Government Procurement Auctions and the Survival of Entrant Firms in the Road Construction Industry*

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July 22, 2010

Abstract

The natural differences in cost uncertainty between entrant and incumbent firms in the road construction industry are intensified by the competitive nature of the project allocation mechanism, making entrants more susceptible to losses and bankruptcy. In this paper, we construct a panel data set that includes patterns of firm entry and exit and auction related information. We use existing and newly developed estimation approaches to examine how procurement auctions of construction contracts shape entrants' success and survival. We find that early subcontracting experience can prolong business life. The evidence also suggests that winning at early stages decreases survival time among those with limited opportunities outside road construction but can have a beneficial effect on the survival of entrants with outside business opportunities.

JEL Classification: D44, H57, L74.
Keywords: Government procurement, entry, uncertainty, learning, subcontracting, survival analysis.

1 Introduction

The empirical literature is relatively silent in documenting the survival of entering firms in industries relying on the procurement auction process for most of their business activity. Yet, it is estimated that 15% of the world output is generated through public procurement (Lewis and Bajari, (2010)). Consider the road construction industry which in the US absorbed about 160 billion dollars in the past two years. The industry faces challenges stemming from the intensity of competition through the procurement process and potential winner's curse effects from projects with uncertainty. Some

*The authors would like to thank George Deltas, Timothy Dunne, Danny Gierhart, Thomas Jeitschko, Joakim G. Laguros, Richard Sicotte, conference participants at the 2009 International Industrial Organization Conference and seminar participants at the University of Cyprus. We are indebted to staff at the Texas Department of Transportation and Texas Workforce Commission for providing useful information. The authors obtained these data under an agreement of confidentiality and disclosure of the actual data is subject to certain restrictions.

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of the firms have business opportunities outside road construction intensifying competitive pressures through intermittent participation in the bidding process. In this paper, we consider entrants in the state of Texas to investigate their duration in business. We use a newly-constructed data set of firms in the period 1999-2006 that allows an empirical examination of the relationship between competition in procurement auctions and firms' growth and exit.

The presence of uncertainty in construction costs due to price fluctuations, project characteristics or lack of experience can affect firm survival and inhibit future competition. The intense nature of competition induced by the project allocation mechanism increases the hazard for entrants even more. Recent work in sequential private value auctions points to the fact that potential learning benefits for the winner make bidders engage into risky behavior in early auctions (Jeitschko and Wolfstetter (2002) and De Silva, Jeitschko and Kosmopoulou (2005)) creating often a serious bankruptcy problem (Leufkens, Peeters and Vermeulen (2006)). The presence of common cost uncertainty intensifies early bidding aggressiveness providing a theoretical explanation of the winner's curse effect (Virag (2007)) in a sequential setting. Recognizing the nature of competition on a project by project basis allows one to understand better the underpinnings of survival in this industry.

A number of parametric and flexible semiparametric approaches for duration models reveal several determinants of firm longevity associated with the procurement auctions. Our analysis indicates that winning a contract within a few months from the start-up date has adverse effects on business duration. We explore the role of subcontracting activity on firm survival and the timing of the first win as primary contractors. We provide evidence suggesting that having a network of subcontractors that can share information and part of the risk can have a significant effect on the survival rate of firms. In addition, starting out in business as a subcontractor increases business duration. Fluctuations in the cost of construction, or uncertainty induced by the nature of the projects undertaken by entrants, affect negatively the survival of firms.[1] Potential losses associated with an early win hinge upon the existence of alternative business options. Kirchkamp, Poen, and Reiß (2009) use theory and experiments to show

[1]For example, the cost associated with bridge construction and repair is often uncertain and those uncertainties persist beyond price fluctuations related to business cycle movements.

that bidders respond to outside options. Having alternative business opportunities could lessen or even offset the negative impact of limited experience on survival. We find that winning at early stages has a beneficial effect on survival among entrants with outside business opportunities, while it decreases survival time among those with limited opportunities outside road construction.

This paper is related to the literature that investigates firms' entry and exit. Most empirical studies to this point have drawn evidence from the manufacturing industry having for the most part a different focus. The existing literature relates survival rates for new businesses to size, scale, organizational structure (Audretsch, (1991)), technology (Winter, (1984)), market growth (Bradburg and Caves, (1982)) and pre-entry experience (see, e.g., Helfat and Lieberman (2002) for a review). Consistent with this literature, in road construction, entrants' survival is adversely affected by initial size. A few recent studies on firm dynamics in service industries, retailing and agriculture appear in Dunne, Jensen and Roberts (2009) and Seim (2001). Our paper also relates to studies of survival not in the industry but in a market. De Silva, Kosmopoulou and Lamarche (2009) use data from the Oklahoma Department of Transportation and evaluate the impact of an information release policy on market survival.

The paper is organized as follows. Section 2 discusses a theoretical model framing our statistical analysis and section 3 presents the data. Section 4 provides empirical results on the survival of all entrants. Section 5 provides evidence from firms with limited or no business opportunities outside the state procurement contracts. Section 6 has concluding remarks.

2 Modeling Framework

We consider a simple dynamic framework that creates a link between government procurement contracts and the analysis of duration models (see Honoré and de Paula, (2010)). Firm i is in the construction industry primarily competing for contracts and determines how long it will continue being active in business by selecting an exit time T. Consider π to be the profit function of a firm consisting of the gross payoff from contracting activity, and the payoff from complementary business activity. The profit related to procurement contracting, π_C, is a function of auction, bidder specific covariates, and rival characteristics $\mathbf{x} \in \mathbf{X} \subset \mathbf{R}^{p_1}$, contracting experience, subcontracting experience and project risks $\mathbf{s} \in \mathbf{S} \subset \mathbf{R}^{p_2}$, and firm age related learning effects. At any time t, therefore, the profit function of a representative firm takes the following form:

$$\pi(\mathbf{x}, \mathbf{s}, t) = \pi_C(\mathbf{x}, \mathbf{s}, t)\ \theta - h(\mathbf{s}, f). \tag{2.1}$$

The parameter θ can enhance the profit related to procurement contracting and could be interpreted as a firm specific productivity index. Alternatively, it could be related to the level of involvement in complementary activity that can affect business profit. In particular, θ exceeds 1 if complementary activity is extensive and can be less than 1 if it is limited. We assume that $\pi_C(\mathbf{x}, \mathbf{s}, t) = V(\mathbf{x}, \mathbf{s})\phi(t)\mu(\mathbf{x})$ where $V(\mathbf{x}, \mathbf{s})\phi(t)$ is the ex post value of a contract to a firm. The variable $V(\mathbf{x}, \mathbf{s})$ is the net payoff related to auction and bidder specific characteristics and ϕ is a continuous, strictly increasing function embodying firm age related learning effects. The function $\mu(\mathbf{x})$ is the probability of winning a contract. Finally, $h(\mathbf{s}, f)$ is a cost function related to fixed operating costs f and subcontracting experience that can increase cost efficiency.

Assuming an exponential discount rate ρ, we can express the cumulative net profit from business until time t as:

$$\int_0^t \pi(\mathbf{x}, \mathbf{s}, z)dz = \int_0^t [V(\mathbf{x}, s)\phi(z)\mu(\mathbf{x})\ \theta - h(\mathbf{s}, f)]e^{-\rho z}dz. \tag{2.2}$$

Let $V(\mathbf{x}, \mathbf{s})\mu(\mathbf{x}) = W(\mathbf{x}, \mathbf{s})$. Then,

$$\int_0^t \pi(\mathbf{x}, \mathbf{s}, z)dz = \int_0^t [W(\mathbf{x}, \mathbf{s})\phi(z)\ \theta - h(\mathbf{s}, f)]e^{-\rho z}dz. \tag{2.3}$$

Optimizing behavior with respect to t requires that the firm will continue to be in business as long as the benefit of being active at time t exceeds the cost or

$$W(\mathbf{x}, \mathbf{s})\phi(t)\ \theta \geq h(\mathbf{s}, f). \tag{2.4}$$

Clearly, both age related learning effects and engagement in complementary business are enhancing the benefits and can prolong business activity. Early contracting activity may not hurt the prospects of survival as long as there is extensive involvement in complementary business. A firm is exiting at time period T when:

$$W(\mathbf{x}, \mathbf{s})\ \phi(T)\ \theta = h(\mathbf{s}, f). \tag{2.5}$$

In other words, exit occurs at $T = \phi^{-1}\left(\frac{h(\mathbf{s},f)}{W(\mathbf{x},\mathbf{s})\ \theta}\right)$ or,

$$\ln \phi(T) = -\ln W(\mathbf{x}, \mathbf{s}) - \ln \theta + \ln h(\mathbf{s}, f) \tag{2.6}$$

The economic model in (2.6) leads to a simple, yet convenient statistical model that fits within a class of duration models. For instance, appropriate choices for $\phi(T)$ and $W(\mathbf{x}, \mathbf{s})$ lead to the Accelerated Failure Time (AFT) model (Lancaster (1990)) with an error term of the form $\epsilon = -\ln \theta + \ln h(\mathbf{s}, f)$. We consider this framework in sections 4 and 5 accommodating to several estimation issues. Specifically, we (1) use a more flexible semiparametric approach uncovering the differential impact of government procurement contracts on short and long durations in business, (2) account for firm unobserved heterogeneity and (3) consider the possibility of endogenous covariates.

3 Data

Our firm-level data were obtained from two sources: the Texas Department of Transportation (TxDOT) and the Texas Workforce Commission. The data that contain information on bidding activity for highway construction contracts were obtained from TxDOT. They span the period between July 1999 and December 2006. All projects are auctioned off using a first-price sealed-bid format. The data set contains information on project types, the engineer's cost estimate for each project, the number of bidders that requested plans, the number of bids submitted per project, the winning bidders, and the winning bids. It also contains the location and complexity of each project and the number of days until its completion. A detailed description of the initial information that was collected and the variables that were subsequently constructed are in Tables A.1 and A.2 in the appendix. The data set also provides the names of subcontractors for the winning bidders and corresponding negotiated subcontractor dollar values. The first column of Table 3.1 reports information on all firms that held

Variable	TxDOT Full Sample	TxDOT Texas Firms	TxDOT QCEW Firms	TxDOT-QCEW Entrants
Number of firms that held plans	1744	1539	867	214
Number of firms that submit at least a bid	1094	976	578	87
Number of firms that at least won once	674	611	386	42
Number of prime bidders worked as a subcontractor	509	464	331	54
Total number of plans held	50661	47145	32083	1629
Total number of bids	29761	27954	19144	376
Total number of wins	6864	6478	4482	202
Average relative bid	1.086	1.087	1.085	1.016
	(0.250)	(0.246)	(0.250)	(0.254)
Average relative winning bid	0.976	0.979	0.977	0.962
	(0.182)	(0.180)	(0.181)	(0.186)
Average initial number of employees	–	–	–	11.80
				(30.23)
Average number of employees	–	–	125.60	20.39
			(232.35)	(47.91)
Average number of months survived	–	–	165.21	46.56
			(140.06)	(23.11)

Table 3.1: Descriptive statistics. The TxDOT sample includes construction auction data obtained from the Texas Department of Transportation. The sample called TxDOT - Texas Firms includes firms located in the state of Texas. The TxDOT-QCEW sample contains establishments for which we have end dates, and auction data. The sample used in our analysis includes new firms that entered the market in the period July 1999-December 2006.

plans (plan holders) during this period.[2] There are 1744 different plan holders and 1094 bidders in this data set. Table 3.1 also provides information on relative bids and relative winning bids which are bids that are normalized by their engineering cost estimates. The average relative bid is 1.086 and the average relative winning bid is 0.976. Column 2 of this table reports summary statistics for firms located only in the state of Texas.

Firm-level monthly employment and quarterly wage data for Texas were obtained from the Texas Workforce Commission's Quarterly Census of Employment and Wages (QCEW) data base. This data

[2] Any contractor considering to bid on a project must request a plan from the state. The list of plan holders defines the potential competitors in an auction. The plan holder list is public information and becomes available to all bidders.

base, as required under the Texas unemployment insurance (UI) program, provides establishment-specific monthly employment and quarterly total wages. It also includes each firm's business start-up date, the specific location of the establishment, and the six-digit North American Industry Classification System (NAICS) code. Separate establishments of the same firm are identified and reported in separate records. In this study, we combine all the branch data with the 'main office' data, as the business activity with TxDOT is directed through the main office. Following the definition of entry and exit provided by Baldwin and Gorecki (1991) and Dunne, Roberts and Samuelson (1988, 1989)), the start-up date of the firm signifies entry and the number of employees dropping to zero signifies an exit event.[3]

While the TxDOT data have auction and bidder information, the QCEW data have employment data and liability dates (or business establishment dates). In order to be able to examine the role of bidding and winning on entrants' survival, we restrict the sample to TxDOT firms for which we have entry and exit information. In column 3 of Table 3.1, we report the number of plan holders that were matched using names and addresses. These 867 plan holder firms that represent about 56 percent of the TxDOT firms located in Texas have approximately 126 employees each.

In this paper, our primary focus is on the sample of entrants presented in the last column of Table 3.1. This sample includes firms that started a business in Texas before they participated in procurement auctions, and entrants that were not contractors in other states.[4,5] The empirical analysis will be based on 214 plan holders and 42 firms that won a project at least once in their early stages, resulting in a panel of more than 9,000 observations. Of all 214 entrant firms, 54 have worked as subcontractors. Entrants initially employed about 12 workers, reaching an average of 20 workers later.[6] Descriptive

[3] The data allows us to identify changes in the names of firms. Those changes should not be counted as exit (Dunne et al. 1988). Moreover, we can identify horizontal mergers.

[4] Based on our previous work (see, e.g., De Silva, Kosmopoulou, and Lamarche (2009)), with data from the Oklahoma Department of Transportation, we were able to identify firms located in Texas that bid in procurement auctions in the state of Oklahoma. The evidence reveals that approximately 1 out of 10 projects were won by firms located in Texas, and these winners were incumbents firms.

[5] Besides our main interest in the entrant group, we do not consider incumbent firms because we cannot observe their full history of bidding and winning. For instance, for firms established in 1980, we only observe their winning patterns in the period 1999-2006. Their first observed win cannot be associated with significant uncertainty and lack of experience.

[6] To reduce potential measurement error issues, we delete the smallest firms (see, e.g., Dunne, Roberts, and Samuelson 1989). We exclude from the analysis firms with less than four employees.

Variable of Interest	Firms		Test
	Matched	Unmatched	(p-values)
TxDOT auctions			
Average relative winning bid	0.977	0.983	0.195
Average ratio of bids to plans held	0.594	0.592	0.235
Average share of asphalt component's value	0.254	0.257	0.211
Average share of bridge component's value	0.206	0.203	0.165
Number of firms	867	672	
Entrants in highway, street, and bridge construction industry			
Average initial number of employees	13.833	13.914	0.989
Average number of employees	17.598	19.005	0.785
Number of firms	91	58	

Table 3.2: Comparing matched and unmatched firms. The table presents a simple comparison of relevant characteristics between two groups of matched and unmatched firms from Table 3.1.

statistics of all variables used in this study are presented in Table A.3 in the appendix. They are grouped in six categories identified as (1) effects related to uncertainty, (2) entry conditions, (3) first contract conditions, (4) firm and project characteristics, (5) market factors, and (6) cohort effects.

The data allows also the opportunity to compare the matched and unmatched firms.[7] While auction level data could be used to evaluate differences in relative winning bids, bidding frequencies and project type distributions, firm level data could be used to investigate differences in the sizes of firms. The results shown in the first four rows of Table 3.2 suggest that the basic bidding and project type related measures are not significantly different between the matched and unmatched firms that were participating in TxDOT auctions. The QCEW data, through the NAICS codes, allow us also to find firms in construction.[8] The latter part of Table 3.2 provides a comparison of employment statistics for both the matched and unmatched groups of entrants in highway, street, bridge construction. The p-values suggest no statistically significant differences at the mean level.

Using the sample of matched entrants described in the last column of Table 3.1, Figure 3.1 shows the

[7] We faced few challenges in matching data. One is that TxDOT identifies firms by trading names, while the Texas Workforce Commission in the QCEW dataset provides tax account names. There are establishments for which the trading name is not the same as the tax account name. Firms that were initially not matched by name were matched by address. An added difficulty for some firms was that TxDOT include firms' address, while QCEW includes P.O. boxes.

[8] These are all firms that do business not only in road construction but commercial buildings, residences, etc. Of the unmatched entrant firms 97% seem to be small businesses in plumbing, heating and air-conditioning, painting and wall covering, electrical and building finishing work. Most of these firms may not be qualified to participate in TxDOT auctions. The remaining 3% of the unmatched entrants are primarily doing highway, street, bridge construction potentially linked directly to TxDOT activity.

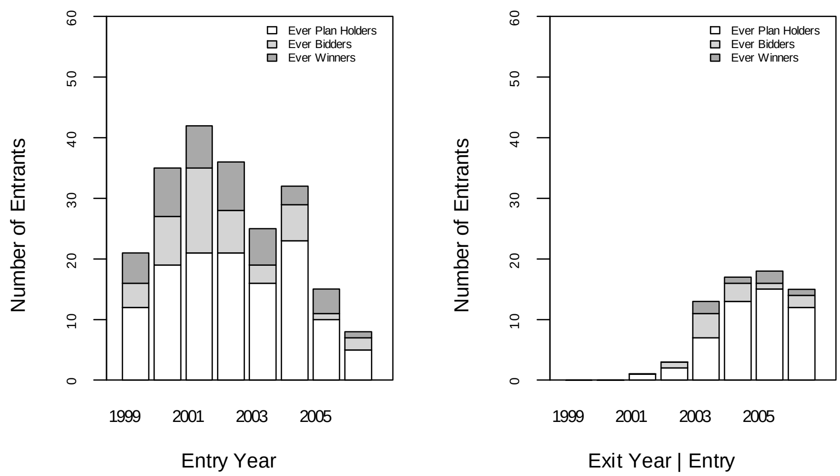

Figure 3.1: Frequencies for the number of entrants and exitors. The x-axis on the left panel considers the year of entry for entrants after July 1999. The x-axis on the right panel considers the year of exit for firms that entered the market after July 1999. The shaded areas denote firms' activities related to the procurement auctions.

empirical distributions of firms' entry and exit. The first panel presents the number of plan holders that enter the market. Approximately 41 percent of firms became bidders and 20 percent became winners in the period of analysis. We see that the number of firms entering the market increases in the period 1999-2001, and tends to decrease after 2001. Nevertheless, the year of entry does not seem to be a critical determinant of the probability of winning. While 20 percent became contractors in the period 1999-2001, 19 percent became contractors in the period after. The second panel presents the number of plan holders that exited the market in the same period of analysis. The evidence indicates that no firm that entered the market in either 1999 or 2000 exited the market in those years.

Table 3.3 provides additional details on the distribution of firms. Approximately 36 percent of the 214 firms are either contractors and/or subcontractors, while the remaining 64 percent are neither primary contractors nor subcontractors. Within this first group, 23 percent of the plan holders have been working as both contractors and subcontractors, 31 percent of them are exclusively primary contractors, and the remaining 46 percent of the firms are exclusively subcontractors. It is interesting

	Number of Firms	Exit Rate
Primary contractor and subcontractor	18	0.133
		(0.352)
Primary contractor but not a subcontractor	24	0.182
		(0.395)
Subcontractor but not a primary contractor	36	0.444
		(0.504)
Neither a primary contractor nor a subcontractor	136	0.326
		(0.470)
Primary contractor with previous subcontracting experience	8	0.000
		(0.000)
Primary contractor with no previous subcontracting experience	34	0.207
		(0.412)
Firms entering the market (July 1999 - December 2006)	214	0.317
		(0.466)

Table 3.3: Exit rates and the role of previous experience. Exit rate is defined as the number of firms that exit the market over the total number of firms that entered the market in the period of analysis.

to see that the exit rate increases from 0.13 to 0.44 if the firm is not a primary contractor. Another interesting aspect of Table 3 relates to the contractors' experience. Contractors with previous subcontracting experience have considerably lower exit rate than contractors with no previous experience as subcontractors.

Although these findings are new and naturally important, they are based on a measure that does not account for observable characteristics that may be influencing the exit event. In Table 3.4, we estimate a simple probit equation for the event y of market exit, $probit(\mathbf{y}|\mathbf{x}, \mathbf{s}) = \mathbf{x}'\boldsymbol{\beta} + \mathbf{s}'\boldsymbol{\gamma}$. The dependent variable y indicates whether a firm i exited the market at month t, while the vector $\mathbf{x}$ includes some firm and business environment controls. The vector $\mathbf{s}$ contains indicators for whether the entrant has previous subcontracting and/or contracting experience, and interactions of these indicators with entrants' age. The first rows present regression results that are similar in nature to those found in the literature. The positive and statistically significant coefficients on initial size suggest that the probability of exiting increases with the total number of employees at the time the firms were established in business (Geroski, (1995)). However, the negative and significant coefficients related to the size of the firm over time suggest that survival is positively associated with its size. Moreover,

Independent variables	Specifications		
	(1)	(2)	(3)
Initial size	0.177**	0.193**	0.199**
	(0.066)	(0.066)	(0.067)
Size	-0.330**	-0.386**	-0.376**
	(0.062)	(0.069)	(0.070)
Age	-0.037**	-0.038**	-0.040**
	(0.003)	(0.003)	(0.004)
Contractor with previous experience	-0.914**		-0.935**
	(0.348)		(0.462)
Contractor with previous experience × age	0.019**		0.017*
	(0.007)		(0.010)
Subcontractor with previous experience		0.274	0.485
		(0.336)	(0.360)
Subcontractor with previous experience × age		0.004	-0.001
		(0.007)	(0.009)
Cost index	2.043*	2.058*	2.010*
	(1.129)	(1.089)	(1.109)
Unemployment			-0.074
			(0.080)
Cohort effects	Yes	Yes	Yes
Number of observations	9167	9167	9167

Table 3.4: Descriptive evidence on the probability of exiting the market. The estimates are obtained from a sample that includes firms that held a plan in the period of analysis. ** Denotes statistical significance at the 5 percent level and * denotes statistical significance at the 10 percent level. Robust standard errors adjusted for clusters are in parentheses.

we find that primary contractors with previous experience have a smaller probability of exiting the market than primary contractors with no previous experience.

3.1 A few illustrative graphs

Graphs on business activity of individual contractors can provide intuition about the role of procurement auctions on firm survival. Figure 3.2 considers six contractors and offers a cursory look at employment patterns as a function of time.[9] These firms were selected for their value in emphasizing timing of activities and survival paths that later prove to be quite representative. The panel to the left focuses on the timing of the first win and subcontracting experience. The longitudinal dimension of the data tentatively ascribes influence of a firm's chronological age at the time of the first win (indicated by the letter c) on duration in business. Moreover, one might observe that prior subcontracting experience (denoted by the letter s) appears to be a determinant of firm dynamics and growth.

The right panel in Figure 3.2 focuses on relative risks associated with involvement in different type of projects. As seen on the graph, the contractor who does asphalt work has a steady employment growth despite the fact that contracting activity for TxDOT starts only after the first four and a half years in business. The size of the two entrants in bridge work tends to increase until the first projects are won (indicated by the letter b). Immediately after that, the size of both companies tends to decrease leading eventually to market exit (denoted by e). For these firms survival in business may be associated with uncertainty induced by the projects undertaken and lack of outside business options that can affect the timing of the first win.

Although the graphs may provide important insights to guide the analysis that follows, they do not represent a systematic way of analyzing how a firm's survival is related to the timing of the first win, previous subcontracting experience or the risks associated with the nature of projects undertaken. Our next sections are designed to overcome these limitations.

[9] We investigated also the profile of plan holders' relative size. In general, plan holders who were neither subcontractors nor contractors in the period of analysis are small firms with no significant growth patterns.

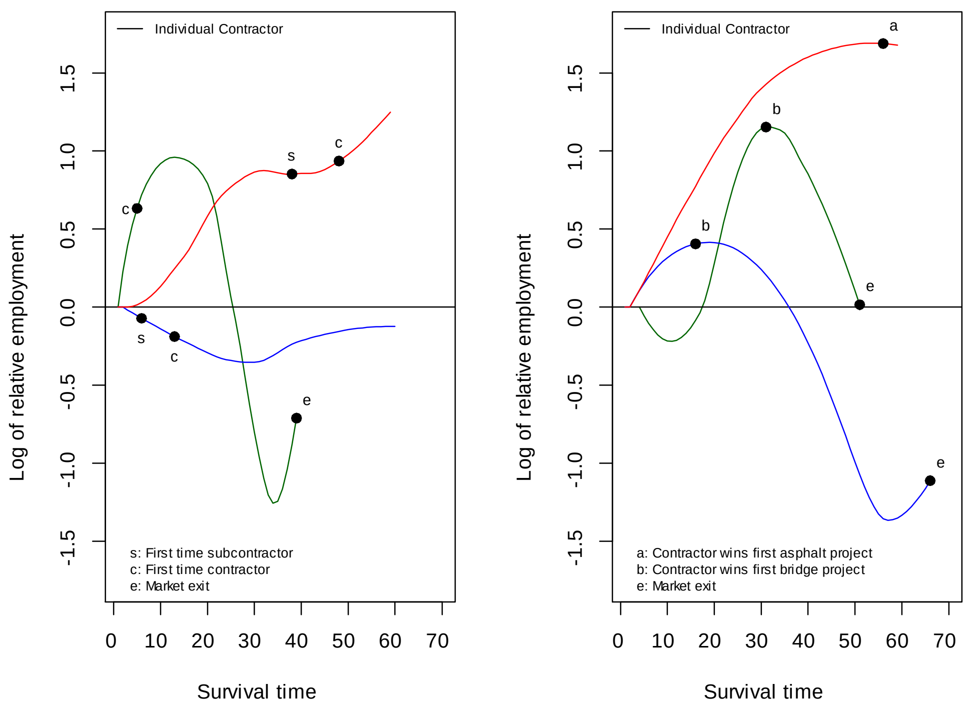

Figure 3.2: Profile of contractors' relative size. The y-axis shows the logarithm of employment relative to initial employment and the x-axis the number of months from establishment in business. The letters s and c indicate events in the firms' life related to the procurement auctions: s denotes first time subcontractor, and c indicates the timing of the first win as primary contractor. The letters a indicates asphalt, b denotes bridge, and e denotes exit time.

4 Empirical Results

In this section, we investigate more closely the role of procurement auctions on firms' survival. First, as it is customary in the literature (Audretsh and Mahmood (1995), Disney, Haskel and Heden (2003), Klepper (2002), Thompson (2005)), we estimate parametric survival models. We then turn our attention to the estimation of several semiparametric survival models, including a model that incorporates firms' efficiency differences.

4.1 Duration in the road construction industry

Our empirical analysis begins in Table 4.1 with an investigation of the role of subcontracting experience on entrants' duration in business. The economic model (2.6) can be expressed as the Accelerated Failure Time (AFT) model,

$$\log(T) = \mathbf{x}'\boldsymbol{\beta} + \mathbf{s}'\boldsymbol{\gamma} + \epsilon, \tag{4.1}$$

by assuming a Weibull hazard function $\Lambda_0(t) = t^\sigma$ and $W(\mathbf{x}, \mathbf{s}) = \exp(\mathbf{x}'\tilde{\boldsymbol{\beta}} + \mathbf{s}'\tilde{\boldsymbol{\gamma}})$. Under these assumptions, we have that $\boldsymbol{\beta} = -\tilde{\boldsymbol{\beta}}/\sigma$, $\boldsymbol{\gamma} = -\tilde{\boldsymbol{\gamma}}/\sigma$, and the error term ϵ is identically and independently distributed (*iid*) with an extreme value distribution $F(\epsilon) = 1 - \exp(-\exp\epsilon))$. To evaluate the sensitivity of the results, Table 4.1 considers two hazard distributions, the Lognormal and the Weibull. The vector $\mathbf{x}$ includes bidder specific covariates such us initial employment and size of the establishment. The vector $\mathbf{s}$ includes an indicator for whether the contractor has previous subcontracting experience and changes in the cost index of the projects undertaken by these new firms. In the last two columns of 4.1, we include the unemployment rate to possibly account for changes in the conditions of the state economy.

Our almost exclusive focus in the first two columns of Table 4.1 is on the estimated effect of previous contractors' experience on firm survival. The results reveal that winners with previous subcontracting experience have better prospects of survival than those winners without previous subcontracting experience. It is interesting to see that, considering primary contractors, the estimates on initial size, size, and cost index lead to similar conclusions as in Table 3.4. When we include the unemployment

	Distributions		Distributions	
	Lognormal	Weibull	Lognormal	Weibull
Contractor with previous	3.032**	5.795**	1.966**	3.924**
subcontracting experience	(0.660)	(1.757)	(0.434)	(0.993)
Cost index	-4.117**	-3.917*	-2.707**	-2.720**
	(1.952)	(2.228)	(1.073)	(1.242)
Initial size	-0.577**	-0.558**	-0.365**	-0.362**
	(0.209)	(0.255)	(0.133)	(0.122)
Size	0.509**	0.488**	0.338**	0.321**
	(0.105)	(0.130)	(0.093)	(0.084)
Unemployment			-0.259**	-0.270*
			(0.107)	(0.146)
Cohort effects	Yes	Yes	Yes	Yes
Number of:				
Contractors	42	42	42	42
Observations	1903	1903	1903	1903

Table 4.1: Parametric survival models estimated from a sample of contractors. We consider two standard distributions, Lognormal and Weibull. We present the results considering the AFT metric. ** denotes statistical significance at the 5 percent level and * denotes statistical significance at the 10 percent level. Robust standard errors are in parentheses.

rate to possibly account for macroeconomic fluctuations, the estimate of the coefficient of interest is reduced, but it is still positive and significant. The negative estimated coefficient on unemployment rate suggests that the survival of firms could be lower during periods of high unemployment, typically associated with economic recessions. Overall, all the variants of the models estimated and presented in Table 4.1 suggest that subcontracting experience seems to play an important positive role on primary contractors' survival.

4.2 A semiparametric approach

The framework developed in section 2 implies that the *iid* assumptions and the choice of the distributions in Table 4.1 are perhaps inappropriate for the empirical analysis. It seems natural to relax these assumptions by letting the (latent) cost function to be influenced by the level of subcontracting experience $h(\mathbf{s}, f)$. The simplest, yet important case of $h(\mathbf{s}, u) = \exp((\mathbf{s}'\boldsymbol{\delta})u)$ gives rise to a family of linear location-scale shift models of the form,

$$\log(T) = \mathbf{x}'\boldsymbol{\beta} + \mathbf{s}'\boldsymbol{\gamma} + (1 + \mathbf{s}'\boldsymbol{\delta})u, \quad (4.2)$$

	Quantile				
	0.10	0.25	0.50	0.75	0.90
Winning the first contract	-0.697**	-0.841**	-0.169**	0.004	-0.022
early (0–6 months). (γ_1)	(0.132)	(0.141)	(0.052)	(0.023)	(0.016)
Winning the first contract	-0.573**	-0.402**	0.372**	0.251**	0.130**
(7–18 months). (γ_2)	(0.158)	(0.160)	(0.057)	(0.024)	(0.016)
Winning the first contract	0.250**	0.465**	0.364**	0.226**	0.188**
late (19–36 months). (γ_3)	(0.113)	(0.116)	(0.043)	(0.019)	(0.013)
Winning an asphalt project	-0.002	-0.079	0.015	0.082**	0.078**
(first contract)	(0.093)	(0.100)	(0.038)	(0.016)	(0.010)
Winning a bridge project	-0.537**	-0.462**	-0.121**	-0.004	-0.033**
(first contract)	(0.073)	(0.077)	(0.029)	(0.012)	(0.008)
Average number of subcontractors	0.038**	0.003	-0.006	0.004	0.002
in active projects	(0.010)	(0.012)	(0.005)	(0.003)	(0.002)
Cost index (percentage change)	-0.386**	-0.235**	-0.131**	-0.046**	-0.033**
	(0.117)	(0.113)	(0.047)	(0.022)	(0.012)
Initial Size	-0.575**	-0.597**	-0.262**	-0.098**	-0.083**
	(0.041)	(0.047)	(0.017)	(0.007)	(0.004)
Size	0.516**	0.544**	0.228**	0.043**	0.028**
	(0.035)	(0.035)	(0.012)	(0.005)	(0.003)
Unemployment	-0.314**	-0.222**	-0.321**	-0.263**	-0.252**
	(0.075)	(0.081)	(0.031)	(0.013)	(0.008)
Other controls:					
First contract conditions	Yes	Yes	Yes	Yes	Yes
Entry conditions	Yes	Yes	Yes	Yes	Yes
Firm and project controls	Yes	Yes	Yes	Yes	Yes
Business cycle controls	Yes	Yes	Yes	Yes	Yes
Cohort effects	Yes	Yes	Yes	Yes	Yes
Wald tests (p-values):					
$\gamma_1 = \gamma_2$	0.317	0.001	0.000	0.000	0.000
$\gamma_1 = \gamma_3$	0.000	0.000	0.000	0.000	0.000
Number of observations	1797	1797	1797	1797	1797

Table 4.2: Quantile regression results for the logarithm of survival times. The models include firms that entered the market in the period July 1999 - December 2006, and became contractors. ** Denotes statistical significance at the 5 percent level and * denotes statistical significance at the 10 percent level.

where u is an *iid* random variable distributed as G. This essentially implies that we allow for an arbitrary choice of the distribution function of the error term. The associated conditional quantile regression function is,

$$Q_{\log(T)}(\tau|\mathbf{x},\mathbf{s}) = \mathbf{x}'\boldsymbol{\beta} + \mathbf{s}'\boldsymbol{\gamma} + (1+\mathbf{s}'\boldsymbol{\delta})G_u^{-1}(\tau), \tag{4.3}$$

$$= \mathbf{x}'\boldsymbol{\beta}(\tau) + \mathbf{s}'\boldsymbol{\gamma}(\tau), \tag{4.4}$$

where $\tau \in (0,1)$ is a quantile of the conditional survival times distribution, $\boldsymbol{\beta}(\tau) = \boldsymbol{\beta} + G_u^{-1}(\tau)$ and $\boldsymbol{\gamma}(\tau) = \boldsymbol{\gamma} + \boldsymbol{\delta}G_u^{-1}(\tau)$. Notice that the slope coefficients do not exert a location shift as in model (4.1), allowing us to examine the covariate effects across the quantiles τ's of the conditional survival times distribution. Quantile regression has several equivariance properties including the so called equivariance to monotone transformations. Logarithmic functions are monotonic, therefore we can write the previous model as $Q_{\log(T)}(\tau|\mathbf{x},\mathbf{s}) = \log(Q_T(\tau|\mathbf{x},\mathbf{s}))$. We can consider the model as, $Q_T(\tau|\mathbf{x},\mathbf{s}) = \exp\{\mathbf{x}'\boldsymbol{\beta}(\tau) + \mathbf{s}'\boldsymbol{\gamma}(\tau)\}$.

We begin estimating equation (4.4) considering the approach for duration data proposed by Koenker and Geling (2001).[10] In Table 4.2, we explore in detail the effect of the timing of the first win, and we introduce first contract conditions, entry conditions, firm and project controls, and business cycle controls as well as cohort effects to control for observed heterogeneity. As mentioned earlier, the full descriptions of those variables are in Table A.3 in the appendix. Table 4.2 presents results for the effect of the covariates of interest on few quantiles $\tau = \{0.1, 0.25, 0.5, 0.75, 0.9\}$ of the conditional distribution of the logarithm of survival times. The approach allows us to examine in more detail the covariate effects on duration in business. For instance, consider the estimated effect of size on survival that is 0.516 at the 0.1 quantile and 0.028 at the 0.9 quantile. They suggest that size is important for survival at the lower tail of the conditional survival times distribution, but it has a modest effect at the upper tail. The 0.321 mean estimate presented in the last column of Table 4.1 seems to be uninformative on

[10] Alternative quantile regression approaches are proposed by Portnoy (2003) and Peng and Huang (2008). One may see our empirical strategy as essentially letting the quantile regression mimic the time varying effect of the covariates. Our setting can be interpreted as a particular case of a model with time-varying coefficients, $\log(T_i(t)) = \mathbf{x}'_{it}\boldsymbol{\beta}_t + \mathbf{s}'_{it}\boldsymbol{\gamma}_t + u_i(t)$, where T_i denotes bidding time at duration t. While this model includes coefficient changing over time, the quantile regression coefficient $(\boldsymbol{\beta}(\boldsymbol{\tau})', \boldsymbol{\gamma}(\boldsymbol{\tau})')'$ changes as a function of the quantile (Fitzenberger and Wilke (2006)).

how size can affect business life across the survival distribution.

We see that the effect of winning a contract early at the median of the distribution of survival times is negative and significant, which suggests that undertaking a project soon after a firm is established decreases its duration in business by $|\exp\{-0.169\} - 1| \approx 15.5$ percent. As the theory suggests (Jeitschko and Wolfstetter (2002), Leufkens, Peeters, and Vermeulen (2006)), firms that bid for potentially significant on-the-job learning effects face the risk of substantial losses early on. In the lower tail, the reduction of the survival time is an even more dramatic 50.2 percent. Moreover, the results show a clear pattern in terms of the "optimal" timing for winning a project. Winning a project relatively early decreases survival time, but winning late increases the stay in business. Firms that won the first contract within 1.5 to 3 years from establishment stay longer in the market. A cursory look at the at the tails of the distribution of survival times suggests that the effect of learning on survival may not be linear.[11]

The higher uncertainty in bridge projects exposes inexperienced bidders to higher risks. The effect of winning a bridge work project is negative and significant, considerably smaller in the lower tail than in the upper tail. This evidence suggests that survival in business decreases 41.5 percent at the 0.1 quantile and 3.2 percent at the 0.9 quantile. On the other hand, the effect of the average number of subcontractors employed is positive and significant at the lowest quantile, suggesting that firms that use subcontractors in their projects last longer in business than the ones that do not subcontract any tasks. Subcontracting allows one to share valuable information to reduce uncertainty and risks.

When we turn to the estimates for the effect of changes in costs due to changes in input prices, we find that these fluctuations seem to have a heterogeneous impact across quantiles. Changes in the prices of inputs of a firm's active projects have a negative and significant effect among firms that survived in business for a very short period of time, becoming smaller the longer the period of time they survived. This result could be interpreted as suggesting that uncertainty introduced by price fluctuations had its most dramatic influence on those with high hazard rates. Lastly, the effect of

[11] Notice that we reject the hypothesis of equality of the effect of winning early and winning later on survival at standard significance levels.

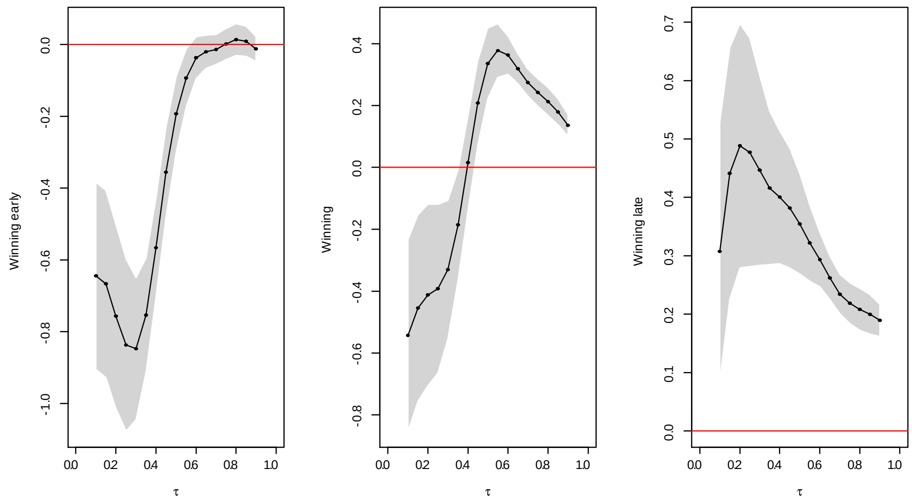

Figure 4.1: Quantile regression results for covariate effects on survival in business. We show the estimated effects of becoming a contractor within 6 months, 7-18 months and 19-36 months from establishment. The quantiles of the conditional duration distribution are denoted by τ. The continuous dotted lines show the estimates, and the shaded region represents a .95 (pointwise) confidence interval.

initial size, size and unemployment leads to conclusions consistent with Table 4.1.

Figures 4.1 and 4.2 offer an opportunity to explore in more detail the effects of interest. The figures present estimates of the effects of the main covariates as a function of the quantile τ of the conditional distribution of survival times. In each plot, the continuous dotted line shows the smoothed quantile regression estimates, and the shaded region represents a .95 (pointwise) confidence interval for the point estimates. For instance, the first panel in Figure 4.1 shows estimates of the effect of winning the first contract within the first 6 months from establishment. While the effect is negative and significant at the 0.2 quantile, it is close to zero at the 0.8 quantile. The advantage of Figure 4.1 over Table 4.2 is that it allows us to carefully examine the difference between the distributions of survival times at any quantile τ. In light of the theory, we would expect to see an increasing effect at each quantile τ if we move from the first panel to the third panel. We observe that the estimates related to the effect of experience at the time of winning the first contract are negative and significant in the first panel, and positive and significant in the third panel, suggesting that the prospect of survival of entrants including

	Tests		
	Wald Type Test	Khmaladze Test (Location shift)	Khmaladze Test (Location-scale shift)
Winning the first contract early	5.36	4.77	5.98
Winning the first contract	5.60	2.79	1.57
Winning the first contract late	1.23	0.84	2.13
Winning an asphalt project	0.54	1.94	0.82
Winning a bridge project	6.80	5.07	1.55
Average number of subcontractors	1.57	3.80	2.42
Cost of the active projects	2.23	4.94	1.54
Joint effect	9.44	627.36	403.54

Table 4.3: Tests for the equality of effects across the duration distribution. The critical values at 0.05 for the coordinatewise test are 2.38 (first column) and 2.10 (second and third columns). The critical value at 0.05 for the joint effect tests are 1.44 (first column) and 20.11 (second and third columns).

the ones who are relatively new in business is severely reduced if they undertake a project early on but can be dramatically improved if they wait, at least, one calendar year. The other results on bridge work and subcontracting shown in Figure 4.2 are also in agreement with the theory. Undertaking projects with uncertainty early on is too risky and subcontracting out some tasks reduces that risk.

In Table 4.3, we formally evaluate if the effects associated with the procurement auctions are significantly different across the quantiles of the duration distribution. The tests are described in the appendix. We reject the null hypothesis of equality of effects in the case of 'winning a contract early', 'winning a contract', and 'winning a bridge project'. The evidence considering the Khmaladze test for the location shift hypothesis leads to similar conclusions to the Wald type tests considered in the first column.[12] Regarding the location-scale shift hypothesis, the effects are insignificant at 5 percent, with the exception of the variables 'winning the first contract early', 'winning the first contract late' and 'average number of subcontractors'. The evidence suggests that the procurement auctions have a heterogeneous effect on duration in business.

[12]Notice that the parameter $\boldsymbol{\gamma}(\tau)$ models the effects associated with uncertainty and experience, providing an opportunity to investigate how these factors influence the location, scale and shape of the conditional survival times distribution. If the covariate effects are location shifts, we would expect to see similar estimates in the quantiles τ. On the other hand, if the covariate effects represent location-scale shifts, we expect to observe increasing (decreasing) shapes.

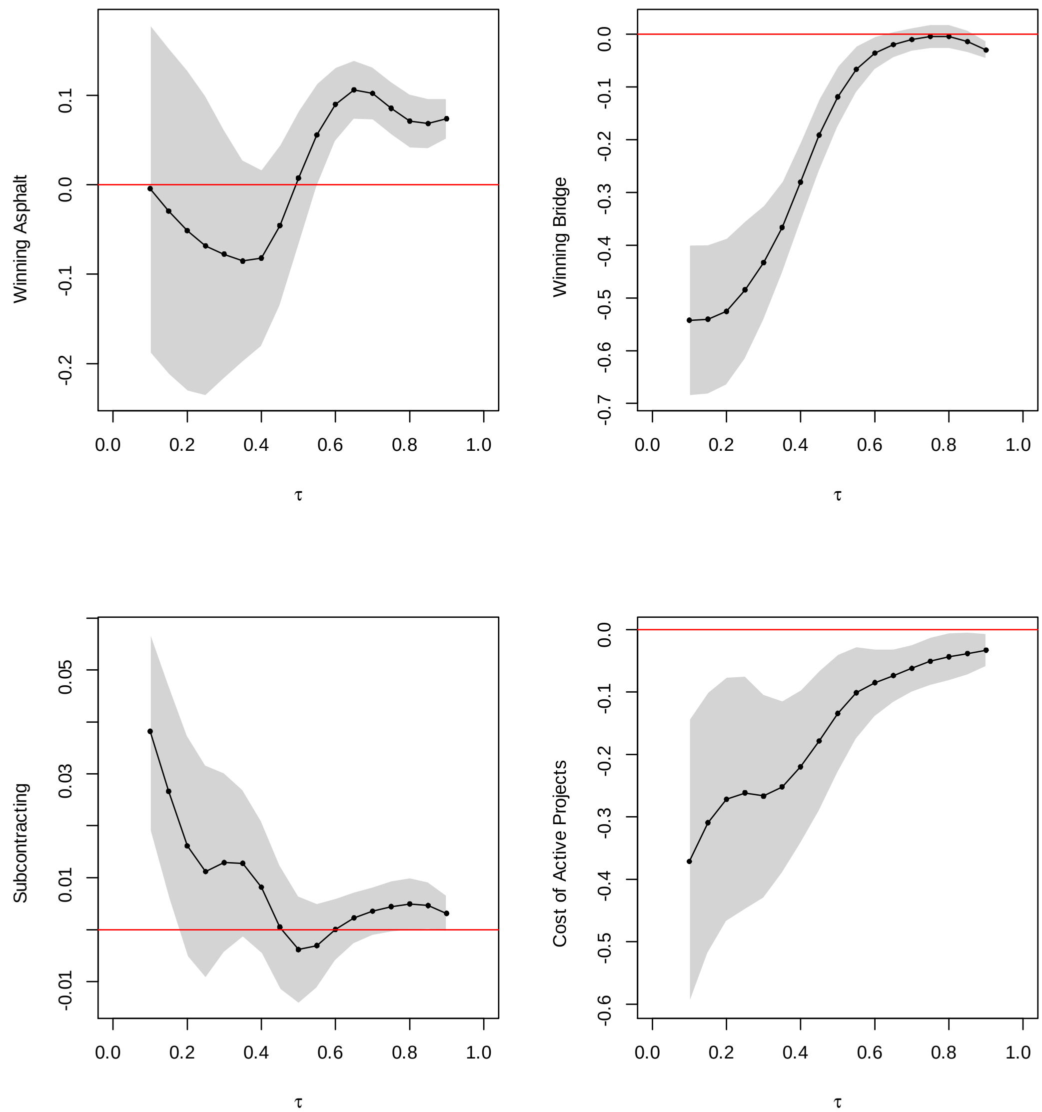

Figure 4.2: Quantile regression results for the main effects. The panels present the effect of winning an asphalt project, a bridge project, as well as the effect of subcontracting and the effect of a change in the price of inputs in active projects. The quantiles of the conditional duration distribution are denoted by τ. The continuous dotted lines show the estimates, and the shaded region represents a .95 (pointwise) confidence interval.

	Quantile				
	0.10	0.25	0.50	0.75	0.90
Winning the first contract	-1.319**	-1.336**	-0.913**	-0.761**	-0.686**
early (0–6 months). (γ_1)	(0.211)	(0.210)	(0.207)	(0.207)	(0.202)
Winning the first contract	-0.557**	-0.649**	-0.525**	-0.420*	-0.280
(7–18 months). (γ_2)	(0.218)	(0.218)	(0.218)	(0.218)	(0.218)
Winning the first contract	0.097	-0.014	-0.119	-0.119	-0.093
late (19–36 months). (γ_3)	(0.192)	(0.192)	(0.194)	(0.194)	(0.193)
Winning an asphalt project	-0.145	-0.247	-0.247	-0.129	-0.111
(first contract)	(0.181)	(0.177)	(0.178)	(0.177)	(0.176)
Winning a bridge project	-0.440**	-0.534**	-0.203	-0.061	-0.017
(first contract)	(0.172)	(0.167)	(0.170)	(0.168)	(0.166)
Average number of subcontractors	0.086**	0.062**	0.024**	0.010	0.002
in active projects	(0.011)	(0.009)	(0.010)	(0.008)	(0.005)
Cost index (percentage change)	-0.265	-0.319**	-0.122*	-0.101*	-0.082*
	(0.267)	(0.141)	(0.063)	(0.057)	(0.046)
Other controls:					
First contract conditions	Yes	Yes	Yes	Yes	Yes
Entry conditions	Yes	Yes	Yes	Yes	Yes
Firm and project controls	Yes	Yes	Yes	Yes	Yes
Business cycle controls	Yes	Yes	Yes	Yes	Yes
Cohort effects	Yes	Yes	Yes	Yes	Yes
Shrinkage parameter	0.66	0.66	0.66	0.66	0.66
Number of observations	1797	1797	1797	1797	1797

Table 4.4: Penalized quantile regression results for the logarithm of survival times. The models include firms that entered the market in the period July 1999 - December 2006, and became contractors. ** Denotes statistical significance at the 5 percent level and * denotes statistical significance at the 10 percent level.

4.3 Latent productivity

Although we attempt to control for all sources of variation by introducing a large set of covariates, we are naturally concerned about the role of firm's unobserved productivity. Recall that our model (2.6) for duration T includes $-\ln\theta$. A simple potential way to address the issue is to estimate a variation of model (4.4) of the form,

$$Q_{\log(T)}(\tau|\mathbf{x},\mathbf{s},\alpha) = \mathbf{x}'\boldsymbol{\beta}(\tau) + \mathbf{s}'\boldsymbol{\gamma}(\tau) + \alpha, \tag{4.5}$$

where α represents an omitted variable possibly associated with firm's unobserved productivity. We estimate this model employing recently developed methods on quantile regression (Koenker (2004) and Lamarche (2010)). The estimation method incorporates quantile firms' effects and it uses an ℓ_1 penalty term on the individual effects to shrink the firm's fixed effects to zero. The degree of shrinkage toward zero is controlled by a tuning parameter λ. The value for this parameter is selected considering the asymptotic approximation developed in Lamarche (2010).

Table 4.4 shows that most of our previous findings on how uncertainty and learning effects impact duration are robust to the inclusion of firm fixed effects. Winning early has a negative effect on the survival of entrants but winning relatively late tends to have a larger effect at the lower tail. In theory, bidders with some experience will bid less aggressively relative to their costs, generating more profit in the first win (see De Silva, Dunne and Kosmopoulou (2003)). As a result and within this framework, it is natural to expect that $\gamma_1 < \gamma_2 < \gamma_3$ at any quantile τ of the conditional survival times distribution. Notice also that the effect of winning a bridge project on duration continues to be negative and significant at the lower tail, and the effect of the number of subcontractors employed continues to be positive and significant at the 0.1 quantile.

5 Firms with Limited Business Opportunities Outside Road Construction

The potential losses associated with an early win may be curtailed by the existence of alternative business options. Such firms may not be competing as vigorously their profit margins away early on.

Industry	Number of: Plan holders (1)	Plan holders (2)	Contractors (1)	Contractors (2)	Plan holders Exit rate	Plan holders Subcontractor rate
Highway, street,	91	60	16	13	0.398	0.198
and bridge construction					(0.492)	(0.400)
Landscaping services	18	0	4	0	0.353	0.222
					(0.492)	(0.428)
Commercial and institutional	14	0	2	0	0.357	0.214
building construction					(0.497)	(0.426)
New single-family	7	0	2	0	0.286	0.143
housing construction					(0.488)	(0.378)
Electrical contractors	8	0	4	0	0.125	0.375
					(0.353)	(0.517)
Other building	8	4	3	2	0.125	0.250
finishing contractors					(0.353)	(0.463)

Table 5.1: Firms' type according to the North American Industry Classification System. Exit rate is defined as the number of firms that exit the market over the total number of firms that entered the market in the period of analysis. Subcontractor rate is defined as the number of subcontractors over the total number of contractors offering services in the industry. In each category, column (1) includes all firms and column (2) includes firms with limited outside options.

In light of theoretical and experimental evidence in Kirchkamp, Poen, and Reiß (2009) on the effect of the presence of an outside option in bidding, it is of interest to revisit our findings and distinguish among firms by their dependence on road construction procurement, and consequently, their access to outside business options.

In Table 5.1, we group firms by activities according to the North American Industry Classification System (NAICS).[13] The table presents firm classifications, the number of firms, their exit rates and their likelihood of doing subcontracting work. Although it is in principle plausible to classify firms using the NAICS code, its level of aggregation is an obvious limitation. Consider for instance, firms that were reported to provide services in the highway, street, and bridge construction industry. This category includes a contractor offering services in bridge construction as well as a contractor offering plumbing services. While firms in bridge construction may have limited options outside procurement contracting, firms offering plumbing services have other opportunities in business.

After discussions with state highway and civil engineers and based on the original NAICS classifica-

[13] This classification allows us to distinguish among commercial and institutional building contractors, electrical contractors, highway, street and bridge contractors, firms offering landscaping services, new single-family housing contractors, and other building finishing contractors.

tion and additional information obtained from descriptions of their activities, we created two relevant groups: firms with outside options (e.g., landscaping, plumbing, heating, etc.) and firms with few or no outside options (e.g., bridge construction, highway and street construction, etc.). Notice that the first group includes firms whose survival in the industry does not crucially depend upon the outcome of the procurement auction process, and the second group include firms whose survival mainly depend upon road construction contracts. Table 5.1 shows that approximately 66 percent of plan holders and 81 percent of primary contractors in highway, street, and bridge construction are firms with limited opportunities outside procurement auctions.

5.1 Endogenous covariates in the duration model

At this point in the analysis, it may be natural to challenge the notion that subcontracting represents an external covariate (see, e.g., Lancaster (1990)). The argument would be that the number of subcontractors employed in active projects may not be determined independently of whether the firms remained in business. Therefore, it is of interest to estimate the following structural equations model:

$$\log(T) = \mathbf{z}'\boldsymbol{\gamma}(u) + \delta(u)s, \tag{5.1}$$

$$s = g(w, \mathbf{z}, \mathbf{v}), \tag{5.2}$$

where $\mathbf{v}$ and u are not independent, and $u|\mathbf{z}, \mathbf{s} \sim U[0,1]$, with U denoting a uniform distribution. The variable s is the number of subcontractors in active projects and w is the number of plan holders in active projects. The variable $\mathbf{z}$ includes controls for the timing of the first win and the changes in the cost index of the projects undertaken by these new firms. It also includes first contract conditions, entry conditions and cohort effects.

Due to the possibility of endogenous covariates, we estimate the model presented in (5.1)-(5.2) by developing a simple empirical strategy. We accommodate recent developments on quantile regression for the structural equations model (see, e.g., Chernozhukov and Hansen (2005) and Harding and Lamarche (2009)) to estimate the conditional quantile function associated with equation (5.1). This can be seen as an extension of the ideas behind existing methods developed for the classical case of

	Quantile				
	0.10	0.25	0.50	0.75	0.90
			Firms with outside options		
Winning the first contract	3.506**	1.404**	0.756**	0.229*	0.181**
early (0–6 months). (γ_1)	(0.788)	(0.407)	(0.202)	(0.118)	(0.091)
Winning the first contract	-2.569	-1.886**	-0.876**	-0.133	-0.132
(7–18 months). (γ_2)	(2.503)	(0.686)	(0.377)	(0.258)	(0.190)
Winning the first contract	1.673	0.380	0.353*	0.489**	0.457**
late (19–36 months). (γ_3)	(1.665)	(0.312)	(0.189)	(0.116)	(0.106)
Winning an asphalt project	-2.735**	-1.821**	-0.672*	0.075	0.126
(first contract)	(1.324)	(0.527)	(0.249)	(0.164)	(0.130)
Winning a bridge project	-1.197*	-0.989**	-0.452**	-0.184*	-0.208**
(first contract)	(0.655)	(0.332)	(0.170)	(0.098)	(0.075)
Average number of subcontractors	0.405**	0.358**	0.180**	0.033	0.029
in active projects	(0.075)	(0.069)	(0.038)	(0.035)	(0.045)
Cost index (percentage change)	-0.692*	-0.665**	-0.183	-0.035	-0.138
	(0.365)	(0.182)	(0.113)	(0.107)	(0.122)
Number of observations	1015	1015	1015	1015	1015
			Firms with few or no outside options		
Winning the first contract	-2.578**	-1.983**	-1.016**	0.056	0.149
early (0–6 months). (γ_1)	(0.875)	(0.559)	(0.382)	(0.283)	(0.219)
Winning the first contract	-0.541	-0.812	-0.776	-0.266	-0.498*
(7–18 months). (γ_2)	(0.782)	(0.515)	(0.362)	(0.283)	(0.283)
Winning the first contract	0.148	0.574	0.301	-0.447	-0.515
late (19–36 months). (γ_3)	(1.378)	(0.894)	(0.694)	(0.562)	(0.485)
Winning an asphalt project	-0.513	-0.043	-0.199	-0.115	-0.151
(first contract)	(0.516)	(0.287)	(0.216)	(0.170)	(0.144)
Winning a bridge project	-1.349**	-0.830**	-0.528**	-0.099	0.064
(first contract)	(0.557)	(0.306)	(0.246)	(0.191)	(0.162)
Average number of subcontractors	0.413**	0.229**	0.083**	-0.040	-0.046
in active projects	(0.054)	(0.033)	(0.028)	(0.028)	(0.030)
Cost index (percentage change)	-0.905**	-0.582**	-0.298**	0.052	0.012
	(0.377)	(0.144)	(0.095)	(0.091)	(0.092)
Number of observations	782	782	782	782	782

Table 5.2: Quantile regression results for the logarithm of survival times. The models include the following time invariant variables: first contract conditions, entry conditions, and cohort effects. The models include firms that entered the market in the period July 1999 - December 2006, and became contractors. ** Denotes statistical significance at the 5 percent level and * denotes statistical significance at the 10 percent level.

endogenous covariates in duration models (see, e.g., Lancaster (1985), Olsen and Farkas (1988), and Chesher (2002)).

Table 5.2 extends the empirical analysis presented in Table 4.2 by including only time invariant covariates while splitting the sample of contractors in two subsamples. The upper panel presents evidence from the sample of firms with outside options, and the lower panel shows results from the sample of firms with few or no business opportunities outside road construction.

The evidence for firms whose survival depends on the procured government projects suggests a negative and significant effect of winning early at the lowest quantiles of the survival distribution. Although this finding is consistent with the results from Table 4.2, it is interesting to see that the estimated effects are larger in absolute value. For instance, at the 0.1 quantile, the estimate decreases from -0.697 in Table 4.2 to -2.578 in Table 5.2. This could be interpreted as suggesting that early bidding activity could have more damaging effect on survival for firms with few or no outside options (e.g., bridge contractors). It is also corroborated by the systematic difference between the corresponding upper and lower panel estimates of Table 5.2. While the estimated effects of winning early are positive and significant across quantiles among firms with outside options, they are negative and significant in the lower tail for firms with few or no outside options. We also see some contrasting results in terms of winning an asphalt project. With regard to the effect of the average number of subcontractors in their projects, we observe interesting similarities in the lower tail. Subcontracting increases durations in business among firms with short tenure and few or no outside options, which appears to be intuitive because subcontracting allows firms to share information reducing uncertainty and risk. On the other hand, the effect of the change in prices of inputs of the firms' active projects on the survival distribution seems to lead to the same observations for the two samples of firms. The effects are negative in the lower tail of the survival time distribution and, some of them, significant at 5 percent.

6 Conclusion

This paper constructs a new data set of entrants and uses recently developed estimation approaches to study how procurement auctions shape firms' survival. The timing of the first win, the nature of involvement in projects early on (as subcontractor or primary contractor) and the level of uncertainty embedded in those projects are important determinants of firm survival in the market. For firms with limited or no outside business opportunities, winning early could have significant adverse effects on survival. For firms with outside options waiting is not necessarily beneficial. Uncertainty introduced by price fluctuation had an impact on firms that exited the market relatively soon.

In light of these findings, in more uncertain projects like bridgework, it would be best for a firm to acquire sufficient experience on a smaller scale as a contractor or subcontractor before it bids on a larger project. In the face of price volatility, the contracting agency could use price adjustment contract provisions to prevent speculations and excessive firm failure. Such clauses could also protect Transportation Departments from inflated bidding behavior of firms that attempt to counter uncertainty.

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A Appendix

A.1 Inference

We employ a Wald-type statistics (see, e.g., Koenker and Bassett 1982) that can be used for testing a basic general linear hypothesis on a vector $\boldsymbol{\xi}$ of the form $H_0 : \mathbf{R}\boldsymbol{\xi} = \mathbf{r}$, where $\mathbf{R}$ is a matrix that depends on the type of restrictions imposed. We evaluate the null hypothesis of equality of effects across quantiles considering a vector $\boldsymbol{\xi} = (\boldsymbol{\gamma}(\tau_1), ..., \boldsymbol{\gamma}(\tau_J))'$. More general hypothesis including evaluating the vector over a range of quantiles are analyzed considering the Kolmogorov-Smirnov statistics (see, e.g., Koenker and Xiao 2002, and Koenker 2005). The null hypothesis is $H_0 : \boldsymbol{\gamma}_k(\tau) = \mu_k + \sigma_k \boldsymbol{\gamma}(\tau)$, where k indicates the covariate, μ_k is the location parameter and σ_k is the scale parameter. Note that $\sigma_k = 0$ implies that the covariate effect affects only the location of the conditional distribution of survival time. Alternatively, if $\sigma_k > 0$, the covariate effect affects both the location and scale of the conditional distribution of the response. These hypotheses can be evaluated considering the test developed in Koenker and Xiao (2002).

A.2 Variable definitions and descriptive statistics

In this section, we present the definition of the variables used in this study and basic descriptive statistics. The data set was constructed using data from: Texas Department of Transportation (TxDOT), Quarterly Census of Employment and Wages (QCEW) from Texas Workforce Commission, US Bureau of Labor Statistics, Federal Reserve Board, and US Bureau of Economic Analysis.

Variables	Description and construction of the variables
Project type dummies	All projects are grouped into six main categories based on the description and bid items share of the ECE of the project. They are asphalt paving projects, bridge projects, drainage and erosion control, concrete projects, traffic signal projects and miscellaneous projects.
Engineer cost estimate (ECE)	Value of the engineer's cost estimate.
Number of plan holders	Number of plan holders in an auction.
Expected number of bidders	The expected number of bidders is calculated using past information for each bidder and the plan holder list. This gives a probability of bidding for each bidder. This variable is constructed as in Hendricks, Pinkse, and Porter (2003). For each bidder at time t, we take the past bidding to plan holder ratio. Then for an auction at time t, we sum across these participation probabilities for all plan holders in an auction.
Winning bid	The lowest bid on an awarded project.
Complexity	The total amount of bid items (project components) in a project described by the Texas Department of Transportation (TxDOT).
Active projects	Firm's projects that are still under construction.
Complexity in active projects	Average number of bid items in active projects.
Winning the first contract early (within 0–6 months)	A dummy variable identifying a first win in the first 6 months from establishment.
Winning (within 7–18 months)	A dummy variable identifying a first win within 7–18 months from establishment.
Winning the first contract late (within 19–36 months)	A dummy variable identifying a first win within 19–36 months from establishment.
Winning asphalt (first project)	A dummy variable identifying that a firm won an asphalt project first.
Winning bridge (first project)	A dummy variable identifying that a firm won a bridge project first.
Rival's winning to plan holder ratio	The measure of rivals' past average success in auctions is constructed as the average across rivals of the ratio of past wins to the past number of plans held. This variable incorporates two aspects of past rival bidding behavior. It incorporates both the probability of a rival bidding given they are a plan holder and the probability the rival wins an auction given that they bid. These probabilities are updated monthly using the complete set of bidding data in Texas. The probabilities are initialized using data from 1997.
Distance to the project location	The logarithm of the distance to a project is constructed as the distance between the county the project is located in and the distance to the county of the firm's location [log(distance+1)]. The county location is measured by the longitude and latitude at the centroid of the 'county seat.'

Table A.1: Variable definitions.

Variables	Description and construction of the variables
Backlog	This variable is similar to the variables used by Bajari and Ye (2003) and Jofre-Bonet and Pesendorfer (2003). For each project awarded, both the value of the contract and the length of the contract in days are given. We assume that a project is completed in a uniform fashion over the length of the contract. A contract backlog is constructed in each month by summing across the remaining value of all existing contracts.
Rivals minimum backlog	This variable contains the minimum backlog of the rival firms in an auction [log(backlog+1)]. See the capacity utilization discussion above for a detailed explanation of how the backlog variable is constructed.
Initial number of employees	Number of employees at the initial month of entry.
Size	Logarithm of total employment
Highway cost index (weighted sum of items)	Highway cost index is a composite indicator covering the unit costs of excavation, resurfacing, and construction, and reflects cost changes for materials such as reinforcing steel, bituminous concrete, portland cement and other ingredients for highway projects across Texas counties.
Cost index of active projects	The cost index of the projects was obtained using the highway cost index c_{tk} of different categories k (e.g., earthwork, bridge, etc.) provided by TxDOT. We construct each firm's weighted cost considering $\bar{c}_{it}=\sum_k \lambda_{itk} c_{tk}$, where λ represents a weight determined by the composition of tasks.
Unemployment rate	The monthly unemployment rate in Texas.
Prime interest rate	US Prime interest rate.
Average number of permits	This is the number of building permits issued for Texas. The data come from the US Bureau of Economic Analysis.
Three months average of building permits	This variable measures the three month moving average of the number of building permits for Texas.
Cohort effects	Indicators for firms' entry year.

Table A.2: Variable definitions (Cont.).

Type of Covariates	Variables	Sample Average	
		All Firms	Contractors
Effects related to uncertainty	Winning within 0–6 months	0.050	0.246
	Winning within 7–18 months	0.032	0.157
	Winning within 19–36 months	0.073	0.358
	Winning asphalt (first project)	0.036	0.172
	Winning bridge (first project)	0.054	0.259
	Cost index of active projects	239.120	238.885
	Average number of subcontractors in active projects	0.219	1.053
Entry conditions	Size (logarithm of total initial employment)	1.524	1.611
	Unemployment rate at the time of entry	5.234	5.213
	Interest rate at the time of entry	6.883	6.958
	Average number of permits at the time of entry	0.972	0.930
First contract conditions	Logarithm of the engineer cost estimate	2.532	12.193
	Drainage and erosion control projects	0.002	0.009
	Concrete projects	0.023	0.111
	Traffic signal projects	0.067	0.325
	Miscellaneous projects	0.030	0.093
	Expected number of bidders	0.932	4.490
	Rival's winning to plan holder ratio	0.098	0.472
	Distance to the project location	0.793	3.820
	Rivals minimum backlog	2.197	10.581
Firm and project characteristics	Size (logarithm of total employment)	2.234	2.677
	Number of active projects	0.218	1.050
	Complexity in active projects	2.434	11.661
	Distance to the project location	5.494	26.414
	Backlog (in logs)	0.657	3.120
Market factors	Monthly level unemployment rate	5.682	5.655
	Prime interest rate	5.841	5.918
	Three months average of building permits	1.065	1.062
	Highway cost index (weighted sum of items)	144.354	144.566
Cohort effects	Indicators for firms' entry year	2001	2001

Table A.3: Descriptive statistics for the independent variables.