Title
The Role of Repeated Interactions, Self-Enforcing Agreements and Relational [Sub]Contracting: Evidence from California Highway Procurement Auctions

Authors
Gil, Ricard
Marion, Justin

Publication Date
2009

The Role of Repeated Interactions, Self-Enforcing Agreements and Relational [Sub]Contracting: Evidence from California Highway Procurement Auctions

Ricard Gil and Justin Marion
University of California, Santa Cruz*

January 2009

Abstract

We examine the impact of relationships between contractors and subcontractors on firm pricing and entry decisions in the California highway procurement market using data from auctions conducted by the California Department of Transportation. Relationships in this market are valuable if they mitigate potential hold-up problems and incentives for ex post renegotiation due to contractual incompleteness. An important characteristic of informal contracts are that they must be self-enforcing, so that the value of relationships between firms and suppliers depend on the extent of possibilities for future interaction. We construct measures of the stock of contractors' prior interactions with relevant subcontractors and find that a larger stock of relationships leads to lower bids and a greater likelihood of entry. Importantly, this relationship does not hold in periods of time and areas with little future contract volume, suggesting that the self-enforcement mechanism is crucial in providing value for informal contracts.

*We thank participants of the International Industrial Organization Conference and seminar participants at UC Santa Cruz, the Federal Trade Commission, George Washington University and the Department of Justice for helpful comments. All remaining errors are ours.

1 Introduction

Relational contracting has long played an important role in the interaction between firms and their suppliers. The close relationships that firms have with their suppliers allow them to enact implicit contracts, obtaining first-best outcomes not achievable otherwise through formal contracts. In many circumstances it may be prohibitively expensive to completely specify in advance all relevant contingencies and product attributes to the transaction at hand. It is in these cases that relational contracting proves most useful since it helps a firm and its supplier respond to unforeseen circumstances when needed or induces the supplier to provide the informally agreed optimal product quality when the attributes of the supplied product are not verifiable to a third party.

There exists a growing empirical literature that establishes the prevalence of such informal contracts and their role in vertical relations as well as the type of formal contracts chosen between parties in the presence of long-standing relational contracts.[1] Our paper contributes to this growing literature by documenting how both past *and* future interactions affect supplier choice and firm performance in the government sector, in particular, in highway procurement contracts in California. As noted by Bull (1987), Klein (1996) and others, an important factor characterizing a relational contract is that it cannot be enforced by a third party and therefore must be self-enforcing. The standard relational contract specifies an action that the supplier needs to undertake at the risk of losing all future business. When the value of deviating from the action in the implicit contract exceeds the present value of continuing the relationship, the relationship is no longer self-enforcing and ceases to have value in solving the information asymmetry problems that formal contracting could not address, such as contractual incompleteness, moral hazard, or holdup. Therefore, the current value of the relationship depends on the value of future business between the two parties.

In this paper, we empirically examine the value of relationships between contractors and subcontractors in the highway construction market. We consider the effect of contractor-subcontractor relationships on the bidding, entry, and subcontractor choices made by the contractor, and how these effects depend on the continuation value of the relationship as measured by the volume of future contracts procured by the government. Taking into account the continuation value of the relationship constitutes one of the main contributions of this paper. Most of the empirical literature in this area measures relationships by the stock of prior interactions between a firm and its supplier.

[1] Early examples of this empirical work include Macaulay (1963) or Asanuma (1989).

While this does not directly measure continuation value, it may proxy for the expected future value of the relationship if a regularly used supplier can expect to be utilized by the firm in the future. However, prior relationships potentially have value both in solving incomplete contracts as well as through improving relationship specific productivity unrelated to contracting, such as by mitigating coordination costs.[2] Therefore, it is useful to more directly measure continuation value.

We begin by setting up a theoretical framework where projects are comprised of two tasks. A firm will produce a task by itself and subcontract the other task to a subcontractor. When subcontracting, bidders choose a subcontractor depending on the subcontractor specific coordination costs and the value of their future relationship. Whereas past interactions with a subcontractor diminish current coordination costs, future interactions deter subcontractors from engaging in moral hazard behavior and therefore enhances the value of present activities. We argue that since contractors choose their subcontractors according to their task production costs, coordination costs, and *ex post* renegotiation costs, prior and future interactions play an important role in their decisions. We then derive testable implications regarding the nature of subcontracting decisions and take these implications to the data.

We evaluate the empirical validity of these implications using data from 5,120 highway procurement auctions conducted by the California Department of Transportation (Caltrans) between May 1996 and October 2005. When submitting a bid in this market, firms must list the significant subcontractors they intend to use on the project up for bid. Overall, the data consist of 26,125 bids from 1,735 contractors of which 805 win at least one contract. These bids specify roughly 2,900 unique subcontractors. We therefore are able to measure the stock of relationships a firm has with its subcontractors over time and across markets.

We find that greater stocks of prior relationships are associated with lower bids by firms, as well as a greater likelihood of auction entry. This finding is robust to different measures of the stock of prior relationships. Furthermore, firms are more likely to use subcontractors that they have worked with in the past.

The most important result of the paper is that the effects of relationships on bidding, entry, and subcontractor utilization depend on the extent of future business. We interact past interactions with the number and dollar value of upcoming contracts within the geographic market. If no

[2] Kellogg (2008) empirically estimates the gains in firm-specific productivity from past repeated interactions for oil well drilling in Texas.

contracts are up for bid within the following year, the value of the stock of prior relationships on bidding and entry is statistically indistinguishable from zero. However, the greater is the extent of future business, the more prior subcontractor relationships lowers the bid and raises the likelihood of entry. Importantly, only upcoming projects occurring within one year matter, which is consistent both with firms having better information regarding these projects and with discounting.

Data from public highway construction auctions offers a significant advantage over traditional private goods markets when trying to identify the importance of the continuation value of the firm-supplier relationship. In most settings, the observed sales of a firm depends in part on the success of the relationship between the firm and its suppliers – more productive relationships lead to lower prices and more sales. This creates an identification problem, since the volume of future business is tied to the productivity of the relationship. In the highway construction market, the arrival rate of projects is determined by transportation needs, and therefore future projects are exogenous to the success of prior relationships between contractors and their subcontractors.

The paper is organized as follows. Next, we describe the relevant literature and specify what is the contribution of this paper within it. Section 3 describes the institutional details and section 4 presents our theoretical framework. In this section, we use important institutional characteristics of the California Highway procurement sector to build up a simple framework that resembles reality as much as possible and yet allows to obtain testable implications. In section 5, we describe the data at use and in section 6 we take our testable implications to the data. Section 6 also presents and discuss the methodology used in this paper and the empirical challenges that we encountered. Section 7 concludes.

2 Literature Review

As this paper focuses on the consequences of repeated interactions and long-standing relationships on firm performance in California highway procurement contracts, we believe that this paper builds on and contributes to two strands of the literature. These are the literature on implicit and relational contracting and the literature that studies procurement and construction contracts as a special type of business.

2.1 Literature on Implicit and Relational Contracting

The role and importance of informal agreements is sometimes minimized by the large existing literature on formal contracting. Despite this, the nature of informal agreements together with the existence of implicit and relational contracting has been the subject of study of many for some time now. Bull (1987) is among the earliest research on this topic followed by others such as Klein and Murphy (1988), Baker, Gibbons and Murphy (1994), Klein (1996) and more recently Board (2008). This literature studies the emergence of informal contracting when formal contracting may yield suboptimal outcomes. This set of theories emphasizes two main points. First, informal agreements will only emerge when they improve on the result of formal agreements, and second that their sustainability hinges on the capacity of participating parties to self-enforce these agreements leveraging the gains derived from future interactions between them.

The appeal of this idea has found applications in many different scenarios and as a consequence a literature surrounding the idea of future interactions sustaining informal agreements has developed. Some examples of this growing literature have been into topics as diverse as subjective pay performance (above Baker, Gibbons and Murphy (1994)), quality provision (Klein and Leffler (1981)) or the boundaries of the firm (Baker, Gibbons and Murphy (2002)), and industries such as oil drilling (Corts and Singh (2004)), dry cleaning (Gil and Hartmann (2007)) or movies (Gil (2004)).

2.2 Literature on Procurement and Construction Contracts

Our paper also contributes to a more applied literature that documents the allocation of procurement contracts and in particular procurement of construction contracts. Examples of the former type are Guasch, Laffont and Straub (2008) where they examine the contractual adjustments of procurement contracts for utility concessions in a group of Latin American countries. Examples of the latter are Bajari and Tadelis (2001) and (2006), and Bajari, McMillan and Tadelis (2008) where they examine theoretically and empirically the procurement of construction contracts. In general, these analyses ignore the fact that bidders in these auctions have ongoing relationships with the public agency and reputations that leave room for some degree of *ex post* adjustment. Similarly, the subcontracting of parts of the conceded utility contract tends to be unobserved by the econometrician and therefore its analysis omitted. Our paper focuses on these two exact components that have been ignored previously and hopes to shed light on the role of past and (expected) future repeated interactions in procurement.

A number of prior papers have also examined the California highway procurement auctions. In particular, Bajari, Houghton and Tadelis (2006) examine the role of incomplete contracts and ex post adjustments, and Krasnokutskaya (2003) estimates a structural auction model in the presence of unobserved heterogeneity. There has been also a number of papers examining the effect of preferential in these auctions on auction participation and bidding behavior. Examples of these are Krasnokutskaya and Seim (2005), and Marion (2007a, 2007b). Our paper here differs from these and others in that it focuses on the subcontracting strategies of the contractors bidding for these highway construction projects and estimates the consequences of repeated interactions in contractor performance in these auctions.

Two recent papers on empirical contracting study topics closely related to our paper. Miller (2008) estimates the cost implications of contractual incompleteness in subcontracting decisions for a set of bridge construction contracts procured by the California Department of Transportation. Kellogg (2008) empirically examines the impact of repeated past interactions on the productivity of well drilling in Texas. Our paper differs from these two papers in that we focus on the role of future contracting possibilities to mitigate moral hazard problems and we empirically demonstrate the difference between the role of past repeated interactions and the continuation value of ongoing relationships.

Finally, this paper also relates to an economic literature that studies the construction industry for its unique organization of production. In particular, we highlight the contributions of Eccles (1981), and González, Arruñada and Fernández (1998) and (2000). The first documents the loose nature of the boundaries of the firm that appear to sustain transactions in this industry, while the latter two focus on the fragmentation of this sector and how specialization may lead firms to rely on subcontracting and outsourcing more often than similar firms in other industries.

3 Institutional Details: Bidding on California Highway Auctions

The California Department of Transportation (Caltrans) awards road construction and repair contracts through sealed-bid first-price auctions. Potential bidders are solicited through a newsletter that details the bid letting date and the details of the project. A firm can bid on any project for which it has been prequalified to do the specified category of work; this prequalification is based on the firm's equipment, training, licensing, and past work history. The engineer provides a list of the items required to complete the project and the quantities of each item.[3] The bidder provides a unit price for each item, and its bid is based on the dot product of the vector of item quantities and prices.

In its bid, the firm must list each subcontractor whose work accounts for at least 0.5 percent or $10,000, whichever is greater, of the contract value. Each subcontractor must be prequalified to do the listed work. Following existing regulation, at most 40 percent of a project can be subcontracted out. The other important restriction regarding subcontracting that applied through much of the period of our study regards affirmative action. Until 1998 for contracts using state funds and 2006 for federally funded contracts, contractors were often required to award a percentage of contract dollars to Disadvantaged Business Enterprises (DBEs), subcontractors owned by minorities and women.

While Caltrans attempts *ex ante* to specify the relevant details of the contract, unforeseen contingencies often arise after contract award (see Bajari et al, 2006). These changes to project specifications many times lead to costly renegotiation between the contractor and Caltrans. While we do not have direct evidence, these change orders likely also alter the scope or scale of the subcontractors' tasks as well in ways difficult to specify *ex ante*.

4 Theoretical Framework

In this section, we present the theoretical framework that we use to provide some structure on how contractors may decide on their subcontracting strategies. We intend this framework to be the source of testable implications that we can take to the data regarding the relationship between a contractor's bidding behavior and its relational contracts with the available subcontractors. For this reason, we define the different costs incurred by both parties in the process and the timing of actions until the contractor posts its bid in the procurement auction. Later, in the following section, we take these implications to the data.

[3] The item prices are used when relatively small differences arise between the quantity of an item the engineer predicts will be required and how much is actually required. When large differences between project specifications and actual required work occur, a potentially costly renegotiation of contract terms is undertaken. (Bajari et al, 2006)

4.1 Introduction of the Model

We present a static model that has intertemporal implications. In this model, a contractor $i \in I$ is considering submitting a bid for a project k in period t. Projects are allocated by the government using first-price sealed-bid auctions.

For simplicity we assume that every project is comprised of two tasks. One of the two tasks (task 1) is completed by the contractor itself. The other task (task 2) is outsourced to a subcontractor j (out of the J available subcontractors). [4] Let the cost of completing tasks 1 by contractor i be given by c_{1kit}, while the cost of a subcontractor j to produce task 2 in period t is c_{2kjt}.

In employing a subcontractor for task 2, the contractor incurs a coordination cost $\gamma_{ijkt}(e)$ that depends on effort e exerted *ex post* by the subcontractor. This coordination cost varies across contractor-subcontractor matches depending on their location and the location of project k as well as the number of times that they have actually worked together in a project in the past. To switch *ex post* from the initially chosen subcontractor j to another subcontractor $-j$, the contractor incurs a switching cost ϕ_{i-jtk}.

4.2 Timing of Actions and Solution by Backward Induction

The timing of actions and interactions between agents is represented in Figure 1. In period 0, all participating I contractors learn their costs to produce project k and the costs associated with hiring each subcontractor, including the direct construction cost as well as the coordination and *ex post* switching transaction costs specific to each contractor-subcontractor match. This means that we assume perfect symmetric information between participating contractors and subcontractors.

In period 1, contractor i decides which subcontractor j to use for task 2. At this point, contractor i compares all available subcontractors by their costs of producing task 2 $c_{2.kt}$ and her coordination costs with each of them $\gamma_{i.kt}(e^*)$, taking as given the effort (unobservable to a third party and therefore non-contractible) optimally exerted by the subcontractor.

In period 2, contractor i and subcontractor j bargain over what price subcontractor j will receive for its performance of task 2. To simplify our analysis, we assume that all *ex ante* bargaining power is on the contractor side due to competition between subcontractors[5] (at this stage subcontractors

[4]This assumption could be extended easily to situations where the contractor is allowed to outsource all tasks or required to outsource a specific task. This is sometimes the case when particular expertise is required for a given task.

[5]Subcontractors are not receiving zero profit but the value of their best alternative option.

may appear on multiple bids for a same project). To this extent, it is not important how contractor and subcontractor split the coordination cost $\gamma_{ijkt}(e^*)$ but the fact that the total cost of contractor i of dealing with subcontractor j is $\gamma_{ijkt}(e^*) + c_{2jkt}$. In period 3, the contractor observes all her costs for project k and posts her bid given all outcomes occurred in the previous periods.

In period 4, the winner of the auction is determined. If the contractor has won, it now must deal with possible moral hazard from the subcontractor side. *Ex post*, the subcontractor may not provide the amount of effort e^* expected by the contractor. This may cause delays and eventually extra compensation for the subcontractor on labor and capital costs. These extra costs would eat up part of the contractor profits and therefore it is in her best interest to provide incentives to the subcontractor to exert the optimal amount of effort. The contractor could contract with another subcontractor $-j$ to finish the job, but we will assume that there exists an *ex post* switching transaction cost ϕ_{i-jtk} that keeps her locked into this relation and allows the subcontractor to hold her up.

4.2.1 Period 4: The Moral Hazard Problem of the Subcontractor

We now solve the model through backward induction. Once contractor i wins the auction for project k, it must deliver the project at the quality and time agreed with the buyer. To do this, it relies on the performance of the subcontractor j through the coordination cost $\gamma_{ijkt}(e^*)$. Subcontractor effort e can take two possible values, $e = \{e^*, 0\}$. This effort cannot be contracted upon *ex ante* because it is not observable to third parties, but we assume that the contractor can observe it. The coordination costs will be higher if $e = 0$ such that

$$\gamma_{ijtk}(0) > \gamma_{ijtk}(e^*).$$

Due to the switching cost ϕ_{i-jkt}, the subcontractor can hold-up the contractor by demanding additional payment to provide the desired effort level e^*. In this case, the contractor i will stay with subcontractor j as long as

$$\phi_{i-jkt} \geq \gamma_{ijtk}(0) - \gamma_{ijtk}(e^*)$$

or the maximum amount that the subcontractor can hold up the contractor for the amount of the switching cost.

To solve the contractual incompleteness problem, the contractor can leverage the value of future interactions. We call $V(y_{ij})$ the value of future relationships for the subcontractor, which is the expected discounted value of future interactions y_{ij} between contractor and subcontractor. The contractor will then offer an informal contract to the subcontractor that specifies the subcontractor effort e^*. Following the standard mechanism in the literature of informal and relational contracting (see Bull (1987), Baker, Gibbons and Murphy (1994), Klein (1996) or Klein and Leffler (1981)[6]), the punishment mechanism enforcing this contract is the threat to end the relationship, which is valued by the subcontractor at $V(y_{ij})$.[7] There is no increase in disutility for effort e^* since the initial contract was already compensating this amount of effort and therefore the problem at hand is all based on the moral hazard on the side of the subcontractor.

The subcontractor will find it optimal to exert e^* if

$$V(y_{ij}) \geq \gamma_{ijtk}(0) - \gamma_{ijtk}(e^*), \tag{1}$$

or in other words, if the gain from shirking, $\gamma_{ijtk}(0) - \gamma_{ijtk}(e^*)$, is outweighed by the continuation value of the relationship, which depends on the surplus from future interactions and the discount rate of the subcontractor.

The cost of subcontracting task 2 to subcontractor j is therefore

$$\widetilde{c}_{2kjt} = \gamma_{ijt}(e) + c_{2kjt} + z,$$

where z is the mark-up above cost on the task performed by subcontractor j and e is determined by evaluating (1). This mark-up is determined below in period 2.

4.2.2 Period 3: Maximizing Profits by Posting the Bid

Each contractor i in auction k chooses its bid to maximize expected profits:

$$\pi_{ikt} = (b_{ijkt} - c_{1kit} - \widetilde{c}_{2kjt}(e^*)) * \Pr(b_{ijkt} < b_{-ikt}).$$

The bid here is subscripted by j since the optimal bid will depend on which subcontractor was chosen in period 1. Denote the Bayes-Nash equilibrium strategy $b(c_{1kit}, \widetilde{c}_{2kjt})$. While we do not explicitly solve for the equilibrium of the auction game, the characteristics of the resulting equilibrium are well known in the literature. Bids are monotonically increasing in costs, and firm profits are decreasing

[6] In our setting, the provision of quality per se is not central and therefore we differ from the main purpose in Klein and Leffler (1981). Instead, the contractor cares about other aspects that are more generally referred as quality such as punctuality and thoroughness. The contractor here will combine the number of interactions and the "price" M such that the subcontractor does not find optimal to take away the maximal amount ϕ every time that they interact.

[7] For expositional purposes and simplicity we implicitly normalizes the fallback option to zero, though in reality this may not be necessarily optimal.

in costs.[8] For this reason, the subcontractor choices the firm makes in periods 1 and 2 are not affected by strategic bidding considerations – it will maximize profits to choose a subcontracting strategy that minimizes cost.

4.2.3 Period 2: Bargaining Between Contractor and Subcontractor

We now concentrate on the bargaining process that takes place between contractor i and each subcontractor j in period 2. We assume perfect information between contractor and subcontractor regarding the cost to subcontractor j of producing task 2, c_{2kjt}, and the coordination cost γ_{ijkt} subject to the effort e^* exerted by subcontractor j.

In this stage, the contractor is simultaneously bargaining with all available subcontractors over the cost of providing task 2. We assume here that there is no sensible cost of switching back and forth among subcontractors in this negotiation and therefore all the bargaining power is on the contractor side. For this reason we take the total cost for contractor i to deal with subcontractor j exactly the amount of the coordination and task costs such that

$$\widetilde{c}_{2kjt}(e^*) = \gamma_{ijkt}(e^*) + c_{2kjt}$$

and therefore the mark-up z charged by subcontractor j will be 0.

4.2.4 Period 1: Contractor's Choice of Subcontractor

Finally, in period 1 the contractor decides which subcontractor to use to complete task 2 in order to maximize total expected profit. The objective function of contractor i is given by

$$\max_{j \in \{i,J\}} \pi_{ijkt} = (b_{ijkt}(c_{1kit}, \widetilde{c}_{2kjt}(e^*)) - c_{1kit} - \widetilde{c}_{2kjt}(e^*)) * \Pr(b_{ijkt}(c_{1kit}, \widetilde{c}_{2kjt}(e^*)) < b_{-ikt})$$

where

$$\widetilde{c}_{2kjt} = \gamma_{ijtk}(e) + c_{2kjt}.$$

The contractor i then chooses subcontractor j of the J available to maximize its expected profit.

[8] It is worth noting that the equilibrium strategy will not be symmetric here even if firm costs are drawn independently and firms have access to the same subcontractors. This is because even *ex ante* identical firms will end up with different cost structures since a firm's cost in an auction depends in part the subcontractor coordination cost. As a firm works with a subcontractor, coordination costs go down by assumption in our model. Therefore, firms who happen to have favorable costs draws in the past, and therefore more past wins and subcontractor interactions, will have a lower cost of hiring subcontractors. Therefore, a more precise way to characterize the equilibrium strategy would be to describe it as conditional on coordination costs. However, we do not want to distract from the important point, unchanged by this consideration, that expected profits are higher for firms with lower cost, and therefore firms will choose the subcontractor that yields the lowest cost.

4.3 Testable Implications

The theoretical framework above contains several testable predictions regarding the relation between the variables in the model in any given period t. The main predictions are the following:

- A contractor i will be more likely to set a lower bid and win an auction for a given project k when outsourcing to a subcontractor j for which coordination costs γ_{ijt} are lower and the value of future interactions $V(y_{ij})$ is larger. And as a consequence,

- A contractor i will be more likely to choose for a given project k a subcontractor j for which coordination costs γ_{ijt} are lower and the value of future interactions $V(y_{ij})$ larger.

To give these predictions empirical content, we start by discussing coordination costs relevant for the highway construction market. One dimension in which it is easy to observe differences in coordination costs across contractor-subcontractor pairs is the geographical dimension manifested as the distance between contractor, subcontractor and the project location. In particular, a contractor and subcontractor located in close geographic proximity will face lower coordination costs. The importance of distance in this market well-established, and we will take it as given in our empirical approach by grouping contractors and subcontractors located geographically close to each other. We also account for coordination costs through the number of past interactions between contractor and subcontractor, which we expect would lower coordination costs.

Given the assumption that coordination costs decline with more contractor-subcontractor interactions on winning projects, we obtain the first testable implication: *the higher the number of bids won in the past (and therefore the number of projects worked in together) jointly by a contractor and subcontractor, the higher the likelihood that they will post a joint bid and the higher the likelihood the bid will be low enough to win that auction.* Notice that this testable implication goes through holding the location of both contractor and subcontractor, as well as all other dimensions relevant to the project, constant.

The second testable implication has to do with the impact of future interactions in the subcontractor's provision of effort. Our model suggests that when the contractor is able to leverage the value of future interactions, this will induce the right amount of subcontractor effort and therefore enable the contractor to post a lower bid and increase the probability of winning the auction. In this case, the testable implications is that at any given point in time and for any given contractor-subcontractor pair we should observe that *the higher the number and value of (expected) future* *interactions, the higher the likelihood of posting a joint bid in the current period and the higher the likelihood the bid will be low enough to win that auction.*

In the next section, we proceed to present the data and describe the empirical methodology that we use in this paper to test for these implications.

5 Data Description

The data used in this study includes the universe of 5,120 road construction and repair contracts put up for bid by Caltrans between May 1996 and October 2005. For each contract up for bid, a set of information describing the project is given, including the road and county where the work will take place; a short description of the nature of work to be completed; the estimated number of working days to complete the project; and an engineer's estimate of the cost of completing the project. The engineer's estimate is formulated by Caltrans, and reflects project-specific factors incorporating past bids on similar projects. For every general contractor submitting a bid, the value of the bid and a list of first tier subcontractors is given.[9] Caltrans assigns a unique identifier to each firm, so it is possible to track prime contractors across contracts. In addition, we have assigned unique identifiers to subcontractors based on the firm name.[10] In all, we observe 26,125 bids from 1,735 different firms, of which 805 win at least one contract. These bids listed roughly 2,900 contractors.

It is worth mentioning a few of the drawbacks of the data. First, we only observe contracts administered by Caltrans and not those administered by local governments, which represent a significant fraction of the market. According to the 2002 Census of Governments, local governments in California expended $2.39 billion in capital outlay for highways compared to $2.99 billion for the state government. As a result, we will tend to understate the stock of relationships between contractors and subcontractors, the extent of future opportunities, and the degree of project backlog. Furthermore, our data is truncated at May 1996, which indicates that we are not able to form measures of prior relationships and project backlog that include projects prior to this date. This is handled more easily, as we can control for the initial stock of relationships using firm fixed effects. Finally, even among the contracts in our data, we do not observe subcontractors to which only a small portion of the contract was awarded, nor do we know if subcontractors were switched out

[9] A first tier subcontractor performs at least $10,000 or half of a percent of the contract, whichever is greater.

[10] Due to many small permutations of spellings for the same firm, these numbers are assigned by hand.

after the awarding of the project. The former is a problem depending on the form of the production function of relationships. If relationships are proportional to the intensity of utilization, then this is less of a problem than if relationships depend only whether or not two firms have interacted.

In Table 1 we present summary statistics of the data. In Panel A, we describe the characteristics of the auctions. The average auction has 5.15 participants, though this varies across auctions. The maximum number of bidders observed in the data is 30, though most auctions have fewer than eight bidders. The average engineer's estimate is $3.13 million, and there are significant differences in scale across projects. The engineer's estimate for the median project is only $620,000, and estimates range from a low of $12,930 to a high of $800 million. This considerable variation in project scale is also reflected in the workdays the engineer anticipates will be required. The average working days are 163.4, while the median is only 70. The average project requires 34.8 items.

In Panel B, we describe characteristics of the observed bids. The average observed bid is $3.12 million, closely matching the average engineer's estimate. The average bid is nine percent above the engineer's estimate. While high bids are sometimes rejected for exceeding the engineer's estimate by more than ten percent, we still see some firms bidding substantially above the engineer's estimate, with the highest being 37 times greater. The average bidder lists 4.35 first tier subcontractors, with the most intensive user of subcontractors listing 38. Finally, we describe the experience of the typical firm and the average stock of relationships with subcontractors. The average bidder enters an auction having won 18 prior auctions, with the median bidder having won 4. The average bidder has used the subcontractors listed in the bid a total of 7.6 times on previous auctions won. This figure is particularly skewed, as the median bid involves only one prior subcontractor relationship while the max involves 404.

Panel C of Table 1 describes similar figures for the winning bidders. While the average bidder submitted a bid nine percent above the engineer's estimate, the average winner bid four percent under the engineer's estimate. Bid winners do not appear more or less apt to subcontract, as they utilize virtually the same number of subcontractors as the broader population of bidders. They do tend to have significantly more experience, however, as the average winning bidder has won 26 prior auctions. They also have a higher stock of past interactions with the listed subcontractors, having used them 11.9 times on prior winning bids. This appears to be in large part due to these firms' greater number of past wins.

In the empirical models to follow, we will consider the entry and subcontractor utilization decisions of the largest firms in the industry. We limit that part of our analyses to the largest firms because we run into problems of degrees of freedom if including all participating bidders and because the actions of this sample of firms provide enough variation to examine the issues of our interest. We will also define the stock of relationships the firm has developed with subcontractors in a relevant geographic market. To better understand these aspects of the empirical work, we next describe the concentration of the market across firms and geographical areas.

In Table 2 we show the top twenty firms in terms of contracts won.[11] The industry is remarkably unconcentrated, with the largest 20 firms accounting for only 28 percent of contracts won. Granite Construction, to our knowledge the only publicly traded company in the data, wins the most auctions, capturing nearly eight percent of contracts. Considering market share based on winning bids, they won auctions worth $1.2 billion, or 7.5 percent of total awarded contract dollars. The next largest firm, Peterson Chase, won only 1.9 percent of contracts.

This lack of concentration in the Caltrans highway construction market masks a potentially significant geographic element. Firm costs have been found to rise significantly with distance (see for instance Bajari and Ye, 2003). We may expect that in a large state like California, relevant markets are more local. We consider a definition of the relevant market using Caltrans districts, of which there are 12. Figure 2 displays a map of the districts of California laid over the counties. Geographically, these districts are quite large. The most significant exception to this is Orange County which comprises a district of its own.

In Table 3, we present evidence regarding the degree to which firms operate within one district. In this table, we show the average number of wins of firms who win at least one contract and the fraction of those wins that came in the firm's primary district.[12] We see that the average firm wins 6.4 auctions, 82 percent of which were in its primary district. Since this may be skewed due to the significant fraction of firms that won only one contract, we also restrict attention to those firms that won more than one contract. Of these firms, 69 percent of auction wins came from within the firm's primary district.

[11] We define market share based on the number of contracts won rather than on the dollar value of those contracts. We observe several joint ventures between firms that occur only once or very few times. We do not attempt to allocate market share between the firms in a joint venture, but we treat the joint venture as a separate firm. There are also a handful of very large large projects that significantly skew the data. In one instance, a firm won only one auction in the entire data for $1.4 billion, making them the largest firm in market share above Granite Construction, who won 407 auctions.

[12] We define primary district here as the one in which the firm won the highest number of auctions.

The subcontractor market surprisingly exhibits a similar degree of geographic concentration. Among subcontractors who appeared on at least one winning bid, the average subcontractor was utilized 9.5 times. Of this utilization, 84 percent occurred within the subcontractor's primary district, almost identical to that observed for prime contractors. Similarly, if we restrict attention to firms that participate more than one time, 67 percent of utilizations occur within the primary district. Subcontractors therefore seem to be geographically concentrated, and interestingly no more so than prime contractors.

6 Empirical Methodology and Results

6.1 Empirical Methodology

In this section, we describe the approach we will take to investigate the role of relationships between firms and their subcontractors. We first need to define the two measures of relationships we will use. To measure relationships, we will examine the set of subcontractors that are relevant for the project at hand and that the firm used on prior winning bids. For the first measure, we consider relevant subcontractors as those headquartered in the same Caltrans district as the current project. We then count the times that a bidder participating in the auction has previously worked with these subcontractors on a project. For the second measure, we consider a narrower set of subcontractors, those who the firm lists on its current bid, regardless of where the subcontractor is located. We then count the prior interactions with that firm on winning bids.

We then utilize these measures of the stock of subcontractors, s_{ik}, for firm i on project k by estimating a regression of the form

$$y_{ik} = \beta_0 + \beta_1 log(1 + s_{ik}) + BX_{ik} + \phi_i + \epsilon_{ik} \tag{2}$$

where y_{ik} is the relevant outcome variable, either the log of the submitted bid or an entry indicator, X_{ik} is a vector of covariates, and ϕ_i is a contractor fixed effect. We add one prior to taking the log of the stock variable as a significant portion of its observations are zero. When investigating entry, we focus attention on the 20 largest firms in terms of auction participation, forming an auction participation indicator for each of these firms on each auction conducted in the sample.

The vector X_{ik} contains covariates describing project characteristics such as year and month effects, an engineer's estimate of project cost, the number of items required for the project, and the number of working days the project is likely to require. It also includes firm specific covariates that potentially vary across auctions, such as prior experience on projects in the area and an estimate of the firm's backlog of uncompleted projects.[13] Controlling for these variables is important. Since the subcontractor stock variable is based on subcontractor utilization on past *winning* projects, it will be directly correlated with the number of wins the firm has and with recently won contracts that are not yet completed. While the effect of experience on bids is mixed, firms have been found to bid higher when facing short run capacity constraints (see Jofre-Bonet and Pesendorfer, 2003).

Finally, the firm fixed effect potentially plays an important role. Our data is truncated at May of 1996, so it is not possible to measure firm interactions prior to this date. The initial stock of subcontractor interactions are captured in this fixed effect.

As already discussed, the coefficient β_1 should depend on the continuation value of relationships, since relational contracts must be self-enforcing. We measure this continuation value using the number of future contracts f_{ik} observed in the project district. We also separately consider the value of these future contracts. We introduce this measure into the empirical specification by interacting it with the firm's stock of prior interactions:

$$y_{ik} = \beta_0 + \beta_1 log(1 + s_{ik}) + \beta_2 log(1 + f_{ik}) * log(1 + s_{ik}) + \beta_3 log(1 + f_{ik}) + BX_{ik} + \phi_i + \epsilon_{ik}. \quad (3)$$

To account for forward looking bidders who may take the future opportunity cost of winning the current auction into account, we only consider those future projects occurring after the anticipated completion of the current project. Our primary coefficient of interest will be β_2, which describes how the value of relationships depends on future contracting opportunities. It is valuable to control directly for future contract volume in addition to this interaction, since future contract opportunities may affect the bid through channels aside from the informal contract mechanism. For instance, the prospects of high future volume may induce subcontractor entry. Also, if there is learning by doing, then there is incentive to win contracts now so that the firm will have a lower cost for future contracts.

According to our testable implications regarding coordination costs and the future value of interactions, past interactions lower coordination costs ($\beta_1 < 0$). Moreover, contractors may only profit from lower coordination costs due to past interactions if there are future interactions at stake ($\beta_2 < 0$).

[13] We measure backlog by the fraction of the dollar value of outstanding projects that are not yet completed. To obtain this measure, we assume that projects are completed linearly by day, that the firm begins work on the project award date, and that the firm takes the estimated working days to complete a project it has won.

6.2 Results

6.3 Firm bidding

We begin by presenting the results documenting the correlation between the stock of subcontractor relationships and bidding behavior. In Table 4, we present estimates of (2) using as a measure of relationships the prior interactions with subcontractors headquartered in the project district. In column 1 we find a significant negative relationship between the stock of interactions and the bid a firm submits. This beneficial effect on the firm's bid holds up after controlling for bidder fixed effects in column 2. The other covariates we consider are largely consistent with the prior literature on the highway construction market. Backlog is associated with higher bids, consistent with the presence of short-run capacity constraints, and each opposing bidder reduces the firm's bid by around one percent. We also find that while, conditional on firm fixed effects, past wins are positively associated with bids, past wins within the project county are negatively associated with bids.

In column 3 of Table 4, we examine whether the age of the relationship matters by splitting up interactions by three month intervals, and those interactions occurring more than one year ago. We find that our initial results are driven by interactions occurring at least nine months prior, suggesting that more established relationships are more important than recent interactions with subcontractors.

In columns 4 and 5 of Table 4, we consider the interaction of the stock of relationships with the degree of future contracting opportunities in the project district. We consider separately the number of future contracts and the dollar value of these contracts. We find that both more future contracts and more future contract dollars increase the value of the stock of relationships. Interestingly, when this interaction is included in the specification, the main effect of the relationship stock variable is cut in magnitude by two-thirds and becomes statistically indistinguishable from zero. This suggests that relationships have no value when the continuation value of the relationship is zero. This result is consistent with our testable implications and in general with implications from the relational contracting literature. The coefficients of all the other covariates remain unchanged and statistically significant to including the number and value of future interactions.

In Table 5, we present similar estimates using an alternative measure of the stock of relationships, past interactions with the subcontractors listed on the firm's bid. We obtain results that are very similar to those using the first measure of the stock of relationships. We again find that firms with more relationships bid lower, and that the beneficial effect of relationships is greater as there is a greater degree of future potential business. Again, without the self-enforcement mechanism of future business, past relationships seem to have little effect on their own. All other controls used in the specifications presented in Table 5 have the same qualitative effect on the dependent variable as they did in Table 4.

Given the results presented in Tables 4 and 5, one may worry that our two measures of future business volume may be capturing unobserved heterogeneity that is correlated with more aggressive bidding but has nothing to do with the self-enforcing informal agreement between contractor and subcontractor. For instance, areas with a high contract volume, and therefore a higher future contract volume, may be places where subcontractors are more valuable. In Table 6, we present results supporting the notion that more aggressive bidding is driven by our explanation of stronger self-enforcing agreements between contractors and their subcontractors. We divide the number and value of future contracts into two groups, those taking place within one year of the current period and those taking place between one and two years from the current period. Upcoming contracts should play a more important role in self-enforcing agreements since there is more uncertainty regarding projects in the more distant future, and due to discounting. Our results in Table 6 show that only the number and volume of future contracts within one year of the current period are relevant for the current bid of contractors. In each specification, we find a small and statistically insignificant coefficient on the interaction between the stock of relationships and future contracts opportunities occurring between one and two years out.

Thus far, our results do not shed light on the depth of relationships between contractors and subcontractors. The two measures of subcontractor relationships do not distinguish between contractors who have developed a relationship with a particular subcontractor from a firm with an equal number of total subcontractor interactions that are spread more evenly across subcontractors. To investigate the role of the depth of a subcontractor relationship, for each contractor we consider the share of its interactions that are held with its most frequently used subcontractor. Conditional on the stock of relationships, this measure will indicate whether it is more valuable to have these relationships concentrated among a few suppliers or spread among many suppliers. We show our results in Table 7. These results suggest that the stock of prior relationships is more valuable when concentrated in one subcontractor. However, concentrating in one supplier does not increase the importance of future business opportunities. This is true whether future business opportunities are measured using the number of contracts or their dollar value. This may suggest that concentrating in a few suppliers may lower bids through lower coordination costs, while relationship depth is not important for self-enforcing informal contracts.

6.4 Participation decision

Next we consider the role of subcontractor relationships in the entry decision for the twenty largest firms in the industry, as defined by those firms participating in the most auctions. For each auction, we form twenty observations indicating whether each firm participates in the auction. We again form measures of the stock of each firm's subcontractor relationships within the project district.[14]

Table 8 presents the results of regressing the participation indicator on the measure of the stock of subcontractor relationships. Consistent with the bidding results in previous tables, results in columns 1 and 2 show that entry becomes more attractive as the relationship stock goes up. In contrast with the results from the specification of bids, more recent interactions have a stronger impact on entry than do older interactions (see column 3). Finally, the impact of relationships again depends on their continuation value, as the interaction of relationships and future contracts is positively related to entry while in this case the direct effect of relationships is actually negative. These results are robust to the introduction of bidder fixed effects and the covariates used in previous tables.

6.5 Subcontractor utilization decision

Lastly, we consider the role of relationships and continuation value in the subcontractor choice by a contractor for a given project. As with the specifications of participation we display in Table 8, we limit our sample here to the 20 largest contractors in our sample. We consider all subcontractors that each one of these large contractors has ever listed during our sample period. We then form a dummy variable indicating whether firm i used subcontractor j on the particular auction k. We then regress this utilization dummy on the stock of prior relationships between the two firms, and as before we also consider an interaction between this measure and future contract opportunities within the project district.[15]

One concern with this specification is the fact that subcontractors are chosen in the basis of lower joint construction and coordination costs. Since we do not separately observe construction costs, if these are correlated with coordination costs and therefore with relationship stocks, we

[14] It is not possible to measure interactions with listed subcontractors, as this is only observed for participating firms.

[15] Subcontractor choice is not independent since if a firm is using one subcontractor to complete a task it is not using another. Subcontractor choice is also unlikely to be independent across bidders within the same project since some subcontractors will have unobserved cost advantages. For these reasons, we adjust the standard errors for clustering at the contract level.

may obtain biased estimates of the effect of past interactions on subcontractor utilization. To address this, we control for two variables that reflect subcontractor cost. One is an indicator of whether other bidders also use the same subcontractor, which captures the otherwise hidden subcontractor cost advantage. The other is an indicator of whether the project takes place on the subcontractor's primary district. Since distance is an important determinant of a firm's cost in this industry, subcontractors located near the project will have a cost advantage.

Our results are presented in Table 9. Subcontractors with whom the contractor has an existing relationship are more likely to be chosen. Furthermore, this becomes even more true as future business opportunities, as measured by the number of contracts, increases. In contrast to our prior results, this does not hold true when future opportunities are measured by contract dollars. As expected, the bidder is more likely to use a particular subcontractor if other firms in the same auction are using that same subcontractor. Also, firms are more likely to choose subcontractors located in the same district of the project.

7 Conclusions

In this paper we have examined how relationships between contractors and subcontractors influence bidding behavior and participation decisions of contractors in California highway procurement auctions. We present a simple theoretical framework that yields two main testable implications. First, contractors with a bigger stock of past interactions with their subcontractors should be able to post lower bids (due to lower coordination costs) that eventually allows them to win more auctions. Second, contractors with a potentially higher number of future interactions with their subcontractors should be able to post lower bids (due to better mitigation of moral hazard problems) and therefore be more likely to win the auction at stake.

Our results provide support for our model predictions. First, we find that a higher number of past interactions is correlated with lower posted bids. Second, we find that a higher number of future potential contracts in the contractor and subcontractors' Caltrans district is also correlated with lower posted bids. Moreover we find that the interaction between past interactions and future potential interactions is not only strongly correlated with lower posted bids, but also that controlling for this interaction wipes out the direct effect of past interactions. We also examine the effect of past and future interactions on auction participation and find qualitatively similar results.

These findings imply that firms are only able to use gains from repeated past interactions when future business opportunities are present.

This result is important and constitutes the main contribution of this research. Prior empirical literature in relational contracting has tended to use past interactions as a proxy for future interactions. Our result here demonstrates that such a strategy could lead to potentially wrong conclusions. Our paper is also important because it is, to the best of our knowledge, the first test confirming the importance of future interactions holding constant past and present characteristics of the agents involved in a transaction.

8 References

Asanuma, B. (1989) "Manufacturer–supplier relationships in Japan and the concept of relationship-specific skill," *Journal of the Japanese and International Economies*, Vol. 3, No. 1, pp. 1–30.

Baker, G., Gibbons, R. and K. J. Murphy (1994) "Subjective Performance Measures in Optimal Incentive Contracts," *The Quarterly Journal of Economics*, Vol. 109, No. 4, pp. 1125-1156.

Baker, G., Gibbons, R. and K. J. Murphy (2002) "Relational Contracts and the Theory of the Firm," *The Quarterly Journal of Economics*, Vol. 117, No. 1, pp. 39-84.

Bajari, P., Houghton, S. and S. Tadelis (2006) "Bidding for Incomplete Contracts: An Empirical Analysis," NBER Working Paper # 12051.

Bajari, P. and S. Tadelis (2001) "Incentives Versus Transaction Costs: A Theory of Procurement Contracts," *The Rand Journal of Economics*, Vol. 32, No. 3, pp. 287-307.

Bajari, P. and S. Tadelis (2006) "Incentives and Award Procedures: Competitive Tendering vs. Negotiations in Procurement," chapter 5 in Handbook of Procurement, edited by Nicola Dimitri, Gustavo Piga and Giancarlo Spagnolo.

Bajari, P., McMillan, R. and S. Tadelis (2008) "Auctions versus Negotiations in Procurement: An Empirical Analysis," *Journal of Law, Economics and Organization*, forthcoming.

Bajari, P. and L. Ye. (2003) "Deciding Between Competition and Collusion," *Review of Economics and Statistics* 85:4, p. 971-989.

Board, S. (2008) "Relational Contracts and the Value of Loyalty," Working Paper UCLA Economics Department.

Bull, C. (1987) "The Existence of Self-Enforcing Implicit Contracts," *The Quarterly Journal of Economics*, Vol. 102, No. 1, pp. 147-160.

Corts, K. and J. Singh (2004) "The Effect of Repeated Interaction on Contract Choice: Evidence from Offshore Drilling," *Journal of Law, Economics, and Organization*, Vol. 20, No. 1, pp. 230-260.

Eccles, R. (1981) "The Quasifirm in the Construction Industry," *Journal of Economic Behaviour and Organisation*, Vol. 2, pp. 335–357.

Guasch, J.L., J.J. Laffont, and S. Straub. (forthcoming) "Renegotiation of Concession Contracts in Latin America," *International Journal of Industrial Organization.*

Gil, R. (2004) "Contracting in the Spanish Movie Industry," University of Chicago Economics Department Dissertation.

Gil, R. and W. Hartmann (2007) “Airing Your Dirty Laundry: Social Networks, Reputational Capital and Vertical Integration,” mimeograph, University of California, Santa Cruz.

González, M., Arruñada, B. and A. Fernández (1998) “Regulation as a Cause of Firm Fragmentation: The Case of the Spanish Construction Industry,” *International Review of Law and Economics*, Vol. 18, pp. 433–450.

González, M., Arruñada, B. and A. Fernández (2000) “Causes of subcontracting: evidence from panel data on construction firms,” *Journal of Economic Behavior & Organization*, Vol. 42, pp. 167–187.

Guasch, J. L., Laffont, J. J. and S. Straub (2008) “Renegotiation of concession contracts in Latin America: Evidence from the water and transport sectors,” *International Journal of Industrial Organization*, Vol. 26, No. 2, pp. 421-442.

Jofre-Bonet, M., Pesendorfer, M. (2003) “Estimation of a dynamic auction game,” *Econometrica*, Vol. 71, No. 5, pp. 1443-1489.

Kellogg, R. (2008) “Learning by Drilling: Inter-Firm Learning and Relationship Persistence in the Texas Oilpatch,” Center for the Study of Energy Markets Working Paper #173.

Klein, B. (1996) “Why Hold-Ups Occur: The Self-Enforcing Range of Contractual Relationships,” *Economic Inquiry*, Vol. 34, No. 3, pp. 444-63.

Klein, B. and K. Leffler (1981) “The Role of Market Forces in Assuring Contractual Performance,” *The Journal of Political Economy*, Vol. 89, No. 4, pp. 615-641.

Klein, B. and Murphy, K. M. (1988) “Vertical Restraints as Contract Enforcement Mechanisms,” *Journal of Law and Economics*, Vol. 31, No. 2, pp. 265-97.

Krasnokutskaya, K. (2003) “Identification and Estimation in Highway Procurement Auctions under Unobserved Auction Heterogeneity,” mimeograph, University of Pennsylvania.

Krasnokutskaya, E. and K. Seim (2005) “Preferential treatment Program and Participation Decisions in Highway Procurement,” mimeograph, University of Pennsylvania.

Macaulay, S. (1963) “Non-Contractual Relations in Business: A Preliminary Study,” *American Sociological Review*, Vol. 28, No. 1, pp. 55-67.

Marion, J. (2007a) “Are Bid Preferences Benign? The Effect of Small Business Subsidies in Highway Procurement Auctions,” *Journal of Public Economics*, Vol. 91, No. 7-8, pp. 1591-1624.

Marion, J. (2007b) “How Costly is Affirmative Action? Government Contracting and California’s Proposition 209,” *Review of Economics and Statistics*, forthcoming.

Miller, D. (2008) “Subcontracting and Competitive Bidding on Incomplete Procurement Contracts,” manuscript.

Figure 1: Timing of model

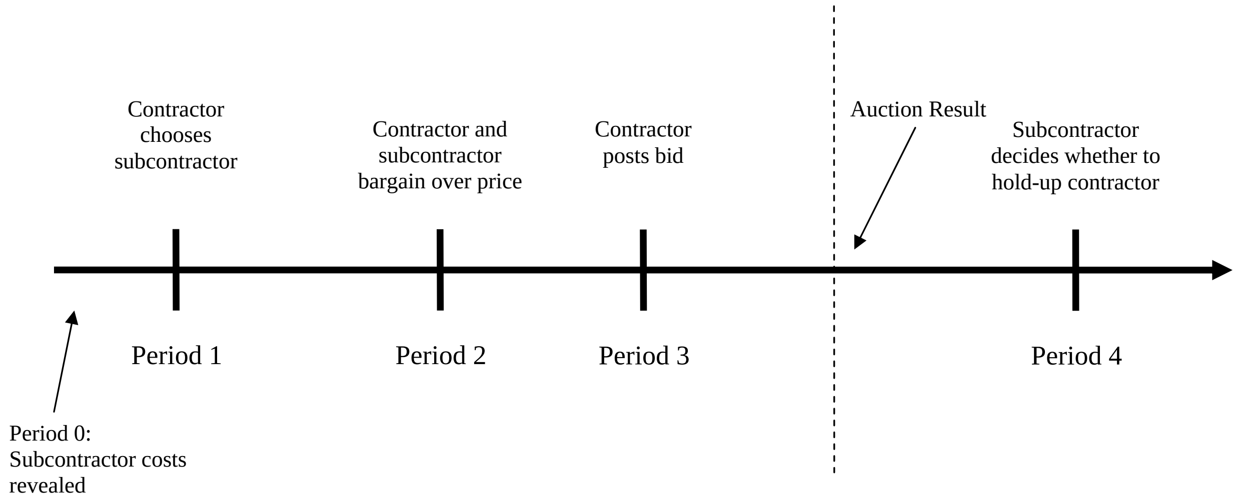

Figure 2: Caltrans districts

Table 1: Summary statistics

	Mean	Median	SD	Min	Max
Panel A: Contract characteristics					
Bidders	5.15	5	2.81	1	30
Engineer's estimate	$3.13 mill.	0.62 mill.	19.0 mill	12930	800 mill
Workdays	163.4	70	233.9	5	2310
Num. of items	34.77	23	38.1	1	349
Panel B: All bidders					
Bid	$3.12 mill	0.64 mill	18.4 mill	16410	1.4 bill.
Bid/estimate	1.09	1.05	0.37	0.21	37.3
Num. of subs.	4.35	4.0	3.58	0	38
Past wins	18.05	4.0	49.80	0	405
Past utilization of listed subs	7.57	1.0	22.16	0	404
Panel C: Winning bidders					
Bid	$3.17 mill	0.59 mill	27.0 mill	16410	1.4 bill.
Bid/estimate	0.96	0.94	0.22	0.21	3.00
Num. of subs.	4.36	4.0	3.57	0	34
Past wins	26.15	7.0	63.03	0	405
Past utilization of listed subs	11.91	2.0	30.85	0	404

Panel A describes the summary statistics of 5120 contracts awarded by Caltrans from May 1996 through October 2005, nearly all contracts awarded during this time. The number of items reflects how many distinct items are listed on the contract. The workdays variable measures the engineer's evaluation of the time to completion in days. Panel B provides information on the 25631 bids observed on these auctions. Panel C provides information on the bids that won the 5120 auctions.

Table 2: Market concentration

	Contracts won		Value ($mill)	
Granite Construction	407	7.95%	1230.0	7.59%
Peterson Chase	99	1.93%	139.1	0.86%
All American Asphalt	71	1.39%	116.2	0.72%
Teichert Construction	68	1.33%	172.9	1.07%
American Civil Constructors	61	1.19%	228.5	1.41%
Clayborn Contracting Group	59	1.15%	19.8	0.12%
Parnum Paving	57	1.11%	82.3	0.51%
Western States Surfacing Inc.	56	1.09%	47.1	0.29%
J.F. Shea Co. Inc.	55	1.07%	147.9	0.91%
W. Jaxon Baker Inc.	55	1.07%	142.4	0.88%
TDS Engineering	52	1.02%	16.0	0.10%
M. Bumgarner Inc.	50	0.98%	31.8	0.20%
J. McLoughlin Engineering Co.	47	0.92%	66.9	0.41%
E.L. Yeager Construction	45	0.88%	814.9	5.03%
Watkin and Bortolussi	41	0.80%	25.1	0.15%
Mercer Fraser Co.	41	0.80%	48.2	0.30%
Sim J. Harris Co.	41	0.80%	29.6	0.18%
Baldwin Contracting Co.	40	0.78%	92.2	0.57%
Modern Alloys Inc.	39	0.76%	31.6	0.20%
Beador Construction Co.	37	0.72%	16.9	0.10%
	1421	27.7%	3499.5	21.5%

These are the twenty largest firms in terms of number of contracts won. Listed are the number of contracts won by firm and the share this represents of all contracts awarded between May 1996 and October 2005. Also listed are the dollar value of contracts won and the firm's share of the total value of awarded contracts.

Table 3: Geographic concentration

	Mean	Median	SD	Min	Max
Prime contractors					
All prime contractors					
Total wins	6.36	2	17.31	1	407
In primary district	0.82	1	0.25	0.2	1
N	805				
Greater than one win					
Total wins	10.12	4	21.82	2	407
In primary district	0.69	0.67	0.26	0.2	1
N	473				
Subcontractors					
All subcontractors					
Part. in winning bid	9.54	2	37.03	1	932
In primary district	0.84	1	0.25	0.13	1
N	2076				
Greater than one participation					
Part. in winning bid	17.98	5	50.84	2	932
In primary district	0.68	0.67	0.26	0.13	1
N	1044				

The set of prime contractors includes all those firms that were observed winning at least one Caltrans contract between May 1996 and October 2005. Total wins describes the number of times in the sample a firm won an auction. The variable “In primary district” describes the fraction of these wins in that occurred in the district where the firm won the most auctions. The sample is further narrowed down to include only those firms that won more than won auction. For subcontractors, we count the number of times the firm appeared as a subcontractor on a winning bid, and the fraction of those appearances that occurred in the district where the firm had the most appearances.

Table 4: Subcontractor relationships within district and the firms' bids

Dependent variable: Log of bid

	(1)	(2)	(3)	(4)	(5)
Log stock of subs. in district	-0.009	-0.009		-0.003	-0.002
	(0.002)***	(0.003)***		(0.004)	(0.004)
Log stock in Dist. past 90 days			-0.001		
			(0.003)		
Log stock in Dist. 90-180 days prior			0.003		
			(0.003)		
Log stock in Dist. 180-270 days prior			0.003		
			(0.003)		
Log stock in Dist. 270-360 days prior			-0.009		
			(0.003)***		
Log stock in Dist. $>$ 360 days prior			-0.008		
			(0.002)***		
Log stock*Log future contracts in dist.				-0.002	
				(0.001)*	
Log future contracts in district				-0.011	
				(0.004)***	
Log stock*Log future dist. $ (X100)					-0.045
					(0.021)**
Log future dist. $ (X100)					-0.146
					(0.081)*
Log # past wins	-0.002	0.030	0.029	0.031	0.031
	(0.002)	(0.005)***	(0.005)***	(0.005)***	(0.005)***
Log # wins in project county	-0.012	-0.008	-0.007	-0.007	-0.008
	(0.003)***	(0.003)**	(0.003)**	(0.003)**	(0.003)**
Log backlog	0.000	0.001	0.001	0.001	0.001
	(0.000)	(0.000)***	(0.000)**	(0.000)***	(0.000)***
Bidders	-0.008	-0.010	-0.010	-0.010	-0.010
	(0.001)***	(0.001)***	(0.001)***	(0.001)***	(0.001)***
Log(items)	0.014	0.024	0.024	0.022	0.022
	(0.004)***	(0.005)***	(0.005)***	(0.005)***	(0.005)***
Number of workdays	0.000	0.000	0.000	0.000	0.000
	(0.000)***	(0.000)***	(0.000)***	(0.000)**	(0.000)**
Log engineer's estimate	0.956	0.946	0.946	0.944	0.945
	(0.003)***	(0.003)***	(0.003)***	(0.003)***	(0.003)***
Firm effects		X	X	X	X
Month, year, and district effects	X	X	X	X	X
Observations	24763	24763	24763	24763	24763
R-squared	0.97	0.98	0.98	0.98	0.98

The dependent variable is the log of the firm's bid. The stock of subcontractors is the sum of the firm's prior interactions on winning bids with subcontractors headquartered in the project district. Future contract dollars in district is the sum of the engineer's estimate for all projects occurring in the next 360 days in the project's district. One has been added to each variable for which logs were taken, except for the number of items and the engineer's estimate, to deal with missing values.

Standard errors corrected for clustering by contract are in parenthesis.

*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.

Table 5: Alternative measure: Subcontractor relationships with listed subcontractors and firms' bids

Dependent variable: Log of bid

	(1)	(2)	(3)	(4)	(5)
Log Stock with listed subs.	-0.016	-0.011		-0.005	-0.002
	(0.003)***	(0.003)***		(0.004)	(0.004)
Log Stock past 90 days			-0.001		
			(0.003)		
Log Stock past 90-180 days			0.007		
			(0.004)*		
Log Stock past 180-270 days			-0.002		
			(0.004)		
Log Stock past 270-360 days			-0.012		
			(0.004)***		
Log Stock $>$ 360 days prior			-0.010		
			(0.003)***		
Log stock*Log future dist. contracts				-0.002	
				(0.001)**	
Log future contracts in district				-0.011	
				(0.004)***	
Log stock*Log future dist. $					-0.063
					(0.023)***
Log future dist. $					-0.135
					(0.078)*
Log past wins	0.002	0.035	0.033	0.036	0.036
	(0.002)	(0.005)***	(0.005)***	(0.005)***	(0.005)***
Log past wins in project county	-0.014	-0.010	-0.010	-0.010	-0.010
	(0.003)***	(0.003)***	(0.003)***	(0.003)***	(0.003)***
Log backlog	0.000	0.001	0.001	0.001	0.001
	(0.000)	(0.000)**	(0.000)*	(0.000)**	(0.000)**
Bidders	-0.009	-0.010	-0.010	-0.010	-0.010
	(0.001)***	(0.001)***	(0.001)***	(0.001)***	(0.001)***
Log(items)	0.017	0.025	0.025	0.022	0.023
	(0.004)***	(0.005)***	(0.005)***	(0.005)***	(0.005)***
Number of workdays	0.000	0.000	0.000	0.000	0.000
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Log engineer's estimate	0.958	0.948	0.948	0.946	0.948
	(0.003)***	(0.003)***	(0.003)***	(0.003)***	(0.003)***
Firm effects		X	X	X	X
Month, year, and district effects	X	X	X	X	X
Observations	25714	25714	25714	25714	25714
R-squared	0.97	0.97	0.97	0.97	0.97

The dependent variable is the log of the firm's bid. The stock of subcontractors is the sum of the firm's prior interactions on winning bids with subcontractors listed in the firm's bid. Future contract dollars in district is the sum of the engineer's estimate for all projects occurring in the next 360 days in the project's district. One has been added to each variable for which logs were taken, except for the number of items and the engineer's estimate, to deal with missing values.

Standard errors corrected for clustering by contract are in parenthesis.

*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.

Table 6: Contract opportunities in the more distant future

Dependent variable: Log of bid

	Measure of stock of relationships			
	Stock in district		Stock with listed subs	
	(1)	(2)	(3)	(4)
Log stock*Log # future contracts < 1yr	-0.002		-0.003	
	(0.001)*		(0.001)**	
Log # future contracts < 1yr	-0.011		-0.011	
	(0.004)**		(0.004)**	
Log stock*Log # future contracts 1-2 yrs	0.000		0.001	
	(0.001)		(0.001)	
Log # future contracts 1-2 years	0.015		0.015	
	(0.007)**		(0.007)**	
Log stock*Log future contract \$ < 1yr (X100)		-0.044		-0.063
		(0.022)**		(0.024)***
Log future contract \$ < 1yr		-0.148		-0.134
		(0.084)*		(0.081)*
Log stock*Log future contract \$ 1-2 yrs		-0.006		0.002
		(0.029)		(0.031)
Log future contract \$ 1-2 years		0.263		0.243
		(0.183)		(0.182)
Log stock	-0.004	-0.001	-0.007	-0.002
	(0.005)	(0.006)	(0.005)	(0.006)
Constant	0.626	0.608	0.828	0.795
	(0.216)***	(0.214)***	(0.055)***	(0.055)***
N	24763	24763	25714	25714
R-squared	0.98	0.98	0.97	0.97

The dependent variable is the log of the firm's bid. The stock of subcontractors measure used in specifications (1) and (2) is the sum of the firm's prior interactions on winning bids in the same district as the current project. The stock of subcontractors measure used in specifications (3) and (4) is the sum of the firm's prior interactions on winning bids with subcontractors listed by the firm on the current project. Future contract dollars in district is the sum of the engineer's estimate for all projects occurring either within one year or between one and two years in the project's district. One has been added to each variable for which logs were taken, except for the number of items and the engineer's estimate, to deal with missing values. Other covariates included in the specifications match those described in Table 4.

Standard errors corrected for clustering by contract are in parenthesis.

*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.

Table 7: Value of relationship depth

Dependent variable: Log of bid

	(1)	(2)	(3)
Top sub. share*Log stock in district	-0.011	-0.021	-0.017
	(0.006)*	(0.013)*	(0.015)
Log stock in district	-0.007	0.001	0.001
	(0.003)**	(0.005)	(0.005)
Top sub. share*Log stock in district*Log # future contracts		0.004	
		(0.004)	
Log stock in district*Log future contracts in district		-0.003	
		(0.001)**	
Log # future contracts in district		-0.012	
		(0.004)***	
Top sub. share*Log stock in district*Log future dist $ (X100)			0.043
			(0.088)
Log stock in district*Log future dist $ (X100)			-0.053
			(0.028)*
Log future dist $ (X100)			-0.152
			(0.084)*
Constant	0.564	0.571	0.561
	(0.213)***	(0.209)***	(0.212)***
N	24763	24763	24763
R-squared	0.98	0.98	0.98

The dependent variable is the log of the firm's bid. The stock of subcontractors is the sum of the firm's prior interactions on winning bids in the same district as the current project. The top subcontractor share is the fraction of the firm's relationship stock concentrated in its most frequently used subcontractor. Future contract dollars in district is the sum of the engineer's estimate for all projects occurring in the next 360 days in the project's district. One has been added to each variable for which logs were taken, except for the number of items and the engineer's estimate, to deal with missing values. Other covariates included in the specifications match those described in Table 4.
Standard errors corrected for clustering by contract are in parenthesis.
*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.

Table 8: The entry decision of the twenty largest firms

Dependent variable: Participation indicator

	(1)	(2)	(3)	(4)	(5)
Log Stock in District	0.012	0.008		-0.004	-0.004
	(0.001)***	(0.001)***		(0.001)***	(0.001)**
Log Stock in District past 90 days			0.023		
			(0.002)***		
Log Stock in District past 90-180 days			0.011		
			(0.002)***		
Log Stock in District past 180-270 days			0.003		
			(0.002)		
Log Stock in District past 270-360 days			0.011		
			(0.002)***		
Log Stock in District > 360 days prior			0.005		
			(0.001)***		
Log stock*Log future contracts in dist.				0.004	
				(0.000)***	
Log future contracts in district				0.000	
				(0.001)	
Log stock*Log future dist. $					0.078
					(0.008)***
Log future dist $					-0.042
					(0.018)**
Log past wins	0.005	-0.000	-0.021	-0.002	-0.001
	(0.001)***	(0.002)	(0.005)***	(0.002)	(0.002)
Log past wins in project county	0.068	0.068	0.066	0.069	0.068
	(0.001)***	(0.002)***	(0.002)***	(0.002)***	(0.002)***
Log backlog	-0.056	-0.014	-0.018	-0.011	-0.012
	(0.011)***	(0.012)	(0.017)	(0.012)	(0.012)
Bidders	0.001	0.001	0.001	0.001	0.001
	(0.000)**	(0.000)**	(0.000)	(0.000)***	(0.000)**
Log(items)	0.009	0.009	0.013	0.010	0.009
	(0.001)***	(0.001)***	(0.001)***	(0.001)***	(0.001)***
Number of workdays	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Log engineer's estimate	0.006	0.006	0.009	0.006	0.006
	(0.001)***	(0.001)***	(0.001)***	(0.001)***	(0.001)***
Firm effects		X	X	X	X
Month, year, and district effects	X	X	X	X	X
Observations	101540	101540	66945	101540	101540
R-squared	0.12	0.12	0.13	0.12	0.12

The dependent variable is an indicator for auction participation, where the sample includes all auctions and the 20 largest firms in terms of auction participation. The stock of subcontractors is the sum of the firm's prior interactions on winning bids with subcontractors headquartered in the project district. Future contract dollars in district is the sum of the engineer's estimate for all projects occurring in the next 360 days in the project's district. One has been added to each variable for which logs were taken, except for the number of items and the engineer's estimate, to deal with missing values.

Standard errors corrected for clustering by contract are in parenthesis.

*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.

Table 9: The subcontractor utilization decision of the twenty largest firms

Dependent variable: Indicator for bidder i using subcontractor j on contract k

	(1)	(2)	(3)	(4)	(5)
Log stock prior interactions	2.431	2.762	2.061	1.690	2.246
	(0.041)***	(0.044)***	(0.035)***	(0.106)***	(0.130)***
Log stock*Log # future contracts				0.084	
				(0.023)***	
Log # future contracts				-0.009	
				(0.028)	
Log stock*Log future contract $ (X100)					-0.010
					(0.007)
Log future contract $ (X100)					0.008
					(0.005)
# of other bidders using sub.			0.321	0.321	0.322
			(0.005)***	(0.005)***	(0.005)***
Project in sub.'s primary district			0.016	0.016	0.016
			(0.000)***	(0.000)***	(0.000)***
Log past wins (X100)			-0.064	-0.073	-0.064
			(0.036)*	(0.036)**	(0.036)*
Log past wins in project county (X100)			-0.036	-0.036	-0.036
			(0.011)***	(0.011)***	(0.011)***
Number of bidders			-0.042	-0.042	-0.042
			(0.004)***	(0.004)***	(0.004)***
Log engineer's estimate			0.039	0.038	0.038
			(0.011)***	(0.011)***	(0.011)***
Number of workdays			0.000	0.000	0.000
			(0.000)***	(0.000)***	(0.000)***
Log number of items (X100)			0.363	0.363	0.363
			(0.020)***	(0.020)***	(0.020)***
Log backlog (X100)			0.004	0.004	0.004
			(0.003)	(0.003)	(0.003)
Firm effects		X	X	X	X
Month, year, and district effects			X	X	X
N	1790046	1788088	1774881	1774881	1774881
R-squared	0.01	0.02	0.16	0.16	0.16

The dependent variable is an indicator for whether a particular subcontractor was used by the contractor on that particular auction. The sample includes the 20 largest firms in terms of auction participation. The stock of prior interactions represents the number of times the contractor has worked with that particular subcontractor on prior winning contracts. Future contract dollars in district is the sum of the engineer's estimate for all projects occurring in the next 360 days in the project's district. One has been added to each variable for which logs were taken, except for the number of items and the engineer's estimate, to deal with missing values.
All specifications include controls for year and firm effects, and columns 2-4 contain controls for month dummies.
Standard errors corrected for clustering by contract are in parenthesis.
*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.