Presence of Competition between Paving Material Substitutes and Impact on Material Costs

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Abstract

Each year, state DOTs make decisions about which paving jobs to let, and whether they should be designed as concrete, asphalt, or let as alternates. There is wide variation in the amount spent on concrete pavement and asphalt pavement across the states and over time. Asphalt and concrete pavement materials can be considered substitutes because they perform a similar function for consumers. We explore the question: Does the presence of competition between pavement material substitutes within a state impact pavement material prices? Using pay item information from 47 state DOTs since the year 2005 from the Oman BidTabs database, we calculate for each material the weighted average unit costs each year, adjust them for year-to-year change, and average those over the study period. We select the percent of total spending on concrete within a state for a given year as the metric to represent presence of competition. Comparing these, we find that the presence of competition has a significant impact on concrete unit costs. A negative linear trend is observable but not significant for asphalt. Therefore, this result suggests that if a state were to sustain a higher presence of competition for multiple years, they could expect to pay a lower unit cost for concrete overall.

Introduction

Across the United States, the use of concrete and asphalt pavement differs greatly. Relatedly, the cost of the paving materials varies widely from job to job, state to state, and over time. Concrete and asphalt pavement materials can be considered substitutes, which are goods that perform similar functions (Frank 2006). Through analysis of multi-year state DOT bid data, we explore the question: Does the presence of competition between pavement material substitutes within a state impact pavement material prices?

In microeconomic theory, the demand curve of a product A is expected to shift to the left in response to a fall in the price of a substitute product B (Frank 2006). Consumers are expected to shift their purchasing habits toward the substitute B, causing the demand for product A to decrease. As shown in Figure 1, the consumer is now able to purchase the same quantity of product A at a lower price.

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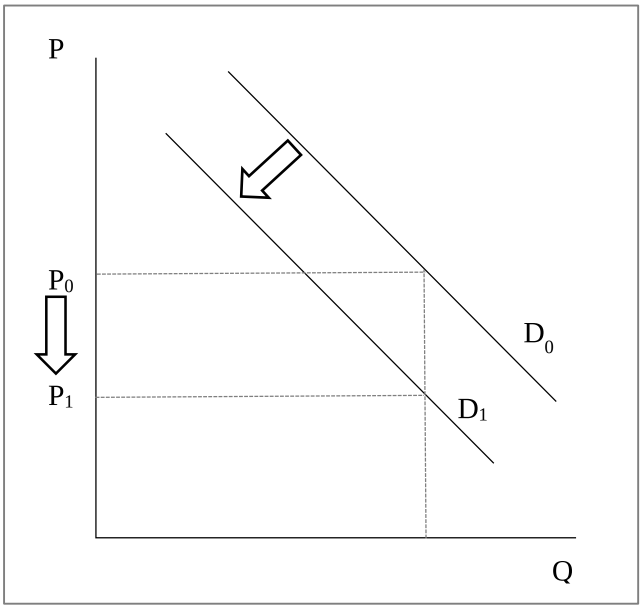

Figure 1: Shift in demand curve (D) in response to fall in price of substitute. P refers to price of the good, Q refers to quantity demanded of the good, and D refers to the demand curve. D_0 and P_0 occur at time 0, while D_1 and P_1 occur at time 1 after the fall in the price of the substitute. Adapted from Frank (2006).

Michael Porter's (1980) text *Competitive Strategy: Techniques for Analyzing Industries and Competitors* has been highly influential in modern business strategy. "Porter's Five Forces", which determine the competitive intensity and attractiveness of a market, derive from this work, and include: supplier power, threat of new entrants, bargaining power of suppliers, rivalry among existing competitors, and threat of substitutes. "Substitutes limit the potential returns of an industry by placing a ceiling on the prices firms in an industry can profitably charge". Examples of inter-industry product substitutes include natural and artificial sweeteners, cotton and polyester, cloth and disposable diapers, security guards and electronic alarms, and conventional and modular building construction (Porter 1980). Recent examples of products under threat of substitution include coal from shale gas, steel from aluminum, platinum from palladium, and nickel from pig iron (EY 2013).

Figure 2 illustrates that an industry perceiving a threat from an emerging industry is likely to respond by reducing its costs, either by foregoing profits or making R&D investments. "If the threatened industry chooses to invest to try to bring its quality-adjusted costs down, it is clear that the target at which learning and scale-related cost reductions in the emerging industry must shoot is a moving one" (Porter 1980).

However, we hypothesize that the dominant industry is likely only to feel threatened if the emerging industry has captured a noticeable portion of the market share. Without the perception of a threat, the dominant industry is unlikely to compete on price and invest to reduce its unit cost. This is observed in Figure 2; even as the emerging industry's unit costs drop rapidly, the dominant industry's unit costs continue to steadily grow until the emerging industry becomes cost-competitive.

The consumer clearly benefits when the two industries are competing and driving each other's costs down. However, if the emerging (or re-emerging) industry does not foresee that it will be able to capture a significant portion of the market, it is unlikely to invest to become cost-competitive. To stimulate that competitive activity, a large consumer like a state DOT may benefit by spreading out its purchasing between the two industries.

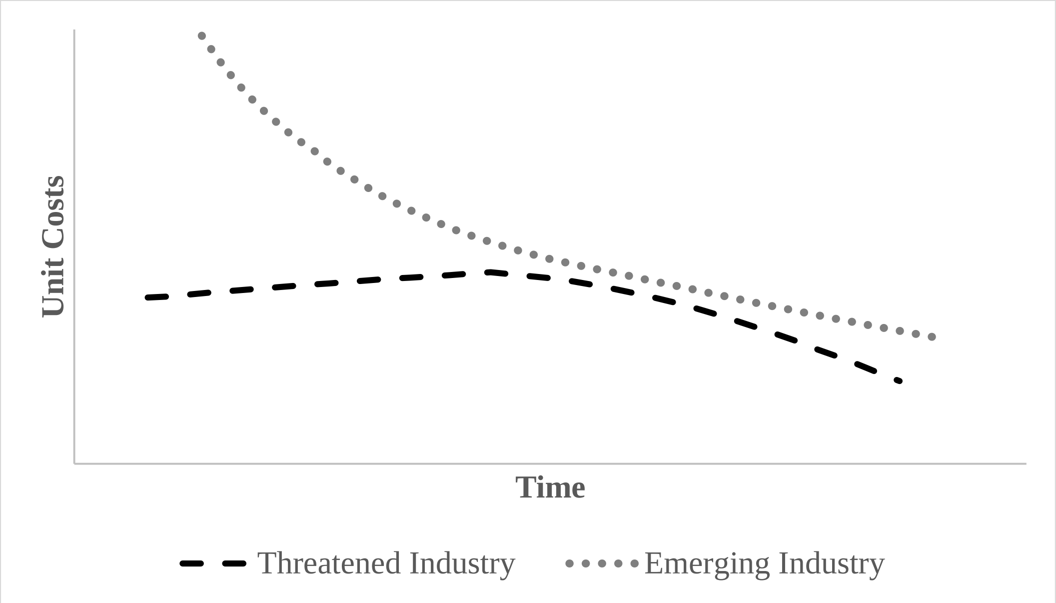

Figure 2: Response of threatened industry to substitution, if threatened industry chooses to lower costs instead of let technology atrophy. Adapted from (Porter 1980).

We further hypothesize that in states with a more competitive pavement market, the unit cost of all materials is lower; Figure 3 demonstrates this concept. The unit costs of both paving materials A and B are assumed to be higher at the extremes, where either A or B is dominant. The unit costs are assumed to be minimum when the industries are equally present and actively competing for greater market share, which is represented here by percent of total spending. We use pavement price data from state pavement pay item database to test this hypothesis.

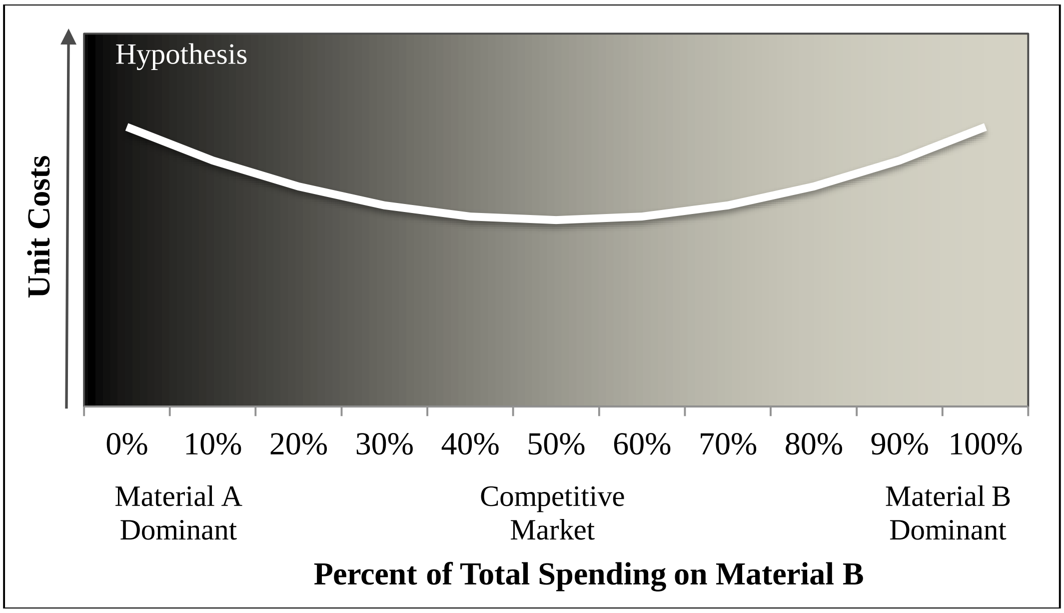

Figure 3: Hypothesis of material A and B unit cost trends compared to percent of total spending on material B

Methods

Overall approach

We selected the percent *p* of total spending on concrete each state-year to represent inter-industry competition; the material choice was arbitrary since percent of total spending on asphalt would yield equivalent results. To compare unit costs *u* over multiple years, we adjusted for year-to-year change. Comparisons were made using averages over a time period. In order to test the impact that the percent of total spending has on the material unit costs, regression analyses were performed on the multi-year average data.

Data source and scope

The pavement construction data utilized was from Oman BidTabs database. All states except Alaska, Hawaii, and New Jersey have input the pay item details for state DOT road construction jobs including the pay item number, description, pay item category, job ID, bid date, cost, and quantity. Paving jobs at the county, city, and local level are not included unless they are bid through the state DOT. Some design build jobs are not included since they do not have delineated pay items. Also included are details about the job such as the county, total cost, number of bidders, top three bids, and top three bidder firms.

Our period of analysis was from 2005 to 2014, since all of the 47 states input data as of 2005. For consistent and common quantity metrics, all asphalt pavement items were converted to tons if they had been provided in volumetric units using a standard density of 146pcf. Similarly, all concrete items were converted to cubic yards from square yards. To do so, the concrete depth information was extracted from the pay item description by researchers at the Portland Cement Association (PCA) and multiplied by the provided square yards.

Pay item screening process

We screened the pay items in the analysis through two steps. First, only Oman BidTabs pay item categories 3 (asphalt pavement) and 26 (concrete pavement) were included. Next, we screened the pay items by their descriptions. The goal was to include only asphalt or concrete material pay items representative of legitimate asphalt and concrete paving alternatives. For example, there is not currently a concrete alternative to chip sealing. Bridge approach slabs are typically constructed of concrete. Patches, the most commonly excluded pay item, are not part of regular paving. Fog coats, sealers, and diamond grinding represent other materials or activities. Some states include aggregates within a concrete or asphalt pay item, whereas others list it separately. The separate aggregate pay items were included in the analysis since they would become averaged in the materials unit cost per job and therefore be equivalent compared with states that included aggregate within the paving material pay item.

Asphalt pay items that included the following terms (or abbreviated equivalents) were screened out: aggregate surfacing, blotter, chip seal, cold planing, concrete items, contractor retained ac, ditch items, fly ash, fog coat, mill, patches, repairs, sami, scarifying, slurry seal, surface treatment, tack coat, and trial mixes. Similarly, concrete pay items that included the following terms (or abbreviated equivalents) were screened out: 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.

For the years 2005 to 2014, this pay item screening process retained 73% of the asphalt pay items representing 94% of the asphalt payment spending, and 57% of the concrete pay items representing 88% of the concrete spending. The top five excluded terms from asphalt pay items in terms of spending were: patch, coat, liquid, mill and repair. For concrete, the set was: patch, repair, approach, full, and precast.

Note that pay items were not screened for having a small contribution to the job. As a result of that, we include pay items of one material even when the job was dominated by the other material. While a threshold of percentage or quantity could have been chosen, there is a not a clear choice given the variety and complexity of different jobs across the country.

Data aggregation and preparation

Our analysis was conducted using the statistical analysis software Stata 12. Stata allows rapid computation with complex and large datasets. Microsoft Excel was additionally used for data preparation.

There were two levels of data aggregation using Stata's *collapse* command. The first combined the pay items into their respective jobs. The second combined the jobs into their respective states and years.

The dependent variable in the analyses is the weighted average unit cost, u, of the materials. We acknowledge but do not adjust for the reality that in some states, the asphalt bid price is adjusted with escalators during the course of the project. This u is found at both levels of aggregation by dividing the sum of the cost c of the material by the sum of the quantity q.

$$u = \frac{\sum c}{\sum q}$$

In order to be able to simultaneously analyze trends across several years, the year-to-year change in material prices needs to be accounted for. Common methods include factoring out inflation or a price index. Here, we took advantage of the data itself, and calculated an average u_y per material per year across all states, shown in Figure 4.

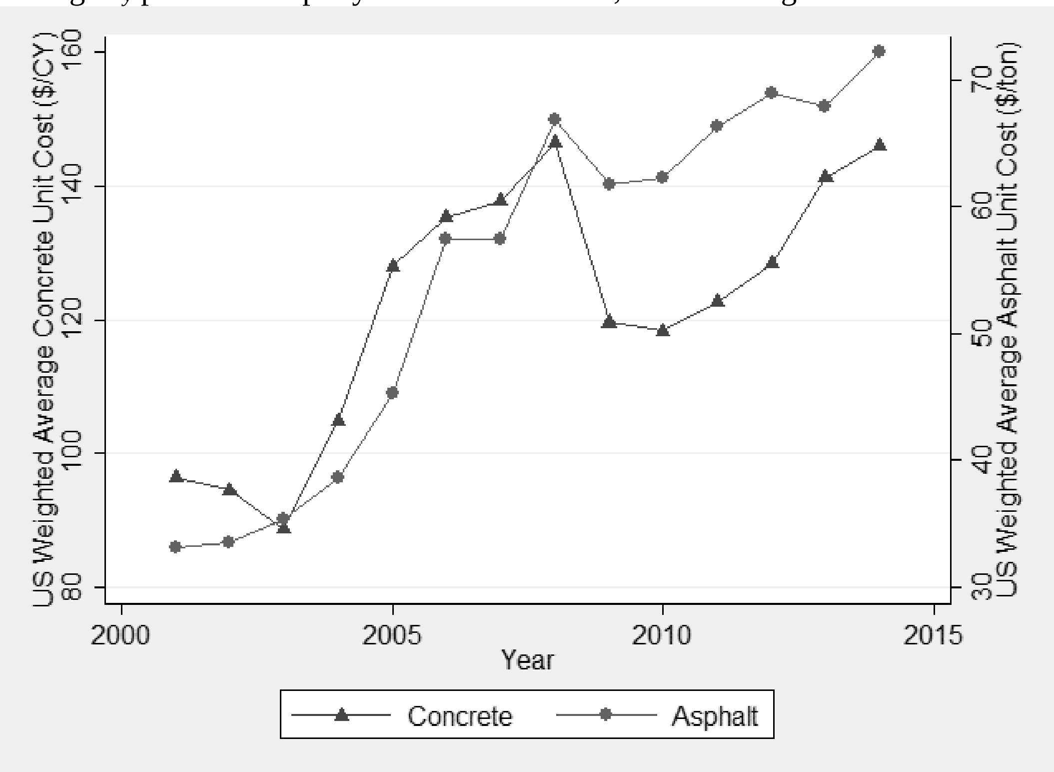

Figure 4: US weighted average of concrete and asphalt unit cost u_y from 2001 to 2014, as inferred from Oman BidTab data.

This was then subtracted from the material costs in each state and year to arrive at a "relative difference unit cost", u_Δ. A state s and year y with an average $u_{s,y}$ would have a $u_{\Delta\ s.y}$ equal to 0, a high $u_{s,y}$ would have a positive $u_{\Delta\ s.y}$, and a low $u_{s,y}$ would have a negative $u_{\Delta\ s.y}$.

$$u_{\Delta\ s,y} = u_{\ s,y} - u_y$$

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The metric selected to represent inter-industry competition is the market share, or percent of total spending on a material in each state-year. The percent of total spending on a material each state-year, $p_{s,y}$ is simply the total spending on a material (we chose concrete, denoted by *con* in variables) divided by the total spending on both materials in each state *s* and year *y*.

$$p_{s,y} = \frac{\sum c_{con\,s.y}}{\sum c_{con\,s.y} + \sum c_{asp\,s.y}} \times 100$$

For both unit cost and percent total of spending on a material, the unweighted average across all years *N* in the study for each state was calculated: $\bar{u}_{\Delta s}$ and $\bar{p}_s$, respectively. This was done in order to compare the typical level of spending and typical unit cost between states. To do so assumes that across the 10 years in the study period there was low variation within each state, and that only considerable, sustained changes in *p* could dramatically influence *u* due to the time needed for firms within industries to adjust and react.

$$\bar{u}_{\Delta\,s} = \frac{\sum_y u_{\Delta\,s,y}}{N}$$

$$\bar{p}_s = \frac{\sum_y p_{s,y}}{N}$$

Analysis

In order to test the impact that the percent of total spending has on the material unit costs, ordinary least squares regression analyses were performed on the multi-year average data. A linear regression was performed comparing the unweighted asphalt average $\bar{u}_{\Delta s}$ and $\bar{p}_s$. Since a non-linear relationship is observed between the unweighted concrete average $\bar{u}_{\Delta s}$ and $\bar{p}_s$, the natural log of $\bar{p}_s$ was taken before regression was performed. The variation of $u_{\Delta\,s,y}$ and $p_{s,y}$ within each state was observed in order to discern how reflective the means were of the populations.

Results and Discussion

<u>Our analyses suggest that if a state were to sustain a higher percent spending on concrete *p* for multiple years, they could expect to pay a lower unit cost for concrete overall</u>. In **Error! Reference source not found.**, the relationship between $\bar{u}_{\Delta s}$ and $\bar{p}_s$ is presented for concrete. The concrete figures exclude VT, ME, and NH since across the study period these states had two, zero, and zero years with any concrete spending, respectively. A lognormal curve relationship is observable in the concrete case, which conforms to our hypothesis presented in Figure 3 of gradually decreasing unit costs as spending levels approach a competitive market. **Error! Reference source not found.** presents the linear fit of the average relative difference unit cost of concrete $\bar{u}_{\Delta s}$ for each state from 2005-2014 versus the log-transformed $\bar{p}_s$. There exists a clear negative relationship (Adj. R-Squared=0.70), demonstrating that states which spend more on concrete on average pay a lower concrete unit cost on average.

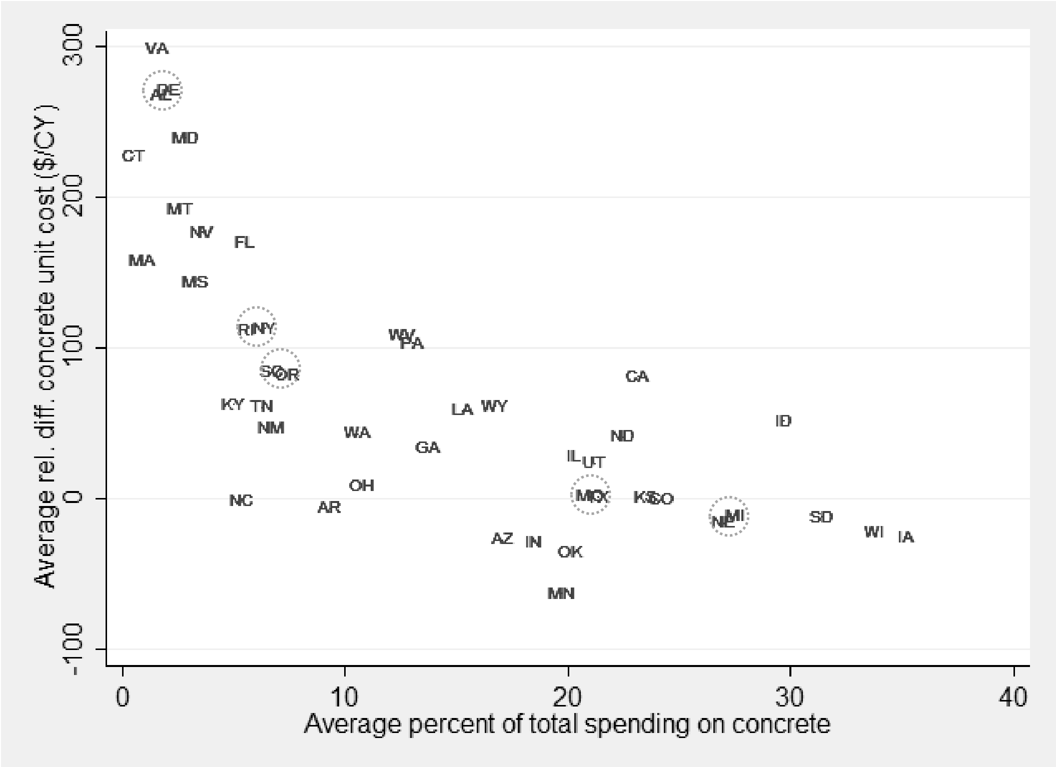

Figure 5: The 2005-2014 average relative difference concrete unit cost $\bar{u}_{\Delta s}$ versus the 2005-2014 average percent spending on concrete for each state $\bar{p}_s$ (excluding VT, ME, and NH). State abbreviations are used to indicate data points. From left to right, the overlapping labels indicated by dotted circles are: AL & DE, RI & NY, SC & OR, MO & TX, and NE & MI.

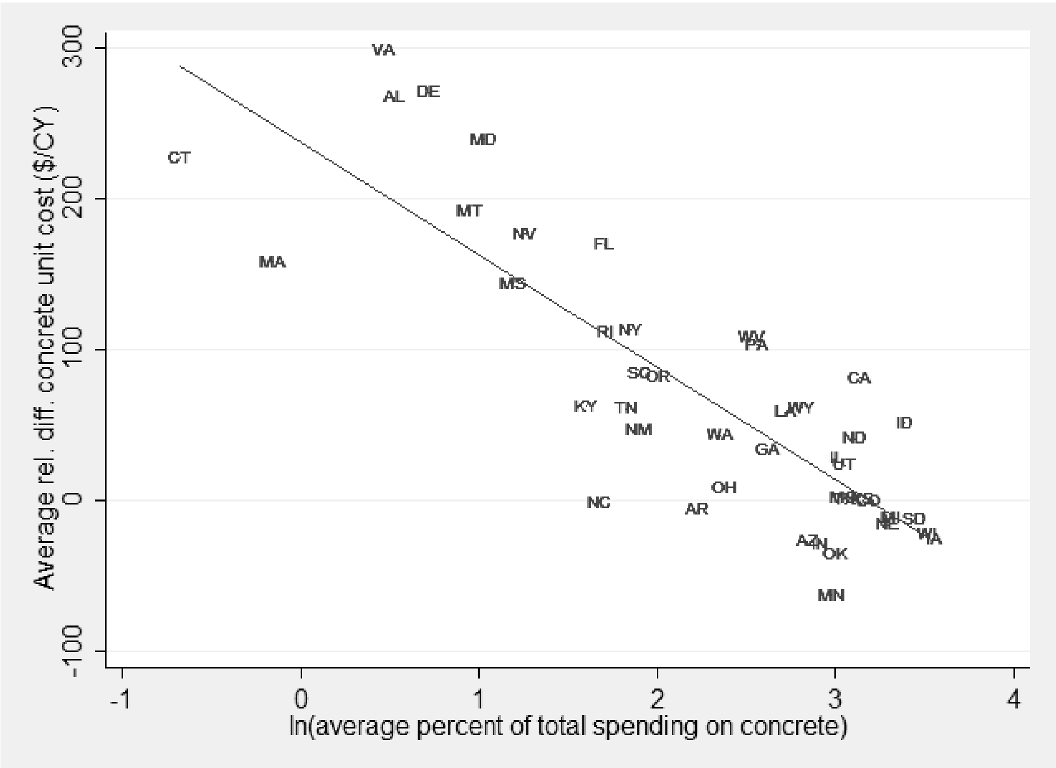

Figure 6: The 2005-2014 average relative difference unit cost $\bar{u}_{\Delta s}$ versus the natural log (ln) of the 2005-2014 average percent spending on concrete for each state $\bar{p}_s$ (excluding VT, ME, and NH). Adj. R-squared = .70 and P>|t|=0.000. State abbreviations are used to indicate data points.

In order to explore the assumption of low variation in both metrics across the years in the study period, Figure 7 and Figure 8 provide the distributions of $p_{s,y}$ and concrete unit cost $u_{\Delta\, s,y}$ for each state, sorted by ascending means. A trend of higher distributions with increasing means is observed, suggesting that the mean is a reasonably representative metric. A notable deviation from the trend is the distribution of $p_{s,y}$ in Rhode Island (RI) in Figure 8. RI generally has negligible percent spending on concrete aside from one year of high spending in 2014, and thus the mean is higher than the typical spending. However, the data may be anomalous since total spending on materials in RI in 2013 and 2014 is under $.04 million, compared to at least $1.8 million annually since 2005. Removing RI from the analysis has only a minute effect on the regression coefficients and significance.

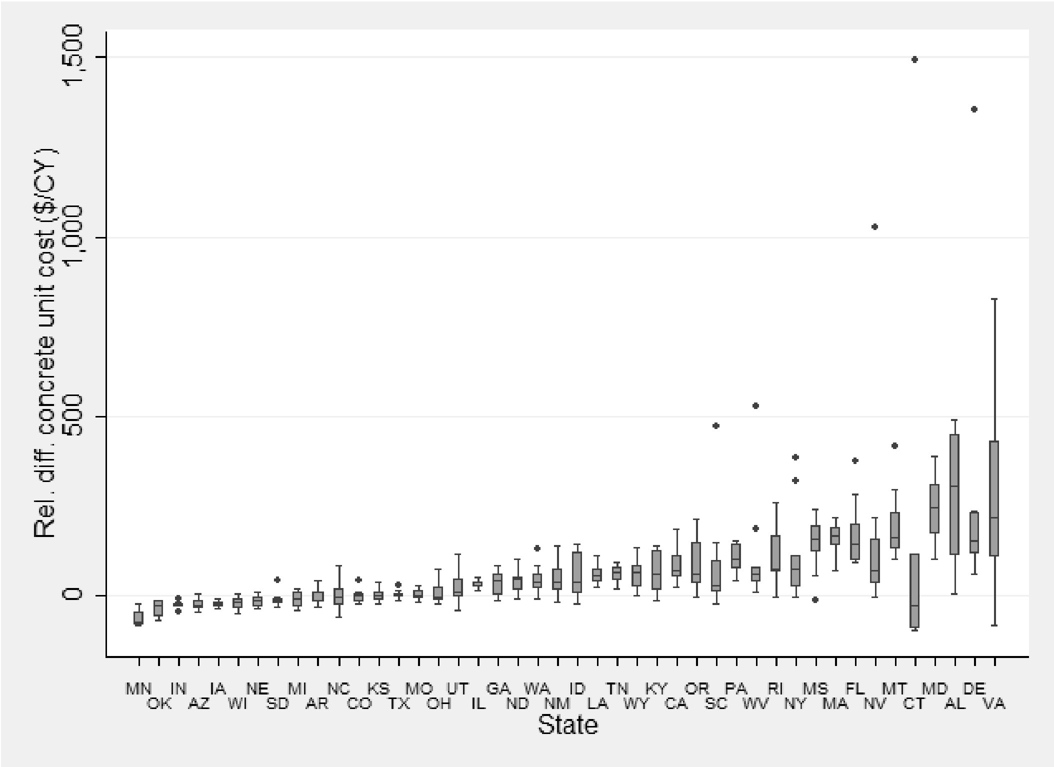

Figure 7: Box plots of the relative difference unit cost of concrete $u_{\Delta\, s,y}$ for each state (excluding VT, ME, and NH), sorted by the 2005-2014 mean $\bar{u}_{\Delta s}$.

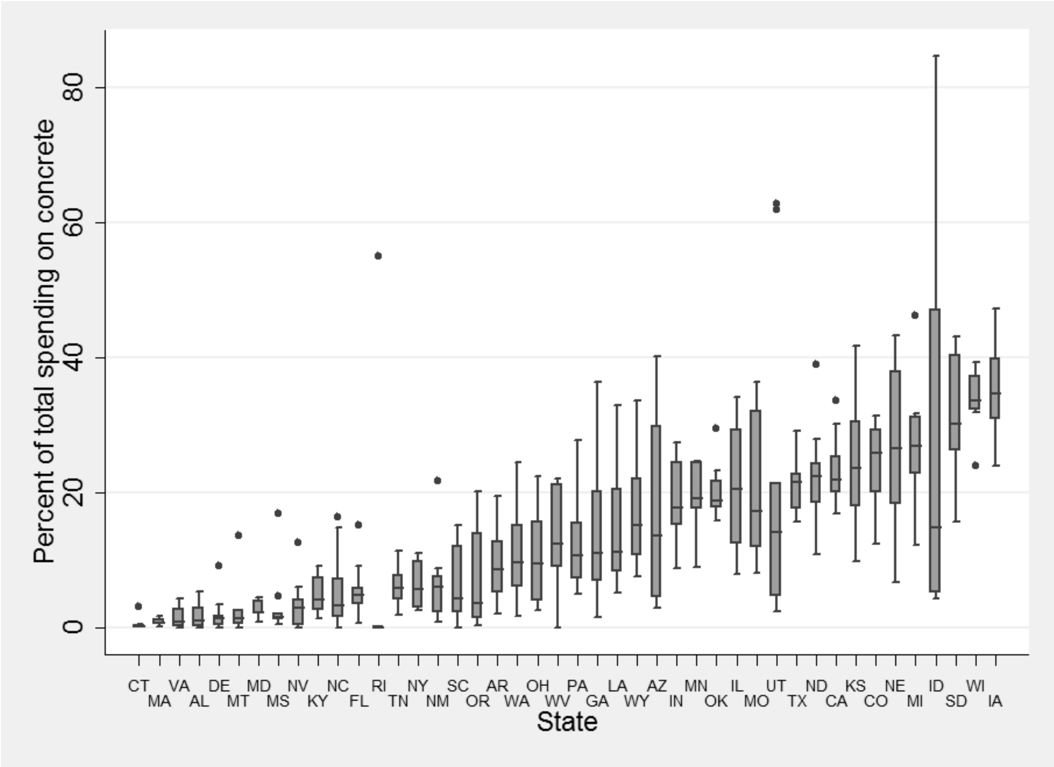

Figure 8: Box plot of the percent of total spending on a concrete in each state-year, $p_{s,y}$ for each state (excluding VT, ME, and NH), sorted by the 2005-2014 average percent spending on concrete for each state $\bar{p}_s$.

<u>The presence of inter-industry competition does not appear to explain the variation in asphalt unit costs.</u> In Figure 9, the relationship between $\bar{u}_{\Delta s}$ and $\bar{p}_s$ is presented for asphalt. In the asphalt case, although the regression coefficient is significant (P>|t|=0.000) suggesting a negative relationship, $\bar{p}_s$ explained little of the variance in $\bar{u}_{\Delta s}$ (Adj. R-Squared=0.05). Figure 2 provides a possible explanation: even in states with a growing concrete market share, it could be that a threshold has not been crossed and the asphalt industry is not yet feeling threatened by the concrete industry. Without a perceived threat, the industry thus is not yet responding by investing to reduce its costs. Analyses of *u* and *p* trends over time within each state could illuminate this phenomenon.

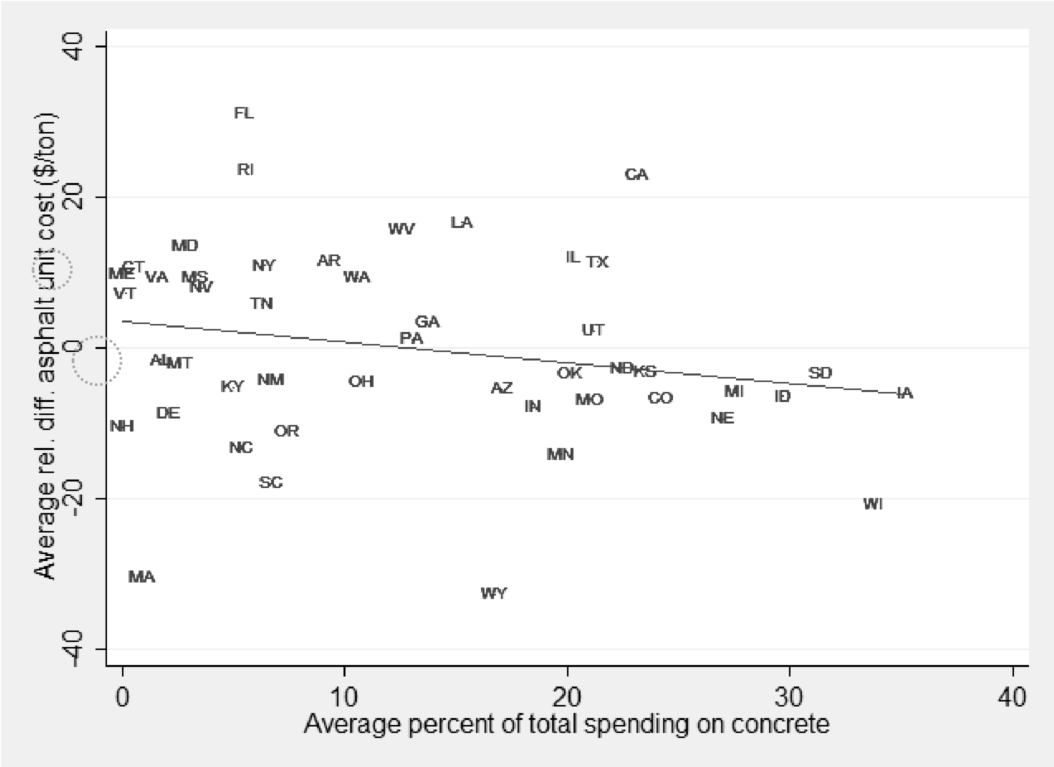

Figure 9: The 2005-2014 average relative asphalt difference unit cost $\bar{u}_{\Delta s}$ versus the 2005-2014 average percent spending on concrete for each state $\bar{p}_s$. State abbreviations are used to indicate data points. From left to right, the overlapping labels indicated by dotted circles are: ME &CT and AL &MT.

In conclusion, our hypothesis that in states with a more competitive pavement market, the unit cost of all materials is lower is confirmed by our analyses for concrete unit costs, but is not confirmed for asphalt unit costs. To further confirm this finding for concrete, analyses could be performed to control for the effect of other predictors as well. These could include economy of scale metrics like size of the job and total spending in a year; industry presence in a state such as count of cement plants, firms, concrete pavers, or employees; intra-industry metrics such as count of bidders; and monthly constituent (cement and asphalt) price indices.

Our other hypothesis that the dominant industry is likely only to feel threatened if the emerging industry has captured a noticeable portion of the market share was not directly tested through this analysis, but may explain some of the variation in asphalt unit costs. To explore this concept, two separate types of analyses could be performed. One type could involve testing the difference in the distributions of unit costs in states below a threshold of percent spending on concrete and in states above it. Another type of analysis could look at the material unit costs and percent on spending on concrete trends over time within a given state. The goal would be to observe how asphalt unit costs respond to changes in percent of concrete spending as well as changes in concrete unit costs.

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