Disadvantaged Business Enterprise Goals in Government Procurement Contracting: An Analysis of Bidding Behavior and Costs

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Motivation

- Minority preference policies have been a part of government procurement programs in the United States since the late 1960's.
- Their goals are to:

  ⇒ enhance the opportunities of minority businesses (DBE) and

  ⇒ counter the effects of past discrimination.
- Two incentive schemes have been used:

  ⇒ requiring participation of DBE as subcontractors and

  ⇒ bid preference programs.
- Critics of these policies claim that they result in reverse discrimination, limit competition, and raise project costs.
- Number of studies have attempted to quantify the effect of various DBE policies.

  ⇒ Results are mixed – Ayres and Crampton (1996), Denes (1997), Holzer and Neumark (2000), Krasnokutskaya and Seim (2007), Marion (2007a & b, 2009).

Motivation (cont.)

- **Our analysis focuses on policies that set DBE participation goals.**
- DBE rule requires that prime contractors subcontract out a set percentage of the overall value of a project to minority firms.
- Such a requirement could affect the prime contractor's make-or-buy decisions in two ways.
  - ⇒ It may influence the overall level of subcontracting a firm uses on a project.
  - ⇒ It may also influence who the firm subcontracts with on a project.
- **This paper examines whether project costs differ between auctions that have DBE goals and auctions without such goals.**

Our approach

- We employ a structural auction model to infer contractors' costs from observed bids in order to compare the costs across project types.

- We use nonparametric methods developed by Guerre, Perrigne, and Vuong (2000) and Haile, Hong, and Shum (2006) to estimate the distribution of latent costs, allowing us to control for project heterogeneity and selection.

Our results

- Our findings show that there is little difference in costs between projects that are assigned DBE goals and projects that are not assigned such goals.
- When we examine an even more homogeneous sample of projects, we find even greater similarity in costs between the two project groups.
- We also construct estimates of the markup of the bid above the cost and find that the magnitude of the markup is consistent with that reported in the literature and varies little between auctions with and without DBE requirements.

Data

Our firm-level auction data were obtained from The Texas Department of Transportation (TxDOT)

- Data contain information on bidding activity for highway construction contracts.
- They span the period between 1998 and 2007.
- All projects are auctioned off using a first-price sealed-bid format.
- The data set contains information on project types, the engineer's cost estimate for each project, the number of bidders that requested plans, the number of bids submitted per project, the winning bidders, the winning bids, Federal or State project, and DBE goal.
- It also contains the location, complexity of each project, the number of days until its completion, and subcontractor information.

Overview of the Auction Setting.

- First price sealed bid auctions are held monthly.
- The low bid is typically awarded the contract.
- A list of projects for a month is made available to bidders shortly after the prior months bid letting.
- A firm that wishes to bid on a project must purchase a plan from the state. Firms purchasing plans are referred to as plan holders. Plans include details of the project plus a list of project items.
- The identity of plan holders is public information and is known to all bidders prior to the bid letting.

Overview of DBE goals and paving projects.

- DBE goals range from zero to 15 percent with about two-thirds of projects having DBE goals above zero.
- State projects and federally funded projects of less than $400,000 do not have DBE goals.
- Paving projects make up about one half of the overall number of projects.

Figure 2: Average Relative Bid for Paving Projects by DBE intensity.

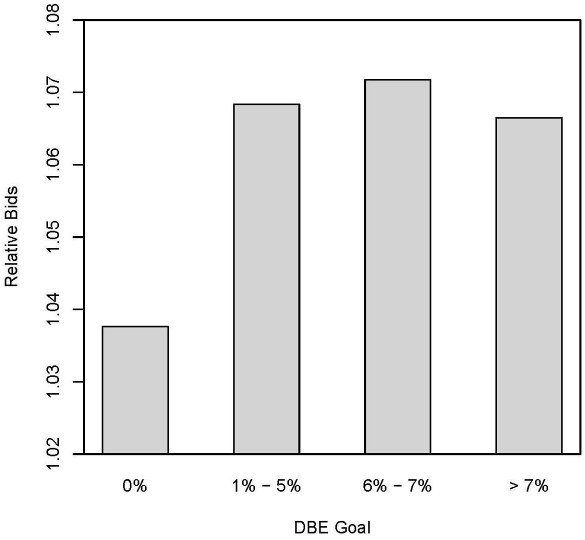


Table 1: Summary statistics.

Variable	Without DBE Goals	With DBE Goals
Number of projects	1839	1220
Number of state projects	1241	-
Average number of bidders	3.805	3.892
	(1.774)	(1.922)
Average engineer's cost estimate	2.969	4.240
(in millions of dollars)	(2.824)	(3.913)
Average relative bid	1.035	1.066
	(0.192)	(0.176)
Average number of bid components	40.506	81.560
	(30.181)	(49.509)

Table 2: Descriptive bid regressions.

Variable	Log of Bids				
	(1)	(2)	(3)	(4)	(5)
DBE projects	0.051*	0.003	0.001		
	(0.008)	(0.008)	(0.008)		
State projects	-0.010	-0.002	0.004		
	(0.008)	(0.008)	(0.008)		
DBE: 0% (Fed projects)				-0.003	0.003
				(0.008)	(0.036)
DBE : 1% - 5%				0.001	0.008
				(0.009)	(0.038)
DBE : 6% - 7%				-0.004	0.003
				(0.010)	(0.039)
DBE : $>$ 7%				-0.009	-0.001
				(0.010)	(0.039)
Log ECE	0.973*	0.954*	0.943*	0.944*	0.944*
	(0.004)	(0.003)	(0.005)	(0.005)	(0.005)
Log complexity		0.073*	0.054*	0.055*	0.054*

Table 2: Descriptive bid regressions (cont.)

Variable	Log of Bids				
	(1)	(2)	(3)	(4)	(5)
Log complexity		0.073*	0.054*	0.055*	0.054*
		(0.005)	(0.008)	(0.008)	(0.009)
Log complexity × state projects					0.002
					(0.010)
Log days to complete the project			0.022*	0.022*	0.022*
			(0.006)	(0.006)	(0.006)
Log backlog			0.001*	0.001	0.001
			(0.000)	(0.000)	(0.000)
Log distance			0.010*	0.010*	0.010*
			(0.002)	(0.002)	(0.002)
Division effects (24)	Yes	Yes	Yes	Yes	Yes
Time effects (119)	Yes	Yes	Yes	Yes	Yes
Material shares (11)	No	No	Yes	Yes	Yes
Number of observations	11745	11745	11745	11745	11745

Model

- There are n risk neutral bidders who compete for a government contract in a first price sealed bid auction where the low bidder is awarded the contract.
- There are two types of projects, indexed by j, those that have no DBE goals and those that do (i.e., $j = \{0, 1\}$).
- The cost of contract j to a bidder i, is private and denoted by c_{ij}. The density of the private cost c_{ij} is f_j and is strictly positive on the support $[c_{L_j}, c_{H_j}]$.
- A bidder who is awarded the contract j at a bid of b_{ij} receives a net profit of $b_{ij} - c_{ij}$. Each bidder is maximizing expected profit given by:

$$E[\pi_{ij}(b_{1j}, b_{2j}, ..., b_{nj}, c_{ij})] = (b_{ij} - c_{ij})\left(1 - F_j\left(\varphi(b_{ij})\right)\right)^{n-1}.$$

Model (cont.)

In the symmetric independent private value (IPV) case, the equilibrium bid function is

$$\beta(c_{ij}|F_j, n) = c_{ij} + \frac{\beta'(c_{ij})[1 - F_j\,(c_{ij})]}{(n-1)f_j\,(c_{ij})} \tag{1}$$

where $b_{ij} = \beta(c_{ij})$ and $\varphi(b_{ij}) = c_{ij}$.

- Let $G_0(b)$ be the distribution function of bids in projects without DBE goals and $G_1(b)$ the distribution function of bids in projects with DBE goals. Let $g_0(b)$ and $g_1(b)$ be the associated densities. Considering the standard monotonicity condition imposed on the equilibrium bid function $\beta(c)$, we write $F(c) = F(\beta^{-1}(b)) = G(b)$, and $f(c) = g(b)\ \beta'(c)$.

Model (cont.)

We substitute these expressions into the equilibrium bidding function.

Then the latent cost of undertaking a project without DBE goals can be written as,

$$c_0 = b_0 - \frac{1}{n_0 - 1} \frac{1 - G_0(b_0)}{g_0(b_0)}, \tag{2}$$

Similarly, the latent cost associated with a project that has DBE goals is,

$$c_1 = b_1 - \frac{1}{n_1 - 1} \frac{1 - G_1(b_1)}{g_1(b_1)}, \tag{3}$$

where n_0 and n_1 are the number of firms bidding in projects without and with DBE goals.

Identification and estimation issues

- The identification and estimation of equations 2 & 3 rely on the assumptions associated to the IPV framework.
- We require a sample of projects that are relatively homogeneous and fit the IPV framework.

Nonparametric estimation and auction heterogeneity

- The projects considered in this study are not identical. As such, it is likely then that project characteristics shift the distribution of bids.
- If this is the case, nonparametric methods may produce biased estimates.
- Standard non-parametric methods can be used to estimate $(1 - G(b|x))/g(b|x)$, where the vector $x \in X \subset R^p$ includes variables capturing observed project heterogeneity (e.g., GPV 2000).
- We incorporate auction specific characteristics (e.g., ECE) replacing the unconditional distribution functions $G_j(b)$ and $g_j(b)$ in equations 2 & 3 by conditional distributions of a form $G_j(b|x)$ and $g_j(b|x)$.
- These conditional functions can be estimated by considering the empirical version of standard definitions, $\hat{g}_j(b_j|x_j) = \hat{g}_j(b_j, x_j)/\hat{f}_j(x_j)$ and $\hat{G}_j(b_j|x_j) = \hat{G}_j(b_j, x_j)/\hat{f}_j(x_j)$.

Nonparametric estimation (cont.)

Following GPV (2000) and LPV (2000), the estimation of the conditional version of equations 2 & 3 is completed in two steps.

- In step 1, we estimate the pseudo cost c_j separately for each equation, and
- in the second step, we use the pseudo values and the project characteristics (x_j) to estimate the conditional cost distribution of firms bidding in auctions either with or without DBE goals.

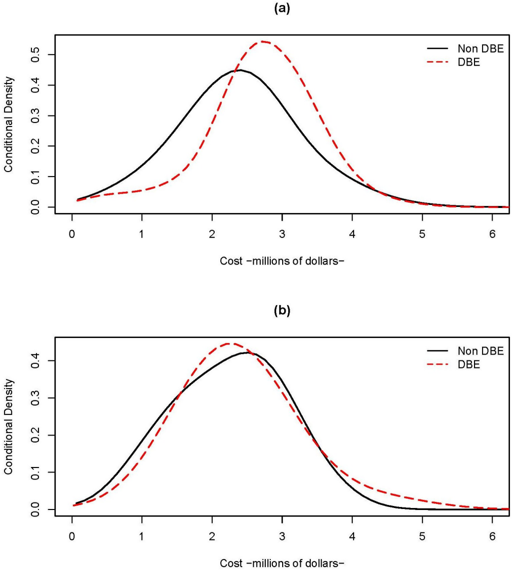
Nonparametric estimation (cont.)

From related literature (Bajari and Ye (2003), De Silva *et al*., (2008)) and our discussions with state highway and civil engineers, asphalt projects appear to best match these requirements.

Two ways to obtain an even more homogeneous sample.

- First, we restrict attention to asphalt projects with an estimated cost between 1 million and 20 millions, asphalt component higher than 50% of the engineer's cost estimate, bridge and earthwork components less than 5%, and NO sub-grade and base course tasks. **Projects (a)**
- Second, we select maintenance contracts related exclusively to surface treatment. **Projects (b)**

The chart (a) is for Asphalt & the chart (b) is for Surface Treatment projects.



Nonparametric estimation (cont.)

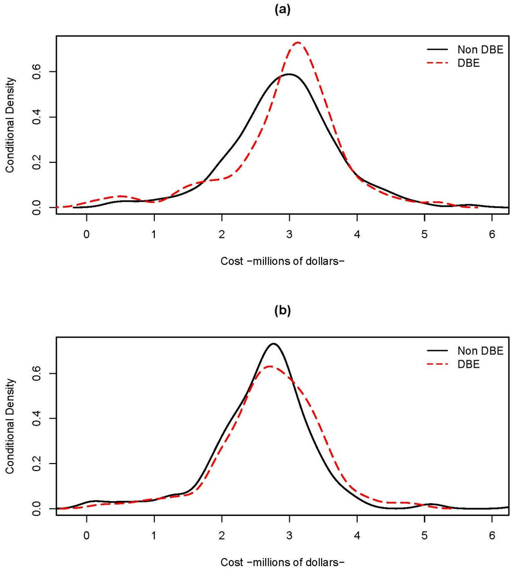
In our application, one needs to control for many auction-specific characteristics. Recall the model estimated in Table 2.

Next we use HHS (2006) two-stage approach to obtain the cost distributions.

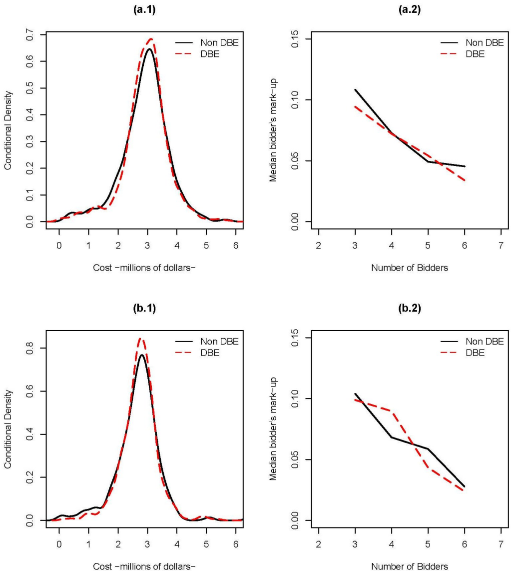
- The advantage of using this method relative to the approach developed by GPV (2000) is that allows controlling for more than one auction-specific characteristic without increasing the sample size.
- The basic idea is to impose an additively separable structure on how observable factors and latent auction heterogeneity affect costs.

Cost densities for DBE and non-DBE projects - HHS

The chart (a) is for Asphalt & the chart (b) is for Surface Treatment projects.



Estimates of the median bidders' markup



Additional Considerations on Selection Issues

A more important issue seems to be associated with DBE assignments.

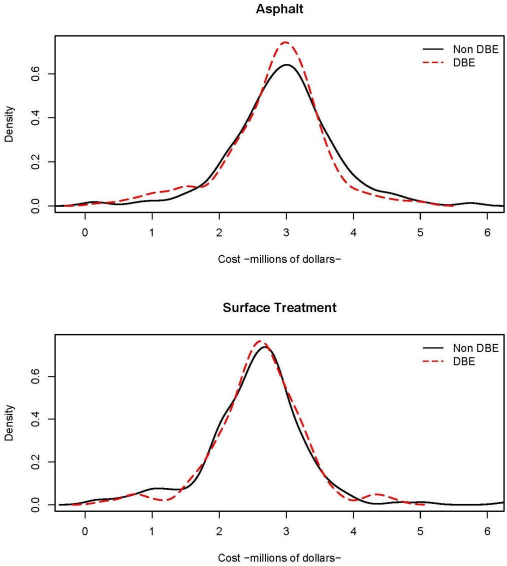
It is likely that the state would assign DBE status to a project with a large number of tasks involved.

This type of selection bias could be incorporated into the analysis by replacing the selection probability by a non parametric function (Das, Newey, and Vella (2003.))

A more convenient approach for this setting with a relatively large number of covariates, is to estimate the selection probability by the propensity score.

Next we obtain the homogenized bids conditional on p-score.

Cost densities for DBE and non-DBE projects



Conclusion

- Our empirical results show little difference in the level of bids submitted or in the estimated costs between projects with DBE goals and projects without such goals.
- When we utilize an even more homogeneous sample of projects, the differences are even less.
- Finally, we show that the implied markups generated from the HHS approach are consistent with those reported in the literature and do not differ substantially for auctions with and without DBE goals.
- A simple interpretation of the result is that the supply and quality of DBE subcontractors was sufficient during our period of analysis so that prime contractors were effectively unrestricted in their bidding due to the presence of DBE requirements.

Conclusion

- Texas has a relatively large number of minority-owned construction firms in comparison to the average state, reflecting the large minority population of the state.
- Our findings do not necessarily mean the program has had no effects on contracting. The program may have encouraged the formation and success of minority and women-owned businesses increasing the supply of DBE subcontractors. Alternatively, the program may have affected project costs but the effects may have occurred outside our window of observation.
- That said, our results suggest that during the period under study DBE subcontracting requirements did not substantially raise the bids or costs of prime contractors.

Thank you!

Asphalt project data

	Asphalt projects				Surface treatment projects			
	All Bidders		3 and 4 Bidders		All Bidders		3 and 4 Bidders	
	Non DBE	DBE	Non DBE	DBE	Non DBE	DBE	Non DBE	DBE
Bid (millions	3.202	3.159	3.121	3.298	2.820	2.907	2.840	3.631
of dollars)	(2.111)	(2.009)	(2.010)	(1.874)	(2.447)	(2.590)	(2.226)	(3.275)
Engineer's cost	3.203	3.169	3.075	3.332	2.822	2.875	2.772	3.620
estimate	(1.920)	(1.965)	(1.793)	(1.902)	(2.423)	(2.457)	(2.030)	(3.207)
Bridge work	0.006	0.007	0.005	0.009	0.004	0.005	0.005	0.009
	(0.011)	(0.013)	(0.010)	(0.013)	(0.009)	(0.011)	(0.010)	(0.014)
Earth work	0.011	0.011	0.011	0.012	0.012	0.008	0.012	0.011
	(0.013)	(0.014)	(0.013)	(0.015)	(0.015)	(0.013)	(0.014)	(0.016)
Pavement	0.058	0.036	0.049	0.025	0.006	0.014	0.007	0.025
	(0.179)	(0.131)	(0.166)	(0.095)	(0.021)	(0.061)	(0.023)	(0.092)
Concrete	0.006	0.006	0.005	0.007	0.004	0.004	0.005	0.007
	(0.011)	(0.011)	(0.010)	(0.012)	(0.009)	(0.011)	(0.010)	(0.013)
Subcontracting	-	6.584	-	6.286	-	6.543	-	6.578
goals		(2.358)		(2.373)		(2.436)		(2.819)

Asphalt project data (cont.)

	Asphalt projects				Surface treatment projects			
	All Bidders		3 and 4 Bidders		All Bidders		3 and 4 Bidders	
	Non DBE	DBE	Non DBE	DBE	Non DBE	DBE	Non DBE	DBE
Complexity	32.451	37.766	32.377	42.327	30.723	33.174	31.350	37.513
of the project	(14.788)	(18.504)	(15.498)	(19.603)	(14.797)	(17.274)	(15.530)	(18.674)
Days to complete	84.820	89.026	81.013	88.822	70.981	71.659	67.040	77.766
the project	(61.082)	(49.377)	(61.029)	(42.346)	(62.592)	(34.544)	(49.821)	(35.568)
Number of	4.230	4.644	3.413	3.443	4.207	4.851	3.469	3.416
bidders	(1.821)	(2.099)	(0.493)	(0.498)	(1.757)	(2.135)	(0.500)	(0.494)
Number of:								
Auctions	206	175	112	76	134	126	68	50
Observations	751	664	368	248	473	475	226	126

Related literature

- Denes (1997)

  ⇒ Compares bids submitted between solicitations restricted to small businesses and unrestricted solicitations.

- Krasnokutskaya and Seim (2007)

  ⇒ Analyze bid preference programs in California highway procurement

- Marion (2007)

  ⇒ Distortion in participation patterns in bid preference programs in CA is responsible for a 3.8% increase in the cost.

Related literature

- McAfee and McMillan (1989) and Maskin and Riley (2000)

  $\Rightarrow$ By invoking bid preferences the state gives an advantage to DBE bidders and compels the non-DBE bidders to bid more aggressively. Since the competitive pressure is reduced for DBE bidders they bid less aggressively than otherwise; and when the item is awarded to them, they impose additional cost on the state.

- Marion (2009)

  $\Rightarrow$ Shows that the subcontracting goals set for highway construction contracts in CA raise DBE usage significantly, so that the constraints appear to bind.

Nonparametric estimation (cont.)

Given the potential benefits of using the logarithm of bids rather than bids, we consider the logarithmic transformation for the variable of interest c_j (see Li, Perrigne and Vuong (2000), and Marion (2007)).

We define the pseudo cost $\hat{c}$ as follows:

$$\hat{c}_j = \begin{cases} \exp(a_j)(1 - m_j(a_j, z_j)) & \text{if } \max\{h_{jG}, h_{jg}\} \leq a_{jil} \leq a_{j\max} - \max\{h_{jG}, h_{jg}\} \\ +\infty & \text{otherwise,} \end{cases} \quad (4)$$

where the variables $a_j = log(b_j)$, $z_j = log(x_j)$, and

$$m_j(a_j, z_j) = \frac{1}{n-1} \frac{1 - \hat{G}_j(\mathbf{a}_j|\mathbf{z}_j)}{\hat{g}_j(\mathbf{a}_j|\mathbf{z}_j)}.$$

Nonparametric estimation (cont.)

In the first stage, we now use Equation 4 to obtain $\hat{\mathbf{c}}_0$ and $\hat{\mathbf{c}}_1$, and in the second stage, we use these pseudo costs and the engineer's cost estimate to estimate the conditional distributions $\hat{g}_0(\hat{\mathbf{c}}_0|\mathbf{x}_0)$ and $\hat{g}_1(\hat{\mathbf{c}}_1|\mathbf{x}_1)$.

Note that we require a sample of projects that are relatively homogeneous and fit the IPV framework.

Testing the IPV assumptions

- Our analysis was performed using the symmetric independent private value framework, which essentially implies exchangeability of marginal distributions and independence (Athey and Haile (2007))
- Under exogenous variation of bidders, this framework suggests that the marginal distributions for $n = 3$ and $n = 4$ must be equal, because the costs are invariant to n (Lemma 1, HHS (2006))
- We perform a Wilcoxon test to evaluate if the costs distributions have same locations and Kolmogorov-Smirnov test for independence to evaluate if the cost distributions in auctions with 3 and 4 bidders are significantly different.
- The tests seem to suggest that the sample of projects exclusively related to surface treatment fits the framework better.

Nonparametric estimation (cont.)

- HHS (2006) method uses residuals obtained from a mean regression model $G(x)$, where $G(\cdot)$ is a known function and $\mathbf{x}$ is a vector of observed auction characteristics.

- We assume that $G(\cdot)$ is a linear function and $\mathbf{x}$ includes controls for project's size, complexity of the project, controls for length of the project and an interaction term between calendar days and engineer's cost estimate, controls for project's type, the location of the project, the distance to the project location, and the capacity commitment of the firm.

- The second stage simply uses the homogenized bids to estimate the cost's distribution of firms bidding in auctions either with or without DBE goals.

Variability bands for the estimated densities - HHS

	Quantiles of the Cost Distribution				
	1.000	2.000	3.000	4.000	5.000
			Asphalt projects		
Non-DBE	[0.003, 0.068]	[0.085, 0.309]	[0.487, 0.753]	[0.059, 0.285]	[0.001, 0.052]
DBE	[0.004, 0.094]	[0.077, 0.323]	[0.496, 0.867]	[0.025, 0.274]	[0.000, 0.034]
			Surface treatment projects		
Non-DBE	[0.009, 0.118]	[0.136, 0.726]	[0.190, 0.806]	[0.000, 0.148]	[0.000, 0.028]
DBE	[0.001, 0.119]	[0.088, 0.656]	[0.178, 0.908]	[0.001, 0.197]	[0.000, 0.029]

The intervals were constructed considering a block bootstrap procedure. The quantiles are in millions, and we considered 10,000 bootstrap repetitions.