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DO FEDERAL DAVIS-BACON AND DISADVANTAGED BUSINESS ENTERPRISE REGULATIONS AFFECT AGGRESSIVE BIDDING? EVIDENCE FROM HIGHWAY RESURFACING PROCUREMENT AUCTIONS

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ABSTRACT. Previous empirical studies examine the effect of asymmetries across bidders on auction outcomes. This paper tests for asymmetries in behavior when bidders are confronted with different regulatory environments. Data from federal and state highway resurfacing projects in Colorado are used to determine if bids are more aggressive when contractors switch from federal projects, with Davis-Bacon prevailing wage and Disadvantaged Business Enterprise regulations, to less-regulated state projects. Results from fixed effects estimates of winning bids indicate that the level of aggressive bidding is not altered with a change in regulations, at least not with respect to the policies and types of projects examined here.

INTRODUCTION

This paper examines the bidding behavior of contractors that completed federal and state highway resurfacing projects in Colorado. While there is regulatory overlap between state and federal highway projects in Colorado, projects funded by the federal government also include Davis-Bacon prevailing wage and disadvantaged business enterprise requirements. The ability of contractors to bid aggressively (lower) may be limited if the regulations on federal projects affect bidder behavior. A sample of contractors, that were awarded federal and state highway maintenance projects between 2000 and 2011, is used to determine if bids are more aggressive when contractors switch to less regulated projects funded by the State of Colorado.

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Many recent empirical studies focus on asymmetries among bidders and auction outcomes. For example, the bids of first-time, entrant firms may be influenced by the lack of production experience in the new area or by incomplete information about the costs of bid components. Consequently, the bids of entrants are more widely dispersed around the central bid tendency (see Li & Philips, 2012). Others find that entrants bid more aggressively than incumbent firms (see De Silva, Dunne & Kosmopoulo, 2003). Therefore, encouraging new firms to participate in public procurement auctions is viewed as a way to increase competition and reduce collusive behavior among incumbents (see Estache and Iimi 2008). Tenders from contractors that are closer to a project location are more aggressive and price setters bid strategically while other firms bid their costs (see Flambard & Perrigne, 2006; Crawford, Crespo & Tauchen, 2007). While previous research focuses on asymmetries across bidders and auction outcomes, the present study tests for changes within bidders confronted with different regulatory settings.

Federally funded highway projects in all states require the payment of Davis-Bacon prevailing wage rates, adherence to disadvantaged business enterprise (DBE) targets, and compliance with anti-discrimination and disability regulations.[1] State funded projects in Colorado mirror federal discrimination and disability regulations, but do not require prevailing wage payments or DBE targets.[2] Also, information provided by Colorado Department of Transportation (CDOT) personnel indicates that state and federal highway projects are built to the same safety and quality standards in Colorado. Consequently, when contractors switch from state-funded to federally funded highway resurfacing projects in Colorado, bids are influenced by any additional constraints presented by Davis-Bacon and DBE policies.

The Davis-Bacon Act requires contractors and subcontractors involved in federally funded public works construction to pay workers, at a minimum, wage and benefit rates that the U.S. Department of Labor has determined to prevail in an area. The prevailing wage rate is the rate paid to the majority of workers in a detailed job classification. If the same rate is not paid to a majority of workers, then the weighted average wage is used. Union rates prevail if these wages represent the majority. Unionization rates in the Colorado construction industry are low, averaging 7.4 percent between 2000 and 2011 (see Hirsch & Macpherson, 2015). Consequently, average wage rates prevailed for most of the detailed job classifications involved in highway resurfacing over the period of the study. Information provided by the Laborers International Union Local #720 indicates that highway resurfacing involves operating engineers, truck drivers, and laborers. Davis-Bacon wage rates can be found at Wage Determinations On-Line.gov.

The DBE intends to enhance the participation of disadvantaged subcontracting companies by requiring that at least 10 percent of the total costs for federally funded highway projects be allocated to firms owned and controlled by socially and economically disadvantaged individuals. According to personnel from the Colorado Department of Transportation (CDOT) the minimum target for transportation projects in Colorado was about 12 percent between 2000 and 2011.

The effect of these regulations on the costs of construction is controversial. For example, Vincent and Monkkonen (2010), Dunn, Quigley, and Rosenthal (2005), and Fraundorf, Farrell, and Mason (1984) find that prevailing wage requirements increase construction costs from 9% up to 37%. On the other hand, Azari-Rad, Philips, and Prus (2002; 2003), Bilginsoy and Phillips (2000), Duncan and Prus (2005), Duncan, Philips, and Prus (2014) fail to find a statistically significant prevailing wage effect. These studies are all based on examinations of buildings, including schools, low income housing, and offices, etc. and use data obtained from Dodge Data & Analytics, or from comparable sources. Regardless of the source, these data typically provide information such as project square feet, number of stories, location, time of year of construction, and whether the project is new, or an addition. These variables allow researchers to control for general differences between projects that are, and are not constructed by prevailing wage regulations. One limitation of these data is adequate controls for differences in project size and complexity. This is an issue as government projects built under prevailing wage requirements are often compared to private projects that are not covered by wage regulations. Government buildings may be larger, but may also have greater life-expectancies that also add to construction costs (See Azari-Rad, Phillips, & Prus, 2003). While total project square feet may control for differences in project size, this measure does not capture quality or complexity differences between projects. The omission of measures of project quality and complexity may contribute to the range of results concerning the cost effect of prevailing wage regulations. This omission may cause bias in the measurement of the prevailing wage cost effect. The effect of the specification error associated with inadequate controls for project complexity is illustrated in the empirical analysis below.

Other studies that examine highway construction costs employ data that provide superior measures of project size and complexity. For example, De Silva, Dunne, and Kosmopoulou (2003), De Silva, Dunne, Kosmopoulou, and Lamarche (2012), and Thiel (1988) estimate highway construction costs with data obtained from state departments of transportation that include the departments' engineer's cost estimate. If a highway project is larger, the engineer's estimate will be larger. If projects differ in complexity or involve qualitative differences, these are reflected in the cost estimate. Consequently, the engineer's estimate is highly correlated with project costs. In examinations of highway construction costs in Oklahoma and Texas, De Silva, et al. (2003) and De Silva, et al. (2012) report elasticities of the engineer's estimate with respect to project cost that are close to one. Thiel (1988) reports a similar elasticity in his examination of highway projects in Illinois, Louisiana, Massachusetts, Nevada, and Texas. These studies also report very high t-statistics for the engineer's estimate elasticity (ranging between 32 and 320) and R^2 values (ranging between 0.97 and 0.99).

Elsewhere I have compared the costs of state and federally funded highway maintenance projects in Colorado (see Duncan, 2015). This comparison includes the engineer's estimate and other project characteristics. While this study finds that federal projects covered by DBE and Davis-Bacon prevailing wage regulations are no more expensive than state-funded highway projects, there is no examination of asymmetric bid behavior as contractors move between regulatory regimes. The current study utilizes the Colorado highway data to examine this issue.

Data from highway procurement auctions have also been used to examine the effect of DBE requirements on bid costs. For example, De Silva, Dunne, Kosmopoulou and Lamarche (2012) find no difference in the average bids of state and federally funded highway paving projects in Texas. Federal projects are covered by DBE policies, but Texas does not have a similar requirement for state-funded construction. These authors also report that federal projects with higher DBE goals are no more costly than projects with lower goals. Marion (2009) uses data from highway construction in California to examine the effect of Proposition 209. This proposition eliminated preferential treatment based on race or sex in public employment, school admissions, and state-funded contracting. Marion reports that after the implementation of Proposition 209, the cost of state-funded projects fell by 5.6% compared to federal projects that remained covered by the DBE. While the studies by Desilva et al. and Marion yield conflicting results, both include detailed information on project characteristics including the engineer's estimate.

If Davis-Bacon and DBE requirements are associated with higher project costs, asymmetric bids are expected as contractors move between comparable state and federal projects. However, symmetric bids for state and federal projects are evidence that the federal regulations are not related to project costs. Tests for asymmetric bid behavior are conducted with and without the engineer's estimate to illustrate the specification error associated with omissions of project size and complexity. The unbalanced panel of contractors who won state and federal highway resurfacing projects in Colorado between 2000 and 2011 is described in the next section. Following sections include a description of the fixed effect bid cost model used to determine if Davis-Bacon and DBE policies are associated with asymmetric bid behavior. Potential sample-selection bias related to a sample of contractors who participated in federal and state projects is addressed. Results from alternative specifications of the basic model are also discussed. The paper concludes with implications for policy and further research.

DATA AND FIXED EFFECTS REGRESSION MODEL

CDOT bid tabulations contain information on the source of funding, project bids, the number and identity of bidders, and the letting date of a project. Data also include information on the location of the project, type of terrain (mountainous, plains, etc.), and CDOT's engineer's estimate of the cost of the project. This estimate is an item-by-item list of the specific tasks involved with the project such as asphalt planing, finish grading, etc. It is through the content of the engineer's estimate that parity in safety and quality requirements between state and federally funded projects is achieved. According to CDOT personnel, it is an institutionalized practice to base the engineer's estimate on the applicable prevailing wage rate, even if the project is not covered by the Davis-Bacon Act. The engineer's estimate for federal projects is not adjusted for disadvantaged business enterprise requirements.

CDOT follows a low price, sealed bid format where contractors have access to bid openings, but not the engineer's cost estimate prior to the letting date. Bid openings include a description of the project and the range of the estimated cost (less than $600,000, between $600,000 and $1.5 million, etc.).[3] Low bids that are less than 15% of CDOT's cost estimate are ordinarily accepted. Those low bids exceeding the engineer's estimate by more than 15% may necessitate additional justification from the winning contractor or a re-examination of CDOT's cost estimate. Bids on projects with an estimated cost of $1 million or more are rejected if there are fewer than three bidders and the low bid exceeds CDOT's estimate by more than 10%. For projects with an estimated cost less than $1 million, the low bid must be within 25 percent of the estimate if there are fewer than three bidders.

CDOT bid tabulations were used to obtain data on resurfacing projects awarded between 2000 and 2011 (see CDOT Bid Archives). Specifically, projects were selected if work emphasized the overlay of hot mix asphalt, patching, and other highway resurface treatments. There were approximately 130 state and federal highway resurfacing projects in Colorado over the study period. This study uses a subset of projects consisting of contractors who won and completed at least one state and one federal resurfacing project between 2000 and 2011.[4] This unbalanced panel consists of 91 projects that were completed by 13 different winning contractors. The average number of projects completed per contractor is seven, the minimum is two, and the maximum is 27. There are 44 state projects and 47 federal projects. The data extend over two business cycles.

Fixed or random effects models are typically employed in the estimation of panel data. The choice between these two models is based on specificity. Since the current study is examining specific regulations (Davis-Bacon and DBE), fixed effects is the appropriate method. If the study were examining the cost effect of government regulations, and Davis-Bacon and DBE policies were randomly selected from all forms of regulations, then random effects would be appropriate. Additionally, since interest here is only in generalizing the results for Davis-Bacon and DBE policies, fixed effects are the model of choice. If the goal is to make inferences about regulations in general, and these two policies are conceptualized as randomly drawn from a larger universe of regulations, random effects is appropriate.[5]

Basic Model:

$$\text{Ln Real Winning Bid}_{it} = \beta_0 + \beta_1 \text{ Contractor}_i + \beta_1 \text{ State Project}_{it} + \beta_2 \text{ Ln \# Bidders}_{it} + \beta_3 \text{ Ln Real Engineer's Estimate}_{it} + \beta_4 X_{it} + \beta_5 Z_{it} + \mu_{it}$$

where Ln Real Winning Bid is the natural log of the real low bid awarded to contractor *i* at time period *t*.

CDOT maintains a record of post-construction follow-up maintenance for three years. This time frame does not cover the period of the study and attempts to obtain this information for the limited time span were unsuccessful. Therefore, the low or winning bid is the measure of project total cost. CDOT calculates price indexes for different construction categories that are based on material costs, not labor costs (see CDOT Construction Cost Index). The CDOT resurfacing index is used to adjust all dollar measures for inflation. The base year is 1987. The individual-level effect is measured by the Contractor variable. State Project is equal to one if the project was funded by the State of Colorado and this variable is equal to zero if the project was funded by the federal government. Federal projects included in this study are resurfacing projects on interstate highways 25, 70 and 76. State-funded highway projects are distributed across Colorado. Ln # Bidders is equal to the natural log of the number of contractors bidding on the project. Ln Real Engineer's Estimate is the natural log of CDOT's estimate of the cost of the project. X is a vector of project characteristics such as whether the project involved asphalt removal/planning, the removal of other materials and structures, concrete (instead of asphalt) resurfacing, landscape work, finish grading, and whether the project-timeline requires a fixed number of working days or a fixed date of completion. The vector Z includes measures of the region of the state where the work was completed and terrain type. This vector also includes year dummy variables for the estimation of a two-way fixed effects model. The error term is μ.

As discussed in the literature review, a limitation in the empirical estimation of a prevailing wage cost effect has been the availability of measures of detailed project characteristics. The model discussed above allows for the sequential introduction of measures of project characteristics to illustrate the bias in the cost effect due to the omission of relevant variables.[6] The basic model allows for a test of the cost differential of state projects with minimal controls for project characteristics. This model (Model 1 in Table 2 below) includes the log of the number of bidders and the vector Z of general project characteristics. Auction theory implies that bid costs decrease with increased bid competition. Vector Z contains measures of project terrain type and regional location. Project terrains include mountainous, rolling, plains and, urban. The *a priori* assumption is that construction costs will be relatively high in urban terrains due to limitations imposed by work space constraints and high traffic flows. Project region variables include the central, northern, southern, and Denver-metro area of Colorado. The *a priori* assumption is that costs will be lower in the Denver-metro area due to factors such as reduced travel time, availability of supplies, etc. The year dummy variables measure the effect of the business cycle. Model 2 includes additional measures of project specifics such as whether the resurfacing work involved the removal of asphalt and other materials and structures, finish grading by a motor grader, landscaping, concrete resurfacing, and if the contract required a fixed completion date. Data reported in Table 1 indicate that federal projects are more likely to be characterized by these additional tasks, excepting concrete resurfacing and fixed completion dates. The *a priori* assumption is that these additional activities will be associated with increased construction costs. Many of these activities involve additional work, but it is unknown, *a priori*, what the effect of project completion date and concrete work will have. CDOT's engineer's estimate is added in Model 3. As illustrated in the literature review, this variable has been used in other studies to control for differences in project size and complexity and is positively related to costs. As more measures of detailed job characteristics are included in models 2 and 3, the size of the state project variable should diminish (in absolute value).[7]

A sample size of 91 observations raises concerns over the statistical power of the regression estimate. In this case, the concern is focused on the sample size needed to insure a reasonable chance of rejecting the null hypothesis for the State Project dummy variable. Green (1991) suggests a sample size between 77 and 94 observations to identify a large effect size for the type of estimate used here (with 20 to 30 regressors). These conditions provide for a conventional power norm of 0.80 with a two-tailed test and a 0.05 significance level. Green's effect and sample sizes vary with the expected R^2. A smaller sample size is needed when previous research suggests a high R^2. The larger the expected R^2, the larger the effect size. Green's analysis of large effect size is based on an R^2 of 0.26. Previous research examining winning bids for highway maintenance projects reports R^2 values ranging between 0.97 and 0.99 (see De Silva, Dunne and Kosmopolou, 2003; Desilva et al., 2012). This implies a sample size smaller than that recommended by Green to achieve a high level of statistical power.[8]

Variations of the basic model are estimated to address sample selection bias, random effects, the endogeneity of the number of bidders, the use of a different price index, and the estimation of a complete interaction model (with the State variable multiplied by each of the independent variables for Model 3). Since the sample consists of contractors who were awarded state and federal projects, sample selection bias may be a concern. The two-step method developed by Heckman (1979) is used to determine if the estimate of winning bids, without taking selection into account, yields inconsistent results. To address the issue of endogeneity, an alternative specification replaces the number of bidders with a variable measuring the expected number of bidders using the technique of instrumental variables estimation. The fixed effects model is based on the assumption that the individual-level (contractor) effects are related to the other regressors. Results from a random effects estimate and a Hausman test are also presented to determine if the contractor-specific effects are unrelated to the independent variables. The basic model uses the CDOT resurfacing index to adjust all dollar measures for inflation, but results based on CDOT"s composite index is discussed. Results of these alternative specifications are discussed below.

RESULTS

Summary statistics for the 44 state and 47 federal highway resurfacing projects performed between 2000 and the second quarter of 2011 are reported in Table 1. All dollar measures are adjusted for inflation using the CDOT quarterly resurfacing index and are reported in 1987 dollars. These data indicate that, on average, federal resurfacing projects are more expensive and larger than state projects. For example, the average winning bid for federal projects is approximately $1.78 million (with a range from $128,000 to $4.78 million) and a standard deviation of almost $915,000. The average winning bid for a state project is about $322,000 (with a range between $60,000 and $1.15 million) and a standard deviation of approximately $238,000. The broad range between small and large projects included in the sample raises concerns over hetereoskedasticity in the regression analysis below.

To address this issue, a Wald test for group-wise hetereoskedasticity is conducted and heteroskedasticity-consistent standard errors are used in the regression analysis. Robust standard errors from the STATA program are used in the regression analysis below.

TABLE 1
Summary Statistics for Contractors Performing State and Federal Highway Resurfacing Projects, 2000-2011

Variables	Mean	
	Federal Project	State Project
Real Low Bid	$1,784,871** (914,575)	$321,835 (238,379)
Engineer's Estimate	$1,879,530** (947,062)	$349,734 (277,242)
# Bidders	4.426 (1.25)	3.932 (1.86)
Asphalt Removal (Planing)	0.936** (0.06)	0.409 (0.08)
Removal (Other than Asphalt)	0.596** (0.07)	0.182 (0.07)
Finish Grading	0.696** (0.07)	0.068 (0.07)

TABLE 1 (Continued)

Variables	Mean	
	Federal Project	State Project
Seeding & Mulching	0.596** (0.07)	0.091 (0.07)
Concrete	0.021** (0.05)	0.091 (0.07)
Fixed Completion Date	0.128** (0.07)	0.818 (0.07)
Central Region	0.277** (0.07)	0.181 (0.07)
Southern Region	0.191 (0.07)	0.181 (0.07)
Northern Region	0.277** (0.07)	0.364 (0.08)
Greater Denver Region	0.255 (0.07)	0.273 (0.08)
Mountainous Terrain	0.361** (0.07)	0.273 (0.08)
Rolling Terrain	0.319** (0.07)	0.273 (0.08)
Plains Terrain	0.128 (0.07)	0.113 (0.07)
Urban Terrain	0.191** (0.07)	0.341 (0.08)
N=	47	44

Source: CDOT Bid Archives. Standard deviations in parentheses (deviations for dummy variables are the standard deviations of the sample proportions). ** The mean for federal projects is different at the 0.05 level from the comparable mean for state projects.

CDOT's engineer's estimate of the cost of federal projects is also higher relative to state projects (about $1.9 million for the average federal project versus $350,000 for the typical state-funded project). All of the differences between state and federal projects described above are statistically different at the 0.05 level. The average number of bidders on federal projects is 4.4 compared to 3.9 for state projects. However, this difference is not statistically significant. Data reported in Table 1 also identify some of the specific differences between state and federal projects. For example, about 94% of federal projects require the removal of asphalt (planing) while only 41% of state projects require this type of additional work. Similarly, about 60% of federal projects require the removal of other materials and structures relative to 18% for state projects. Approximately 70% of federal projects involve finish grading while only 7% of state projects require this kind of work. While federal projects are more likely to involve seeding and mulching, contracts for state projects are more likely to concern concrete resurfacing and to require a fixed completion data (versus allowing for a given number of working or calendar days). These differences are statistically significant at the 0.05 level. A significantly larger portion of federal projects are located in the central region, compared to the distribution of state projects. However, the reverse is true for state projects in the northern region of the state. Differences in the portion of state and federal projects in southern Colorado and in the greater Denver area are not statistically significant. The southern region variable collapses CDOT regions 5 and 2 since there are no interstate highways in the southwestern portion of Colorado. Federal projects are more likely to take place on mountainous and rolling terrains. State projects are relatively more numerous in urban areas, compared to federal projects. These differences are statistically significant at the 0.05 level. There is no difference in the percent of federal and state projects in the plains.

Regression results are reported in Table 2. The dependent variable is the log of the winning (low) bid. Results from three models are reported in Table 2 to observe changes in the relative costs of state projects as measures of project size and complexity are added to the estimate of the low bid. Robust standard errors are reported for regression coefficients for all models that provide for asymptotically valid standard errors to correct for hetereoskedasticity. Results from modified Wald tests for group-wise heteroskedasticity for the fixed effects estimates indicate that the null hypothesis of homoskedasticity is decisively rejected for models 1, 2, and 3 in Table 2. The computed Chi^2 is 2,500 or higher for these estimates (with a p-value of 0.000).

Results for Model 1 indicate a coefficient for State Projects of –1.801 that is statistically significant at the 0.01 level. Using the formula ($100[e^{\beta_i}-1]$) to interpret this coefficient indicates that state

TABLE 2
Fixed Effects Regression Results of Winning Bids
Dependent Variable = Log of Low Bid

Variables	Coefficients		
	Model 1	Model 2	Model 3
State Project	−1.801*** (0.098)	−1.687*** (0.208)	−0.029 (0.039)
Log of Engineer's Estimate	-	-	0.961*** (0.017)
Asphalt Removal (Planing)	-	0.526λλ (0.288)	0.056 (0.051)
Removal (other than asphalt)	-	−0.159 (0.206)	0.001 (0.042)
Finish Grading	-	0.345 (0.262)	0.078λλλ (0.023)
Seeding & Mulching	-	−0.110 (0.137)	0.040 (0.036)
Concrete	-	0.191 (0.533)	0.026 (0.078)
Fixed Completion Date	-	0.368** (0.145)	−0.019 (0.046)
Log # Bidders	0.168 (0.131)	0.026 (0.141)	−0.039* (0.021)
Central Region	−0.099	−0.047	−0.001
Southern Region	−0.254	−0.159	0.023
Northern Region	0.143	−0.190	0.026
Mountainous Terrain	0.293	−0.010	−0.018
Rolling Terrain	−0.344λλ	−0.376λ	-0.062λλλ
Plains Terrain	0.406λλ	0.291λ	−0.006
2001	−0.858***	−0.607*	0.035
2002	−0.623***	−0.651***	0.090
2003	−0.400**	−0.339	0.164**
2004	−0.055	0.083	0.183**
2005	−0.470*	−0.451**	0.167*
2006	−0.094	−0.210	0.093
2007	−0.432	−0.540	0.160*
2008	−0.587***	−0.481	0.165**
2009	−1.173***	−1.328***	−0.110
2010	0.045	−0.267	0.054

TABLE 2 (Continued)

Variables	Coefficients		
	Model 1	Model 2	Model 3
2011 (to QII)	–0.853**	–0.622	0.193
Constant	14.368*** (0.307)	14.040*** (0.333)	0.346 (0.268)
N=	91	91	91
R^2=	0.761	0.790	0.990

Source: CDOT Bid Archives. Robust standard errors in parentheses. * significant at the 0.10 level, ** significant at the 0.05 level, ***significant at the 0.01 level (two-tailed tests). For one-tailed tests: ^ significant at the 0.10 level, ^^ significant at the 0.05 level, ^^^ significant at the 0.01 level.

projects are approximately 83% less expensive than comparable federally funded projects. This finding supports the view that bids are more aggressive on less-regulated state construction. However, this estimated cost savings for state projects is too large to fully ascribe to the absence of federal regulations given that prevailing wage requirements apply to labor costs that constitute approximately 21% of total costs for highway, street and bridge construction in Colorado and CDOT disadvantaged business enterprise goals are 12% of project costs.[9] It is likely that the state project variable is influenced by omitted measures of projects size and complexity.

Other results for Model 1 indicate the absence of statistically significant effects for the number of bidders, between regions, and mountainous terrains. Contrary to *a priori* expectations, projects on rolling terrains are less expensive than the reference category (urban terrain). But, projects on the plains are more expensive than those in urban settings. These differences for both coefficients are only statistically significant at the 0.05 level (one-tailed test). Because of the *a priori* assumptions discussed above, the coefficients for the region, terrain, and additional work variables (excepting concrete and fixed completion date) are evaluated with one-tailed tests. The trend in the year variables suggests that costs are lower in each year compared to 2000, with significantly lower costs in 2001-2003, 2005, 2008, 2009 and 2011. This pattern is not consistent with observed trends in resurfacing material costs in Colorado over the business cycle. For example, CDOT reports a sharp increase in the Construction Cost Index starting in 2003, peaking in 2008, and stabilizing during 2009 and 2010 before rising again in 2011 (see CDOT Construction Cost Index). Overall, the model explains about 76.1 percent of the total variation in the log of winning bids.

Model 2 includes more detailed measures of project characteristics. When these measures are included the estimated cost impact of state projects increases to –1.687, suggesting that state projects are approximately 81% less expensive than comparable federal projects (based on $100[e^{-1.687} - 1]$). Including the detailed measures of project characteristics in Model 2 is associated with a two-percentage point decrease in the estimated cost of state projects, compared to Model 1 (83%). While this coefficient is consistent with the view that bids on state and federal projects are asymmetric, the measured cost savings is too large to realistically reflect the absence of regulations on state projects.

Other results for Model 2 indicate that projects requiring the removal of asphalt (planing), and a fixed completion date are more expensive than projects without these requirements. The differences with respect to asphalt planing and a fixed completion date are significant at the 0.05 level (for one and two-tailed tests, respectively). Projects requiring the removal of other materials, finish grading, seeding and mulching, or concrete resurfacing (instead of asphalt) do not differ from projects without these requirements in a statistically significant way. The coefficient for the log of the numbers of bidders remains insignificant in Model 2. No statistical significance can be ascribed to differences between regions. The results for the terrain variables match those from Model 1, excepting significance at the 0.10 level (one-tailed tests). The trend in the year variables suggests lower costs relative to the reference year of 2000 with statistically lower costs in 2001, 2002, 2005, and 2009. Again, this estimated trend is inconsistent with the observed trend in material costs in Colorado over this time period. With additional measures of project characteristics the R-squared increases to 79%. The change in the R^2 between models 1 and 2 is not statistically significant. The computed F statistic with the addition of the six additional independent variables in Model 2 is 1.5.

Model 3 includes the most comprehensive list of variables that measure the size and complexity of projects. With the addition of the engineer's estimate the percentage impact of state projects decreases substantially (to approximately negative 3%) and is no longer statistically significant. This finding indicates that when more complete controls for project size and complexity are added to the estimate of the winning bid, there is no statistically significant difference in aggressive bidding as contractors switch from federal projects with Davis-Bacon and disadvantaged business enterprise policies to less-regulated state projects.

This finding with respect to the coefficient for state projects does not change when Model 3 is estimated without a measure of the number of bidders, with instrumental variables, a different price index, random effects, the interaction of State Project with all of the independent variables included in Model 3, or a correction for sample selection. For example, it is possible that the regulatory requirements of federal projects crowd contractors into state-funded resurfacing projects. This implies that the effect of state projects on the winning bid should be measured without the control for the number of bidders. When Model 3 is estimated with the omission of Ln # Bidders, the coefficient for the state variable is –0.028 (t-value = –0.70). When the number of bidders is replaced with a measure of the expected number of bidders in an instrumental variables estimate, the coefficient for state project is –0.031 (z score = –0.40).[10] The coefficient for the state project variable when the CDOT composite cost index is used to adjust for inflation is –0.0393 (t-value –0.98) and is –0.084 (z = –1.23) when random effects are estimated. Additionally, the results of a Hausman test indicate the fixed effects model is preferred to the random effects model. The chi^2 statistic from the Hausman test is 40.59 indicating that the null hypothesis that random effects estimate is consistent is rejected at the 0.03 level. The coefficient for the state project variable is –0.415 (t-value = –0.35) when this dummy variable is interacted with all of the independent variables included in Model 3.[11]

Sample selection may cause inconsistent estimates because the data set contains only contractors who were awarded state and federal projects. To address the potential problem of selectivity bias the two-step method developed by Heckman (1979) was also estimated. The auxiliary probit model specifies selection into the sample of contractors that won state and federal awards versus 34 contractors that completed only state projects over the period. Since some of these 34 contractors completed only one resurfacing project between 2000 and 2011, the contractor identifiers used in a fixed effects estimate reported in models 1-3 are not included in the two-step self-selection method. The coefficient for the state variable from an estimate of the winning bid is –0.064 (z = –0.72) when the auxiliary probit model includes the year, region, and terrain dummy variables along with a proxy of contractor size (the number of prequalified work specialties for each contractor as of 2011). The inverse Mills ratio (lambda) did not achieve statistical significance indicating that sample selection is not associated with inconsistent estimates ((z = –1.18). However, this analysis of sample selection is based on limited information contractors' decisions to bid on state and federal projects.[12]

The results for the engineer's estimate indicate that a one percent change in this estimate is associated with a 0.961% change in the winning bid. This effect is statistically significant with a t-value of 56.53. While the elasticity of the winning bid with respect to the engineer's estimate is close to one, it is significantly different from this value at the 0.05 level. The computed t-statistic is 2.29. Including the engineer's estimate increases the R-squared to 0.99. The change in the R^2 between models 2 and 3 is statistically significant at the less than the 0.01 level. The computed F statistic with the addition of the engineer's estimate in Model 3 is 222.2. This is consistent with the other studies, described above, that utilized the engineer's estimate when estimating the winning bids for highway construction.

Including the engineer's estimate provides additional information regarding the cost effects of Davis-Bacon and DBE policies. For example, since CDOT uses prevailing wage rates when estimating the cost of federal and state projects, the engineer's estimate for state projects will be too high relative to the winning bid if the wage policy is associated with increased construction costs. This implies that, holding the engineer's estimate constant, the coefficient for state projects should be negative.[13] Additionally, any anticipated cost impact associated with the DBE is not included in the engineer's estimate of federal projects. If the DBE increases construction costs on federal projects, the coefficient for state projects should be negative. The absence of a statistically significant bid-price difference for state projects suggests that the wage and disadvantaged business policies do not affect the aggressive bid behavior of contractors because the regulations are not related to project cost.

Including the engineer's estimate in the model also provides insight into how CDOT and contractors price features of a project. Holding CDOT's cost estimate constant, contractors price projects requiring finish grading and on rolling terrain from 8% to 6% higher, respectively. These differences are significant at the 0.01 (one-tailed test). The negative and significant coefficient for the number of bidders implies that increased bid competition reduces contractor margins relative to the engineer's estimate. This difference is significant at the 0.10 level. The trend in the year dummy variables suggests that contractor bids exceeded CDOT estimates in 2003-2005 and from 2007 and 2008. As discussed above, 2003-2008 was a period when asphalt material prices rose sharply and the results indicate stronger reactions by contractors to the upward trend in these prices.

In addition to changing material prices, the latter period of the study was influenced by the Great Recession and the American Recovery and Reinvestment Act (ARRA). CDOT received approximately $386 million in ARRA highway stimulus funding that financed projects between 2009 and 2012 (see CDOT ARRA Projects). While ARRA funding provided stimulus to highway construction in Colorado, this occurred during a period of decreased funding from other sources and a collapse in construction industry employment. For example, transportation funding from the State of Colorado decreased 8% between 2008 and 2009, from $1,082 million in 2008 to $995 million in 2009 (See CDOT Fiscal Year 1980 to 2010 CDOT Budget). CDOT funding fell another 2% in 2010 (to $973 million). Construction industry employment in Colorado fell from approximately 162,000 jobs in 2008 to about 112,000 in 2011, a 31% decrease (See U.S. Department of Labor, Bureau of Labor Statistics). Employment increased to 115,000 in 2012. The results for the year dummy variables for Model 3 indicate contractor bids exceeded CDOT estimates during the period when asphalt material prices were increasing, but relative pricing between 2009 and 2011 was no different than the base year (2000). Other evidence suggests increased bid competition during the period of glutted market conditions. For example, an estimate of the number of bidders indicates a statistically significant increase of approximately three more bidders per project in 2009 and 2011, compared to the reference period of 2000.[14] While ARRA provided some stimulus to highway construction in Colorado, the policy does not appear to have offset the cyclical influences on material prices, employment, and bid competition.

CONCLUSION

Previous research examines the effect of asymmetries across bidders on auction outcomes. This study tests for evidence of asymmetric behavior within firms as they switch between different regulatory regimes. Data from federal and state highway resurfacing projects in Colorado indicate that contractors do not bid more aggressively when they switch from federal projects that require Davis-Bacon prevailing wage and Disadvantaged Business Enterprise regulations to state projects that are not covered by these policies. This finding is based on a model that includes the engineer's estimate of project cost, a comprehensive measure of detailed project characteristics. The estimates of construction costs employed here underscore the importance of accurate controls for detailed project characteristics in the broader literature addressing the cost effects of federal regulations.

One possible explanation of symmetric bid behavior is that wages are 'sticky' for those contractors who won state and federal projects over the time period. For example, union signatory contractors agree to pay the union scale and to adhere to the union division of labor regardless of state or federal funding. Therefore, Davis-Bacon wage requirements would not affect the wage rates and labor costs of these contractors with the switch from federal to state projects. However, only one of the contractors included in the sample is a union signatory for the trades involved in highway resurfacing.[15] A more likely explanation is that Davis-Bacon wage requirements are unrelated to bid costs since labor costs for highway projects are approximately 20% of total construction costs and average rates prevailed for almost all of the job classifications involved in resurfacing work in Colorado. Similarly, DBE may not have an effect on bid behavior if subcontractor choice is 'sticky'. The general contractors included in the sample may use the same subcontractors (including DBE subcontractors) on state and federal projects. This may explain why bids do not differ as contractors switch from state to federal projects. Even if the same subcontractors are used, the general contractors who won bids are able to compete with the larger population of contractors who bid on CDOT projects. The finding that Davis-Bacon and DBE regulations do not affect aggressive bid behavior may differ in jurisdictions with higher DBE targets or where union rates prevail.

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NOTES

1. See the U.S. Department of Labor, Davis-Bacon and Related Acts, U.S. Department of Transportation, Disadvantaged Business Enterprise Program, U.S. Department of Justice, Title VI of the Civil Rights Act of 1964, and U.S. Department of Justice, Americans with Disabilities Act.
2. See CDOT Equal Access Program and CDOT Title II, Americans with Disabilities Act. Over the period of this study, the State of Colorado also had a voluntary emerging small business policy that provided incentives for general contractors to involve small subcontractors. According to CDOT staff, this program was seldom used and none of the projects included in this study were affected by this policy.
3. The remaining cost estimates include \$1.5 million to \$5 million, \$5 million to \$10 million, \$10 million to \$20 million and over \$20 million.
4. For clarification, the sample used in this study is a subset of the larger data set of resurfacing projects since contractors that did not complete at least one federal and state project over the period are systematically excluded due to this characteristic.

This type of exclusion can cause bias and methods used to determine if this occurs are discussed below. This sample selection is distinct from censored or truncated data. Censored data would involve including a specific number of low, medium, or high cost projects, for example. On the other hand, truncated data would exclude projects above or below a certain cost level. Sample selection may be associated with truncation if the contractors that participated in state and federal projects limited their activity in very low or very high valued projects.

5. Another factor in the choice between fixed and random effects concerns whether or not the individual-level effects are related to the independent variables included in the estimation of construction costs. This issue is resolved with a Hausman test and is discussed below.

6. The purpose of the sequential introduction of detailed project controls is not guided by step-wise techniques (that determines which variables should be included or excluded based on t-values). Rather, the purpose is to illustrate the issue of specification bias in the measurement of a prevailing wage cost effect.

7. Factorial ANCOVA or factorial MANCOVA are alternative methods of analyzing differences in construction costs between projects with different detailed characteristics. While these techniques can be used to determine differences in average costs between projects with differing levels of detail, they are unable to determine if the effect of the detailed measures are related to costs in a statistical sense. This issue is addressed in regression analysis and this approach is better suited in illustrating omitted variable bias in the state project variable.

8. As described above, the sample of 91 observations consists of 47 federal and 44 state projects. Other methods such as ANCOVA or MANCOVA may be used in the analysis, but the relatively small sample sizes for federal and state projects may constrain the analysis when a large number of factors are considered.

9. Labor costs as a percent of total construction costs can be measured using information from the Economic Census of Construction. For example, dividing the sum of total worker

payroll and proportionally allocated total fringe benefits by the net value of construction work (minus the value subcontracted to others) indicates that construction worker payroll is 21% of total costs for Colorado highway, street, and bridge construction (NAICS 237310). See the Economic Census of Construction, Geographic Series 2007.

10. The expected number of bidders is constructed using the independent variables in Model 3 with an additional measure of bids awarded in the fourth quarter. State and federal budget cycles result in fewer resurfacing contract awards in the fourth quarter, resulting in more bids per project during this time. The coefficient for the Q IV dummy variable in the estimate of the Log of # Bidders is 0.431 (t-value = 3.05). The fourth quarter dummy variable is an appropriate instrument as it is related to the number of bidders and unrelated to omitted variables such as contractor backlog. Since resurfacing work is completed during warm weather (April to October), the fourth quarter variable does not capture the effect of weather that may influence bid costs.

11. The coefficient for the interaction of State Project and Southern Region is the only coefficient that achieves significance at the 0.10 level or less. This coefficient is 0.320 (t-value = 2.30).

12. While results from the two-step model indicate that sample selection is not an issue in the estimate of bid-costs, the model is limited by the availability of data on factors influencing a contractor's decision to bid on state and federal projects. If contractor size is a factor, data are limited on measures such as capital stock or other resources that are associated with a contractor's scale. Collecting this and other measures of company size for each year of the study is not possible. Consequently, the results of the self-selection model should be interpreted with caution. Future research, based on more complete information on contractors, may be able to more adequately address this issue.

13. Another way of expressing this is in terms of the dependent variable as the difference between the log of the winning bid and the log of the engineer's estimate where the coefficient for state variable is also expected to be negative if the wage policy is

associated with increased construction costs. The coefficient from this estimate is -0.023 (t-value = –0.64) based on the specification of Model 3 with the replacement of the # of Bid Items for Ln Engineer's Estimate as a measure of project size and complexity.

14. This is based on an estimate of the number of bidders per project with the same independent variables listed for Model 3. The coefficients for the 2009 and 2011 dummy variables are 3.695 and 3.709, respectively (t-values = 3.69 and 4.59).

15. This contractor is signatory to all three of the unions representing trades involved in resurfacing work (laborers, operating engineers, and teamsters). Another contractor is 'double breasted' with one of five subsidiaries signatory to the operating engineers and teamster unions. However, it is not possible to separate the projects awarded to the signatory from the other subsidiaries.

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