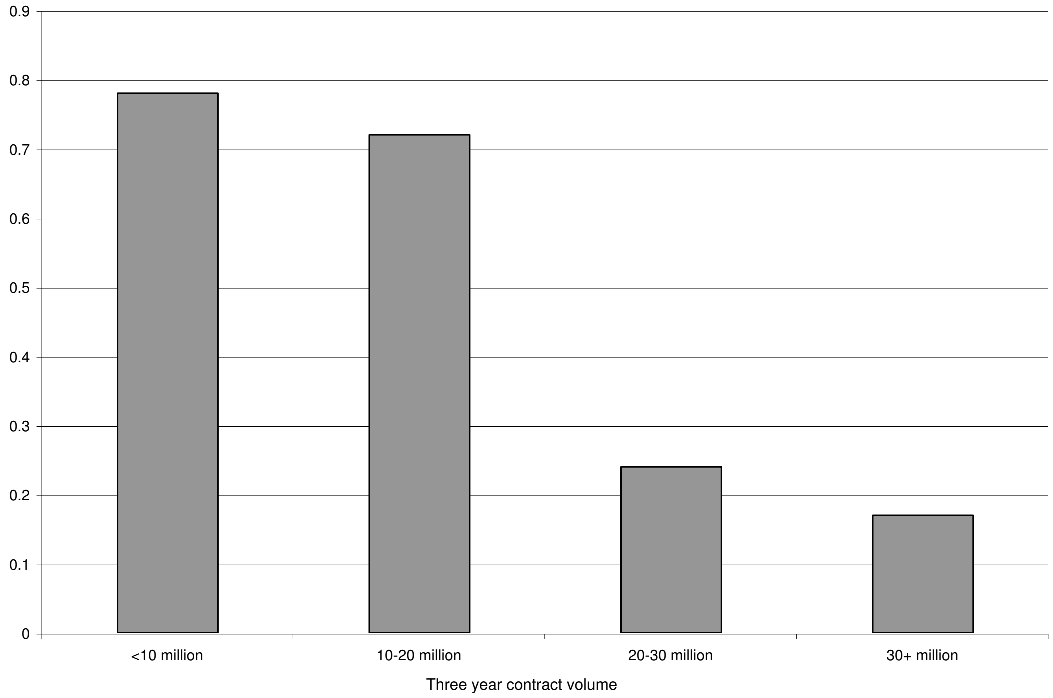

Figure 2: Conditional Distribution of Firm Costs, Evaluated at the Median of the Engineer's Estimate for Non-Preference Auctions

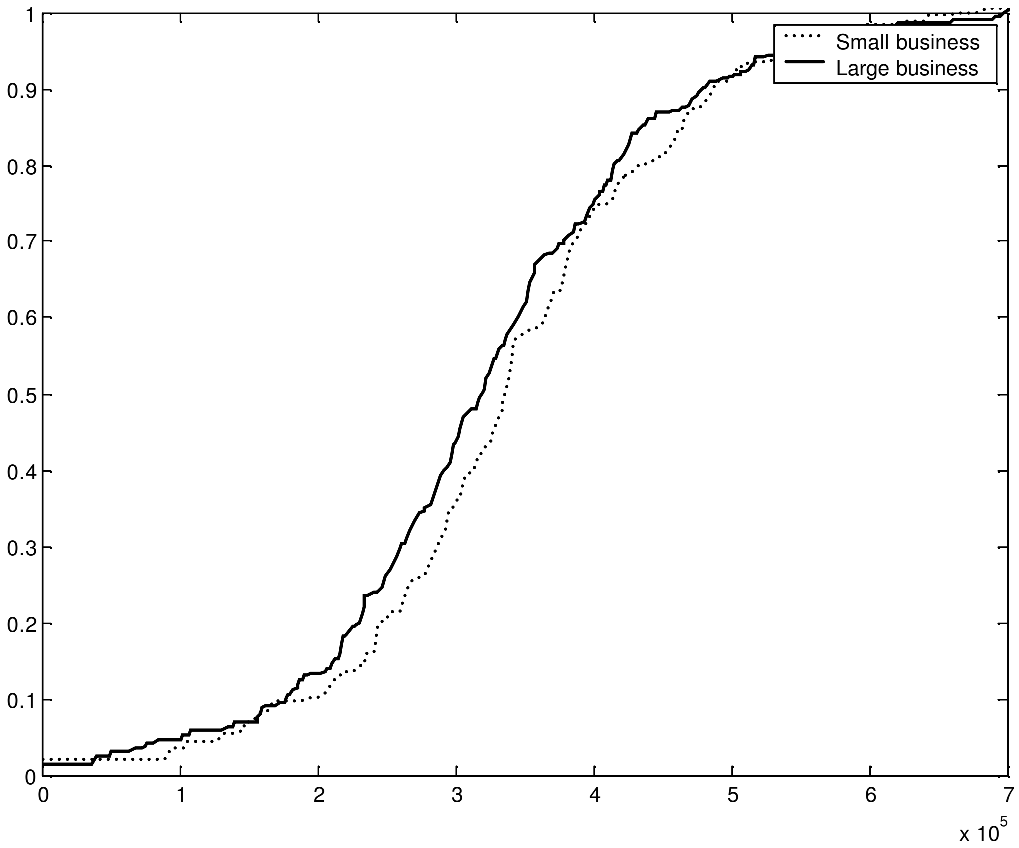

Figure 3: Conditional Distribution of Firm Costs, Evaluated at the Median of the Engineer's Estimate for Preference Auctions

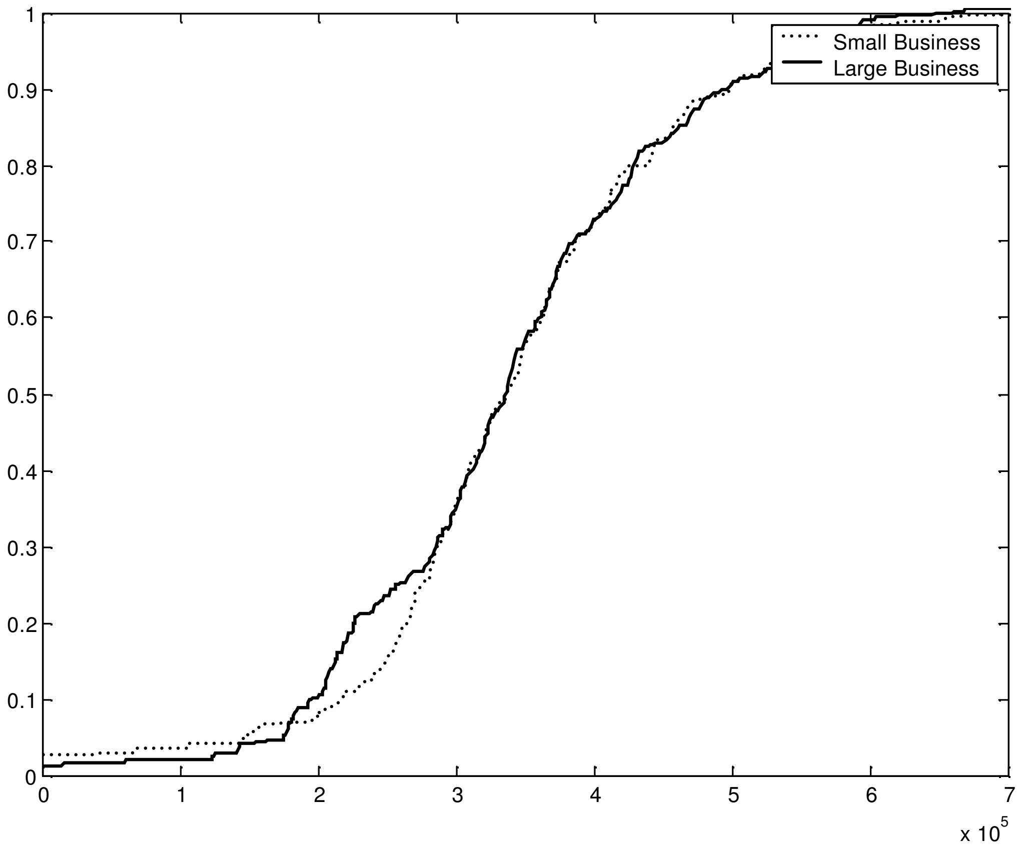

Figure 4: Median Cost by Estimate

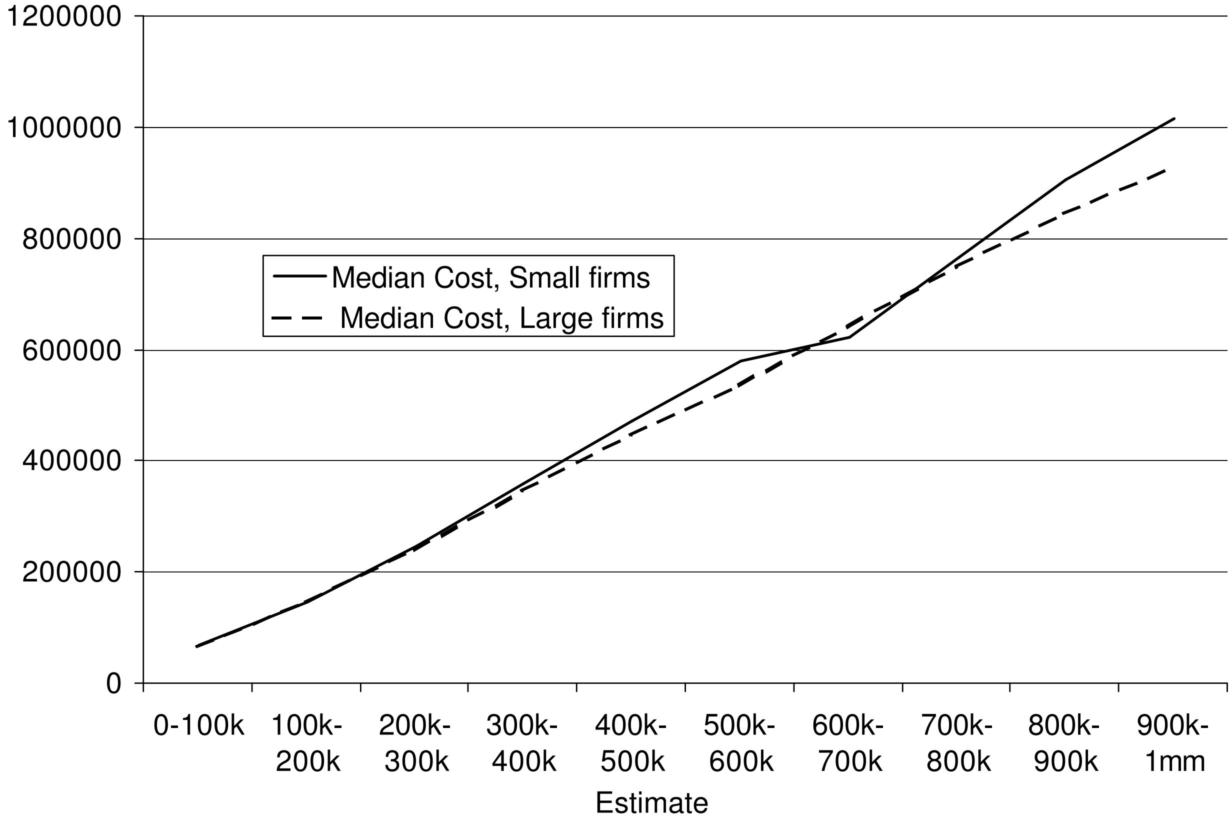

Figure 5: Large Firm Bid Function, $n_s = 2$, $n_l = 3$

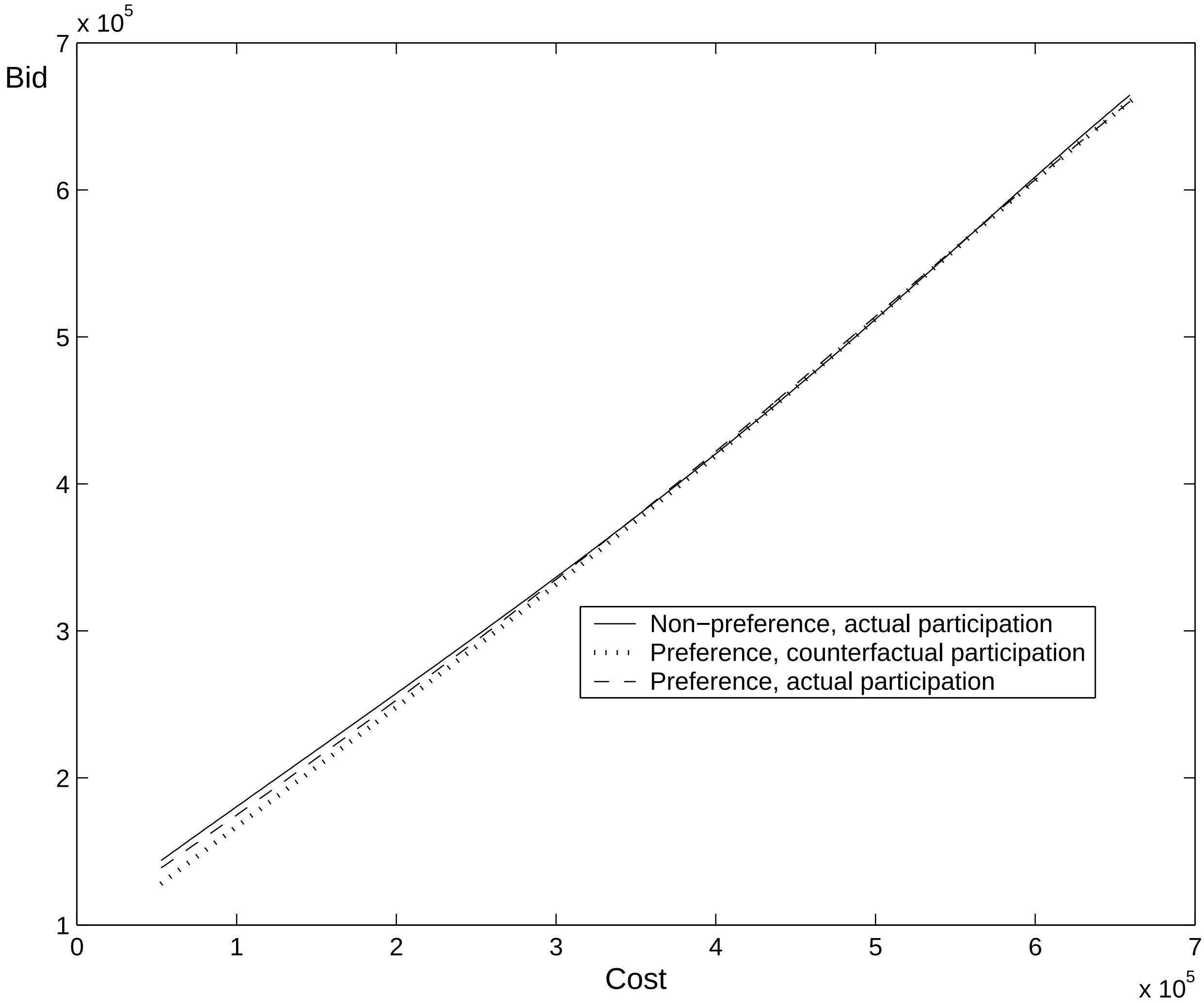

Figure 6: Small Firm Bid Function, $n_s = 2$, $n_l = 3$

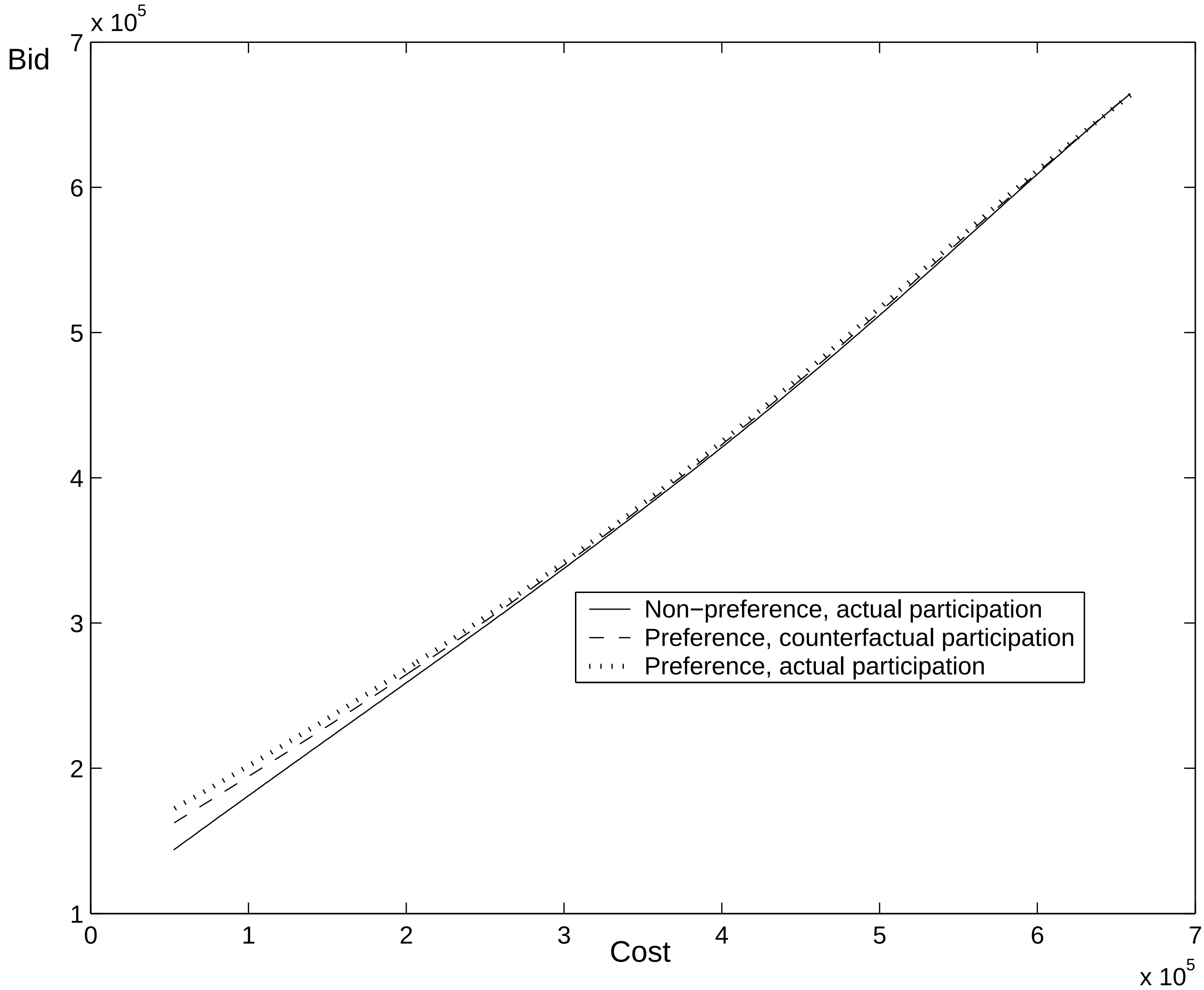

Table 1: Summary Statistics

	State funded Contracts	Federal-aid contracts
Panel A: All projects		
Contracts	2163	2110
Median winning bid	\$0.32 million	\$1.23 million
Median Engineer's Estimate	\$0.36 million	\$1.33 million
Avg. Small bidders	2.28	1.52
Avg. Large bidders	3.20	3.96
Fraction of bidders small	0.41	0.28
Fraction of winners small	0.40	0.21
Winner changed by preference	0.06	–
Fraction of auctions by type of road:		
State highway	0.57	0.60
Interstate	0.31	0.28
U.S. Highway	0.08	0.12
Other	0.04	0.04
Fraction of auctions by type of project:		
Road Construction and Repair	0.50	0.64
Bridge Construction and Repair	0.05	0.06
Landscaping	0.06	0.09
Drainage	0.05	0.05
Panel B: Projects where estimate < \$1 million		
Contracts	1843	856
Median winning bid	\$0.28 million	\$0.41 million
Median Engineer's Estimate	\$0.29 million	\$0.44 million
Avg. Small bidders	2.39	2.33
Avg. Large bidders	2.99	3.62
Fraction of bidders small	0.45	0.39
Fraction of winners small	0.44	0.34
Winner changed by preference	0.07	–
Fraction of auctions by type of road:		
State highway	0.58	0.65
Interstate	0.30	0.25
U.S. Highway	0.08	0.12
Other	0.04	0.03
Fraction of auctions by type of project:		
Road Construction and Repair	0.52	0.53
Bridge Construction and Repair	0.05	0.04
Landscaping	0.07	0.11
Drainage	0.06	0.07

Table 2: Preference auctions and the winning bid

	(1)	(2)	(3)
Preference Auction	0.035	0.018	-0.005
	(0.013)***	(0.013)	(0.015)
$Ln(\widetilde{ENGEST})$	0.963	0.965	0.967
	(0.012)***	(0.011)***	(0.012)***
Workdays (X100)	0.005	0.001	-0.000
	(0.004)	(0.004)	(0.005)
Number of items (100)	0.419	0.461	0.355
	(0.048)***	(0.048)***	(0.057)***
DBE % requirement	0.252	0.220	0.206
	(0.133)*	(0.129)*	(0.150)
Constant	-0.004	0.011	-0.783
	(0.175)	(0.160)	(0.736)
Bidder Controls?	No	Yes	Yes
Firm Effects?	No	No	Yes
Observations	2685	2685	2685
R-squared	0.89	0.91	0.95

The dependent variable is the log of the winning bid.
Each specification controls for road, county, year, and month effects, as well as dummies indicating the broad category of work. $LN(\widetilde{ENGEST})$ is the log of the engineer's estimate relative to its mean.
*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.
Robust standard errors in parentheses.

Table 3: Preferences and firm bidding behavior

	All bids		Top small and large bidders	
	(1)	(2)	(3)	(4)
SB*Pref. Auct.	0.010	0.016	0.032	0.027
	(0.009)	(0.010)*	(0.014)**	(0.016)*
SB	0.014		0.038	
	(0.007)**		(0.010)***	
Pref. Auction	-0.004	-0.014	-0.006	-0.013
	(0.012)	(0.011)	(0.015)	(0.015)
$Ln(\widetilde{ENGEST})$	0.942	0.937	0.946	0.944
	(0.012)***	(0.010)***	(0.018)***	(0.015)***
SB*$ln(\widetilde{ENGEST})$	0.008	-0.005	0.029	0.014
	(0.008)	(0.008)	(0.016)*	(0.015)
Workdays (X100)	0.006	0.008	0.001	0.004
	(0.003)*	(0.003)**	(0.004)	(0.004)
Number of items (X100)	0.283	0.242	0.406	0.323
	(0.039)***	(0.039)***	(0.046)***	(0.048)***
DBE % requirement	0.032	-0.005	0.138	0.113
	(0.104)	(0.104)	(0.118)	(0.126)
Constant	0.616	0.730	0.419	0.191
	(0.171)***	(0.153)***	(0.237)*	(0.219)
Firm Effects	No	Yes	No	Yes
Observations	14738	14738	4542	4542
R-squared	0.87	0.90	0.89	0.93

Dependent variable is the log bid. Columns (1) and (2) use all bids, while Columns (3) and (4) only consider the top small and large bidder on each auction.
Each specification controls for road, county, year, and month effects, as well as dummies indicating the broad category of work and the number of small and large participants.
$LN(\widetilde{ENGEST})$ is the log of the engineer's estimate relative to its mean.
Standard errors are adjusted for clustering by contract.
*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.

Table 4: Selection regressions

	Dependent variable:			
	Small bidders		Large bidders	
Preference Auction	0.07	-0.02	-0.64	-0.48
	(0.09)	(0.10)	(0.08)***	(0.09)***
Controls?	No	Yes	No	Yes
N	2698	2686	2698	2686
R2	0.00	0.32	0.02	0.22

Controls include the engineer's estimate, number of workdays, number of items, indicators for the type of work to be performed, plus year, county and road effects.
*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.

Table 5: Mean number of high-cost and low-cost bidders

	Preference Auctions	Non-preference Auctions
Low cost small bidders	1.18	1.13
High cost small bidders	1.18	1.16
Low cost large bidders	1.41	1.87
High cost large bidders	1.52	1.70
N	1843	855

Firm is defined as low cost if its firm effect from a regression of log bid on preference*sb interaction, small business dummy, preference auction indicator, and controls is below the within-type median.
*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.

Table 6: Number of bid observations by number of bidders

Panel A: Preference Auctions

	Large bidders												
	0	1	2	3	4	5	6	7	8	9	10	11	15
Small													
0	0	21	195	318	376	159	124	35	15	0	0	0	0
1	12	109	273	327	314	264	145	32	36	20	24	0	0
2	31	219	289	391	260	194	109	50	90	0	0	0	0
3	49	187	321	284	260	147	70	99	33	24	26	14	18
4	62	186	298	280	173	107	50	44	12	0	0	13	0
5	60	131	154	70	69	70	33	48	13	56	0	0	0
6	60	91	95	130	67	76	24	0	40	0	0	0	0
7	28	80	124	60	64	11	39	14	13	0	0	0	19
8	16	27	39	11	105	38	14	0	63	0	0	0	0
9	9	20	32	23	11	14	45	0	17	0	0	0	0
10	0	11	12	26	0	0	0	0	34	0	0	0	0
11	0	12	0	28	45	0	0	0	0	0	0	0	0
12	0	0	14	15	0	0	0	19	0	0	0	0	0
13	0	0	0	0	0	0	18	20	0	0	0	0	0
14	0	0	16	0	0	0	0	0	0	0	0	0	0
17	0	0	0	20	0	0	0	0	0	0	0	0	0

Panel B: Non-preference Auctions

	Large bidders													
	0	1	2	3	4	5	6	7	8	9	10	11	12	14
Small														
0	0	16	64	129	102	118	48	70	32	18	0	0	0	0
1	4	56	111	143	220	162	68	81	36	30	11	0	26	0
2	12	63	139	148	154	105	72	71	20	10	12	0	14	0
3	15	44	137	131	159	116	90	46	22	36	13	0	15	0
4	4	65	83	95	123	98	59	11	24	26	0	15	0	0
5	15	27	81	31	36	69	0	60	13	0	0	0	17	0
6	0	7	24	53	20	11	0	26	27	0	0	0	0	0
7	7	8	17	50	54	47	0	0	45	0	0	0	38	0
8	0	18	8	11	12	25	14	0	0	0	0	0	0	22
9	0	0	9	24	26	0	0	0	17	0	38	0	0	0
10	0	11	12	0	0	0	0	17	0	0	0	0	0	0
11	0	0	12	0	29	0	0	0	0	0	0	0	0	0
12	0	0	0	30	16	17	18	0	0	0	0	0	0	0
13	0	0	0	0	0	18	0	0	0	0	0	0	0	0
14	0	0	0	0	0	19	0	0	0	0	0	0	0	0

Table 7: Bid preferences and profits

	All bidders (1)	Top bidders (2)	Winning firm (3)
SB*Pref. Auction	0.218	0.260	
	(0.046)***	(0.068)***	
SB	-0.098	-0.259	
	(0.038)**	(0.055)***	
Pref. Auction	-0.228	-0.239	-0.105
	(0.029)***	(0.048)***	(0.049)**
SB*$ln(\widetilde{ENGEST})$	-0.005	-0.081	
	(0.035)	(0.051)	
$Ln(\widetilde{ENGEST})$	0.462	0.561	0.581
	(0.022)***	(0.036)***	(0.037)***
Constant	3.793	3.177	3.137
	(0.297)***	(0.478)***	(0.497)***
Observations	5943	2318	1198
R-squared	0.30	0.28	0.31

The dependent variable in this regression is the log of the difference between a firm's bid and a nonparametric estimate of its cost.
Controls for dummies for each combination of small and large bidders. $LN(\widetilde{ENGEST})$ is the log of the engineer's estimate relative to its mean.
*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.

Table 8: Bid Preferences and Construction Costs

	Preference Auctions	Non-preference Auctions
Low cost firm loses		
Number of auctions	800	399
Avg. Procurement cost	287649.6	391035.7
Low cost firm loses	44	2
Efficiency loss/contract	823.16	29.45
Difference:	*$793.71*	
As %	*0.28%*	

Table 9: Simulation results: Preferences, Participation, and Efficiency

	Non-preference simulations	Preference Simulations	
Assumed Participation:	*Actual*	*Counterfactual*	*Actual*
	(1)	(2)	(3)
Large firm bid	355.2	351.1	375.1
Large firm margin	14.9%	13.4%	13.8%
Low large firm bid	276.6	270.8	291.8
Small firm bid	364.3	364.8	382.7
Small firm margin	13.3%	13.8%	15.2%
Low small firm bid	323.6	324.4	342.3
Winning bid	255.1	250.3	270.4
Winning cost	198.2	196.7	211.0
n_s	2.12	2.15	2.14
n_l	3.33	3.32	3.11
Simulated auctions	5000	5000	5000

These are average results for 5000 simulated auctions in thousands of dollars, where the number of participants are drawn with probabilities matched to those in the data. Each participant is given a cost draw from a Weibull distribution, whose parameters are fit to match kernel density estimates of costs at the median of the engineer's estimate.

Column (1) displays simulations of non-preference auctions using participation patterns and cost distributions observed from participants in non-preference auctions.

Column (3) shows simulations of preference auctions using participation and cost distributions estimated from preference auctions.

Column (2) presents the counterfactual exercise where preference auctions are simulated using participation probabilities and cost distributions from non-preference auctions.