On the Distributional Impact of Price Adjustment Policies: Bidding Patterns and Survival in the Market *

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Abstract

This paper studies the impact of price adjustment clauses in procurement contracting upon bidding behavior and firm survival. We develop a framework were the policy (i) reduces cost uncertainty, and (ii) have a differential effect on heterogeneous firms. These hypotheses are then evaluated by exploiting the policy exogenous variation in a quantile regression model. Using bidding data from the Oklahoma Department of Transportation, we find that policy effects vary by firm size. Estimates indicate that bidding becomes more aggressive and less dispersed after the implementation of the policy and the effects are more pronounced for small firms. Firms that entered after the policy was enacted exhibit considerably improved chances of survival.

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1 Introduction

The cost of highway construction has almost doubled between 1997 and 2006, displaying an alarming 40% increase in merely three years from 2003 to 2006. At the regional level, several state departments of transportation constructed measures that exhibit similar trends. In Washington, they reported a formidable 92% spike in costs from 1997 to 2006. In California they noted that the price index based on selected construction items increased 120%, and in

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Texas, they documented comparable findings through time (Bohuslave 2006). Price fluctuations in oil-based inputs, such as asphalt concrete, are the main causes for the increasing costs.

To account for the increasing uncertainty in future prices, construction firms bid less aggressively to avoid falling prey to the winner's curse. The Bid-Price Index (BPI), a nationwide indicator published by the Federal Highway Administration, increased 70% in the period 1997 to 2006. More contractors were led to bankruptcy during that period, further undermining competition. These factors have contributed to the decline in government purchasing power. In response, many transportation agencies, coordinated by the Federal Highway Administration, have introduced price adjustment clauses for relevant materials. For selected inputs, if prices deviate beyond a certain threshold, contractors are guaranteed an adjustment in payment by the government agency. The direction of payments is contingent on the price change. Notwithstanding differences in legal details, the common purpose of these initiatives was to place a ceiling on firms' losses by partially reimbursing them for unanticipated rises in costs.

At first glance, indexation of prices renders additional burden on departments of transportations (DOTs) by directly increasing procurement costs.[1] Upon more careful consideration, theory and findings seem to argue for the reverse. It has been shown that if the degree of uncertainty is reduced, firms bid more aggressively, a change favoring government agencies as buyers (see Goeree and Offerman 2003, Kosmopoulou and Zhou 2011). When excessive uncertainty is removed, the market will be able to retain a larger pool of bidders, achieving higher levels of competition and efficiency in the long run.[2] This paper provides empirical evidence of the policy's asymmetric impact contrasting small and large firms.

Studying potential asymmetry of policy effects on firms in highway construction can be especially informative since bidder heterogeneity is a defining feature of this sector (Cho

[1] Assuming no accounts of adjusting bidding behaviors, when there is generally upward pressure in prices, payments from the government agencies to private companies are expected to be higher with such clauses than without.

[2] In fact, data from Oklahoma suggest that estimated savings resulted from enhanced competition outweigh relevant administrative costs of adjustments (such as purchase of index and bookkeeping).

1986). The industry characterized by scale economies and market concentration is highly skewed toward a small set of strong contenders. The ten largest firms in our database, for example, were awarded over half of all auctioned projects and more than 65% of the total contracted value. At the same time, this market displays an above average turnover rate. Compared with manufacturing, the percentage of failed new construction firms is considerably higher (Audretsch and Mahmood 1995). Both statistics suggest that many undersized and startup businesses compete as marginal players and never make it to the short list of major contractors. High volatility in input prices reduces the survival prospect of fringe firms on top of their more limited experience. While large scale firms tend to be better informed, possess more bargaining power and manage to share risk with their input suppliers, small ones are less able to do so and often have to build higher risk premia into their bids. The recent price volatility in oil-based materials reinforces unbalance among competitors.

Adjustment clauses are expected to balance out some of this disparity. By reducing information rents and the impact of network effects enjoyed by large establishments, the policy lessens the comparative disadvantage of firms due to limited sizes, and facilitates competition to ensure a more leveled playing field.[3] Our analysis shows that while all bidders submit more aggressive bids after the state decided to relate payments with ex post price changes, small businesses adjust bids down to a bigger extent. The degree of modification decreases with firms' size of establishment. In addition, when worries about undertaking contracts at great losses are alleviated, smaller firms are encouraged to participate more frequently. Although the probability of winning conditional upon bidding stays roughly unchanged, unconditionally the small firms are more likely to be awarded contracts in the period after. Consequently, firms that entered after the policy implementation exhibit a prolonged market presence and an improved chance for survival.

[3]Auction asymmetries have been studied theoretically and to a smaller extent empirically in the recent literature (see Maskin and Riley 2000, Pesendorfer 2000 and De Silva et al. 2003, De Silva et al. 2009). The work on survival in the market, has largely dealt with how individual firm characteristics, such as capacity, profitability and financial solvency, affect a firm's durability, and whether these relationships differ from one market structure to another (see Dunne et al. 1988, Persson 2004 and Tsoukas 2011).

The remainder of this article proceeds as follows. Section 2 formalizes the theoretical discussion. Section 3 describes the data. Section 4 presents the empirical results and Section 5 concludes.

2 A Modeling Framework

We consider a simple theoretical model of auction competition to formalize the impact of price adjustment clauses on the bidding outcome.[4] A number, n, of bidders compete for a government contract in a low price sealed bid auction held at time t. The project will be completed at time $t+1$. The bidders are risk neutral. A bidder has only an estimate, c^e_{it}, for the cost at the time of bidding. We assume that the true cost $c_{it+1} = c^e_{it} + d_{t+1}$ where d_{t+1} represents the difference between estimated and actual costs affected by market forces and exogenous shocks in the price of basic inputs. The cost c^e_{it} for bidder i is drawn from a twice continuously differentiable distribution F^e_t with strictly positive density f^e_t on the support $\left[c^{e}_{t,}{}^{L} c^{e}_{t}{}^{H}\right]$. Bidders may have different liquidity constraints. Each bidder has some capital available at the time of bidding denoted by $w_{it} \in [\underline{w}, \overline{w}]$ distributed according to F_{w_t}, which is also twice continuously differentiable on its support. We assume that c^e_{it} and w_{it} are independently distributed. Bidders can finance future projects by borrowing at a cost which depends upon capital accumulation through a function $R(c^e_{it} - w_{it})$. Let $R'(c^e_{it} - w_{it}) < 0$. The cost of projects is now becoming $c_{it+1} = c^e_{it} + d_{t+1} + R(c^e_{it} - w_{it})$.

In the context of our empirical study, due to uncertainty in the price of crude oil the actual cost of asphalt to the firms at the time the contract is fulfilled may differ from c^e_{it}. We let the value of $d_{t+1} = \overline{c}_{t+1} - \overline{c}_t$, where $\overline{c}_t$ is the cost index at the time of letting which is known to bidders and $\overline{c}_{t+1}$ is the index at the time construction work ends. $\overline{c}_{t+1}$ it is a random variable with a known distribution ex ante. One can think of cost realizations in the following way: A firm receives a quote from a supplier at time t on the price of asphalt at $t+1$ which is uncertain and depends on market forces beyond the control of local suppliers. The price index represents

[4] This model extends Kosmopoulou and Zhou (2011) to incorporate asymmetries in cash position.

the average price across suppliers at a specific time period affected by exogenous shocks. The differences in the cost index through time capture potential fluctuations in the cost beyond the control of the supplier at time t. The bidder who bids b_{it} and is awarded the contract receives a utility of $u(b_{it}, c_{it+1}, w_{it}) = b_{it} - c^e_{ait} - d_{t+1} - R(c^e_{it} - w_{it})$. Let $s_{it} = c^e_{it} + R(c^e_{it} - w_{it})$ is i's privately observed component of $c^e_{it} + R(c^e_{it} - w_{it})$ at the time of bidding, and y_{1t} denotes the infimum of the remaining $n-1$ estimates of s_{it}. Let the densities f^e_t and f_{w_t} be longconcave.[5] The unique symmetric equilibrium bidding strategy for bidder i in the first price auction held at t is:

$$B(s_{it}) = E(y_{1t} \mid y_{1t} \geq s_{i,t}) + E(d_{t+1}). \tag{2.1}$$

The price adjustment clause may provide additional compensation to contractors for fluctuations in item prices related to asphalt work. With the indexing policy in place the difference between the initial estimate and the realized cost becomes:

$$d^*_{t+1} = \begin{cases} \overline{c}_{t+1} - \overline{c}_t & \text{if} \quad -1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1 \\ \lambda \overline{c}_t & \text{if} \quad \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} > 1 \\ -\lambda \overline{c}_t & \text{if} \quad \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} > -1 \end{cases}$$

where λ is the proportion of price adjustment specified by the indexing policy ($\lambda = 0.03$ in Oklahoma asphalt binder items). For simplicity, one can bound the values of λ between 0 and 1 by assuming that $\overline{c}_{Ht+1} < 2\overline{c}_{Lt}$ and $\overline{c}_{Lt+1} > 0$.

The cost of borrowing often depends upon capital accumulation and uncertainty. The policy makers control the level of uncertainty through the parameter λ, introducing an additional argument in R i.e., we let $R(c^e_{it} - w_{it}, \lambda)$. with $R_1(c^e_{it} - w_{it}, \lambda) > 0$ and $R_2(c^e_{it} - w_{it}, \lambda) > 0$. The cost of borrowing increases in the level of uncertainty.

The bidding strategy becomes:

$$B(s_{it}|\lambda) = E(y_{1t} \mid y_{1t} \geq s_{it}) + E(d^*_{t+1}|\lambda)). \tag{2.2}$$

A reduction in λ reduces the cost of borrowing and the value of the last term in (2). Notice also that, the likelihood of cost overruns increased substantially in the past ten years,

[5] The assumption of logconcavity is discussed in detail in Goeree and Offerman (2003). It guarantees that a lower privately observed cost implies, on average, a lower overall cost thus ensuring monotonicity and existence.

i.e., $E(d_{t+1}) \geq 0$. Assuming rational expectations, it follows that $E(d_{t+1}) \geqq E(d^*_{t+1}|\lambda)$ leading to $B(s_{it}|\lambda) \leq B(s_{it})$. The variance of d^*_{t+1} is lower in relative terms. When there are expectation of price fluctuations leading to higher costs, d^*_{t+1} tends to be less dispersed.[6] As shown in the appendix, the distribution of realized cost in (2.1) is less dispersed relative to costs in (2.2). In particular, the effect of adjustment clauses on the variance of bids can be evaluated by considering the derivative of the variance with respect to the threshold parameter: $\frac{\partial V[B(S_{it}|\lambda)]}{\partial \lambda}$. We show that, based on standard assumptions in the literature, $\frac{\partial V[B(S_{it}|\lambda)]}{\partial \lambda}$ increases as λ becomes larger, implying that bids would become more dispersed when the uninsured corridor is broadened. As a result, post-policy bids are expected to exhibit lower variance.[7]

The literature has provided evidence of a strong correlation between firm size and financial solvency (see Brito and Mello 1995, Hubbard 1998, and Persson 2004). Small size firms face greater liquidity constraints having an impact on growth. The literature on bidding asymmetries has established that, if borrowing costs are convex in wealth and an unconstrained bidder has the same willingness to pay as a constrained bidder, the bid of the constrained bidder will be more aggressive (see Proposition 3 in Quintero Jaramillio (2004)). We show in the appendix that the difference in bid dispersion (caused by the introduction of price adjustment clauses) is expected to be smaller for wealthier and less constrained firms after the policy change i.e., $\frac{\partial V^*}{\partial w_{it}} = \frac{\partial (V[B(s_{it})] - V[B(s_{it}|\lambda)])}{\partial w_{it}}$. In the presence of high uncertainty unconstrained firms will survive longer. Rhodes-Kropf and Viswanathan (2005) focus on debt finance and find that if bidders have asymmetric risk and liquidity constraints, any information rents they receive depend on valuations and their cash positions. Depending on the individual level of risk and liquidity, the interest rate may be too high for some constrained bidders to survive. Bidding aggressiveness becomes more pronounced if bidders are risk averse. Projecting from

[6] The decline in crude oil prices in the middle of 2008 was followed by another considerable increase recently. Overall oil prices are continuing an upward trend with the recent earthquake in Japan creating expectations for a substantial increase in demand for petroleum products in the future (Associated Press 4/11/2011).

[7] We can think of the situation without any ex-post transfers as an unrealistically high λ being set. Therefore, implementing the indexing policy is equivalent to lowering the value of threshold.

the work of Holt (1979), the reduction in uncertainty due to a price adjustment clause will increase expected utility significantly and lead to a decrease in expected bids.

3 Data

We collect a set of panel data via publicly accessible pages on the official site of Oklahoma Department of Transportation (ODOT). Our bidding analysis encompasses data on all projects auctioned off from September 2003 through September 2009.[8] Bidding records from September 2001 to August 2003 are used to synthesize historical information on winning ratios, capacity utilization etc. Data from the period of October 2009 to November 2010 are used to identify exitors from the market. Auction lettings are held on a monthly basis (except for December) using the format of first price sealed-bid auction. A firm with the lowest bid is typically awarded the contract [9]

Auction level data. For each auction on the agenda, firms interested in bidding must purchase a plan. The list of planholders is released before an actual letting to inform participants of potential competition. Observations in our database are generated when a perspective contractor purchases a plan.[10] We know the identity of the planholder, information on the project of interest, a bid if the firm submitted one and the auction outcome, i.e. whether the firm has won or not. Each entry is matched with covariates related to the proposed bid, including an estimated cost by state engineers, nature of the job, days allocated for completion, work site location, the planholder's own attributes such as firm address and bidding history, rival planholders' characteristics, and variables describing the general economic condition at the time of letting. Variable description and construction process are provided in Table A1

[8] In February 2010, the Congress approved a stimulus package to state transportation departments nationwide. Projects funded by stimulus funds in Oklahoma were first auctioned off in March 2010, and are excluded from our bid analysis.

[9] ODOT may reject the winning offer and schedule to re-auction a project later. According to state engineers' comments, rejections are typically due to materially unbalanced bids. We have dropped rejected projects from our database.

[10] It is quite common for a firm to acquire a plan without participating in the actual bidding. Based on our data, planholders submit bids approximately 60% of the time.

of the appendix.

Itemized level data. Each project may employ a number of items as building materials. The state's cost estimate consists of a series of unit price and quantity for each item in the engineer's plan. Hence, a bid is not merely a single number but a vector of unit prices corresponding to specified quantities. Typically the bidder who submits the lowest total amount, the sum of proposed item bids multiplied by the estimated quantities, is awarded the contract. To illustrate the relationship between bids on items and projects Table 1 presents the bidtab report of an asphalt resurfacing work auctioned in March 2008. According to the report, this resurfacing project uses 4 items, namely, asphalt concrete, traffic stripe, cold milling pavement, and construction traffic control. The total estimated cost across all items is \$455,600. Both bidders propose unit prices for each item on the list, and firm B wins the auction with the total bid of \$475,300. The set of unit prices on all contracted items are hereafter referred to as itemized bids, to distinguish them from the overall bid/total bid of a project. Our sample includes 1883 projects with a total awarded value of \$400 million, and a sum of 6900 bids submitted by 240 pre-qualified contractors, most of whom are based in Oklahoma.

The policy. Upon its introduction in June 2006, the price indexing system extensively reduced contractors' concerns for the high price volatility of asphalt related items that all have to face. Special provision 109.12 amended to the standard specification states that, for applicable asphalt binder materials, if the current price index exceeds the base value by more than 3% a lump-sum adjustment is transferred from ODOT to the contractor, with the amount dependent on the quantity of asphalt items and the extent of price deviation. The direction of payment is reversed if the current index declines from its base value by 3% or more. Eligible items cover a wide class of bituminous products of different mixtures and hardness, a complete list of which can be found at the ODOT website.[11]

Descriptive statistics. Out of 1883 projects contracted in the sample window, 1018

[11] http://www.okladot.state.ok.us/c_manuals/specprov2009/oe_sp_2009-109-7.pdf

Item	Description	Quantity	Unit price (DOT)	Estimate	Unit price (Bidder A)	Bid	Unit price (Bidder B)	Bid
1.	Asphalt concrete (tons)	12,000	$35	$420,000	$35.75	$453,000	$37.5	$450,000
2.	Traffic stripe(linear ft)	100,000	$0.3	$30,000	$0.25	$25,000	$0.2	$20,000
3.	Cold milling pavement(sq. yds)	800	$2	$1,600	$2	$1,600	$1.5	$1,200
4.	Traffic control(lumpsum)	1	$4000	$4,000	$1600	$1,600	$4150	$4,150
5	Project estimate/Total bid:			$455,600		$481,200		$475,350

Table 1: *Item bid and total bid – example from a resurface (asphalt) project.*

contain eligible asphalt items (54%). Between periods divided by the policy initiative, the proportion of asphalt projects[12] appears to be fairly similar (52% and 56% of the total volume respectively). Hence, this presents an opportunity to evaluate firms' bidding strategies resulted from the policy change and examine related implications.

Our paper extends the literature of bidding asymmetry by examining the differential effects of asphalt adjustment policy on firms of various scales. Firms are grouped based on their market shares. The category of large firms consists of businesses that won more than 1% of the total awarded value in the sample, with the rest classified as small firms. Under such a division, slightly under one fifth (27 out of 157) of all participating firms are characterized as large, and jointly control 80% of the market.[13,14]

Figure 1 presents probability density graphs of relative bids on asphalt and fuel items separately for small and large firms. The relative bid, calculated as the absolute bid normalized by state engineer's estimate, is used to facilitate comparisons across projects of different scales. Graphs on the left of Figure 1 are based on itemized bids on adjustment eligible asphalt binders products, whereas those to the right depict itemized bids on adjustment ineligible fuel-related materials. Since asphalt and fuel are both by-products of the oil refining process, their market prices are inherently linked. Indeed, the price indices of the two are highly correlated with the coefficient over 0.8 from 2000 to 2010.[15] Therefore, we would expect submitted bids, primarily

[12]That is, projects which involve selected asphalt binder products and are thus entitled to ex post payment adjustments.

[13]Market share was adopted as an alternative to the number of employees, a common measure in the literature but unfortunately unavailable in our dataset. We argue that the dichotomy based on shares of contracted value is a proper proxy because work load is linked tightly to payroll size.

[14]We tried several other values for the cut-off point (e.g. 1.1%, 0.85%, 0.75%) as sensitivity checks. The analysis produced consistent results, confirming the robustness of the choice. As a comparison, Bajari et al. (2009) also employs 1% to distinguish "top" and "fringe" firms in the sample of public construction auctions from Caltran.

[15]Calculated from indices published by the Arizona Department of Transportation (AZDOT) for this extended period. There is one concern with the effectiveness in comparing asphalt and fuel bids: despite the common raw materials, the production process, supply chain, and manufacturing capacity of asphalt binder and fuel related products differ to some extent from each other. Nevertheless, our discussions with department officials reveal that the upward pressure in the price of asphalt and fuel faced by many contractors was linked closely. This probably explains why the majority of states granting ex post payment adjustments on asphalt also have in place similar provisions addressing the concerns of fuel-related materials.

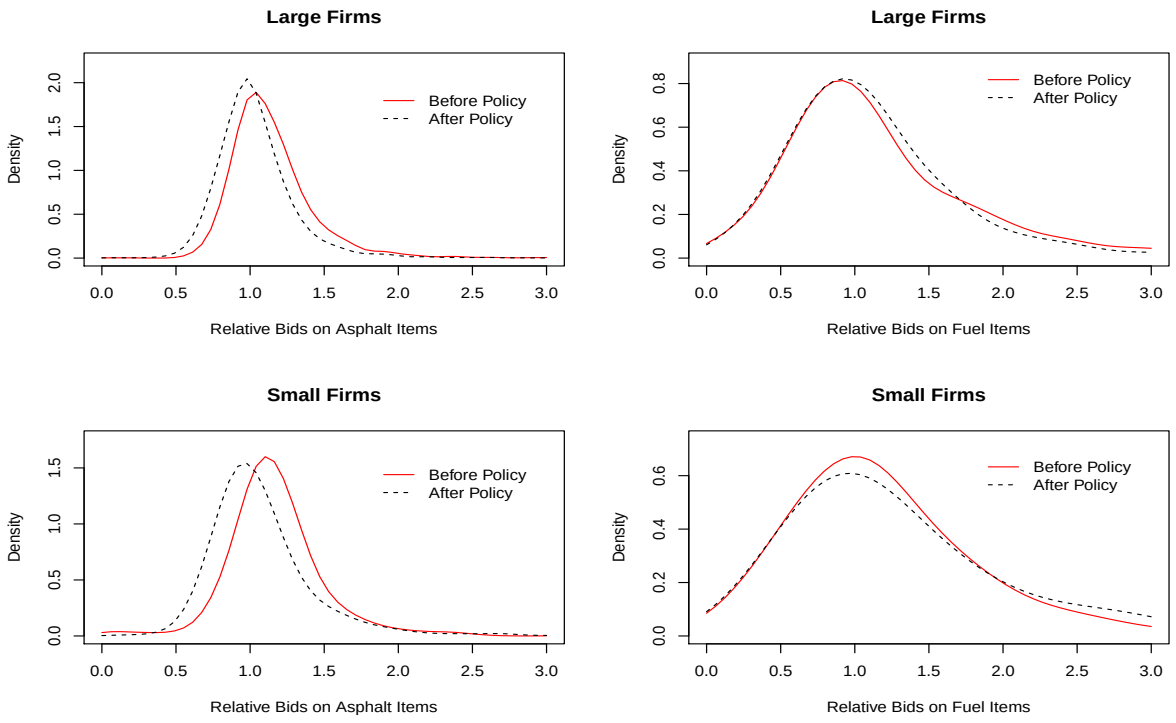

Figure 1: *Kernel densities for relative itemized bids.* The figure contrast relative bids by large and small firms on asphalt and fuel items before and after the policy implementation.

built upon costs of asphalt and fuel items, to have a similar trajectory through time. With kernel estimates, however, we observe a substantial leftward shift in the period after the policy implementation in the bid distributions of asphalt items across firm sizes, unmatched by the panel to the right. If such pattern persists upon controlling for other covariates, it ought to be attributed to the impact of the price adjustment provision.

Now we turn to a comparison across sizes. As previously mentioned, small contractors might be submitting higher bids due to stricter liquidity constraints or limited networks. To discern differences in this dimension, we consider bids by small and large businesses separately. The top row of Figure 1 represents bids submitted by firms occupying 1% or more of the market, and the bottom row displays bids by all others. Overall, firms of various sizes bid in highly comparable ways. This may not be surprising in the light of the fact that projects are awarded solely on the basis of low bids and the competitive feature of auction mechanism. Taking a closer look, the left shift in asphalt bids appears more pronounced for the subset of smaller bidders, and this point will be further explored in the next section. As far as fuel bids are concerned, both groups submitted higher bids in the second period, in agreement with the extensive volatility of the price of fuel since 2006.

Table 2 summarizes descriptive statistics separately for bidders distinguished by size. The sample window naturally divides into two periods upon the introduction of adjustment clauses in June 2006. When all bids are considered, average bids on adjustment eligible asphalt are significantly lower after the policy was enacted across both groups, mirroring the impression in Figure 1. Meanwhile, bids based on fuel fail to display a comparable trend over time.[16] When we restrict attention to winning bids only, the temporal shift for asphalt items carries through, while the difference in fuel items is either insignificant in magnitude or reversed in direction. Another interesting finding is that in the presence of adjustment clauses, small firms are

[16] One exception appears to come from the group of entrants firms. Both asphalt and fuel itemized bids from the post period are lower, but the difference is only statistically different from 0 for eligible items. Moreover, comparisons here have not taken into account of various controlling factors, which may contribute to the observed difference in patterns.

Variables	Large Firms		Small Firms	
	Before	After	Before	After
Relative bid on	1.169	1.042	1.196	1.090
asphalt items	(0.358)	(0.303)	(0.465)	(0.409)
Relative bid on	1.208	1.172	1.271	1.337
fuel items	(0.794)	(0.695)	(0.818)	(0.876)
Winning relative bid	1.126	0.998	1.171	1.051
on asphalt items	(0.274)	(0.263)	(0.563)	(0.412)
Winning relative bid	1.104	1.082	1.088	1.170
on fuel items	(0.681)	(0.702)	(0.723)	(0.806)
Bid dummy	0.598	0.590	0.506	0.539
	(0.490)	(0.481)	(0.500)	(0.498)
Average rivals' winning to	0.161	0.161	0.162	0.161
planholding ratio (ARWP)	(0.032)	(0.032)	(0.039)	(0.037)
Capacity utilization rate	0.225	0.283	0.122	0.128
	(0.247)	(0.252)	(0.230)	(0.230)
Past winning to	0.161	0.159	0.162	0.163
planholding ratio (WP)	(0.054)	(0.049)	(0.116)	(0.123)
Number of planholders	6.393	6.511	6.315	6.344
per auction	(2.876)	(2.901)	(2.846)	(2.833)
Number of bids	3.462	3.533	3.563	3.629
per auction	(1.512)	(1.753)	(1.534)	(1.690)
Expected number of bids	3.605	3.640	3.532	3.590
per auction	(1.660)	(1.677)	(1.584)	(1.607)
Seasonally adjusted	4.742	4.440	4.762	4.437
unemployment rate	(0.432)	(1.143)	(0.518)	(1.105)

Table 2: *Descriptive statistics by large and small firms.* Standard errors are in parentheses.

more likely to actively participate upon acquiring plans. The probability of participation for large firms remain practically the same compared to the period before the policy enactment. In the next section, we formalize the investigation of whether the price escalation policy has encouraged small businesses to participate and improve their chances of survival in the market.

4 Empirical Results

The section carries out a more rigorous and comprehensive study looking for the differential effects of policy change among public procurement contractors. We analyze three aspects of the adjustment clauses. First, we study bidding differences across time periods and firm sizes with a focus on both location shift at the mean level and variation in the shape of distribution of bids. Second, we seek to detect any changes in bidding or winning frequencies caused by the initiative. Finally, accounting for impacts on bids and participation patterns, we consider how the policy has affected firms' duration in the market.

4.1 Distributional effects of adjustment policy on bidding

The institutional details of the asphalt price adjustment clause offers a source of exogenous variation to both small and large firms, and the distinction between 'policy eligible' asphalt items from 'policy ineligible' fuel items leads to a natural comparison. Our basic difference-in-difference method specification is given as follows:

$$y_{ijat} = \beta_1 T_{ja} + \beta_2 A_t + \beta_3 (T_{ja} \times A_t) + \mathbf{x}'_{ijat}\gamma + z'_{at}\delta + w'_t\zeta + \alpha_i + d_j + m_t + \varepsilon_{ijat}, \qquad (4.1)$$

where the unit of observation is a bid submitted by firm i, for item j, in auction a, at time t. Relative bid y_{ijat}, ratio of the bid divided by its engineer's cost estimate, is employed as the primary dependent variable and is comparable among projects of various scales. Asphalt items, which are eligible for policy adjustment, serves as the treated group, while fuel items, which are intrinsically similar but unaffected by the policy, provide a natural comparison group. The variable T_{it} is a group dummy, which is defined as equal to 1 for asphalt items

and 0 for fuel items. The variable A_t is a time dummy, taking the value of 1 for bids submitted after June 2006 and 0 for bids submitted before June 2006. A set of covariates are included to control for observed heterogeneity across firms and auctions, which are classified into three categories: bidder, rival, and business conditions denoted by $\mathbf{x}$, $\mathbf{z}$ and $\mathbf{w}$ respectively. Table A1 in the appendix provides a detailed descriptions.

According to theoretical derivations, the increased bidding aggressiveness should be larger in magnitude for the group of small firms. In addition, we expect the spread of the distribution to become more centralized after the policy enactment, especially for small businesses. This unbalanced change in bidding strategies originates from firms' different ability to accommodate risks and thus unequal benefits derived upon the relief of excessive risks. We can empirically test these hypotheses by estimating quantile regression models. In particular, we investigate the implications of the framework developed in Section 2 by considering the conditional quantile function associated with model (4.1),

$$Q_{Y_{ijat}}(\tau|\mathbf{h}_{ijat}, \alpha_i, d_j, m_t) = \mathbf{h}'_{ijat}\theta(\tau) + \alpha_i(\tau) + d_j(\tau) + m_t(\tau), \tag{4.2}$$

where $Q_{Y_{ijat}}(\cdot|\cdot)$ is the τ-th conditional quantile function, $\theta(\tau) = (\theta_1(\tau)', \theta_2(\tau)')'$ is a vector of parameters with $\theta_1(\tau) = (\beta_1(\tau), \beta_2(\tau), \beta_3(\tau))'$ and $\theta_2(\tau) = (\gamma(\tau)', \delta(\tau)', \zeta(\tau)')'$. $(\alpha_i(\tau), d_j(\tau), m_t(\tau))'$ is a vector of quantile specific bidder, item and time effects, and $\mathbf{h}_{ijat} = [T_{ja} \;\; A_t \;\; T_{ja} \times A_t \;\; \mathbf{x}'_{ijat} \;\; z'_{at} \;\; w'_t]$ is the vector of independent variables. The parameter of interest β_3 reflects changes in the conditional quantile of the bid distribution between eligible and ineligible items in the post-policy enactment period,

$$\begin{aligned}\beta_3(\tau) = [&Q_Y(\tau|T=1, A=1, \mathbf{x}, z, w, \alpha, d, m) - Q_Y(\tau|T=1, A=0, \mathbf{x}, z, w, \alpha, d, m)] - \\ &[Q_Y(\tau|T=0, A=1, \mathbf{x}, z, w, \alpha, d, m) - Q_Y(\tau|T=0, A=0, \mathbf{x}, z, w, \alpha, d, m)]\end{aligned}$$

The policy parameter measures the distance between the quantiles of conditional distributions. Therefore, by estimating $\beta_3(\tau)$ in models for small and large firms, we can use the expression to test whether the conditional distributions of bid changed their location and shapes in the

period after the policy was introduced.

Our main concern is on how policy effects differ among contractors with various different network connections and leveraging abilities.[17] The theoretical predictions of our framework imply that adjustment clauses lead to less disperse bids, with a more pronounce reduction in variance for small firms. Noting that the results in the theoretical framework were obtained for the unconditional variance of bids, we offer evidence by employing Firpo, Fortin, and Lemieux (2009)'s approach to estimate the policy parameter on the unconditional distribution of bids.

The quantile regression panel data model can be estimated by employing an extension of Koenker's (2004) estimator. We solve the following linear programming problem:

$$\{\hat{\theta}(\tau), \hat{\alpha}_i(\tau), \hat{d}_j(\tau), \hat{m}_t(\tau)\} = \arg\min \sum_{i=1}^{n} \sum_{j=1}^{J} \sum_{a=1}^{K} \sum_{t=1}^{T} \rho_\tau(y_{ijat} - \mathbf{h}'_{ijat}\theta(\tau) - \alpha_i(\tau) - d_j(\tau) - m_t(\tau)),$$

where $\rho_\tau(u) = u(\tau - I(u < 0))$ is the quantile regression "check function". Koenker (2005) discusses several methods for doing inference in quantile regression, including rank-based methods, resampling approaches, and estimation of the asymptotic covariance matrices. In this paper, we estimate the asymptotic covariance matrix of the estimator using standard approaches implemented in most of the statistical softwares.

Table 3 reports conditional and unconditional quantile regression results for both groups, restricting attention to five quantiles $\tau = \{0.1, 0.25, 0.5, 0.75, 0.9\}$. While conditional quantiles, largely following the seminal work of Koenker and Bassett (1978), are commonly applied in the empirical literature, unconditional quantiles introduced by Firpo, Fortin, and Lemieux (2009) are used to investigate the effects of explanatory covariates on the unconditional distribution. This offers a closer connection to the theoretical framework laid out in Section 2. Nonetheless, consistency between results of the two routes underline that relative bids on asphalt and fuel items are quite comparable in terms of independent variables: the characteristics of bidders, rivals, and business conditions. With all controls present, firms continue to react positively to adjustment clauses. At the first quartile, policy impacts on inducing more

[17] Variations of these dimensions are captured here by size.

aggressive bids demonstrate statistical and economic significance for both large and small. For instance, an asphalt bid submitted after June 2006 is lowered by at least 8.6%, holding other circumstances the same except for the policy presence. However, discrepancy emerges as we move on to higher quantiles. For the group of small bidder, policy influences permeate through the entire distribution and gain in size as we move up. At the same time, the bid reducing effect of indexation clauses gradually diminishes for large firms, and eventually reduces to zero at the 0.9 quantile. Overall, both conditional and unconditional quantile regressions show that contractors bid more aggressively upon the implementation of adjustment provision, and small firms respond more favorably, especially around upper quantiles of itemized bids.

We now direct attention to how the spread of itemized bids may change after adjustment clauses were introduced. Instead of making parametric assumptions and comparing variances directly, we propose to look for evidence in quantile regressions, which convey a more complete picture of the distribution of policy impacts. Figure 2 provides a visualization for distributions before and after separately for large and small firms. The upper panel displays probability densities, and the lower one shows corresponding cumulative densities. The densities in the upper panels were estimated considering the following kernel density estimators,

$$\begin{aligned}
\hat{f}_{sb}(F_{Y_s}^{-1}) &= \frac{1}{\check{n}_s h_{sb}} \sum_{m=1}^{M} \sum_{i=1}^{n_s} \sum_{j,a,t} K\left(\frac{\Delta F_{Y_{sijat}}^{-1}(0)}{h_{sb}}\right), \\
\hat{f}_{sa}(F_{Y_s}^{-1}) &= \frac{1}{\check{n}_s h_{sa}} \sum_{m=1}^{M} \sum_{i=1}^{n_s} \sum_{j,a,t} K\left(\frac{\Delta F_{Y_{sijat}}^{-1}(1)}{h_{sa}}\right), \\
\hat{f}_{lb}(F_{Y_s}^{-1}) &= \frac{1}{\check{n}_l h_{sb}} \sum_{m=1}^{M} \sum_{i=1}^{n_l} \sum_{j,a,t} K\left(\frac{\Delta F_{Y_{lijat}}^{-1}(0)}{h_{sb}}\right), \\
\hat{f}_{la}(F_{Y_s}^{-1}) &= \frac{1}{\check{n}_l h_{sb}} \sum_{m=1}^{M} \sum_{i=1}^{n_l} \sum_{j,a,t} K\left(\frac{\Delta F_{Y_{lijat}}^{-1}(1)}{h_{la}}\right),
\end{aligned}$$

where $\check{n}_s = Mn_sKJT$, $\check{n}_l = Mn_lKJT$, n_s denotes the number of small firms, n_l denotes the number of large firms, f_{sb} denotes the distribution of bids for small firms in the period before

	Quantiles				
Variables	0.1	0.25	0.5	0.75	0.9
Large Firms Conditional Quantile Regression					
Bids after policy enactment	-0.002	-0.012	-0.026‡	-0.090*	-0.359*
(β_1)	(0.016)	(0.013)	(0.014)	(0.020)	(0.033)
Bids on asphalt items	0.719*	0.770*	0.522*	0.027	-0.205
(β_2)	(0.073)	(0.099)	(0.178)	(0.150)	(0.161)
Bids on asphalt items after	-0.103*	-0.096*	-0.102*	-0.067*	0.103
policy enactment (β_3)	(0.014)	(0.012)	(0.012)	(0.018)	(0.310)
Large Firms Unconditional Quantile Regression					
Bids after policy enactment	0.030	0.042†	-0.031†	-0.077*	-0.278*
(β_1)	(0.026)	(0.017)	(0.014)	(0.025)	(0.069)
Bids on asphalt items	0.378	0.484‡	0.432‡	0.759‡	-0.123
(β_2)	(0.422)	(0.280)	(0.237)	(0.406)	(1.132)
Bids on asphalt items after	-0.052†	-0.109*	-0.137*	-0.082*	-0.029
policy enactment (β_3)	(0.024)	(0.016)	(0.013)	(0.023)	(0.163)
Number of Observations	8305	8305	8305	8305	8305
Small Firms Conditional Quantile Regression					
Bids after policy enactment	-0.043†	-0.059*	-0.005	-0.011	0.126*
(β_1)	(0.021)	(0.011)	(0.010)	(0.026)	(0.048)
Bids on asphalt items	0.930*	0.874*	0.974*	0.794*	0.774*
(β_2)	(0.056)	(0.045)	(0.069)	(0.111)	(0.142)
Bids on asphalt items after	-0.052*	-0.086*	-0.100*	-0.127*	-0.234*
policy enactment (β_3)	(0.018)	(0.010)	(0.009)	(0.024)	(0.046)
Small Firms Unconditional Quantile Regression					
Bids after policy enactment	-0.006	0.008	-0.010	-0.032	0.055
(β_1)	(0.037)	(0.027)	(0.026)	(0.043)	(0.119)
Bids on asphalt items	1.175†	0.676‡	0.224	0.328	0.636
(β_2)	(0.535)	(0.390)	(0.370)	(0.609)	(1.692)
Bids on asphalt items after	-0.023	-0.107*	-0.122*	-0.149†	-0.243†
policy enactment (β_3)	(0.034)	(0.025)	(0.023)	(0.038)	(0.107)
Number of Observations	4399	4399	4399	4399	4399
Controls	Yes	Yes	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes	Yes
Firm Effects	Yes	Yes	Yes	Yes	Yes
Item Effects	Yes	Yes	Yes	Yes	Yes

Table 3: *Conditional and unconditional quantile regressions for large and small firms with firm and item fixed effects.* The symbols ‡,†,∗ denote statistically different from zero at the 0.10, 0.05 and 0.01 level of significance.

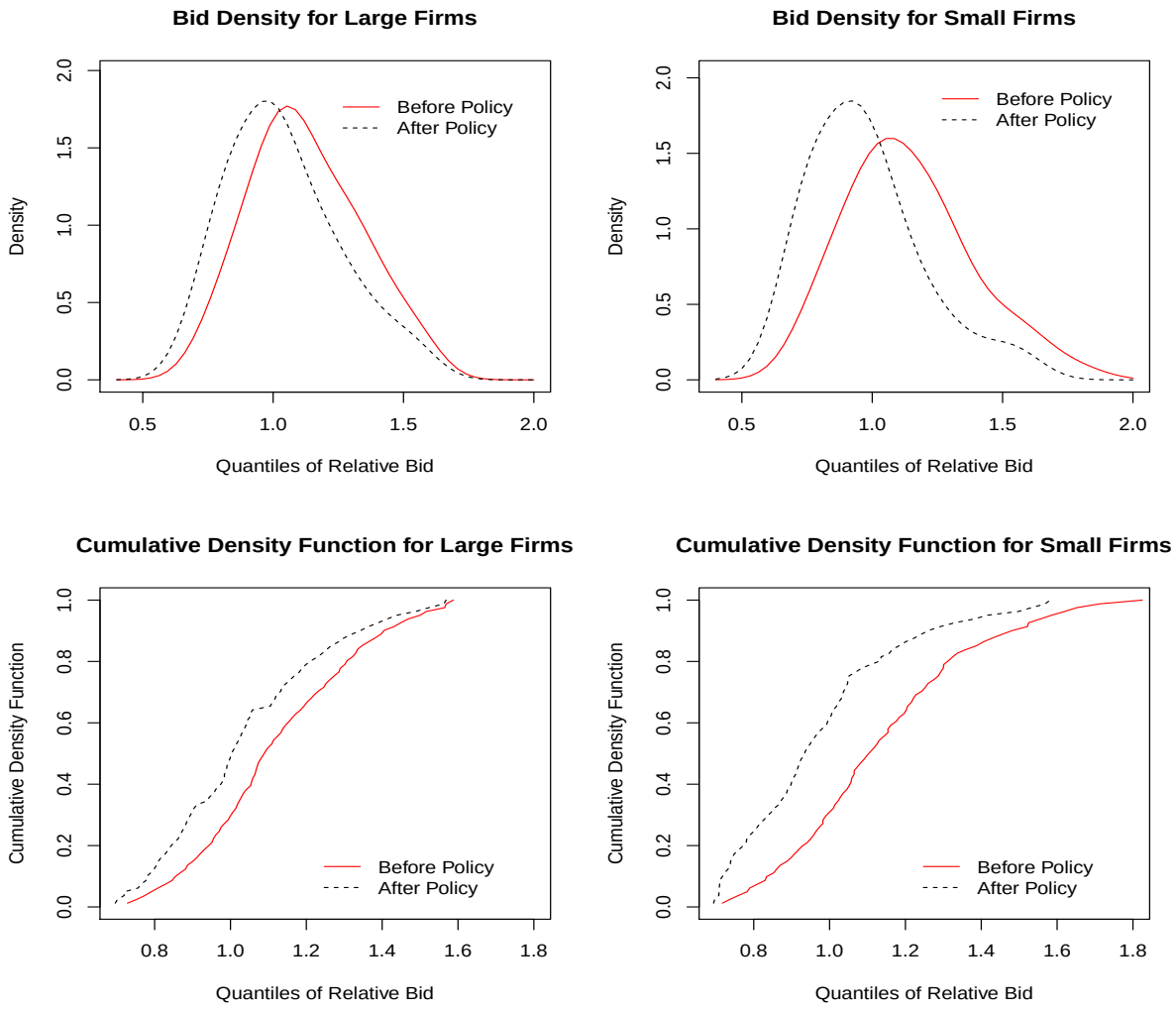

Figure 2: *Density graphs for simulated bids on items.* Data points are generated by employing estimated coefficients from quantile regressions and mean values of all covariates except for treatment status and period indicator, which take 0 or 1 depending on type of item and date respectively.

the policy change, f_{sa} denotes the distribution of bids for small firms in the period after the policy change, f_{jb} denotes the distribution of bids for large firms in the period before the policy change, f_{la} denotes the distribution of bids for large firms in the period after the policy change,

$$\Delta F^{-1}_{Y_{kijat}}(v) = F^{-1}_{Y_k}(\tau|T \times A = v, \bullet) - F^{-1}_{Y_{ijat}}(\tau_j|T \times A = v, \bullet),$$

for $k = \{s, l\}$ and $v = \{0, 1\}$, and

$$F^{-1}_{Y}(\tau|T \times A, \bullet) = Q_Y(\tau|T \times A, \bar{\mathbf{x}}, \bar{z}, \bar{w}, \bar{\alpha}, \bar{d}, \bar{m}),$$

for properly chosen bandwiths h. Therefore, we plug in estimated coefficients of quantile regressions and mean values of all covariates except the treatment indicator and construct estimates based on the quantiles of the distribution of bids over $\tau \in \{0.1, 0.11, ...0.90\}$. The evidence presented in Figure 2 is consistent with the theoretical prediction that the spread of bids on the treated asphalt items narrows down more pronounced for small firms in the second period, driven by the introduction of the policy. For asphalt bids submitted by large firms, there is almost a pure location shift between period. However, for small business, two simultaneous changes seem to appear: a left shift at the mean level and a collapse down of bids to the center of the distribution, suggesting a reduction in the variance. Same impressions are concluded by both probability and cumulative density graphs.

As mentioned previously, the literature has established a close connection between firms' borrowing constraints and their characteristics. In particular, firms of small sizes tend to have limited access to external funds compared to large firms. Therefore, if financial constraints become less binding, those that face restrictions are expected to benefit more, as demonstrated by not only lower average levels but also reduced variation in bids. Our findings illustrated above have lent support to the theoretical prediction presented in section 2, that argues for lower bid variability after the policy implementation by firms with tighter financial constraints.

In the base line setting, we include fixed effects for time, item and firm to account for individual heterogeneity at various levels. As a robustness check for the parameter of interest,

we repeat the same regressions excluding dummies of various item. Table 4 reports regression outcomes under the alternative setting. Consistent findings with Table 3 reassure that β_3, the unique change to bids of the treatment group in the post-policy era, is not sensitive to the structure of specifications.

	Conditional Quantiles			Unconditional Quantiles		
Subsamples	0.1	0.5	0.9	0.1	0.5	0.9
Large Firms	-0.095†	-0.107*	0.086	-0.053†	-0.142*	-0.019
	(0.017)	(0.011)	(0.301)	(0.024)	(0.013)	(0.063)
Small Firms	-0.072*	-0.100*	-0.290*	-0.034	-0.124*	-0.237*
	(0.023)	(0.018)	(0.059)	(0.034)	(0.023)	(0.106)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm Effects	Yes	Yes	Yes	Yes	Yes	Yes

Table 4: *Robustness check on the parameter of interest: bids on asphalt items after policy enactment (β_3).* The symbols ‡,†,∗ denote statistically different from zero at the 0.10, 0.05 and 0.01 level of significance.

4.2 Changes in participation and winning patterns

In this section, we examine participation and winning frequencies contrasting firms of different sizes in the period preceding and following the indexation of asphalt prices. ODOT requires all firms interested in projects to purchase plans first. Only 56% of planholders end up submitting bids at auctions. Hence, we obtain a measure of bidding frequencies by dividing the number of actual bids over the number of plans bought. The likelihood of winning contracts given bidding is constructed in the same way. Table 5 reports binary regression results examining these two patterns. We present estimates under both logistic and complementary log-log specifications, where the Pregibon test of goodness suggests the latter to be a more appropriate choice of functional form.

The firs two columns record the likelihood of participation conditional on acquiring plans. The same set of covariates are employed to control for observable heterogeneity. There are

Variables	Probability of Bidding		Probability of Winning	
	Logit (1)	Clog-log (2)	Logit (3)	Clog-log (4)
	Large Firms			
Bids after policy enactment (β_1)	-0.004 (0.153)	0.006 (0.096)	0.035 (0.234)	0.038 (0.200)
Bids on asphalt projects (β_2)	-0.129 (0.113)	-0.078 (0.071)	0.340 (0.242)	0.273 (0.203)
Bids on asphalt projects after policy enactment (β_3)	0.107 (0.144)	0.064 (0.091)	-0.229 (0.195)	-0.195 (0.169)
	Small Firms			
Bids after policy enactment (β_1)	0.097 (0.107)	0.091 (0.077)	-0.172 (0.148)	-0.137 (0.143)
Bids on asphalt projects (β_2)	-0.572* (0.081)	-0.391* (0.058)	0.002 (0.139)	0.013 (0.146)
Bids on asphalt projects after policy enactment (β_3)	0.213† (0.104)	0.123‡ (0.073)	0.066 (0.162)	0.046 (0.164)
Controls	Yes	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes

Table 5: *Participation and winning patterns of large and small firms.* Choices of functional forms are logistic for (1) & (3), and complementary log-log for (2) & (4). The symbols ‡,†,∗ denote statistically different from zero at the 0.10, 0.05 and 0.01 level of significance.

no noticeable changes in firms' participation strategy after policy initiation, indicated by an insignificant β_1 for both groups. Besides, the negative β_2 suggests that large and small firms share a lower inclination toward bidding for asphalt projects compared to non-asphalt ones, other factors being equal. However, we observe a substantially lifted tendency to bidding on asphalt projects by small contractors after the special provision was enacted, but not shared by their large counterparts. This finding echoes the unilateral increase of *Bid dummy* in the group of small bidders as illustrated in Table 2.

Columns (3) & (4) discloses the probability of winning a contract conditional upon submitting a bid for it. Neither large nor small firms register statistically significant movements in the winning pattern prior and subsequent to the adjustment policy. This is in agreement with results reported in Table 3, where all types of contractors adjusted their bids downward after June 2006, albeit to various extents, and the joint outcome is an unchanged winning pattern. To sum up, Table 5 shows that when excessive risk is relieved, small firms demonstrate higher intentions to submit bids conditional on being planholders. Combined with a non-decreasing probability of winning conditional on bidding, they now stand an improved chance of winning contracts overall.

4.3 Survival of entrants in the market

So far we have analyzed the first two aspects set out at the beginning of this section. Empirical evidence underlines the hypothesis that firms of smaller sizes have more to benefit from adjustment clauses, characterized by more aggressive bidding and a better participation outlook. In this section, we study the impact of policy implementation on small firms via a more direct route: to answer the question of whether it has significantly improved their survival prospects. If small business could survive longer in the presence of price adjustment clauses, they would help to restrain market power, enhance long-run competition and contribute to more efficient allocation of resources. In particular, we measure the duration of survival in the market by the number of months a firm stays active in the monthly ODOT procurement

lettings.

Before producing empirical tests, we need to draw attention to two important facts associated with our study of ODOT data. First, 90 firms entered the local the procurement market during the observation window, 88 of which are small ones. We identify a contractor as a first time bidder if it didn't appear in the historical records extending from January 2002 to August 2003. Since our interest lies in the post-entry performance of small firms, we consider only the pool of small sized entrants, i.e. 88 firms in total. Despite the limited number of observations, our current sample is suitably extensive considering the relative size of Oklahoma's heavy construction industry. According to the U.S. economic census data, there are in total 194 operating establishments performing highway and bridge work in the state in 2007, up from 117 establishments 5 years earlier. Second, when quantifying the duration of survival, we recognize a firm entering the public procurement auctions when it submits a bid for the first time. Meanwhile, a firm is deemed to exit the industry if it has been inactive for 12 consecutive months. The 12 month cut-off is adopted based on the fact that over 95% of projects are completed within 360 days. Since most firms will be exhausting their workload and seeking new opportunities in a year's time, it is quite likely that companies that are inactive for 12 month or longer have retreated from the regional market. To account for firms who have been bidding within the last year of the sample period, we append ODOT data from October 2009 to September 2010 to extend the window for identifying market exitors. If, however, a firm is observed to submit bids in the extension period, it is treated as censored.

A natural starting point of survival evaluation would be to approximate the probability of a new firm bidding t months after initial entry, distinguishing between periods divided by the policy change. Table 6 presents results of standard nonparametric Kaplan-Meier estimator. Judging by the numbers, in the period after June 2006, the cumulative hazard rate for entrants declines less rapidly, indicating that they are observed longer as active competitors. For instance, while the probability of an average firm bidding 12 months into its entry is 57% before adjustments, it becomes 85% after the period. It is also informative to take apart new

Time	Survival Function Estimates					
	All Entrants		Entrant Bidding on Asphalt Projects		Entrant Bidding on Non-asphalt Projects	
	Before	After	Before	After	Before	After
1 month	0.714	0.906	0.857	1.000	0.533	0.608
	(0.076)	(0.042)	(0.079)	-	(0.128)	(0.116)
3 months	0.685	0.882	0.786	1.000	0.458	0.517
	(0.079)	(0.046)	(0.076)	-	(0.131)	(0.143)
12 months	0.566	0.847	0.714	0.917	0.381	0.458
	(0.085)	(0.056)	(0.090)	(0.079)	(0.130)	(0.153)
Wilcoxon test (p-values)	0.007		0.004		0.416	

Table 6: *Kaplan-Meier estimates for bidding duration probability.* Standard errors are in parenthesis.

firms that have participated in asphalt projects which are subject to the policy influences from others who have only participated in non-asphalt projects and were thus least affected by the intervention. The last four columns of Table 6 verify that the extended duration of active participation is statistically significant for entrants bidding on asphalt projects, who exhibit higher probability of being continuously present for 1 month, 3 months, and 12 month intervals. In contrast, for entrants participating in non-asphalt projects alone, the inter period change is much less pronounced, and we fail to reject the null hypothesis of Wilcoxon test that survival probabilities are equal before and after the policy implementation.[18]

Being the least restricted econometric setting, the nonparametric analysis above does not account for other factors potentially affecting the survival of entrants, such as firm sizes. To address this issue, we employ semi-parametric and fully parametric hazard models that

[18]It is worth noting that firms engaging in the two segments of projects displayed quite distinctive survival patterns even before the adjustments clauses kicked in. Many projects using asphalt binder are surfacing and pavement jobs, generally considered private costs and involving less uncertainty concerning the work to perform. On the other hand, more than 60% of ineligible projects are related to bridge constructions which typically contain a notable public cost component and thus are more uncertain. (See Hong and Shum, 2002 for similar classifications of projects.) Since it usually takes cumulative expertise to assss site conditions and evaluate work nature, the perspective of newly entering firms in this category can be more dismal.

Variables	Hazard Models		
	COX PH	Exponential	Weibull
	(1)	(2)	(3)
Entrants after policy enactment	-0.346	0.406	0.029
(β_1)	(0.578)	(0.621)	(0.610)
Entrants bidding on	-0.385	-0.729	-0.591
asphalt projects (β_2)	(0.552)	(0.620)	(0.584)
Entrants after policy enactment	-2.411†	-3.016†	-2.718†
bidding asphalt projects (β_3)	(1.022)	(1.023)	(1.022)
Controls	Yes	Yes	Yes
Number of Observations	88	88	88

Table 7: *Semi-parametric and parametric results for hazard rate function.* Column (1) presents results using Cox proportional hazard model, and (2) & (3) are based on Exponential and Weibull regression models respectively. Standard errors are in parenthesis. The symbols ‡,†,∗ denote statistically different from zero at the 0.10, 0.05 and 0.01 level of significance.

allows us to incorporate the control variables used in previous sections.[19,20] Table 7 presents results for the Cox proportional hazard model, the exponential function, and Weibull function. Consistent with nonparametric evidence presented in Table 6, entrants that have participated on asphalt projects (β_2) display lower hazard rate, but not statistically different from zero after inclusion of the controls. Nonetheless, the group of firms entering the market after the adjustment clauses were enacted and bidding on asphalt work (β_3) had a significantly higher survival chance relative to other entrants. As for other independent variables omitted from the table, establishment size exerts positive impact on duration, agreeing with "the stylized

[19]Some of them are time-independent, such as maximum capacity. Others are time specific, and we accommodate time-dependent variables by adopting their base-line status. For example, unemployment rate is taken to be the value from the initial time of entry.

[20]Entrants cohort effects are attended by the inclusion of yearly dummies for the time of entry.

fact" of the literature (Geroski 1995). [21][22]

Our empirical evidence is only suggestive of a mechanism through which the price adjustment policy can have a beneficial effect on new firms participating in the procurement auctions, namely, the structure of payments and significant reduction in uncertainty will allow firms' to pay now a lower risk premium for external financing. Financial records are unfortunately proprietary. Quiros and Timmermann (2004) have argued that firms with a size disadvantage are more vulnerable to worsening of economic conditions or higher borrowing standards. It is agreed by both theoretical and empirical research (Clementi and Hopenhayn 2002, Tsoukas 2011 among others) that liquidity constraints play a key role in determining business failures. Less stringent borrowing restrictions facilitate the survival of firms, especially the small and inexperienced ones.

5 Conclusion

In June 2006, ODOT began to compliment general construction specifications with a special provision of price adjustments for asphalt binder products. This paper studies the effect of the policy accounting for the different characteristic among participants in this market. Supporting theoretical arguments, our findings show an asymmetric impact of the price adjustment policy, which have implications on bidding outcomes, survival and long run competition in the procurement auctions.

The indexation of selected input prices has induced more aggressive bidding especially from small firms, further confirming the stylized notion that they are generally faced with more adverse liquidity constraints, and have more to gain when investment risks are reduced.

[21] As a sensitivity check, we also utilize a continuous measure for participation in the risk discounted asphalt projects. Compared with the discrete dummy of 0 or 1, the continuous variable counts how many times a firm bid for asphalt projects and provides a more accurate level of its involvement with the policy change. If price indexation is the underlying difference maker in survival perspective, a firm that frequently competes for asphalt auctions is likely to be influenced more substantially than an occasional participant, and thus leads to different duration paths. Parametric regressions under the alternative specifications also yield a β_3 that is negative and statistically different from 0, attesting to the supportive effects of policy change on small entrants' probability of survival.

[22] The results are available upon request.

Small firms are also exhibiting similar competitive behavior to larger ones in the post-policy period. The survival prospect for small entrants has been significantly improved after the policy was implemented, where the positive change is unique to entering firms that have been bidding on policy eligible asphalt projects.

6 Appendix

6.1 Derivation of the Equilibrium Bidding Function

Here we present derivations of the optimal bidding function in (2). Consider a bidder's expected utility from participation:

$U(b_{it}, s_{it}|\lambda) = \left[b_{it} - s_{it} - E(d^*_{t+1}|\lambda) \mid s_t \geq B^{-1}(b_{it}|\lambda))\right] \left[1 - F_s(B^{-1}(b_{it}|\lambda))\right]^{n-1}$.

Differentiating the objective function with respect to b and evaluating the expression at the optimal choice we have:

$\frac{\partial U}{\partial b}|_{b=B(x|\lambda)} = \left[1 - [E(d^*_{t+1} \mid s_t \geq x, \lambda) - E(d^*_{t+1} \mid s_t = x, \lambda)]\frac{1}{B'(x|\lambda)}\frac{f_s(x)}{1-F_s(x)}\right][1 - F_s(x)]^{n-1}$
$-[B(x|\lambda) - s_t - E(d^*_{it+1} \mid s_t \geq x, \lambda)](n-1)[1 - F_s(x)]^{n-2} f_s(x)\frac{1}{B'(x|\lambda)} = 0.$

Simplifying we get:

$\left[\frac{B'(x|\lambda)}{n-1}\frac{1-F_s(x)}{f_s(x)} - \frac{1}{n-1}[E(d^*_{t+1} \mid s_t \geq x, \lambda) - E(d^*_{t+1} \mid s_t = x, \lambda)]\right]$
$-B(x|\lambda) + s_t + E(d^*_{t+1} \mid s_t \geq x, \lambda) = 0.$

We can now show that the following function is indeed the symmetric equilibrium bidding strategy for bidder i in the first price auction:

$$B(x|\lambda) = E(d^*_{t+1} \mid s_t \geq x, \lambda) + E(y_{1t} \mid y_{1t} \geq x, \lambda). \tag{6.1}$$

Differentiating this expression we get:

$$B'(x|\lambda) = [E(d^*_{t+1} \mid s_t \geq x, \lambda) - E(d^*_{t+1} \mid s_t = x, \lambda)]\frac{f_s(x)}{1 - F_s(x)} + E(y_{1t} \mid y_{1t} \geq x, \lambda)\frac{f_{y_1}(x)}{1 - F_{y_1}(x)}.$$

Using the fact that $\frac{f_s(x)}{1-F_s(x)} = \frac{f_{y_1}(x)}{1-F_{y_1}(x)} + \circ(\frac{f_{y_1}(x)}{1-F_{y_1}(x)})$ and replacing (6) and (7) into (5) we get:

$\frac{1}{n-1}[E(d^*_{t+1} \mid s_t \geq x, \lambda) - E(d^*_{t+1} \mid s_t = x, \lambda)] + [E(y_{1t} \mid y_{1t} \geq x, \lambda) - x] - \frac{1}{n-1}[E(d^*_{t+1} \mid s_t \geq x, \lambda) - E(d^*_{t+1} \mid s_t = x, \lambda)]$

$-E(d^*_{t+1} \mid s_t \geq x, \lambda) - E(y_{1t} \mid y_{1t} \geq x, \lambda) + s_t + E(d^*_{t+1} \mid s_t \geq x, \lambda) = 0$

$\iff s = x.$

Together with the monotonocity of B, we show that $B(s_i|\lambda)$ is the bidder's unique optimal strategy, i.e.

$$B(s_i|\lambda) = E(d^*_{t+1} \mid s_t \geq s_{it}, \lambda) + E(y_{1t} \mid y_{1t} \geq s_{it}, \lambda).$$

6.2 The effect of λ on the variance of bids

The variance of bids is:

$$\begin{aligned} V[B(S_{it}|\lambda)] &= V[E(y_{it}|y_{it} \geq s_{it}, \lambda) + E(d^*_{t+1}|\lambda)] \\ &= V[E(y_{it}|y_{it} \geq s_{it}, \lambda)] + V[E(d^*_{t+1}|\lambda)] + 2cov[E(y_{it}|y_{it} \geq s_{it}, \lambda), E(d^*_{t+1}|\lambda)]. \end{aligned}$$

Taking derivative with respect to the policy threshold yields:

$$\begin{aligned} \frac{\partial V[B(S_{it}|\lambda)]}{\partial \lambda} &= \frac{\partial V[E(y_{it}|y_{it} \geq s_{it}, \lambda)]}{\partial \lambda} + \frac{\partial V[E(d^*_{t+1}|\lambda)]}{\partial \lambda} \\ &\quad +2\frac{\partial cov[E(y_{it}|y_{it} \geq s_{it}, \lambda), E(d^*_{t+1}|\lambda)]}{\partial \lambda}. \end{aligned}$$

We consider each term separately.[23] Empirical literature in both business and consumer loan markets (Krainer 2004, Kaplin et al. 2009, Edelberg 2006, Hubbard 1998) shows that the interest rate spread between high-risk and low-risk borrowers increases with credit risk. As the threshold parameter exerts positive influences on firms' probability of default or even bankruptcy, the difference in risk premia between borrowers of high and low grades is expected to increase with λ, which consequently leads to the rise of dispersion of contractors' financial costs, i.e.

$$\frac{\partial V[E(y_{it}|y_{it} \geq s_{it}, \lambda)]}{\partial \lambda} > 0.$$

[23] All the derivations that follow are available analytically upon request.

The higher the value of λ the lower the likelihood of ex post adjustment. As a result, given parameters $\overline{c}_t$ and λ the second term of (XX) has a positive sign:

$$\frac{\partial V[E(d^*_{t+1}|\lambda)]}{\partial \lambda} = V(\overline{c}_{t+1}) \cdot 2P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1) \cdot \frac{\partial P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1)}{\partial \lambda} > 0.$$

Empirical literature in both business and consumer loan markets (Krainer 2004, Kaplin et al. 2009, Edelberg 2006, Hubbard 1998) shows that the interest rate spread between high-risk and low-risk borrowers increases with credit risk. As the threshold parameter exerts positive influences on firms' probability of default or even bankruptcy, the difference in risk premia between borrowers of high and low grades is expected to increase with λ, which consequently leads to the rise of dispersion of contractors' financial costs, i.e.

$$\frac{\partial V[R(s_{it}|\lambda)]}{\partial \lambda} > 0.$$

Recall that, as λ increases both $E(d^*_{t+1}|\lambda)$ and $R(s_{it}|\lambda)$ increase.These terms are positively correlated. It follows that

$$\frac{\partial cov[E(y_{it}|y_{it} \geq s_{it}, \lambda), E(d^*_{t+1}|\lambda)]}{\partial \lambda}.$$

A number of papers (Ehermann 2000, Gertler and Gilchrist 1994 and Martinelli 1997) have noted the asymmetric changes in borrowing costs of firms of different scales when financial constraints become more binding. Although all firms are subject to tightened borrowing conditions, the adverse effects are greater for small firms, represented by a bigger jump in their loan interest rates. Therefore, costs of external financing are expected to increase more rapidly for the small relative to the large firms when general risk is increasing, i.e. $\frac{\partial R(s_{it}|\lambda)}{\partial \lambda \partial s_{it}} > 0$.

To summarize, under mild restrictions, we have shown that and increase in λ has a positive effect on all terms comprising the variance ($\frac{\partial V[B(S_{it}|\lambda)]}{\partial \lambda} > 0$) forecasting a positive correlation between the choice of trigger value for adjustment clauses and the variability of submitted bids. In the context of the June 2006 ODoT's initiative, we expect bids from the post policy period to display smaller variance.

6.3 The effect of capital accumulation (w_{it}) on the variance of bids

Another dimension worth investigating is how distributions of submitted bids differ among firms with different levels of capital accumulation. We will then use the size of a firm as a proxy for capital accumulation in our empirical analysis as is typical in the literature (e.g., Brito and Mello 1995, Hubbard 1998, and Persson 2004).

How does the difference in bid dispersion (caused by the introduction of adjustment clauses) vary for firms that differ in the level of capital accumulation? The answer to this question can be obtained if we differentiate the difference in bid variances across the two periods ($V[B(s_{it})] - V[B(s_{it}|\lambda)]$) with respect to w_{it}, i.e. $\frac{\partial V^*}{\partial w_{it}} = \frac{\partial (V[B(s_{it})] - V[B(s_{it}|\lambda)])}{\partial w_{it}}$.

Using (1) and (2), the expression simplifies to:

$$\begin{aligned} V[B(s_{it})] - V[B(s_{it}|\lambda)] &= V[E(d_{t+1})] - V[E(d^*_{t+1}|\lambda)] + \\ & \quad V[E(y_{it}|y_{it} \geq s_{it})] - V[E(y_{it}|y_{it} \geq s_{it}, \lambda)] + \\ & \quad 2cov[E(y_{it}|y_{it} \geq s_{it}), E(d^*_{t+1})] - 2cov[E(y_{it}|y_{it} \geq s_{it}, \lambda), E(d^*_{t+1}|\lambda)]. \end{aligned}$$

Differentiating with respect to w_{it} we get:

$$\begin{aligned} \frac{\partial (V[B(s_{it})] - V[B(s_{it}, \lambda)])}{\partial w_{it}} &= \frac{\partial (V[E(d_{t+1})] - V[E(d^*_{t+1}|\lambda)])}{\partial w_{it}} + \\ & \quad \frac{\partial (V[E(y_{it}|y_{it} \geq s_{it})] - V[E(y_{it}|y_{it} \geq s_{it}, \lambda)])}{\partial w_{it}} + \\ & \quad 2\frac{\partial (cov[E(y_{it}|y_{it} \geq s_{it}), E(d^*_{t+1})] - cov[E(y_{it}|y_{it} \geq s_{it}, \lambda), E(d^*_{t+1}|\lambda)])}{\partial w_{it}}. \end{aligned}$$

We consider each term separately. Since individual firm's capital accumulation (w_{it}) is not dependent upon exogenous price shocks:

$$\frac{\partial (V[E(d_{t+1})] - V[E(d^*_{t+1}|\lambda)])}{\partial w_{it}} = 0$$

With regard of $\frac{\partial (V[E(y_{it}|y_{it} \geq s_{it})] - V[E(y_{it}|y_{it} \geq s_{it}, \lambda)])}{\partial w_{it}}$, evidence provided by the literature (Krainer 2004, Kaplin et al. 2009, Edelberg 2006, Ehermann 2000, Gertler and Gilchrist 1994) maintains that the spread of interest rates is negatively affected by the level of credit risk, and hence

is reduced moving from high-risk to low-risk borrowers, i.e. $\frac{\partial(V[E(y_{it}|y_{it}\geq s_{it})]-V[E(y_{it}|y_{it}\geq s_{it},\lambda)])}{\partial w_{it}} < 0$.

Assuming that $c^e_{i,t}$ and w_{it} are independently distributed implies that $\frac{\partial(cov[E(y_{it}|y_{it}\geq s_{it}),E(d^*_{t+1})]-cov[E(y_{it}|y_{it}\geq s_{it},\lambda),E(d^*_{t+1}|\lambda)])}{\partial w_{it}} = 0$.

The literature has established a strong correlation between capital accumulation w_{it} and firm size. As mentioned earlier, the practice of using size as a proxy for the level of capital accumulation or liquidity constraints is widespread in empirical research (see Carpenter and Guariglia 2008, Spaliara 2009, Tsoukas 2011). Using here capital accumulation as a proxy for size and the fact that $\frac{\partial V^*}{\partial w_{it}} < 0$, is leading us to infer that small firms have more to gain than big firms from adjustment clauses when it comes to reducing bid variance.

7 References

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8 Referee Appendix

This section provides omitted mathematical details for derivations in the Appendix.

8.1 The effect of λ on the variance of bids

Consider the term $\frac{\partial V[E(d^*_{t+1}|\lambda)]}{\partial \lambda}$, and let $k = E(d^*_{t+1}|\lambda)$.

$\frac{\partial V[E(d^*_{t+1}|\lambda)]}{\partial \lambda} = \frac{\partial V(k)}{\partial \lambda} = \frac{\partial [E(k^2) - (E(k))^2]}{\partial \lambda}$

$k = (\overline{c}_{t+1} - \overline{c}_t) \cdot P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1) + \lambda \overline{c}_t \cdot P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} > 1) + (-\lambda \overline{c}_t) \cdot P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} < -1)$

$k^2 = (\overline{c}_{t+1} - \overline{c}_t)^2 \cdot [P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1)]^2 + (\lambda \overline{c}_t)^2 \cdot [P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} > 1)]^2 + (-\lambda \overline{c}_t)^2 \cdot [P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} < -1)]^2$ $+2 \cdot \lambda \overline{c}_t (\overline{c}_{t+1} - \overline{c}_t) \cdot P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1) P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} > 1)$ $-2 \cdot \lambda \overline{c}_t (\overline{c}_{t+1} - \overline{c}_t) \cdot P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1) P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} < -1)$ $-2 \cdot (\lambda \overline{c}_t)(-\lambda \overline{c}_t) \cdot P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} > 1) P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} < -1)$.

When taking expectations, it is important to recognize that $\overline{c}_t$ and λ are parameters, not random variables. On the other hand, $\overline{c}_{t+1}$ is a random variable with a known distribution.

Keeping this in mind, probability $P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1) = P(-\lambda \overline{c}_t \leq (\overline{c}_{t+1} - \overline{c}_t) \leq \lambda \overline{c}_t) = P(-\lambda \overline{c}_t + \overline{c}_t \leq \overline{c}_{t+1} \leq \lambda \overline{c}_t + \overline{c}_t) = g(\lambda, \overline{c}_t)$, is a deterministic function of $\overline{c}_t$ and λ, with the random component $\overline{c}_{t+1}$ integrated out. Likewise, both $P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} > 1)$ and $P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} < -1)$ are parameters. We proceed as follows:

$E(k) = E[(\overline{c}_{t+1} - \overline{c}_t) \cdot P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1) + E[\lambda \overline{c}_t \cdot P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} > 1)] + E[(-\lambda \overline{c}_t) \cdot P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} < -1)] = P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1) \cdot E(\overline{c}_{t+1} - \overline{c}_t) + P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \geq 1) \cdot \lambda \overline{c}_t + P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq -1) \cdot (-\lambda \overline{c}_t)$

$E(k^2) = [P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1)]^2 \cdot E(\overline{c}_{t+1} - \overline{c}_t)^2 + (\lambda \overline{c}_t)^2 \cdot [P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} > 1)]^2$

$+(-\lambda \overline{c}_t)^2 \cdot [P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} < -1)]^2 + 2 \cdot \lambda \overline{c}_t P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1) P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} > 1) \cdot E(\overline{c}_{t+1} - \overline{c}_t)$

$-2 \cdot \lambda \overline{c}_t P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1) P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} < -1) \cdot E(\overline{c}_{t+1} - \overline{c}_t)$

$-2 \cdot (\lambda \overline{c}_t)(-\lambda \overline{c}_t) \cdot P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} > 1) P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} < -1)$

$[E(k)]^2 = [P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1)]^2 [E(\overline{c}_{t+1} - \overline{c}_t)]^2 + [P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \geq 1)]^2 \cdot (\lambda \overline{c}_t)^2$

$+[P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq -1)]^2 \cdot (-\lambda \overline{c}_t)^2 + 2 \cdot \lambda \overline{c}_t P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1) P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} > 1) \cdot E(\overline{c}_{t+1} - \overline{c}_t)$

$-2 \cdot \lambda \overline{c}_t P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1) P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} < -1) \cdot E(\overline{c}_{t+1} - \overline{c}_t)$

$-2 \cdot (\lambda \overline{c}_t)(-\lambda \overline{c}_t) \cdot P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} > 1) P(\frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} < -1)$.

Canceling terms out we get:

$E(k^2) - (E(k))^2 = [P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1)]^2 \cdot [E(\overline{c}_{t+1} - \overline{c}_t)^2 - [E(\overline{c}_{t+1} - \overline{c}_t)]^2]$

$= [P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1)]^2 V(\overline{c}_{t+1} - \overline{c}_t) = [P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1)]^2 V(\overline{c}_{t+1})$.

In light of the independence between distribution of future price trend $\overline{c}_{t+1}$ and adjustment clauses,

$\frac{\partial [E(k^2) - (E(k))^2]}{\partial \lambda} = V(\overline{c}_{t+1}) \frac{\partial [P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1)]^2}{\partial \lambda} = V(\overline{c}_{t+1}) \cdot 2P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1) \cdot \frac{\partial P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1)}{\partial \lambda}$.

It is apparent that $P(-1 \leq \frac{\overline{c}_{t+1} - \overline{c}_t}{\lambda \overline{c}_t} \leq 1)$ increases when the government sets λ higher, resulting in $\frac{\partial V[E(d^*_{t+1}|\lambda)]}{\partial \lambda} > 0$.

Variable	Description and Construction of the Variable
Project relative bid	Project bid divided by engineer's estimated cost.
Itemized relative bid	A firm submits bids for an exhaustive list of materials used in each project. The project bid equals the weighted sum of unit prices (the bids) and quantities allocated to each item on the list. Itemized bids simply refer to these detailed bids at item level. As opposed to the total bid, a project could have more than one itemized bid when it uses multiple items for construction, which is the norm.
Large and small firms	Division based on market share over 1% or not.
Entrants	Contractors who submit first bids after September 2003.
Asphalt items	Bituminous AC products prescribed in ODOT Special Provision 109-7(a-b)99; used interchangeably with "eligible items" and "bituminous items" in the text.
Fuel items	Diesel fuel related products prescribed in ODOT Special Provision 109-3(a-c)09.
Asphalt projects	Projects that include asphalt items in plans.
Non-asphalt projects	Projects that don't include asphalt items in plans.
Bids after policy	A dummy variable that identifies bids submitted after June 2006.
x	*Bidder Specific Characteristics*
Capacity utilization	The ratio of a firm's current backlog over its capacity. Projects are assumed to be completed in a uniform fashion over its designated contract time. A project's backlog equals the monetary value of yet to be finished part. A firm's backlog equals the sum of backlog values from all of its ongoing projects, which goes to zero upon completion of engaged work and becomes positive when new ones are undertaken. A firm's capacity is assumed to be the maximum of its backlog amounts during the sample period. Historical bidding records (Sep 2001 to Aug 2003) are used to calculate the initial values of capacity utilization rate. For firms that have not undertaken any projects, default value is set at 0. See also Porter and Zona (1993).
Distance to project	The logarithm of distance (in mile) between the city where the firm's is located and the city where the project is located. City location is represented by the longitude and latitude of its center. See Porter and Zona (1993).
Past winning to bidding ratio (WP)	Firms' ratio of winning times to plan holding times in the past 12 months (note that this is a moving window and updated monthly); an indicator of individual bidding strength.
Average rivals winning to plan holder ratio (ARWP)	A measure to capture the average success rate of rivals' past bidding. Based on each firm's past winning to plan holding ratio as constructed above, the average of all rivals' value gives the ARWP for a firm faced with a particular set of competitors. It...

Table continues on next page...

Variable	**Description and Construction of the Variable**
ARWP	incorporates two aspects of rivals' behaviors: the probability of bidding conditional on purchasing a plan and the probability of winning conditional on bidding. See Jofre-Bonet and Pesendorfer (2003) and De Silva et al (2003).
Rival's minimum distance to work site	The logarithm of distance (in mile) from the work site to the location of the closet rival. See Bajari and Ye (2003).
Rival's minimum backlog	The logarithm of the minimum of all rivals' backlog amounts. See capacity utilization rate for the construction of backlog amounts. See Bajari and Ye (2003).
z	*Auction Specific Characteristics*
No. of planholders	The number of firms who have purchased plans and qualified as potential bidders for a project prior to the actual auction.
No. of bidders	The number of firms who have submitted bids; used interchangeably with "number of bids".
Expected No. bidders	Based on its own bidding records of the past 12 month, each firm is assigned a probability of submitting bids conditional on being a plan holder. Consequently, the expected number of bidders in an auction is the summation of the entry probabilities for all firms that hold plans. See De Silva et al (2008).
Project type dummy	All projects are categorized into seven groups based on brief descriptions provided by ODOT, which are asphalt paving, bridge related work, traffic signing and lighting, grading and draining, clearance, concrete work, and miscellaneous projects such as landscaping. The omitted group in regression is miscellaneous projects.
Calendar days	The number of calendar days that are needed to complete the project indicated in the plan.
w	*Variables on General Economic Conditions*
Seasonally adjusted unemployment rate	Monthly unemployment rate for the state of Oklahoma, adjusted for seasonal fluctuations; collected from the Bureau of Labor Statistics (BLS).
Three month average of the real volume of contracted projects	Monthly volume of contracted projects is measured by the logarithm of the amount of all awarded projects at a given month; deflated by the monthly index of producer's prices published by BLS.
Three month average of the number of building permits issued	The logarithm of 3-step moving average of monthly building permits issued to the state of Oklahoma; obtained from the Bureau of Economic Analysis.
Monthly dummies	There are in total 10 monthly dummies since ODOT holds no December lettings.