Effects of Market Concentration and Competition in the Paving Sector

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ABSTRACT

Planning agencies are searching for innovative techniques to cost effectively preserve their existing infrastructure systems. In this study, we investigate the effects of two indicators of increased competition in the paving market as a mechanism to reduce roadway construction costs. The highway construction sector makes for a unique case study due to a rich dataset that allows for the simultaneous consideration of two indicators of competitive intensity: number of bidders on a project (an indicator of intra-industry competition – between firms who pave with the same material) and market concentration (an indicator of inter-industry competition – between firms who pave with material substitutes). To evaluate the relationship among these indicators and pricing, we develop panel data regression models using bid data that spans 10 years for 47 states within the United States. The models embed several covariates that account for cross-sectional and time-varying heterogeneity. Results from the analyses indicate both that a) the paving market functions as a private value auction, in which an increase in bidders reduces construction prices and b) states with more uniform market shares among pavement materials pay lower prices for all materials. For a "typical" roadway project, the parameterized model indicates that states that with the lowest quartile of market concentration pay at least 7% less than states with the highest quartile of market concentration. These findings support the notion that policies that reduce material market concentration have the potential to reduce an agency's costs, allowing it to be more efficient with its limited resources.

Keywords: auction theory; competition; competitive tendering; regression; panel data; roadways

1. INTRODUCTION

Transportation agencies are under increased pressure to maintain and preserve their roadway assets with limited available resources. The Federal Highway Administration (FHWA) estimates that 20% of roadways are deficient across the United States (U.S. Department of Transportation 2015). Perhaps even more alarming, recent studies estimate that more than $1 trillion US dollars, beyond current spending, is needed to address this deficiency (Zhao, Fonseca-Sarmiento, and Tan 2019). This shortfall in capital investment is likely to continue as revenue streams for the Highway Trust Fund decrease due to increased fuel efficiency of the nation's vehicle fleet and stagnant growth in vehicle miles travelled across the United States (Schroeder 2015). In short, transportation agencies are being forced to do more with less.

This fiscal reality means that agencies need innovative approaches to be resourceful within their constrained budgets. In this paper, we focus on the possible role of increased competition in the paving sector as one approach for agencies to be more efficient with spending through reduced costs. Governmental agencies widely use competition to procure public works projects (Armstrong and Sappington 2006). From a planning agency's perspective, an increase in competition should lead to aggressive bidding by firms so that the cost to deliver infrastructure works and transportation services will approach efficient pricing (Amaral et al. 2012; Kennedy 1995). The high-volume pavement sector in the United States provides an interesting case study of this phenomenon because in that sector at least two forms of competition exist: intra-industry competition (between firms who pave with the same material) and inter-industry competition (between firms who pave with material substitutes, namely asphalt concrete (AC) and portland cement concrete (PCC)). Inter-industry competition can oftentimes be found in manufacturing industries (McKillop et al. 1980), in which multiple materials such as plastics and aluminum

(Barnes 1999) can be substituted for one another in order to deliver a final product. In this paper, using a dataset of almost 30,000 projects, we explore the observed relationship between paving cost and indicators of competition both intra-industry and inter-industry. Notably, the competitiveness of a market per se cannot be directly observed. Instead, we make use of commonly discussed indicators of competition – number of bidders for intra-industry and market share of the dominant competitor, a measure of market concentration, for inter-industry effects.

2. Literature Review

Among the public works research, a limited set of literature has empirically estimated the effect of intra-industry competition (specifically, the number of players involved in the bidding process) on the cost to deliver infrastructure projects. Analyzing forty-three large-scale (greater than $5 million) roadway projects, Shrestha and Pradhananga (2010), the most relevant paper to our context, found a negative, significant correlation between the number of bidders for a project and its cost growth (i.e., the difference between actual construction costs and the engineer's estimate). Carr (2005) also finds a significant, negative relationship between cost growth and number of bidders using a dataset composed of over 400 bid items for approximately 20 educational buildings. A notable characteristic of the existing research on the role of competition for roadways delivery is that it does not account for the implicit heterogeneity found across construction projects other than their absolute cost magnitude (Shrestha and Pradhananga 2010). Roadway projects are heterogeneous due to a host of factors: project size, the volume of material employed, duration, location, and overall market conditions at the time of construction are just some examples of factors that may affect bid prices for the same item (Chua and Li 2001; Damjanovic and Zhou 2009; Krasnokutskaya 2011; Ngai et al. 2002). Accounting for such factors is imperative for empirical research to ensure that the findings are robust and not spurious (Amaral et al. 2012;

Athias and Nuñez 2008; Brannman et al. 1987).

Lastly, although several studies have evaluated the effects of what was defined previously as intra-industry competition, no studies (to the authors' best awareness) have considered the effects of inter-industry competition on auction prices in the transportation context. A key hurdle in the path towards understanding the effect of inter-industry competition is measuring it. A metric is required to identify which markets have more intense and which have less intense competition. This topic has been a source of debate in the academic literature for some time. Many studies make use of qualitative questionnaires to assess the competitive intensity (Kwieciński 2017) of a given market. These questionnaires may involve participants commenting on, for example, whether "competition in our industry is cutthroat" (Jaworski and Kohli 1993). Although informative, such measures are not well suited to our purposes here.

Among the quantitative measures of market competitive intensity, two are most common (Kwieciński 2017) – number of competitors and distribution of market share. An increase in the number of competitors in a market is suggested as an indicator of increased competitive intensity (Porter 1990). Generally, however, authors recognize that number of competitors alone is too simple to capture the true intensity of competition (Porter 2008; Ye, Jiang, and Shen 2008). Additionally, number of competitors is not useful for analyzing the paving market at the materials supply level as there are always only two options that are broadly applied. Fortunately, the most widely applied measure of competitive intensity is the uniformity of distribution of market share. The most common variant of this is the Herfindahl-Hirschfeld Index (HHI). Although it is frequently referred to as a measure of competitive intensity (Li, Poppo, and Zhou 2008), HHI specifically measures market concentration and is therefore more precisely described as a measure of the market structure or market context. Nevertheless, there is theoretical justification for using observed market structure to infer competitive intensity. Cowling and Waterson (1976) described a theoretical model that suggests margins decline with more uniform share in a Cournot competitive market. Empirical evidence of this behavior has been mixed. In an extensive 1989 review of empirical studies, Schmalensee (1989) concluded that for inter-industry studies the concentration-profitability relationship was present but small. Borenstein et al. (1999) highlight that other factors and metrics (e.g., the price-responsiveness of demand) can provide a more holistic understanding of competition in a market. Market concentration should, therefore, be viewed as a screening tool to provide a first order understanding of competition in the absence of other available metrics (Borenstein, Bushnell, and Knittel 1999).

Recognizing these shortcomings, we adopt market share of the dominant supplier as an indicator variable for competitive intensity. For a duopoly, dominant market share tracks monotonically with HHI. Following the commonly accepted approach, we assume that a more balanced market is one with more effective competitive intensity. Market share, as measured by spending, of PCC and AC paving materials varies greatly from state-to-state. In fact, over the ten years of data that this study uses, while some state departments of transportation (DOT) have spent nearly 50% of its paving budget on PCC pavements, and there are several states where there is virtually no spending on PCC and, therefore, logically no competition between the materials industries. Consequently, there is an opportunity to explore the potential impacts of differences in market structure in this sector. The exploration of this question is particularly timely as multiple DOTs evaluate policies such as alternate design/alternate bid, where pavement designs of different materials are considered for the same project, to further induce competition in project bidding (Temple et al. 2004).

Our research approach is to develop a set of empirical models to test for an observed relationship between indicators of competition – number of bidders and dominant market share – and bid pricing for pavement systems. The models account for heterogeneity in pricing that arises from factors such as project and market size. Two important limitations underlie our dataset: it only reports tender prices, and it does not detail the environmental context (e.g., expected traffic volume) for a procured project that also impact cost. Fortunately, previous research suggests that (a) there is a high correlation between bid and actual construction costs in roadway construction (Williams 2003) and (b) the difference between bid and actual costs is typically smaller than one finds for other infrastructure systems (Flyvbjerg et al. 2002; Shrestha and Pradhananga 2010). This attribute of roadway construction stems from the extensive experience firms have with a relatively simple, modular system (Flyvbjerg et al. 2002). Furthermore, according to the latest *Highway Statistics* produced by FHWA (Federal Highway Administration 2017), 60% of paved miles under the control and jurisdiction of state DOTs are arterial and interstates, which are typically subject to the highest traffic volumes across a roadway network. As a result, while these concerns are valid, we expect that our results would hold true if actual cost and project-specific traffic information were made available; future research should validate this assumption. Finally, as with all empirical studies of historic data, our results cannot prove causation, but can suggest useful hypotheses for further testing.

3. METHODOLOGY

To characterize the relationship between bid price and both the number of bidders and dominant market share in the paving sector, multivariable regression models are constructed for asphalt and concrete projects using historical state highway bid data. The general structure of these panel data regression models is:

$$Y_{it} = \beta_0 + \beta_1 X_{it,1} + \cdots \beta_p X_{it,p} + \varepsilon_{it} \tag{1}$$

where i and t are indices for the individual projects and time, respectively. The predictor variable, Y, is the logarithmic unit-price for AC and PCC pay items, which is a function of p covariates (X) and their associated effects (β) as well as an error term (ε). Modeling tendered prices in their log form not only helps to deal with concerns around heteroscedasticity but also leads to a more intuitive model; specifically, a shift in the log level of a variable can be approximated as its percent change. This study focuses on PCC and AC related pay items only, which is further detailed in the following section, in order to focus on the bid items that would presumably be affected by both intra-industry and inter-industry competition. A previous study by the authors (Swei et al. 2017) has demonstrated that these pay items tend to be the cost-dominant costs for paving projects and are, therefore, of primary concern for policy-makers and planners.

As mentioned previously, the competitiveness of a market per se cannot be directly observed. As such, this study relies on indicators of competition. Here we use as an indicator of intra-industry competition, similar to many other academic works, the inverse of the number of competitive bids ($1/bids_{it}$) received by an agency for a given project (Amaral et al. 2012; Athias and Nuñez 2008; Brannman et al. 1987; Damjanovic and Zhou 2009; Gómez-Lobo and Szymanski 2001; Hong and Shum 2002; Shrestha and Pradhananga 2010). One would expect a positive coefficient estimate, where a decrease in the inverse number of bidders (increase in number of bidders) for a project decreases prices.

For inter-industry competition we use as an indicator, the average market share for the dominant material within a given state (DMS_{it}). The average of this value for each state between 2009 and 2013 is shown in Figure 1. While the relative use of PCC and AC pavements for a specific location depends on a host of factors (e.g., availability of materials, implementation of policies that may promote a particular material), it nevertheless provides a quantitative metric to measure their relative presence and potential effect on local paving prices. As can be noted in Figure 1, no state within our dataset over the five-year period had a PCC spending share that exceeded 50%, and so the dominant material across this study is always AC pavements. Given the nature of our dataset, it is unfortunately not possible to comment as to whether a PCC-dominant system exhibits similar behavior as an AC-dominant system.

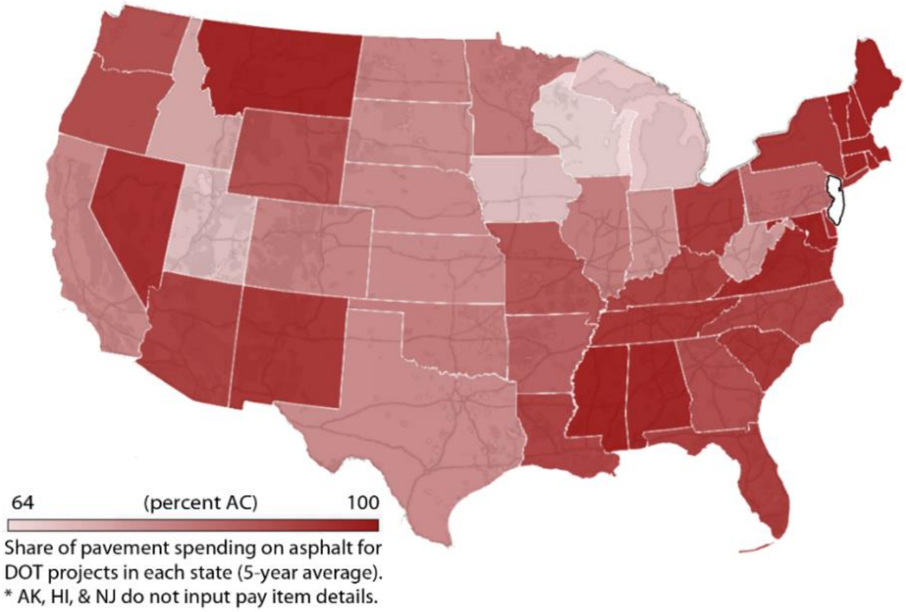

Figure 1. Average share of pavement spending on asphalt (AC) projects across different state DOTs from 2009-2013.

Because dominant material market share depends on aggregating project spending, it may be endogenous and create an identification problem for the model. (Stock and Watson 2015; Maddala 1992). Results of the Durbin-Wu-Hausman test, which are later discussed, suggest that endogeneity is present for this case. To address this issue, we follow the approach described by Wilkins et al. (2001) and apply a two-stage least squares (2SLS) solution approach using lagged dominant material share (DMS_{it-1}) as an instrumental variable (IV). Quantitative evidence of the validity of DMS_{it-1} as an instrument are presented at the beginning of the results section.

One other type of endogeneity could exist within our modeling context. Specifically, cases where both AC and PCC designs are considered for the same project thereby making AC and PCC prices simultaneously determined. In the industry, these are commonly referred to as alternate design/alternate bid (AD/AB) projects. A recent study by the National Cooperative Highway Research Program found that about 40% of responding states (16 of 40 survey respondents) had AD/AB projects (Gransberg et al. 2017). These states had practiced AD/AB for 8 years on average and had executed a total of 333 projects. Excluding states with less than five years of AD/AB experience, states let approximately 3 projects per year using this process. Assuming that 40% of all states let 3 projects per year, this would translate to 540 AD/AB projects over our nine-year dataset. This represents less than 2% of our dataset and should not influence the results significantly.

Existing empirical research interested in the effects of competition will typically regress the unit-price of a service or commodity against competition indicator variables and $p-1$ covariates that capture the cross-sectional and time varying heterogeneity across the samples (Amaral et al. 2012; Damjanovic and Zhou 2009). These sources of heterogeneity are captured in the specified model to address possible bias issues in the estimation of the competition effect. Time-varying heterogeneity is considered within our panel data regression models by including $T-2$ dummy variables, DT_t, where t is a specific year and T is the total number of years of bid data within our sample. We incorporate $T-2$ rather than $T-1$ dummy variables due to our instrument being lagged dominant market share. Controlling for such heterogeneity via fixed effects is important given the high material-price volatility of fuel-based paving products (Pittenger et al. 2012).

In our study, we account for cross-sectional heterogeneity by integrating a series of covariates suggested by the literature and discussions with industry professionals. These covariates are listed in Table 1. As noted earlier, there are other drivers of cross-sectional heterogeneity (e.g., project site characteristics) that were not available within our dataset.

Table 1. Description of covariates considered within the panel data regression models to account for time-varying and cross-sectional heterogeneity.

Covariate	Variable Formulation	Effect Accounted for by Covariate
Time Dummy Variable (DT_t)	$DT_t = \begin{cases} 1 & t = t^* \\ 0 & t \neq t^* \end{cases}$	Fixed-effect variable that accounts for changes in job prices over time
Project size: Quantity of Materials ($q_{m,it}$)	$\ln q_{m^*,it}$	Economies-of-scale for a given project
State market size: State lane-miles (s_{it})	$\ln s_{it}$	Market size and its impact on bid unit-prices
State's use of price adjustment clauses (D_{PAC})	$D_{PAC} = \begin{cases} 1 & PAC = \text{True} \\ 0 & PAC = \text{False} \end{cases}$	Effect of shifting material volatility risk from the contractor to the agency

Definition of Symbols:
DT_t – Dummy variable that takes on a value of 1 if the i^{th} sample occurs in year t^*
$q_{m,it}$ – Project size: Quantity of material *m* for job *i* in year *t*
s_{it} – State market size: State lane-miles for sample *i* in year *t*
D_{PAC} – Dummy variable that takes on a value of 1 if a state uses price adjustment clauses for any increase in material prices between date of bid and actual construction

Infrastructure works typically exhibit economies-of-scale (Amaral et al. 2012; Athias and Nuñez 2008; Damjanovic and Zhou 2009). To capture this effect of project size, we include quantity of materials used for each job ($q_{m,it}$) as one predictor variable, where $q_{m,it}$ is defined as the natural log of the quantity of material *m* for job *i* in year *t*. Additionally, differences in institutional and/or market structure between state planning agencies may induce further variation within our dataset (Gómez-Lobo and Szymanski 2001; Thiel 1988). Consequently, we consider the potential effects of market size, measured as the lane-miles of pavement existing in a state in a given year per FHWA's *Highway Statistics* (Federal Highway Administration 2017). While it would be more conventional to use spending to measure market size, we use lane-miles to avoid a risk of an additional endogeneity problem in the model. Lastly, state DOTs have differing policies regarding price adjustment clauses, in which the risk associated with the potential rise of construction materials between the bidding and project procurement phases is shifted from the contractor to the agency (Ilbeigi and Castro-Lacouture 2017). We incorporate within our modeling framework a dummy variable, D_{PAC}, for those states in which price adjustment clauses are in effect for any increase in material prices.

To comment on the statistical significance of these variables, we rely on t-statistics from the resulting parameterized models. We generate plots of the resulting residuals to characterize the degree to which heteroscedasticity (i.e., non-constant variance in the residual term) is present in the model.

3.1 Description of Dataset

The data used in this study comes from Oman BidTabs, which catalogs bid information for state DOT roadway projects across the United States (Oman Systems Inc. 2015). All states except Alaska, Hawaii, and New Jersey have information stored within this database for each pay item used in roadway construction since 2005. For this analysis, we use nine years of data, from 2005 to 2014, constituting more than 30,000 observations.

The Oman BidTabs database identifies the following information for each pay item: its pay number and category, the associated project with that pay item, and the recorded date, price, and quantity for the bid. Other characteristics of a project, such as its location, total cost, number of bidders, top three bids, and top three bidder firms, are also available with each record. The unit-price of PCC jobs is provided in volumetric metrics (i.e., dollars per cubic yard), the current industry standard, whereas the unit-price of AC jobs is typically listed by weight (i.e., dollars per ton), the industry standard for flexible pavements. In instances where the quantity of materials for an asphalt pay item is listed in terms of volume, we convert that quantity into tons assuming that material density is 145 lbs./ft^3 (16 kg/m^3). The majority of competitively bid projects itemize costs for each pay item but do not delineate material and non-material costs (e.g., transportation of materials to site, labor, and equipment) within those pay items. In our analysis, we aggregate information for multiple pay items within a project if they are of a similar material and used for the same project. Conversely, we exclude some design-build projects in this analysis because they do not differentiate between pay items for a job.

This analysis excludes non-paving specific pay items (e.g., bridge slabs, patching). AC pay items that included the following terms (or abbreviated equivalents) were excluded from our analysis: aggregate surfacing, blotter, chip seal, cold planing, concrete items, contractor retained AC, ditch items, fly ash, fog seal, mill, patches, repairs, SAMI (asphalt-rubber Stress Absorbing Membrane Interlayers), scarifying, slurry seal, surface treatment, tack coat, and trial mixes. Similarly, PCC pay items that included the following terms (or abbreviated equivalents) were removed: approach slabs, cement slurry, colored concrete, diamond grinding, ditch paving, expansion joint, gore areas, latex concrete overlays, patches, patterned concrete, precast panels, pressure grouting, repairs, sealers, sealing, slope paving, stamped concrete, and trial mixes.

Our initial analyses indicated that unit-prices were highly variable for small projects. For such jobs, where fixed costs dominate variable costs, construction site variability and its effect on capital equipment and resource requirements tends to increase the unit-price variability for relevant pay items. Additionally, our discussions with industry professionals suggested that such variability may be the result of life cycle cost analyses (LCCA) not being required for small jobs, less attention being paid to prices on jobs with low material quantities, and firms opportunistically profiting from the prior phenomena. In light of this observation, our study only considers jobs where the quantity of materials used is at least equivalent to a 6 in. (15 cm) thick, 5 lane-mile (8 lane-km) long pavement section.

For the years of our analysis, these two screens (non-paving items and small jobs) retained 73% of the asphalt pay items, representing 94% of the asphalt payment spending, and 57% of the concrete pay items, equaling 88% of the concrete spending. Table 2 provides descriptive statistics regarding the regressors used in our study.

Table 2. Summary statistics for selected regressors used in analysis.

Regressor	**Units**	**Average**	**5th Percentile**	**25th Percentile**	**Median**	**75th Percentile**	**95th Percentile**
$q_{concrete,it}$	Cubic Yards	36,040	6,400	10,130	19,470	45,960	114,600
$q_{asphalt,it}$	Tons	36,690	11,900	16,190	24,580	41,650	100,540
s_{it}	Miles	25,096	5,429	10,288	15,079	33,837	80,455
$bids_{it}$	Number	3.67	1	2	3	5	8
DMS_{it}	%	0.85	0.62	0.76	0.85	0.97	1

$q_{m,it}$ – Project size: Quantity of material m for job i in year t
s_{it} – State market size: State lane-miles for sample i in year t
$bids_{it}$ – Number of bids received for job i in year t
DMS_{it} – Dominant Market Share as percent of state market spending on asphalt projects for sample i in year t

4. RESULTS

To understand the relevance of endogeneity in this modeling, we carried out a Durbin-Wu Hausman test which requires constructing two model variants for each material. The first model set comprises all covariates including dominant market share (DMS_{it}). The OLS estimates of the parameters for these models are shown in Table 3. These models also served to characterize the validity of DMS_{it-1} as an instrumental variable (IV). A good instrument would be a variable that is both correlated with our potentially endogenous variable (DMS_{it}) and uncorrelated with the residuals (ε_{it}). We found that DMS_{it-1} satisfied these two conditions based on the strong linear correlation between DMS_{it-1} and DMS_{it} (0.59 for PCC, and 0.64 for AC) and exogeneity as indicated by near zero correlation between DMS_{it-1} and ε_{it} (0.05 for PCC, and 0.03 for AC). The second set of models in Table 3 are two stage least squares (2SLS) models with all covariates using the IV DMS_{it-1}. Coefficients for these models are summarized in Table 3 and can be found directly adjacent to the OLS estimates. Durbin-Wu-Hausman results of 7.04 for the AC models and 46.77 for the PCC model were computed. Both values reject the null hypothesis of exogeneity for DMS_{it} at the 1% level. Based on this, the 2SLS models were adopted for further investigation.

As can be noted in Table 3, for all four panel regression models, we report t-statistics for each parameter estimate in parentheses. As mentioned previously, our models incorporate the following variables: (a) time fixed effects to control for price fluctuations over time (DT_t), (b) the quantity of materials required for a job ($q_{m,it}$), (c) the market size of a given state (s_{it}), and (d) whether a particular state uses price adjustment clauses for any increase in material prices between the time of bidding and construction (D_{PAC}), (e) the number of bidders for specific project ($bids_{it}$) and (f) the lagged market share of the dominant material (DMS_{it}). In the finalized 2SLS regression models, t-statistics for all but three covariates (DT_{2007}, DT_{2008}, and DT_{2013} for concrete unit-prices) are significant at the 1% level. DT_{2008} and DT_{2013} for concrete unit-prices are significant at a 5% level. DT_{2007} for concrete unit-prices is significant at a 10% level.

Table 3 also lists the significance of our two competition indicator variables: (a) the (inverse) number of bidders for a given project and (b) the percent spending across a given state that is of the dominant material (dominant market share). Both parameter estimates are significant at the 1% level across both material types. The positive coefficient estimate for (inverse) number of bids implies that the bidding process within the pavement industry behaves like a private value auction, in which the “competition effect” ultimately reduces construction prices. The positive coefficient associated with dominant market share indicates that, as a state DOT moves towards a single-material market, the average price for a project increases for both materials. While the coefficient estimate of dominant market share is both positive and significant for the asphalt (0.34) and concrete (1.39) models, the absolute magnitude of its effect is considerably larger in the case of concrete. One likely reason for this outcome is that a reduction in the dominant market share not only possibly induces increased competition in this duopoly but also facilitates contractors producing the less dominant technology to establish their own presence (e.g., supply chains) to cost-effectively construct pavements.

Table 3. Summary table of parameter estimates for panel data regression models with t-statistics listed in parentheses. Values with * reject the null hypothesis at the 10% level, all others at 1%. For concrete unit-price, the percentage of a project completed in asphalt ($r_{m,it}$), marked with †, accepts the null hypotheses at these levels.

	ln *unit-price of asphalt pay items*		**ln *unit-price of concrete pay items***	
	OLS	**2SLS**	**OLS**	**2SLS**
Parameter	**Time-Varying Fixed Effects**			
$\beta(DT_{2006})$	-0.26 (-27.93)	-0.26 (-27.79)	-0.11 (-3.31)	-0.08 (-2.36)
$\beta(DT_{2007})$	-0.22 (-24.12)	-0.22 (-23.99)	-0.07^{*} (-2.07)	-0.06^{*} (-1.66)
$\beta(DT_{2008})$	-0.09 (-9.63)	-0.09 (-9.77)	-0.08^{*} (-2.17)	-0.10^{*} (-2.83)
$\beta(DT_{2009})$	-0.14 (-16.38)	-0.14 (-16.37)	-0.18 (-5.82)	-0.18 (-5.41)
$\beta(DT_{2010})$	-0.12 (-13.64)	-0.12 (-13.60)	-0.18 (-5.43)	-0.17 (-5.00)
$\beta(DT_{2011})$	-0.08 (-8.16)	-0.07 (-8.07)	-0.15 (-4.40)	-0.13 (-3.72)
$\beta(DT_{2012})$	-0.05 (-5.22)	-0.05 (-5.34)	-0.17 (-5.09)	-0.19 (-5.49)
$\beta(DT_{2013})$	-0.05 (-5.50)	-0.05 (-5.54)	-0.09^{*} (-2.74)	-0.09^{*} (-2.47)
Constant	4.37 (100.13)	4.32 (90.03)	5.18 (38.52)	4.65 (28.62)
	Cross-Sectional Sources of Heterogeneity			
$\beta(\ln q_{m,it})$	-0.08 (-25.67)	-0.08 (-25.66)	-0.16 (-19.13)	-0.14 (-15.95)
$\beta(\ln s_{it})$	0.04 (15.99)	0.04 (16.16)	0.11 (10.52)	0.07 (5.66)
$\beta(D_{PAC})$	-0.09 (-16.15)	-0.10 (-16.14)		
	Competition Effects			
$\beta(1/bids_{it})$	0.14 (15.50)	0.14 (15.00)	0.21 (4.54)	0.18 (3.57)
$\beta(DMS_{it})$	0.28 (15.63)	0.34 (11.70)	0.35 (5.06)	1.39 (7.95)
Sample Size	25,210		2,583	

Definitions:
β – Parameter estimate
DT_t – Dummy variable that takes on a value of 1 if the i^{th} sample occurs in year t^{*}
$q_{m,it}$ – Project size: Quantity of material *m* for job *i* in year *t*
s_{it} – State market size: State lane-miles for sample *i* in year *t*
D_{PAC} – Dummy variable that takes on a value of 1 if a state uses price adjustment clauses for any increase in material prices between date of bid and actual construction
$bids_{it}$ – Number of bids received for job *i* in year *t*
DMS_{it} – Dominant Market Share as percent of state market spending on asphalt projects for sample *i* in year *t*

These two findings are potentially of great significance, as it suggests that policies that increase competition among firms who pave with the same material or more balanced market share among alternative materials will allow planning agencies to accomplish more with their limited available resources. This second observation is unique to this study.

Figure 2 presents a box-and-whisker plot that illustrates the effect that each covariate that enters our models has on the response variable (i.e., the unit-price of an activity). We iteratively move each variable towards its 5th, 25th, 75th, and 95th percentile values while holding all other parameters at their sample median. The selection to model impact via this approach, rather than other common methods such as generating standardized regression coefficients, is because very few of the variables are actually Gaussian distributed. As can be noted in Figure 2, the variables that have the largest impact in our panel data regression models are (a) project size and (b) the dominant market share.

The results indicate that states that have the lowest quartile of dominant market share (i.e., market share of one material, asphalt, below 76%) should expect to pay at least 7% and 26% less than states in the highest quartile (i.e., market share of one material, asphalt, above 97%) for a typical asphalt and concrete project, respectively. This estimate is based on the ratio of the minimum and maximum inner quartile values in Figure 2. Increasing from the lowest quartile of number of bidders (i.e., no more than 3 bidders) to the highest quartile (i.e., 5 or more bidders), on the other hand, is only expected to reduce prices by 5% for both a typical asphalt and concrete project.

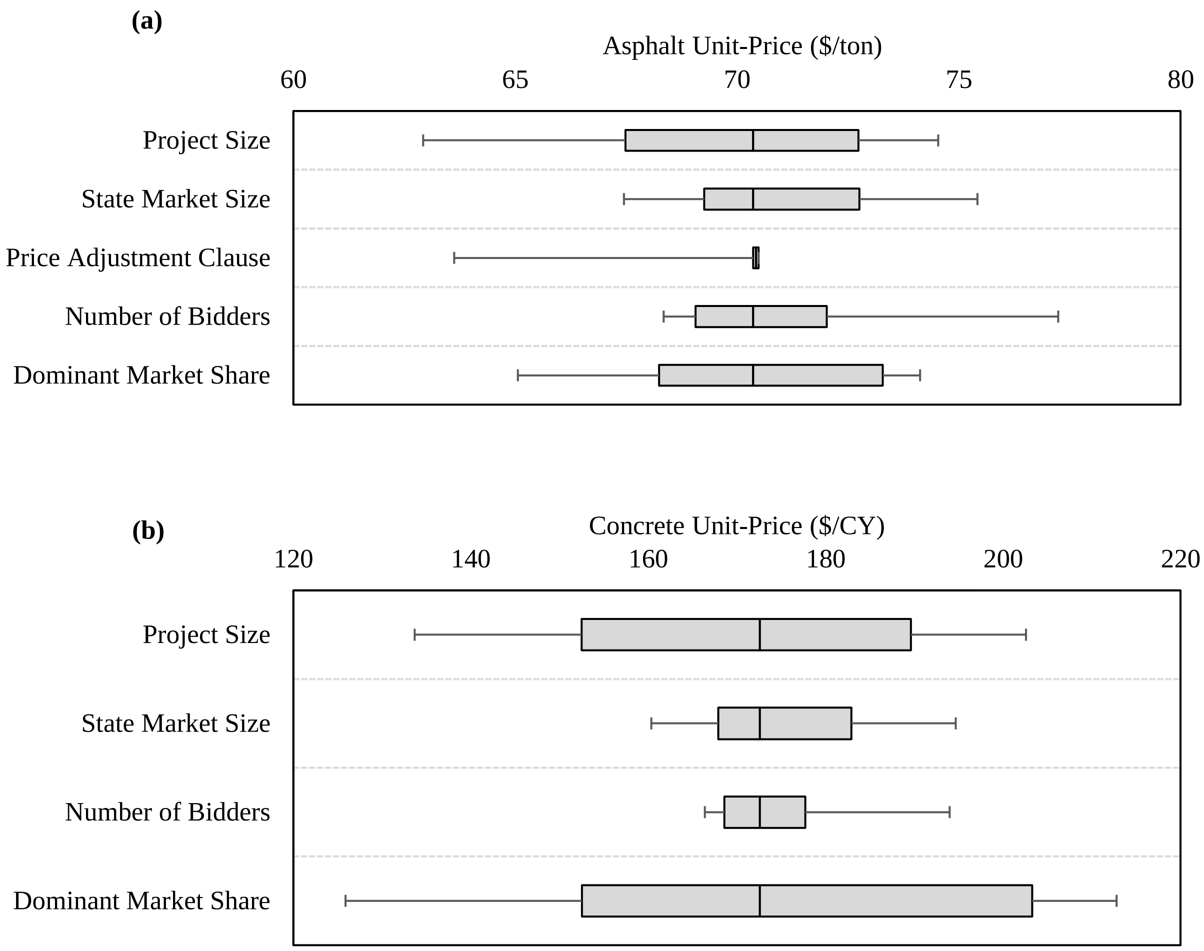

Figure 2. Box-and-whisker plot illustrating the effect that each variable that enters the (a) asphalt and (b) concrete regression models has on unit-bid prices. Whiskers represent the 5th and 95th percentiles and boxes represent inner quartiles (i.e., 25th and 75th percentiles). Specific values of the 5th, 25th, median, 75th, and 95th percentiles for each variable are listed in Table 2.

5. CONCLUSIONS AND FUTURE WORK

Transportation planning agencies and officials are searching for new, innovative methods to reduce the cost of roadway construction. In this study, we evaluated the significance and effect of two market attributes that are typically associated with increased competition in the paving sector. Whereas previous studies of the construction sector have only considered the impact of intra-industry competition, we have also accounted for the effect of market concentration for the paving market. We explored these effects by constructing panel data regression models on project bid data for 27,800 paving jobs let between 2005 and 2013 across 47 states. These regression models considered cross- sectional and time-varying heterogeneity implicitly found in panel data through the introduction of multiple covariates and fixed effect variables. Additionally, a 2SLS solution approach was adopted to address endogeneity of market concentration within the model.

The results strongly suggest that characteristics indicative of increased competition are associated with lower construction bid prices. Specifically, the results indicate that while an increase in the number of participants in the competitive bidding process tends to reduce tender prices, a potentially greater source of savings for an agency may derives from policies that lead to less market concentration (i.e., disparity in market share) among paving materials. It is important to reemphasize that the proposed models are capable of estimating the "state" of indicators of competition across a location; however, they do not characterize the effect of specific policies available to policy-makers to increase overall competition. Potential policies include the introduction of alternate design/alternate bid for large- scale projects and the utilization of life-cycle costing as part of the tendering process. In states with significant market concentration, a transition period may be necessary where the minority material industry is intentionally cultivated.

It is important for readers to recognize the limitations of this research. First and foremost is that statistical correlation, as is observed and reported here, does not establish causation. At best these results suggest a hypothesis that requires further testing. Additionally, this work relies on bids, rather than actual, construction cost data; a future study should validate our conclusions by using actual cost data. Furthermore, there are limitations in our ability to correctly identify projects in which PCC and AC pavements would be in direct competition with one another. Lastly, future work should look at possible policy changes that aim to induce competition in order to evaluate their possible restructuring of the paving sector, as has been done for other types of transportation services.

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