

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

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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 due to contractual incompleteness and incentives for ex post renegotiation. 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.

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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. It must be in the interest of both parties in the transaction to fulfill their obligations to the contract. In other words, the value of the relationship depends on whether both parties have the right incentives to maintain the relationship into the future. For this reason, 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.

Empirically evaluating the importance of future business for the relationship is difficult in most settings since the observed sales of a firm may depend on the success of the relationship. Furthermore, most of the empirical literature in this area measures relationships by the stock of prior interactions. However, prior relationships potentially have value both in solving incomplete

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

contracts as well as through improving relationship specific productivity unrelated to contracting, such as by mitigating coordination costs. In this paper, we account for not only the stock of prior interactions but also potential future interactions and study how these variables may affect contracting choice and firm performance. This constitutes one of the main contributions of this paper and the main differentiating factor with others in the previous literature.

We examine the value of relationships between contractors and their subcontractors in the highway construction and repair market. Subcontracting is pervasive in this market and plays an important role in the strategies pursued by contractors. According to the 1992 Census of Construction Industries, the average highway and street contractor pays 20.8% of its revenue to subcontractors.

We begin by setting up a theoretical framework where projects are comprised of two tasks. A firm may produce both tasks itself or subcontract one of the tasks 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 highway procurement auctions conducted by the California Department of Transportation (Caltrans). These data include information on all 5,120 road construction and repair contracts put up for bid by Caltrans between May 1996 and October 2005. In particular, each contract put up for bid includes information on the characteristics of the project such as the road and county where the project needs to take place, an estimate of the time required to finish the project and an engineer's estimate of the cost of the project. 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. Overall, these bids specify roughly 2,900 subcontractors. We therefore are able to measure the stock of relationships a firm has with its subcontractors over time and across markets. We will use this variation to establish how relationships affect a firm's bid and its likelihood of entry.

These data also provide an excellent opportunity to examine the role of the continuation value of a relationship. Since the arrival rate of projects is determined by transportation needs, future projects are exogenous to the success of prior relationships between contractors and their subcontractors. We form a measure of future business in a market using future projects observed in our data, assuming that expectations of future business are on average correct. This measure is then interacted with the stock of prior relationships to evaluate how the value of relationships depends on future business opportunities.

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. To investigate this, we interact past interactions with the number and dollar value of upcoming contracts within the geographic market separately. If no contracts are up for bid within the following year, the value of the stock of 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.

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 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.

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. Our paper adds to this literature in that we examine a channel through which contractors may benefit of their subcontracting strategies and provide evidence on how repeated subcontracting may enhance firm performance.

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.² 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.

²The 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 dynamic implications. In this model, a contractor i among I contractors is considering submitting a bid for a project k in period t . Following the institutional detail above, we assume that projects are allocated by a government agency in charge using first-price sealed-bid auctions. Therefore, the contractor i will post its bid without observing directly what the posted bids of the other contractors are. As it is usual in an auction setting, the contractor will face a trade-off between markup over cost and the probability of winning.

For simplicity we assume that every project is comprised of two tasks. We simplify the problem at hand further by assuming that at least one of the two tasks (task 1) is required to be conducted by the contractor itself, consistent with the institutional details of this market. The other task (task 2) may be outsourced to a subcontractor j (out of the J available subcontractors). This assumption could be extended easily to situations where the contractor is allowed to outsource all tasks or required to outsource a specific task.³

Let the cost of completing tasks 1 and 2 by contractor i be given by c_{1kit} and c_{2kit} , respectively. If we simplify the outsourcing decisions to whether use a subcontractor and the choice of subcontractor for task 2, then we only care about the cost of subcontractor j to produce task 2 in period t which we call c_{2kjt} that may vary across subcontractors.

Finally, the model is explicit about the nature of the realization of *ex ante* and *ex post* transaction and coordination costs potentially incurred by contractor i when dealing with subcontractor j in project k . These are switching transaction costs ϕ_{ijtk} and coordination costs $\gamma_{ijkt}(e)$. Notice that these costs are indexed per period t and may differ across periods. This is where the dynamic implications come from. In particular, switching costs ϕ_{i-jtk} are costs incurred *ex post* if a contractor i decides to switch for any given reason from its current subcontractor j to any other subcontractor $-j$. On the other hand, there are some coordination costs $\gamma_{ijkt}(e)$ that depend on effort e exerted *ex post* by subcontractor j . These coordination costs γ_{ijtk} vary across contractor-subcontractor match 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. Later in this section we will be more specific about the role of effort e in this setting.

³This is sometimes the case when particular expertise is required for a given task.

4.2 Timing of Actions and Solution by Backward Induction

The timing of actions and interactions between agents is as represented in Figure 1. In period 0, the state of the world is realized and all information is revealed to all I contractors and all J subcontractors. In other words, all participating I contractors know about their costs to produce project k , and they also know the cost of all the J subcontractors (this includes as well 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 what subcontractor j (if any) 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 (non-observable 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 will subcontractor j 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 subcontractors⁴ (at this stage subcontractors 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. In 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.

Not modeled here, the expectation of hold-up and *ex post* renegotiation may change the contractor's bidding strategy as it will try to pass some of these costs onto the buyer (CalTrans in

⁴Subcontractors are not receiving zero profit but the value of their best alternative option.

our example). We simplify this strategic aspect here but would like to point out that others have examined such phenomena (mainly Bajari, Houghton and Tadelis (2007)). Examining renegotiation patterns in this scenario is beyond the purpose of our research and we implicitly assume here that *ex ante* subcontracting decisions made by contractor i (mainly choosing subcontractor j) in the first three periods analyzed in this paper are such that no action (subcontractor switching or *ex post* renegotiation) is necessary in the hypothetical period 4. Let us now start solving this sequential game using backward induction.

4.2.1 Period 4: The Moral Hazard Problem of the Subcontractor

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 since the project will not be finished until task 2 is also finished. Moreover, the contractor is accountable for project k 's outcome and therefore has all incentives to keep an eye on the performance of subcontractor j . On the other hand, subcontractor j can decide whether to exert effort or not. For simplicity, we will assume that effort e can take two possible values such that $e = \{e^*, 0\}$. 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

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

and therefore the subcontractor may require extra compensation to finish the job on time and according to quality expectations. In this case, the contractor would happily switch to another subcontractor to finish the job started by subcontractor j . To do so, it will incur a switching transaction cost ϕ_{i-jkt} and therefore to certain degree it is locked into the relation with subcontractor j . In other words, the contractor i will gladly 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 will be equal to the value amount of the switching cost. This means that potentially the subcontractor could appropriate part of the profits that the contractor had won *ex ante* with its bidding strategy. The question is now what does the contractor do to retain as much of this surplus (or quasi-rent) as possible that has been created by the lock-in effect of the switching cost. Essentially, the contractor

wants the subcontractor to exert effort e^* as expected but has no formal contractual tool to induce him to take such action.

At this point, we bring into the model another intertemporal aspect of the contractor-subcontractor contractual relationship. Taking as given that contractors and subcontractors are not myopic and therefore they realize that they may interact with each other in the future, we allow the contractor to leverage the value of future interactions into the current contractual relationship. To introduce this factor into our model, we call $V(y_{ij})$ the value of future relationships for the subcontractor and this depends on the number and value of future interactions y_{ij} between contractor and subcontractor.⁵ The contractor will then offer an informal contract to the subcontractor that specifies the subcontractor effort e^* and specifies a punishment mechanism that enforces this level of effort. This mechanism is such that the contractor sets the value of future interactions at stake. More specifically, if the subcontractor does not provide the agreed level of effort e^* the contractor will decrease the number and value of future interactions to $V(\hat{y}_{ij})$. 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. 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 contractor will threaten to reduce the value of future interactions if the *ex ante* agreed effort is not honored. Then, the subcontractor will find optimal to exert the expected amount of effort if

$$\delta V(y_{ij}) \geq \gamma_{ijtk}(0) - \gamma_{ijtk}(e^*) + \delta V(\hat{y}_{ij}),$$

where $V(y_{ij})$ is the value of future interactions if provides the agreed effort today, $\gamma_{ijtk}(0) - \gamma_{ijtk}(e^*)$ is the gain of shirking on effort in the current period, $V(\hat{y}_{ij})$ is the gain of future interactions if the subcontractor decides to shirk today, and δ is the discount rate. So if we rearrange the terms in this inequality accordingly, we find that

$$\delta(V - \hat{V}) \geq \gamma_{ijtk}(0) - \gamma_{ijtk}(\bar{e}).$$

⁵We can think of $V(y)$ as coming from the expression

$$V(y) = \sum_{t=1}^{\infty} \delta^t y_t$$

where $y_t = 0$ in some periods when there is no interaction and $y_t > 0$ when there is interaction between contractor and subcontractor.

⁶In 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.

This expression establishes that the contractor will be more likely to induce the right amount of effort the lower the gains from shirking in the current period, the higher the discount rate and the higher the difference between the value of future interactions and the fallback option of subcontractor j . Provided this result, for each of the subcontractors available $e = 0$ if the above condition is not satisfied, and otherwise $e = e^*$ if it is satisfied. Then the real cost of subcontracting task 2 to subcontractor j will become

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

In a side note, we want to point out that the previous result is richer than usual in that it depends on the value of the subcontractor fallback option. For example, if this is a subcontractor that is specialized in a very specific type of tasks it is quite likely that it does not face much competition from other subcontractors and that V will not differ much from \hat{V} . In that particular case, we expect that the contractor will realize this *ex ante* and predict the shirking behavior *ex post* of the subcontractor and therefore include this in her bid.

4.2.2 Period 3: Maximizing Profits by Posting the Bid

Since our focus is on the effect of repeated interactions on the choice of subcontractor and its consequences on bid success, we simplify this stage by assuming that contractor i follows an exogenously set strategy that sets a fix markup over costs such that

$$b_{ijkt} = (1 + m)(c_{1kit} + \tilde{c}_{2kjt}(e^*)).$$

We assume this strategy to be unaltered by the outside environment and the competitive scenario faced by contractor i . Provided this bidding strategy, the expected profit of contractor i in project k , and the objective function that contractor i will maximize, is equal to

$$\pi_{ijkt} = m(c_{1kit} + \tilde{c}_{2kjt}(e^*)) * \Pr(b_{ijkt}(e^*) < b_{-ilkt})$$

and it depends on the probability that the bid will be lower than the bids presented by all the other bidders/contractors, and indirectly will depend on the total cost of the project. This our assumption is emphasizing the importance of the outcomes of the previous two periods in the outcome of the auction and therefore in this model, when maximizing expected profit, contractor i will always choose the subcontracting strategy (in-house production versus outsourcing) that lowers total costs enough to maximize the probability of actually winning the auction.

4.2.3 Period 2: Bargaining Between Contractor and Subcontractor

Once we have assumed the solution above (for simplicity) for period 3, we concentrate in the bargaining process that takes place between contractor i and subcontractor j (and all other subcontractors) in period 2. In this part of our setting we assume perfect information of the variables that play role in the bargaining process such as the cost of subcontractor j in 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 a few 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

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

4.2.4 Period 1: Contractor's Choice of Subcontractor

Finally, in period 1 the contractor decides what subcontractor to outsource task 2 to or whether doing task 2 itself to maximize total expected profit. To do so, the contractor takes as given the mark-up m in the bid originated in period 3 and the resulting level of \tilde{c}_{2kjt} in period 2 to make a choice in this period that maximizes its expected total profit.

In this case, contractor i will maximize its profit by solving the following problem

$$\max_{j \in \{i, J\}} \pi_{ijkt} = m(c_{1kit} + \tilde{c}_{2kjt}) * \Pr((1 + m)(c_{1kit} + \tilde{c}_{2kjt}) < b_{-ilk})$$

where

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

Then contractor i chooses any contractor j of the J available or chooses to do things himself (chooses i) to maximize its expected profit. Since we have assumed the mark-up on the bid m , the contractor will maximize expected profit by choosing a subcontractor that will minimize its cost and maximize his probability of submitting the winning bid. This problem is quite complex to solve analytically since we are not imposing any functional form or relation between the variables and cost elements that vary across subcontractors. Overall it is easy to see that in a given period

t contractor i will maximize expected profit by choosing a subcontractor j with a low cost of task 2 c_{2kjt} , as well as low coordination costs $\gamma_{ijtk}(e)$ and a high value of their future interactions $V(y_{ij})$ at stake if chooses to shirk effort. These loose predictions introduced here are the source of the testable implications that we present next and take to the data later on.

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 win a bid 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.

These predictions have barely any empirical content by themselves and that is why we describe next their empirical testable implications in our context of auctions of California highway procurement contracts and the subcontracting strategies of bidding contractors.

We start by discussing the empirical content of coordination costs γ_{ijt} . One dimension in which it is easy to observe differences across contractor-subcontractor pairs is along the geographical dimension. In particular, a contractor and subcontractor located close to each other geographically speaking will face lower coordination costs. Therefore, *we should observe how a contractor and subcontractor located close to each other are more likely to prepare a bid together and win that auction than a pair contractor-subcontractor that are not located geographically close to each other.*

A different way to measure coordination costs in this context is through the number of past interactions between contractor and subcontractor. We expect that coordination costs go down as contractor and subcontractor interact more. Therefore, we use variation across time to measure differences in coordination costs across time within and across contractor-subcontractor pairs by establishing that coordination costs of production between a contractor and a subcontractor will go down over time with the number of projects undertaken together in the past (and not necessarily the number of joint bids prepared in the past). Therefore, we have another testable implication out of exploiting past histories between a given pair of contractor and subcontractor, and that is the following: *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 lower the coordination costs and therefore the higher the likelihood that they will post a bid jointly in the future and 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.

Finally, the last testable implication has to do with the impact of future interactions in the subcontractor's provision of effort. Our prediction establishes that situations in which the contractor is able to leverage the value of future interactions it will induce the right amount of subcontractor effort and therefore post a competitive bid and potentially increase the probability of winning the auction. The prediction from the model also implies that subcontractors with higher value fallback options will be more likely to shirk *ex post*. In this case, the testable implications is twofold. On one hand, 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 win that auction.*

A separate implication from the model that we do not test here is the relation between subcontractor choice and degree of specialization of the subcontractor. The last prediction of our model is that subcontractors with a higher fallback option value will be less likely to exert the amount of effort initially agreed with the subcontractor. Since fallback option values are difficult to quantify, an alternative option would be to measure the degree of specialization of any given subcontractor such that highly specialized subcontractors may have a high fallback option value since it is difficult for subcontractors to find substitutes for them. Therefore we should observe that *the higher the degree of specialization of a subcontractor (and therefore the higher the value of the fallback option), the lower the probability that a contractor will post a joint bid with that subcontractor and win that auction for a task outside that specialization.* In a sense, this becomes a tautology and therefore it is difficult to test.

Even though the latter prediction comes out of the simple model that we present, we do not test this here and we limit our empirical analyses to the former implications. 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.⁷ 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.⁸ In all, we observe 26,125 bids from 1,735 different firms, of which 805 win at least one contract. These bids listed roughly 3,000 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 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

⁷A first tier subcontractor performs at least \$10,000 or half of a percent of the contract, whichever is greater.

⁸Due to many small permutations of spellings for the same firm, these numbers are assigned by hand.

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. This constitutes evidence of our first empirical implication regarding the importance of geographical proximity.

In Table 2 we show the top twenty firms in terms of contracts won.⁹ 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.¹⁰ 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.

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.

⁹We 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.

¹⁰We define primary district here as the one in which the firm won the highest number of auctions.

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

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

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.¹¹ 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).

¹¹We 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.

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 contracts. We introduce this measure into the empirical specification by interacting it with the firm's stock of prior interactions:

$$y_{ik} = \beta_0 + \beta_1 \log(1 + s_{ik}) + \beta_2 \log(1 + f_{ik}) * \log(1 + s_{ik}) + \beta_3 \log(1 + f_{ik}) + BX_{ik} + \phi_i + \epsilon_{ik}. \quad (2)$$

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.

According to our testable implications regarding coordination costs and future value of interactions, we should expect that future value of interactions always lowers current project bids ($\beta_3 < 0$) and that 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 ($\beta_2 < 0$). In the next section, we test these predictions.

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 (1) 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 one-third and becomes statistically indistinguishable from zero. This suggests that relationships have no value when the continuation value of the relationship is zero.¹² 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 another underlying hidden heterogeneity that is correlated with more aggressive bidding but has nothing to do with the self-enforcing informal agreement between contractor and subcontractor that we present. In Table 6, we present yet another set of results that tries to show that more aggressive bidding is driven by our explanation of stronger self-enforcing

¹²It is also potentially informative to examine the direct effect of future contract interactions, as the firm need not have prior relations with a firm to form a self-enforcing informal contract. We do find that greater future contracting opportunities is associated with a lower bid on the project. We are concerned with interpreting this coefficient however, since it may also reflect dynamic considerations if there is learning-by-doing or other forms of spillovers across projects such location-specific fixed costs.

agreements between contractors and their subcontractors. For this purpose, we divide the number and value of future contracts between 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. Our results in Table 6 show that only the number and volume of future contracts within a year of the current period matters and lowers the current bid of contractors. The fact that future contracts that are further away in time do not matter is not surprising since contractors and subcontractors are less likely to be aware of their existence so far in advanced and shows that there is no underlying correlation across periods and districts driving our results in Tables 4 and 5.

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 subcontractor relationships, we consider how unequally distributed a firm's interactions are across subcontractors. For this purpose, we take the simple approach of quantifying the share of interactions held with the most frequent subcontractor for each contractor. 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 in the project district.¹³

¹³It is not possible to measure interactions with listed subcontractors, as this is only observed for participating firms.

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, Table 9 analyzes the subcontractor choice by a contractor for a given project. As with the specifications 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.

One concern with this specification we worry about is the fact that subcontractors are chosen in the basis of lower joint construction and coordination costs. Since we do not observe construction costs if these are correlated with coordination costs and therefore with relationship stocks we may obtain biased estimates of the effect of past interactions on subcontractor utilization. For this purpose, we use two variables that are correlated with subcontractor cost. One is an indicator of whether other bidders also use the same subcontractor reflecting the (otherwise) hidden subcontractor cost advantage. The other is an indicator of whether the project takes place on the subcontractor's headquarter district. As explained before, travel distance is a big part of the final cost of the project and therefore closer to the project subcontractors 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 it wipes out the effect of past interactions variable when standing alone. We also examine the effect of past and future interactions on auction participation and find qualitatively similar results. These findings come to 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 for two main reasons. Prior empirical literature in relational contracting has tended to use past interactions as a proxy for future interactions. Our result here demonstrates that such strategy could lead to potentially wrong conclusions. Our result is also important because it becomes the first test, to the best of our knowledge, that confirms the importance of future interactions holding constant past and present characteristics of the agents involved in a transaction and the transaction itself.

As we examined in this paper the impact of past and future interactions on bidding behavior, auction participation and subcontractor choice, future research should extend present work to study the efficiency implications of these effects. Specifically, gains from past and future interactions may drive contractors to choose subcontractors with not the lowest task production costs. This may increase overall construction costs if most efficient subcontractors lack stock of past relationships and therefore decrease efficiency in this sector due to the potential moral hazard problem. Future work should document how pervasive this problem is and quantify what the potential gains are.

We feel that this research opens the door to the empirical study of how relations among firms work and help their daily actions. Future research efforts should be conducted to understand further this topic.

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Figure 1: Timing of model

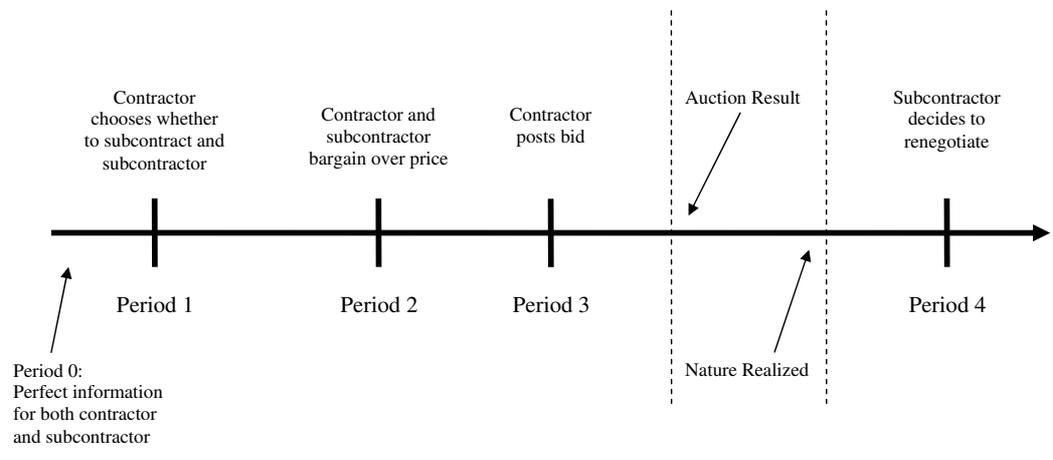


Figure 2: Caltrans districts



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					
<i>All prime contractors</i>					
Total wins	6.36	2	17.31	1	407
In primary district	0.82	1	0.25	0.2	1
N	805				
<i>Greater than one win</i>					
Total wins	10.12	4	21.82	2	407
In primary district	0.69	0.67	0.26	0.2	1
N	473				
Subcontractors					
<i>All subcontractors</i>					
Part. in winning bid	9.54	2	37.03	1	932
In primary district	0.84	1	0.25	0.13	1
N	2076				
<i>Greater than one participation</i>					
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

<i>Dependent variable: Log of bid</i>	(1)	(2)	(3)	(4)	(5)
Log stock of subs. in district	-0.009 (0.002)***	-0.009 (0.003)***		-0.003 (0.004)	-0.002 (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 (0.002)	0.030 (0.005)***	0.029 (0.005)***	0.031 (0.005)***	0.031 (0.005)***
Log # wins in project county	-0.012 (0.003)***	-0.008 (0.003)**	-0.007 (0.003)**	-0.007 (0.003)**	-0.008 (0.003)**
Log backlog	0.000 (0.000)	0.001 (0.000)***	0.001 (0.000)**	0.001 (0.000)***	0.001 (0.000)***
Bidders	-0.008 (0.001)***	-0.010 (0.001)***	-0.010 (0.001)***	-0.010 (0.001)***	-0.010 (0.001)***
Log(items)	0.014 (0.004)***	0.024 (0.005)***	0.024 (0.005)***	0.022 (0.005)***	0.022 (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 (0.003)***	0.946 (0.003)***	0.946 (0.003)***	0.944 (0.003)***	0.945 (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 (0.003)***	-0.011 (0.003)***		-0.005 (0.004)	-0.002 (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 (0.002)	0.035 (0.005)***	0.033 (0.005)***	0.036 (0.005)***	0.036 (0.005)***
Log past wins in project county	-0.014 (0.003)***	-0.010 (0.003)***	-0.010 (0.003)***	-0.010 (0.003)***	-0.010 (0.003)***
Log backlog	0.000 (0.000)	0.001 (0.000)**	0.001 (0.000)*	0.001 (0.000)**	0.001 (0.000)**
Bidders	-0.009 (0.001)***	-0.010 (0.001)***	-0.010 (0.001)***	-0.010 (0.001)***	-0.010 (0.001)***
Log(items)	0.017 (0.004)***	0.025 (0.005)***	0.025 (0.005)***	0.022 (0.005)***	0.023 (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 (0.003)***	0.948 (0.003)***	0.948 (0.003)***	0.946 (0.003)***	0.948 (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 (0.001)*		-0.003 (0.001)**	
Log # future contracts < 1yr		-0.011 (0.004)**	-0.011 (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 (0.007)**	0.015 (0.007)**	
Log stock*Log future contract \$ < 1yr (X100)		-0.044 (0.022)**		-0.063 (0.024)***
Log future contract \$ < 1yr		-0.148 (0.084)*		-0.134 (0.081)*
Log stock*Log future contract \$ 1-2 yrs		-0.006 (0.029)		0.002 (0.031)
Log future contract \$ 1-2 years		0.263 (0.183)		0.243 (0.182)
Log stock	-0.004 (0.005)	-0.001 (0.006)	-0.007 (0.005)	-0.002 (0.006)
Constant	0.626 (0.216)***	0.608 (0.214)***	0.828 (0.055)***	0.795 (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

<i>Dependent variable: Log of bid</i>			
	(1)	(2)	(3)
Top sub. share*Log stock in district	-0.011 (0.006)*	-0.021 (0.013)*	-0.017 (0.015)
Log stock in district	-0.007 (0.003)**	0.001 (0.005)	0.001 (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 (0.213)***	0.571 (0.209)***	0.561 (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 (0.001)***	0.008 (0.001)***		-0.004 (0.001)***	-0.004 (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 (0.001)***	-0.000 (0.002)	-0.021 (0.005)***	-0.002 (0.002)	-0.001 (0.002)
Log past wins in project county	0.068 (0.001)***	0.068 (0.002)***	0.066 (0.002)***	0.069 (0.002)***	0.068 (0.002)***
Log backlog	-0.056 (0.011)***	-0.014 (0.012)	-0.018 (0.017)	-0.011 (0.012)	-0.012 (0.012)
Bidders	0.001 (0.000)**	0.001 (0.000)**	0.001 (0.000)	0.001 (0.000)***	0.001 (0.000)**
Log(items)	0.009 (0.001)***	0.009 (0.001)***	0.013 (0.001)***	0.010 (0.001)***	0.009 (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 (0.001)***	0.006 (0.001)***	0.009 (0.001)***	0.006 (0.001)***	0.006 (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 (0.041)***	2.762 (0.044)***	2.061 (0.035)***	1.690 (0.106)***	2.246 (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 (0.005)***	0.321 (0.005)***	0.322 (0.005)***
Project in sub.'s primary district			0.016 (0.000)***	0.016 (0.000)***	0.016 (0.000)***
Log past wins (X100)			-0.064 (0.036)*	-0.073 (0.036)**	-0.064 (0.036)*
Log past wins in project county (X100)			-0.036 (0.011)***	-0.036 (0.011)***	-0.036 (0.011)***
Number of bidders			-0.042 (0.004)***	-0.042 (0.004)***	-0.042 (0.004)***
Log engineer's estimate			0.039 (0.011)***	0.038 (0.011)***	0.038 (0.011)***
Number of workdays			0.000 (0.000)***	0.000 (0.000)***	0.000 (0.000)***
Log number of items (X100)			0.363 (0.020)***	0.363 (0.020)***	0.363 (0.020)***
Log backlog (X100)			0.004 (0.003)	0.004 (0.003)	0.004 (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.