Self-Enforcing Agreements and Relational Contracting: Evidence from California Highway Procurement

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Abstract

We empirically 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 arising from contractual incompleteness. An important characteristic of informal contracts is that they must be self-enforcing, so 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, most importantly, an exogenous instrument to measure the future value of ongoing relationships that is orthogonal to contractor-subcontractor match specific productivity. We find that a larger stock of relationships leads to a greater likelihood of entry and to lower bids. Importantly, this relationship does not hold in periods of time and areas with little future contract volume, suggesting that the value of the future is crucial in providing value for informal contracts.

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1 Introduction

Relational contracting has long been considered an important component of the interaction between firms and their suppliers. The close relationships that firms have with their suppliers allow them to support 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.

A growing empirical literature establishes the prevalence of 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] 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 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. Future business thus ceases to have value in solving the information asymmetry problems that formal contracting, for whatever reason, could not address, including potentially moral hazard or hold-up.

In this paper, we empirically examine the effect of past and future relationships between contractors and subcontractors in the highway construction market on bidding, auction participation, and subcontractor choices. In contrast to the extant literature, we empirically evaluate the role of the continuation value of the contractor-subcontractor relationship. The highway construction market is a particularly appealing setting to study this issue. In many other settings, the observed continuation value is endogenous to the productivity of the firm-supplier match, as more successful relationships lead to a higher volume of future business. This gives rise to a reverse causality problem, as the measured volume of future business is related to lower prices in the current period for reasons unrelated to the enforcement of informal contracts. In contrast, our empirical analysis introduces an exogenous measure of the continuation value of ongoing relationships between contractors and subcontractors that quantifies the arrival rate of public highway construction projects in any given geographical area within a year of the auction. The arrival rate of projects in a geographical area is driven by transportation needs and is likely orthogonal to the productivity of the contractor-subcontractor match. Hence, the introduction of this truly exogenous instrument for the value of future relationships is a major contribution of this paper.

Most of the literature in this area measures relationships by the stock of prior interactions between a firm and its supplier. 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 (Corts and Singh, 2004). However, prior relationships may also have value through improving relationship specific productivity unrelated to contracting, such as by mitigating coordination costs and enhancing learning by doing (Kellogg, 2008) or developing reputations (Banerjee and Duflo, 2000). Therefore, it is useful to more directly measure both the stock of prior interactions and the continuation value of the relationship.

We begin our analysis by describing the source of contracting difficulties between contractors and subcontractors. When subcontracting, bidders choose a subcontractor in part based on subcontractor-specific coordination costs and the future value of their relationship. Whereas past interactions with a subcontractor may diminish current coordination costs, the prospect of future interactions is expected to deter subcontractors from engaging in moral hazard behavior. Thus it lowers the cost of subcontracting and it enhances the value of present activities. We predict that the higher the number of past interactions and the expected number of future interactions, the lower the costs of subcontracting and therefore the lower the bids posted by the contractor and the greater likelihood of auction participation.

We evaluate the empirical validity of these predictions 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 contractors, 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.

In the key result of the paper, we show that these estimated effects of relationships on bidding, entry, and subcontractor utilization depend on the extent of future business. We interact prior relationships with the number and dollar value of upcoming Caltrans's contracts within the geographic market. If no contracts are up for bid within the following year, the value of the stock of prior relationships on bidding is statistically indistinguishable from zero. However, the greater is the extent of future business, the more prior subcontractor relationships lower a firm's bid. Importantly, only upcoming projects occurring within one year matter, which is consistent both with firms having better information regarding these projects and with discounting. Finally, we find that the impact of relationships is particularly important for projects where subcontractors play a more important role.

We also rule out several alternative explanations for our empirical findings. First, future contracts could increase entry into the highway construction industry. Second, future contracts could increase the value of contractor-specific investments, perhaps through learning-by-doing or other spillovers across projects, which could drive bids down in the current period. Third, more subcontractor-intensive firms may be able to participate in more auctions, and at the same time be more efficient and submit lower bids. We show that the number of highway construction establishments does not respond to the amount of future business, which is not surprising in light of the short-run barriers to entry into the market. Furthermore, we examine subcontractor-intensive firms, and find that these firms do not bid lower, either in general or in times when there is significant future business. Lastly, we estimate two different models accounting for selection, and find that if anything our results become stronger.

The paper is organized as follows. We describe first in Section 2 the relevant literature and specify what is the contribution of this paper within it. Section 3 describes the institutional details and section 4 presents a theoretical discussion of the contracting costs that contractors face when using subcontractors. In section 5, we describe the data. In section 6 we discuss our empirical methodology and present our results. 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 on procurement and construction contracts specifically.

2.1 Literature on Implicit and Relational Contracting

The role and importance of informal agreements is sometimes dwarfed 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 an important subject of study for some time now. Klein and Leffler (1981) were among the earliest contributors on this topic followed by others, such as Bull (1987), Klein and Murphy (1988), Baker, Gibbons and Murphy (1994), Klein (1996) and more recently Board (2008) and Halac (2008). This literature studies the emergence of informal contracting when formal contracting may yield suboptimal outcomes. These theories revolve around two main points. First, they approach the question of whether informal agreements and formal contracts are complements or substitutes as well as whether the latter will emerge when the performance of the former proves to be dissatisfactory (see Poppo and Zenger (2002) and Lazzarini, Miller and Zenger (2004) respectively for motivating evidence). Second, their sustainability hinges on the capacity of participating parties to enforce these agreements via gains derived from future interactions.

The appeal of this latter 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 include studies of topics as diverse as subjective pay performance (Baker, Gibbons and Murphy (1994)), quality provision (Klein and Leffler (1981)), the boundaries of the firm (Baker, Gibbons and Murphy (2002)) and procurement contracting (Calzolari and Spagnolo (2009)), and industries as varied as oil drilling (Corts and Singh (2004)), information technology widely defined (Kalnins and Mayer (2004), Ryall and Sampson (2009), and Shi and Susarla (2010)), dry cleaning (Gil and Hartmann (2011)), taxicabs (Jackson and Schneider (2011)) and movies (Gil (2011)).

A separate, related, literature focuses on prior interactions and their effect on contracting outcomes. Papers such as Banerjee and Duflo (2000) or Crocker and Reynolds (1993) use the number of prior interactions as reputational measure that allows for savings in ex-ante contracting costs and defer any discussion regarding the role of continuation value of relationships. Banerjee and Duflo (2000) in fact present a simple model of contracting that rules out explicitly any role of continuation value and highlights reputational effects. On the other hand, McMillan and Woodruff (1999) and Corts and Singh (2004) among others use the number of prior interactions as a measure of future interactions, which mixes the current cost of contracting with the continuation value of relationships. Our paper differs from these two strands of the literature in that we focus our analysis on the role of continuation value with an exogenous measure with time and geographical variation while allowing the impact to differ according to prior interactions. Ours, together with Macchiavello and Morjaria (2011), is among the very few papers that account for variation in continuation value and the stock of prior interactions and exploit plausible exogenous sources of variation that allows for the study of the role and impact of relational contracting.

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), who 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), Bajari, McMillan, and Tadelis (2008) and Bajari and Lewis (2009), who examine theoretically and empirically procurement in the construction industry. 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, subcontracting tends to be unobserved by the econometrician and is therefore omitted. Our paper focuses on these two aspects specifically.

A number of papers have examined California highway procurement auctions. In particular, Bajari, Houghton and Tadelis (2006) consider the role of incomplete contracts and ex post adjustments, and Krasnokutskaya (2003) estimates a structural auction model in the presence of unobserved cost heterogeneity. Other papers examine the effect of preferential programs in these auctions on both auction participation and bidding behavior. Examples include Krasnokutskaya and Seim (2005), and Marion (2007, 2009). Our paper differs from these and others in that it focuses on the subcontracting strategies for contractors bidding for highway construction projects and estimates the consequences of repeated interactions with subcontractors in affecting contractor performance in these auctions.

We also need to acknowledge, and differentiate from the current paper, two recent contributions that study closely related topics to ours. 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 past interactions on the productivity of well drilling in Texas. Our paper differs from these in that we focus on the role of future contracting possibilities as a way to mitigate moral hazard problems. Our empirical findings demonstrate that in the setting of California procurement auctions even though past repeated interactions are correlated with lower bids it is the future value of projects in an area that drives down bids of contractors. These findings are consistent with the continuation value of ongoing relationships being the main factor that drives down those bids.

Finally, this paper also relates to an economic literature on the construction industry proper. 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 from their subcontracting strategies, and we provide evidence on how repeated subcontracting may enhance contractor 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 specifics of the project. A contractor can bid on any project in the category of work for which it has been prequalified. This prequalification is based on the firm's equipment, training, licensing, and past work history.[2] For each project, the engineer provides a list of the items required to complete the project and the quantities of each item.[3] The bidder then provides a unit price for each item, and its total bid is based on the sum across items of the unit price by the quantity.

In its bid, the contractor 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. The other important restriction regarding subcontracting that was in place 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 certain percentage of contract dollars to Disadvantaged Business Enterprises (DBEs), namely subcontractors owned by minorities and women.

While Caltrans attempts *ex ante* to specify the relevant details of the work, 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 regarding this, we expect that these change orders also alter the scope or scale of the subcontractors' tasks in ways difficult to specify *ex ante*.

4 Theory Discussion

In this section, we discuss the theoretical underpinnings of our empirical work. A more detailed model is contained in Appendix 1. A road construction contractor potentially faces significant problems related to moral hazard and incomplete contracting when hiring a subcontractor to perform a portion of the project. A prime contractor may wish to induce the subcontractor to undertake actions that may be unobservable by a third party, yet known to both the contractor and the subcontractor. Increasing the quality of the goods provided by the subcontractor, perhaps through the timeliness of completing her portion of the project, is one such action that could lower the cost of the prime contractor. Since switching subcontractors in the middle of a contract is potentially costly, subcontractors have an incentive to provide suboptimal quality. To take advantage, the subcontractor can either lower its cost by reducing quality, or demand extra payment from the prime contractor through a renegotiation.

An additional complication with contracting in this industry is the need to cope with unforeseen circumstances. Often, a construction project differs from the original design due to conditions that are unobservable at the time of the design of the project. If these circumstances are significant, it may require a renegotiation of the contract between Caltrans and the contractor, presumably as well as the contracts between the prime contractor and its subcontractors. This renegotiation is costly, and in the presence of switching costs may lead to hold-up opportunities for the subcontractor.

An informal contract, enforced using the continuation value of the relationship, can be used to specify the correct action to be taken by the subcontractor. Since contractors recognize that subcontractors value future business opportunities, contractors use informal contracts that condition future streams of revenue to good performance in current projects. These informal contracts will then align incentives between a contractor and her subcontractors and solve or attenuate the moral hazard and hold-up problem presented above.

Leveraging the value of future contracts lowers the cost of subcontracting, which in turn leads to lower bids on auctions in which contractors participate. Similarly, since the choice of subcontractor and auction participation is not random, prime contractors will prefer to subcontract tasks to subcontractors with whom the continuation value of the relationship is highest. Finally, the cost of subcontracting influences the cost of completing a project, and therefore the likelihood that the firm's expected profits exceeds the cost of entry into an auction. As a result, in situations where the firm has a pool of available subcontractors with a high continuation value, the firm is more likely to enter the bidding for the auction.

Contractors and their subcontractors utilize relationships to enforce contracts, but relationships may also have value in other dimensions. The productivity of a given contractor-subcontractor match is likely to depend in part on the degree of prior interactions. Coordinating the efforts of members of the supply chain is important, as work-flow is important in the highway construction industry. As firms work together more, coordination costs decline through learning-by-doing. Also, the contractor and subcontractor may learn about each other's productivity over the course of working together.

One challenge in formulating testable implications is that the continuation value may alter outcomes in the current period for reasons unrelated to enforcing informal contracts. Since the continuation value of a relationship is correlated with expected future contracting opportunities, it may be associated with firm entry, which potentially lowers the equilibrium price charged for road construction services. Furthermore, firms may invest in relationships when future business is anticipated to be significant.

For the reasons just described, both past interactions and future business opportunities may affect bidding, auction participation, and subcontractor choice in the current period through channels aside from informal contract enforcement. Rather than examine the effect of the stock of relationships or future opportunities separately, our focus will be on the interaction of the two. We will investigate whether existing relationships are more valuable in the presence of future contracting opportunities. The interactive effect is sensible since, as we argued above, repeated interactions between firms and their suppliers lead to greater productivity, perhaps due to lower coordination cost. This suggests that in future projects, a firm is more likely to hire a subcontractor with which it has a relationship, and this match is more likely to both win future auctions and earn higher profits on those projects it wins. Thus, the continuation value is highest when there are both more future contracts, and when a firm has more relationships established with its suppliers.

The two issues described above, those of future opportunities inviting entry and encouraging relationship investment, are silent regarding the coefficient on the interaction term between past relationships and future business. The first story regarding an increase in competition offers no prediction about whether the effect should differ across contractors that hold different relationships with their subcontractors. Similarly, the second story regarding stronger incentives to invest in their current subcontracting relationships has no implications for the correlation between the interaction of past interactions and continuation value and bids posted.

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 project, 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 the 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 and past bids on similar projects. For every general contractor submitting a bid, the value of the bid and a list of subcontractors is given.[4] Caltrans assigns a unique identifier to each firm, so it is possible to track contractors across contracts. In addition, we assign unique identifiers to subcontractors based on the names.[5] 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 subcontractors.

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, our measures will tend to understate the stock of relationships between contractors and subcontractors, the extent of future opportunities, and the degree of project backlog. This is likely to reflect measurement error, which, if independent of the variables of interest, will merely attenuate the estimated coefficients.

It is worth considering when the measurement error will not be independent. First, the flow of local projects could be positively correlated with the flow of state projects due to complementarities between local and state highway improvements. On the other hand the correlation could be negative if local jurisdictions account for the adverse effect state projects have on the capacity of local contractors. The correlation between state and local future opportunities could either be positive or negative. Second, at the contractor level, a firm that wins a state contract may be capacity constrained, making it less likely to win local contracts. Furthermore, some contractors might specialize in state contracts rather than local, also leading to a negative correlation between state and local contracts won. Therefore, our estimates of the effect of the stock of a firm's relationships is likely to be be biased toward zero due to a negative correlation with the error term.

A second issue is that our data is truncated in May 1996. Thus we are unable to form measures of prior relationships and project backlog that include projects prior to this date. The initial stock of relationships using contractor fixed effects will account for much of the variation across firms in the initial stock of relationships. While we do not have the degrees of freedom to consider the full set of contractor*subcontractor fixed effects in the bid regression, one robustness check we considered was to include contractor*district effects, which account for the initial stock of relationships firms have in a particular district. Our results turn out to be robust to the inclusion of these 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 subcontractor switching occurred after the awarding of the project. The former is a problem depending on the form of the production function of relationships. If relationships are related to the intensity of utilization, then this is less of a problem than if relationships depend only on whether or not two firms have interacted.

In Table 1 we present summary statistics for our main variables. In Panel A, we describe auction characteristics. The average auction has 5.15 participants. 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 ranges 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 work items.

In Panel B, we describe the observed bids. The average observed bid is $3.12 million, closely matching the average engineer's estimate. On average, the bids are 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 contractor 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 the winning bids. While the average bidder submitted a bid nine percent above the engineer's estimate, the average winning bid was four percent under the engineer's estimate. Winning bids are not more or less apt to subcontract, as they include virtually the same number of subcontractors as the broader population of bids. Winning contractors 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 the contractor' greater number of past wins.

In the empirical analysis below, we consider the entry and subcontractor utilization decisions of the largest firms in the industry. We limit that part of our analysis to the largest firms because of problems with degrees of freedom when we include all participating bidders. Also, the actions of this subsample of firms provide enough variation to examine the issues of 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 our work, we next describe the concentration of the market across contractors and geographical areas.

In Table 2 we show the top twenty contractors in terms of contracts won.[6] The industry is remarkably unconcentrated, with the largest 20 accounting for only 28 percent of contracts won. Granite Construction, to our knowledge, is the only publicly traded company in the data. It wins the most auctions, capturing nearly eight percent of contracts, and 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 may mask a potentially significant degree of geographic concentration. Costs have been found to rise significantly with distance in this industry (see for instance Bajari and Ye, 2003). One might expect that in a large state like California, relevant markets are more local. In our analysis below, we consider a definition of the relevant market using Caltrans districts, of which there are 12. Figure 1 displays a map of the districts of California laid over 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 contractors operate within one district. In this table, we show the average number of wins of contractors who win at least one contract and the fraction of those wins that came in the contractor's primary district.[7] We see that the average contractor wins 6.4 auctions, 82 percent of which are in its primary district. Since this may be skewed due to the significant fraction that win only one contract, we also restrict attention to those that win more than one contract. Of these, 69 percent of auction wins are from within the contractor'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 contractors. Similarly, if we restrict attention to subcontractors that participate more than once, 67 percent of utilizations occur within the primary district. Subcontractor operations therefore seem to be quite geographically concentrated, but interestingly no more so than those of contractors.

6 Empirical Methodology and Results

6.1 Empirical Methodology

In this section, we describe how we investigate the role of relationships between contractors and their subcontractors. We will use two definitions of relationships. First, we consider the number of interactions a bidder has had on prior completed contracts with each subcontractor listed in its bid. In our second measure, we define the relevant set of subcontractors as those headquartered in the same Caltrans district as the current project. The advantage of the first measure is that it focuses on the relationships with subcontractors most relevant for the current project. The second measure could also be justified. If a firm has a valuable relationship with a subcontractor in the district, yet a different subcontractor was chosen for the project, it reveals that the chosen subcontractor had some cost advantage on that particular contract. It is still the case, however, that the relationship has value, and that a firm with strong relationships within the district will on average have lower costs.

We then utilize these measures of the stock of past interactions with subcontractors, s_{ik}, for contractor i on project k, in a regression of the form

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

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 the observations is 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.[8] 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 systematically higher when facing short run capacity constraints (see Jofre-Bonet and Pesendorfer, 2003).

Finally, as previously mentioned, 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 is 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. One approach to measuring the continuation value of a relationship at a given point in time would be to sum the value of actual future interactions between the contractor and subcontractor. While in many settings this may be the only available approach, it is problematic in that the degree to which a pair of firms works together depends on the quality of the match and would therefore be endogenous – a successful match would lead to both lower bids now and more interactions in the future.

Instead we use the total number of future contracts, f_{ik}, auctioned off by Caltrans within a district as our measure of future interactions. This measure will be correlated with the number of future contracts on which a contractor-subcontractor pair may work together but is still uncorrelated with their specific productivity match since it is determined by district-level transportation needs and budgeting process. We introduce this measure into the empirical specification by itself and also 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 rationally anticipate future capacity constraints brought on by winning the current auction, 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.

Controlling directly for future contract volume accounts for several possible confounding factors. First, anticipated future contract opportunities may invite the market entry of potential subcontractors in the current period. The thicker market for subcontracting could lower costs for bidders if it leads to lower prices for items typically subcontracted. Second, if learning by doing is important, then the effect of learning on future costs will be in part priced into the current bid. A period of high anticipated contract volume creates an incentive for a firm to win contracts now to lower costs for future contracts. Nevertheless, the current shadow price of capital may increase and therefore current bids may increase. Overall, the sign of the direct effect of future contract volume is ambiguous.

We are also cautious in interpreting the estimated coefficient β_1. As discussed in Section 4, prior relationships could have value outside of contract enforcement. This would be true if the coordination costs between a firm and its suppliers goes down with repeated interaction, or if learning-by-doing allows them to work together more efficiently.

6.2 Results

6.2.1 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 equation (1) using as a measure of relationships the prior interactions with subcontractors listed in the current bid. 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. This result is consistent both with the existence of learning by doing and with our prediction that a higher number of past interactions between contractor and subcontractor will lower bids. Similarly, note that experience, as measured by the total number of projects that a contractor has won in the past within the same county, is negatively correlated with the bid posted. This result is also consistent with general (non-specific) learning by doing on the contractor side. The effects of other covariates 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. Also, competition lowers prices, as each opposing bidder reduces the firm's bid by around one percent. We also find that while past wins are positively associated with bids, past wins within the project county are negatively associated with bids. It is not surprising that experience would improve productivity and lower costs, but it is interesting that the coefficient on prior wins is in fact positively associated with a firm's bid. One explanation is that, since we have conditioned on firm wins inside the county, more firm wins overall indicates a firm that has a focus in other regions of the state.[9]

In column 3 of Table 4, we examine whether the age of the relationship matters by separating past interactions occurring within the past year into three month intervals, and also separately considering those contractor-subcontractor interactions occurring more than one year prior to the auction date. 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. To interpret this result we must take into consideration the fact that the average project is estimated to last 163 days and therefore it is not surprising to observe that it takes more than 6 months to learn about the productivity of the listed (and used) 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 at least one-half and becomes statistically indistinguishable from zero. This suggests that relationships have little value when the continuation value of the relationship is zero. This result is consistent, in general, with the implications from the relational contracting literature. The coefficients of all the other covariates remain unchanged in magnitude and statistical significance when we include the number and value of future interactions.

To assess the magnitude of the gains of past relationships, and how they depend on the degree of future business, consider a one standard deviation increase (a value of 1.228) in the stock of relationships variable. Using the coefficients presented in column 5, this increase results in a reduction of 0.89 percent when the future contract volume is one standard deviation below its median and 1.9 percent when future contract volume is one standard deviation above its median. Evaluated at the value of the average winning bid of $3.17 million, these percentage improvements in the winning bid represent $28.0 thousand when the continuation value is relatively low and $60.7 thousand when the continuation value is relatively high. A useful way to gauge the magnitude of the marginal effect is to consider how it affects the likelihood of winning the auction. The average firm has a 16.15 percent chance of submitting the low bid. A firm that reduced its bid by 1.9 percent would increase its likelihood of being the low bidder by 5.7 percentage points, or around one-third.

In Table 5, we present similar estimates using an alternative measure of the stock of relationships, past interactions with the subcontractors whose headquarters are within the project district. 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.

Relationships should be most valuable in projects where subcontracting is more important. When a project requires less subcontracting, less advantage is conferred on those firms who are able to subcontract at a lower cost. To investigate this, we allow the coefficient β_2 to vary across projects depending on the number of specialty items required. Specialty items are designated by Caltrans and require capabilities that the typical prime contractor does not possess. These must normally be subcontracted out. In Table 6, we establish the relationship between the number of specialty items and the utilization of subcontractors. In these specifications, we regress the number of listed subcontractors on the number of specialty items listed in the contract by Caltrans. We see a positive and statistically significant relationship, where each additional specialty item is associated with an additional 0.15 subcontractors. Furthermore, 42 percent of the variation in the number of subcontractors across bidders is explained by the number of specialty items alone.[10] The estimated coefficient is little changed with the inclusion of firm fixed effects, so the correlation is not likely due to the sorting of more subcontractor-intensive firms into projects with many specialty items. In the final column, we include a full set of controls. This reduces the estimated coefficient to 0.07, likely due to the inclusion of the number of contract items, which is correlated both with subcontractor demand and the number of specialty items.

Having established that specialty items strongly influence the demand for subcontractors, we next examine whether the effect of continuation value depends on the importance of subcontracting. The median project requires seven specialty items. We therefore break our data into three parts and run our main specification above for projects that list no specialty items, projects that list between one and seven specialty items, and projects that list more than seven specialty items. We present our findings in Table 7. The results suggest that the interaction between the stock of relationships in the project district and future contracts in a district has a statistically significant effect on posted bids only when the number of specialty items is above the median.[11] This is a useful result, as it establishes a more direct link between subcontracting and our measure of continuation value. Consequently, these results point away from alternative explanations that rely on a spurious correlation between future contracts and current bids, for instance due to unobserved variables that happen to be correlated with our interaction term. These unobserved variables would need to be relevant only for projects with high numbers of specialty items.

Timing of future contracts

One may worry that our measures of future business volume may capture unobserved differences between high- and low-volume areas that are correlated with more aggressive bidding but have nothing to do with the self-enforcing informal agreement between contractor and subcontractor. One way to address this concern is to consider the timing of the arrival of future contracts. The timing of the arrival of projects is relevant for self-enforcing agreements since there is less advance knowledge of projects in the distant future. Also, discounting makes these projects less important in the continuation value of the relationship, and there is also an element of uncertainty regarding how the contractor-subcontractor relationship will evolve in the intervening time.

In Table 8, we present the results of estimating specifications where we distinguish future contracts taking place within one year of the current period from those taking place between one and two years from the current period. Our results show that only the number and volume of future contracts within a year of the current period matter and these lower 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 advance and shows that there is no underlying correlation across periods and districts driving our results in Tables 4 and 5.

Relationship depth

Thus far, our results do not shed light on the role of the depth of relationships between contractors and subcontractors. The two measures of subcontractor relationships do not distinguish between contractors who have developed a deeper relationship with a particular subcontractor and contractors whose relationships are spread more evenly across subcontractors. To investigate the role of relationship depth, we consider how unequally distributed a firm's interactions are across its subcontractors. For this purpose, we examine the share of a contractor's subcontractor interactions in a district that are held with its most used subcontractor.[12] Conditional on the total stock of relationships, this measure will indicate whether it is more valuable to concentrate these relationships among a few suppliers or spread them among many suppliers. We then form a triple interaction between this variable, the firm's total stock of relationships, and future business opportunities. From this, we can tell whether the self-enforcement value of future business is more important for deeper relationships.

Results in Table 9 suggest that the stock of prior relationships is more valuable when concentrated with one subcontractor. However, concentrating to 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 interactions with a few suppliers may lower bids through lower coordination costs, while relationship depth is not important for self-enforcement.

Other Alternative Explanations

Earlier in the paper, we discussed two other alternative explanations. First, an increase in the number of future contracts in a district could increase contractor entry in that district and consequently drive bids down mainly due to a competitive effect. Second, an increase in the number of future contracts could push firms to invest in their current relationships as there will be future opportunities to recover that investment. This investment comes in the form of lower bids as contractors and subcontractors may want to acquire experience together in the current period to perform at lower costs in the future.[13]

As explained in the theoretical discussion and methodology sections, both these alternative explanations would yield a negative coefficient on the variables measuring continuation value. Importantly, however, they do not make any predictions regarding the coefficient on the interaction term. The first story regarding an increase in competition offers no prediction about whether the effect should differ across contractors that hold different relationships with their subcontractors. The second story regarding stronger incentives to invest in their current subcontracting relationships also has no implications for the interaction of past interactions and continuation value and bids posted. As a matter fact, this second story would predict that as firms invest in their relationships firms get better at working with each other and therefore the impact of past interactions would not disappear when there are no future contracts at stake.

Moreover, we have obtained information on the number of firms in California in the highway and street construction sector from the County Business Patterns. As we show in Table A1 in Appendix 2, future contracts do not seem to be correlated with entry of firms in this sector. In this table, we also consider whether the number of contemporary Caltrans contracts is correlated with entry, finding no evidence to that effect once again after controlling for district fixed effects. This holds once we account for district fixed effects, which is necessary since larger districts both have more construction contracts as well as more firms. In columns 7-10 of this table, we also consider whether changes in contract volume is associated with changes in establishments. As shown in columns (1) and (7), there is a correlation between current and future contract growth and the current number of establishments, however this does not hold once we control for year effects. Together, these results suggest that there are periods of time where road construction funding is growing statewide that may induce entry, however this is not true across regions in the same year. Given that our empirical strategy in this paper conditions on year effects and therefore utilizes variation in future contract volume across areas, we can conclude that entry is not a driving factor in our results.

A potential third alternative explanation has to do with the selection of contractors into auctions for larger projects that require more subcontracting. Certain types of contractors might be better at dealing with a larger number of subcontractors and also dealing with more than one project at a time. This kind of selection would also yield the negative correlation that we find in our results between bids and the number of prior interactions between the contractor and their listed subcontractors. Further, it is conceivable that the magnitude of this productivity difference varies across projects and time in ways that are conveniently timed with the increase in future contracts at the district level. To explore the empirical impact of this type of selection, we measure a firm's propensity to subcontract as its average subcontractor utilization across the projects in which it participates. We then introduce this new variable in our regressions, along with its interaction with the log of future contracts. Results in Table 10 show that average subcontractor utilization has no statistical impact on bids and, if anything, subcontractor intensity is positively correlated with the log bid. The results in columns (2) and (3) show that the effect of the interaction of subcontractor intensity with future contracts is not statistically significant. Furthermore, we show in column (4) that the inclusion of this interaction has no impact on our coefficient of interest. This evidence shows that our main results are not driven by contractor selection characterized by a lower cost of subcontracting and simultaneously dealing with a large number of subcontractors and projects.

6.2.2 Participation decision

Next we consider the role of subcontractor relationships on the entry decisions of firms. Reducing contracting costs via the continuation value of a firm's relationship with its subcontractors raises expected profits conditional on entry, and therefore increases the likelihood that expected profits clear the fixed cost of entry. Therefore, more valuable relationships should raise the likelihood of auction entry, and to test this we will first estimate a linear probability model of auction participation similar to the bid regression specified by equation (2).

As we will show in this section, auction entry responds to relationship continuation value. This highlights a potentially important issue for our bid results. Auction entry is endogenous even though we have treated the pool of auction participants as exogenous in the bid regressions. The typical selection story would suggest that our uncorrected OLS estimates are attenuated. If relationships lower bids, they lower the bids of a firm that would have otherwise participated, but more valuable relationships also draw into the bidding a marginal firm that would have otherwise not participated. The group of bidders with strong relationships may therefore be weaker in other respects. Presumably other more complicated selection stories could work in the opposite direction.

In this section, we address this issue, taking two approaches to correct for endogenous entry. First, under some assumptions, theory suggests that the highest bidding firm is the marginal entrant. A general finding in the literature is that bidding functions are monotonic, and expected profits decline as costs rise. With a fixed cost of entry, this implies a cutoff cost above which firms choose not to enter.[14] We therefore expect that the bids we do not observe due to firms' decision not to participate are all higher than the bids we do observe. Therefore, the latent distribution of desired bids of all potential entrants can be thought of as censored at the maximum observed bid, which suggests a tobit specification. The tobit specification will account formally for the possible attenuation mentioned above.

A second approach to addressing endogenous entry in a more general fashion is to estimate a two-step Heckman selection model. Doing so requires an instrument for participation, or else identification comes only through distributional assumptions. The auction participation setting is particularly challenging. Firms enter when expected profits clear the fixed cost of entry, yet expected profits are driven by firm costs. Therefore, a valid instrument must shift only the entry cost, as any other factor that shifts entry will necessarily operate through costs and therefore bids. The instrument we use is the length of time between the date a project is advertised and when the bid letting occurs. We hypothesize that the longer a firm has to assess the project and prepare its bid, the lower its entry cost will be.[15]

To study entry, we must characterize the relevant set of potential entrants. It is not practical or desirable to consider all firms for each auction. First, with 5,120 auctions, and 1,735 firms that are observed submitting a bid, we would be estimating an entry specification on the basis of nearly nine million observations. In addition to the problem of dimension, irrelevant firms will not be induced to enter by marginal improvements in the covariates, thereby leading us to understate the effects of our variables of interest. We treat a firm as a potential entrant if it submits a bid in the same year and district as the current project appears.

In Table 11 we present the results. Columns (1) and (2) display the results of estimating a linear probability model of auction participation, where the dependent variable is a dummy variable taking on a value of one if the firm chooses to enter. We find that the stock of relationships a firm has with subcontractors in a district raises the likelihood of entry, and this effect is enhanced in the presence of future contracts.

In column (3), we show the results of estimating the Tobit specification. We estimate a coefficient on the interaction between the stock of relationships and future contract volume of -0.007, which is substantially larger than the OLS estimate shown in Table 5 of -0.002. This is consistent with the notion that the OLS estimates may understate the effect of continuation value for the average firm due to the increased participation of marginal bidders.

Finally, in columns (4) and (5) we present the estimates for the bid and entry equations from the Heckman two step procedure. We again see that increasing the stock of relationships is associated with a lower bid, and that this effect is enhanced by a high volume of future contracts. As with the Tobit, the estimated coefficients here are substantially larger than in the linear OLS, which again suggests that selection seems to be a factor attenuating estimated coefficients. As with the linear probability specification, entry is more likely when the stock of relationships a firm has with area subcontractors is greater, and this effect grows when future contract volume is higher. The estimates are substantially larger than in the linear probability model. The instrument that we employ, the lead time between project advertisement and bid letting, is positive and significant, with a t-statistic of nearly 3. Each additional ten days of lead time raises the likelihood of participation by 0.1 percent.

6.2.3 Subcontractor utilization decision

Last, we examine the subcontractor utilization decision. As with the participation specifications, we must reduce the dimensionality. In this section, we limit our sample to the twenty largest contractors. We consider all subcontractors that any of these large contractors has ever listed during our sample period. We then form a dummy variable indicating whether firm i used subcontractor j in its bid on project k. We then regress this utilization dummy on the stock of prior relationships between the two firms. As before, we also consider an interaction between this measure and future contract opportunities within the project district.[16]

One concern with this specification is the fact that subcontractors are chosen on the basis of lower joint construction and coordination costs. Since we do not observe construction costs, if these are correlated with coordination costs and thus also with relationship stocks, we may obtain biased estimates of the effect of past interactions on subcontractor utilization. To address this, we add two variables that reflect subcontractor cost. One is an indicator of whether other bidders also use the same subcontractor, which captures the unobserved subcontractor cost advantages. The other is an indicator of whether the project takes place in 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 12. 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 as 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. To do so, we construct a measure of past interactions between contractors and listed subcontractors as well as an exogenous measure of the future value of ongoing relationships using the arrival rate of projects in a predetermined geographical area and within a year of an auction. We highlight that the latter is a valid instrument for future value of ongoing relationships because this is determined by repair needs and it is orthogonal to the contractor-subcontractor productivity match that drives succesful relationships in this industry.

Our paper is, to our knowledge, the first to test the importance of relationship continuation value. We find that a higher number of past interactions is correlated with lower posted bids, and importantly that past relationships are valuable only in periods of time where there exist future contracting opportunities. Prior empirical literature in relational contracting has tended to use past interactions as a proxy for future interactions, and our result demonstrates that such a strategy could lead to potentially wrong conclusions. We also examine the effect of past and future interactions on auction participation and subcontractor choice 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. To bolster our interpretation of the empirical results, we find that the stock of relationships is only important for projects that are more subcontractor-intensive. And we rule out several alternative explanations, including the possibility that endogenous auction participation is driving our bid results.

As we empirically examined in this paper the impact of past and future interactions on bidding behavior, auction participation and subcontractor choice, future research could extend the present study to consider the efficiency implications of these effects. Specifically, gains from past and future interactions may drive contractors to choose subcontractors that do not have the lowest production costs. This may increase overall construction costs if more efficient subcontractors are passed over due to a lack stock of past relationships.

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Appendix 1: Model

In this model, the government procures a project in any given period with a probability p. Once the announcement is done in period t, a contractor i, of all possible I contractors, considers submitting a bid for a project k in period t. The government allocates projects to contractors using first-price sealed-bid auctions.

Assume that every project is comprised of two tasks. Task 1 is required to be conducted by the contractor herself, while task 2 is outsourced to a subcontractor j (out of the J available subcontractors). Let the cost of task 1 be c_{1kit}, while the cost of a subcontractor j to produce task 2 is c_{2kjt}.

There exists a coordination cost $\gamma_{ijkt}(e, n)$ of hiring a subcontractor j that depends on effort e exerted *ex post* by subcontractor j. This effort is non-contractible because it cannot be observed ex-post by a third party. The coordination cost also depends on n which is the number of past interactions between contractor i and subcontractor j. Not surprisingly, coordination cost is lower the higher levels of effort and the higher the number of past interactions. These coordination costs vary across contractor-subcontractor match quality as well as the number of times that they have actually worked together 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}.

The game we describe evolves over four periods. The firm, who knows its construction cost and that of each of the potential subcontractors, selects the subcontractor that will lead to the lowest cost. In period 2, the contractor and its chosen subcontractor bargain over the compensation for the completion of task 2. In period 3, the firm makes its decision to enter the bidding for the auction, and submits a bid that maximizes expected profits. Finally, in period 4, the project is awarded to the firm submitting the lowest bid, and the subcontractor decides whether to hold-up the contractor. Our approach is to characterize the solution to the model by backward induction, which we now describe period-by-period.

8.1 Solution by backward induction

8.1.1 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 $\gamma_{ijkt}(e, n)$. Assume that 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 the contractor can observe it. The coordination costs will be higher if $e = 0$ such that

$$\gamma_{ijtk}(0, n) > \gamma_{ijtk}(e^*, n). \tag{1}$$

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

$$\phi_{i-jkt} \geq \gamma_{ijtk}(0, n) - \gamma_{ijtk}(e^*, n) \tag{2}$$

or, in other words, the maximum amount that the subcontractor can hold up the contractor is the amount of the switching cost.

To address this problem, the contractor can leverage the continuation value of the relationship, V, which is the present discounted value of surplus accruing to the subcontractor through future interactions with with the prime contractor. The manner in which surplus arises for the subcontractor is described in the next section. The contractor will then offer an informal contract to the subcontractor that specifies the subcontractor high level effort e^*.

Following the standard literature of relational contracting, the self-enforcing mechanism is the threat of the contractor to end the relationship. The continuation value of the relationship is given by V, which is the present discounted value of surplus accruing to the subcontractor through future interactions with with the prime contractor. The manner in which surplus arises for the subcontractor is described in the next section. 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 subcontractor side.

The subcontractor will find optimal to exert e^* if

$$V \geq \gamma_{ijtk}(0, n) - \gamma_{ijtk}(e^*, n), \tag{3}$$

or in other words, if the gain from shirking is outweighed by the continuation value of the relationship. Therefore, e becomes a function of V and ϕ_{i-jkt} such that $e = e(V, \phi_{i-jkt})$.

The cost to contractor i of subcontracting task 2 to subcontractor j is therefore

$$\widetilde{c}_{2kjt}(e) = \gamma_{ijt}(e(V, \phi_{i-jkt}), n) + c_{2kjt} + z_{kjt}, \tag{4}$$

where z_{kjt} is the mark-up above cost on the task performed by subcontractor j and e is determined by evaluating the incentive compatibility constraint above.

8.1.2 Period 3: Bid strategy

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

$$\pi_{ikt} = (b_{ijkt} - c_{1kit} - \widetilde{c}_{2kjt}(e)) * \Pr(b_{ijkt} < b_{-ikt}). \quad (5)$$

The bid here is subscripted by j since the optimal bid will depend on which subcontractor is chosen in period 1. The first-order condition of the bidder's problem is

$$b^*_{ijkt} = c_{1kit} + \widetilde{c}_{2kjt}(e) + \frac{\Pr(b^*_{ijkt} < b_{-ikt})}{\frac{\partial \Pr(b^*_{ijkt} < b_{-ikt})}{\partial b_{ijkt}}}. \quad (6)$$

The first-order conditions for each of the participants in the auction represents a system of differential equations, and each are satisfied in the Bayes-Nash equilibrium. While we do not explicitly solve for the equilibrium of the auction game, the characteristics of the resulting equilibrium bid strategy is well known in the literature. Bids are monotonically increasing in costs, and firm profits are decreasing in costs. 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.

8.1.3 Period 2: Bargaining Between Contractor and Subcontractor

In this stage, the contractor is simultaneously bargaining at no extra cost with all available subcontractors over the cost of providing task 2, and therefore it seems right to assume that 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 the sum of the amount of the coordination and task costs plus the cost difference with the second cheapest subcontractor available to contractor i such that

$$\widetilde{c}_{2kjt}(e) = \gamma_{ijkt}(e, n) + c_{2kjt} + z_{kjt}. \quad (7)$$

8.1.4 Period 1: Contractor's Choice of Subcontractor

Finally, in period 1 the contractor decides what subcontractor to outsource task 2 to in order to maximize total expected profit. To do so, the contractor takes as given the mark-up in the bid originated in period 3 and the resulting level of $\widetilde{c}_{2kjt}$ 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

$$\max_{j \in J} \pi_{ijkt} = (b_{ijkt}(c_{1kit}, \widetilde{c}_{2kjt}(e)) - c_{1kit} - \widetilde{c}_{2kjt}(e)) * \Pr(b_{ijkt}(c_{1kit}, \widetilde{c}_{2kjt}(e)) < b_{-ikt}) \tag{8}$$

where

$$\widetilde{c}_{2kjt}(e(V, \phi_{i-jkt})) = \gamma_{ijtk}(e(V, \phi_{i-jkt}), n) + c_{2kjt} + z_{kjt}. \tag{9}$$

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

$$j^* = \arg\max \pi_{ijkt}(b_{ik}, c_{1kit}, \widetilde{c}_{2kjt}(e(V, \phi_{i-jkt}), n), b_{-ikt}). \tag{10}$$

Appendix 2: Market entry

Table A1: Firm entry and contract volume

Dependent variable:	Establishments						ΔEstablishments				ΔLn(Establishments)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Contracts t + 1	1.00	0.09	0.13											
	(0.32)***	(0.07)	(0.13)											
Contracts t				1.40	0.18	-0.02								
				(0.36)***	(0.11)	(0.17)								
ΔContracts t+1							0.31	0.13						
							(0.09)***	(0.12)						
Δ Contracts t									0.29	0.07				
									(0.09)**	(0.09)				
Δ Ln(Contracts t+1)											-0.04	-0.26		
											(0.12)	(0.22)		
Δ Ln(Contracts t)													0.07	0.05
													(0.07)	(0.08)
District FE	No	Yes	Yes	No	Yes	Yes	No	No	No	No	No	No	No	No
Year FE	No	No	Yes	No	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Observations	79	79	79	79	79	79	67	67	67	67	67	67	67	67
R-squared	0.27	0.96	0.98	0.43	0.97	0.98	0.23	0.44	0.17	0.42	0.02	0.27	0.02	0.11

Data includes information between 1996 and 2002. NAICS changed industry classification in 2003 and therefore we left out 2003 and 2004. Robust standard errors in parentheses and clustered at the district level. * significant at 10%; ** significant at 5%; *** significant at 1%

Notes

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

[2]Calzolari and Spagnolo (2009) show that when relational contracting between government and main contractor is valuable to solve moral hazard problems, the government may find it optimal to screen contractors ex-ante and reduce the number of potential bidders so that the continuation value of relationships increases.

[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]More specifically, the list includes all first tier subcontractor, which are those that perform at least $10,000 or half of a percent of the contract, whichever is greater.

[5]Due to many small permutations of spellings for the same firm, these were assigned by hand.

[6]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.

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

[8]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.

[9]Another explanation is that large firms are able to select projects where they are able to choose a higher mark-up of bid above costs.

[10]Estimating the number of subcontractor specification with only project fixed effects indicates that 81 percent of the variation in the number of subcontractors across all bids can be explained by project characteristics.

[11]It is important to note that here we examine the stock of relationships in the district, rather than the alternative measure of relationships, the prior interaction with listed subcontractors. The latter is potentially problematic here,

as contracts requiring specialty items have more listed subcontractors.

[12]While our primary measure of a firm's relationship to this point has been the contractor's interaction with the subcontractors listed in its bid, in this case it is more sensible to use the overall relationships with subcontractors in the district. If we were to instead use listed subcontractors, the measure would have less meaning since there are generally only a handful of listed subcontractors.

[13]A similar "investment" that firms may make involves their relationship with Caltrans. The contractor may behave better in completing a current project in order to improve its relationship with Caltrans. Uncooperative behavior now, in the form of unnecessary cost overruns or taking a tough stance in negotiating change orders, may result in worse treatment from Caltrans in future contracts. Therefore, upcoming contracts in a district may affect current behavior. We were able to obtain final contract payments for around one-quarter of the projects in our data. We find no statistical relationship between project overrun and future contracts, prior relationships with subcontractors, or the interaction between the two.

[14]Two exceptions to this are notable. First, an alternative model of entry holds that firms are identical *ex ante* and only learn their cost draw after paying the entry cost. If this is the case, however, then entry is not endogenous to *ex post* cost, and therefore selection will not bias our empirical results. A second scenario is if firms are not identical, then the cutoff cost will not be exactly the same. Consider an auction with two "high cost" firms and two "low cost firms." A firm drawing from the higher cost distribution will face a tougher set of opponents – two low cost firms and only one high cost firm – than those drawing from the low cost distribution who only face one other low cost firm in the auction. This is very unlikely to lead to a substantial difference in the cutoff cost, however, since the markup over cost tends to be quite low at higher points in the cost distribution.

[15]Some bid lettings occur with very little notice, often just a matter of days. These appear to be unique situations, and so projects with lead times of shorter than two weeks are excluded. Lead time is unsuccessful at predicting entry for these extremely short lead times, but it is successful for somewhat longer lead times. We also see some extremely long lead times, which are likely due to delays or postponements in bid letting. We therefore also exclude lead times of longer than 100 days. Together, this drops approximately 8 percent of bid observations. The median auction has an advertising lead time of 30 days.

[16]Subcontractor utilization decisions are not independent since there can be only one subcontractor for a given task. 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 cluster standard errors at the contract level.

Figure 1: Caltrans districts

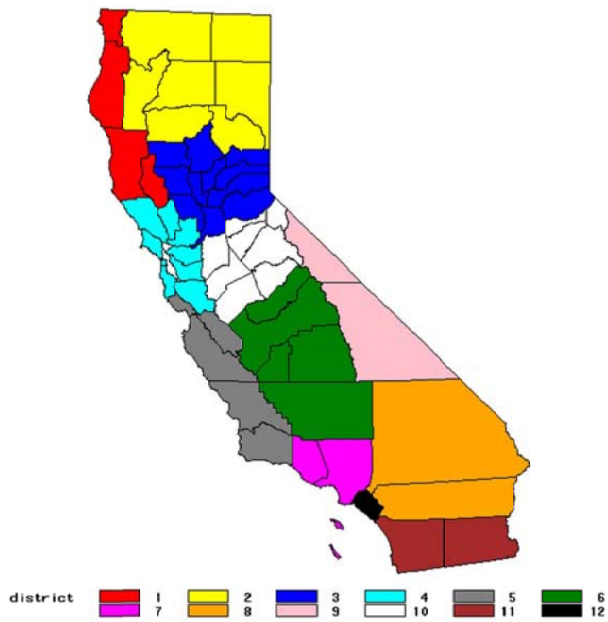

Table 1: Summary statistics

	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 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 5: Alternative Measure: 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 6: Specialty items and subcontractor utilization

Dependent variable: Number of subcontractors

	(1)	(2)	(3)
No. Specialty Items	0.148	0.139	0.073
	(0.004)***	(0.004)***	(0.005)***
Firm effects	No	Yes	Yes
Controls	No	No	Yes
Observations	25876	25876	25713
R-squared	0.42	0.67	0.74

Controls included in the specification shown in column 3 include backlog, number of bidders, year and month dummies, district effects, number of contract items, workdays, and log engineer's estimate.
Standard errors corrected for clustering by contract are in parenthesis.
*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.

Table 7: Bid regressions by number of specialty items

Dependent variable: Log of bid

	(1)	(2)	(3)
Sample:	#s items=0	#s items 1-7	#s items 7
Log(1+stock in district)	-0.013	-0.012	0.001
	(0.023)	(0.008)	(0.005)
Log(1+stock in district)*log(1+future contracts)	0.005	0.000	-0.003
	(0.006)	(0.002)	(0.001)***
Log(1+future contracts)	-0.046	-0.014	-0.005
	(0.025)*	(0.008)*	(0.005)
Constant	1.355	0.851	0.822
	(0.254)***	(0.099)***	(0.071)***
Observations	2349	9907	13922
R-squared	0.96	0.95	0.98

The dependent variable is the log of the firm's bid. The number of s items is the number of specialty items listed in the contract, which typically must provided by a subcontractor, and the median number of s items is seven. The stock of subcontractors is the sum of the firm's prior interactions on winning bids with subcontractors headquartered in the project district. Future contracts is the sum of the number of 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: Contract opportunities in the more distant future

Dependent variable: Log of bid

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

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 9: 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 10: Bidding and firm propensity to subcontract

Dependent variable: Log of bid

	(1)	(2)	(3)	(4)
Log stock in district	-0.011	-0.011	-0.009	-0.003
	(0.003)***	(0.003)***	(0.003)***	(0.004)
Firm Avg Sub. Util.	0.003	0.002		
	(0.001)**	(0.002)		
Avg Sub. Util. * Log future contracts in dist.		0.000	0.000	0.001
		(0.001)	(0.001)	(0.001)
Log # future contracts in dist.		-0.015	-0.017	-0.014
		(0.005)***	(0.005)***	(0.005)***
Log stock*Log future contracts in dist.				-0.002
				(0.001)**
Firm effects	No	No	Yes	Yes
Observations	24763	24763	24763	24763
R-squared	0.97	0.97	0.98	0.98

The dependent variable is the log of the firm's bid. Average subcontractor utilization varies at the firm level, measuring the number of subcontractors the firm uses on an average contract. The stock of subcontractors is the sum of the firm's prior interactions on winning bids with subcontractors headquartered in the project district. Future contracts is the sum of the number of 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.

Since coefficients on the interaction Avg Sub Util*Log(1 + future contracts in district) are hard to read, we report the p-values: 0.56, 0.64, and 0.41 for columns 2,3, and 4, respectively.

Standard errors corrected for clustering by contract are in parenthesis.

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

Table 11: Firm participation

Dep Variable, Methodology	Participation, OLS		log(Bid), Tobit	Heckman Bid equation	Heckman Part. equation
	(1)	(2)	(3)	(4)	(5)
Log(1+stock in district)	0.022	0.013	-0.081	-0.1366	0.1852
	(0.001)***	(0.001)***	(0.003)***	(0.040)***	(0.005)***
Log(1+stock in dist.)*log(1+future contracts)	0.001	0.002	-0.007	-0.0125	0.0159
	(0.000)***	(0.000)***	(0.001)***	(0.004)***	(0.002)***
Log(1+future contracts)	-0.001	-0.001	0.015	0.0103	-0.0335
	(0.000)***	(0.000)***	(0.002)***	(0.009)	(0.005)***
Auction advertise lead time (days)					0.0010
					(0.0003)**
Other Controls	Yes	Yes	Yes	Yes	
Firm effects	No	Yes	No	No	
Observations	514597	514597	514596	476331	
R-squared	0.04	0.06			

In each specification, the pool of potential entrants we consider to include all firms who bid in the same year in the project district. The dependent variable in the specification shown in columns (1) and (2) is an indicator for auction participation. In column (3), we show the results from estimating a specification of the log bid using a Tobit, where the distribution of observed bids in an auction is assumed to be truncated at the maximum bid. The final two columns show the results of a Heckman two step selection estimation, where the excluded variable from the bid equation is the number of days in advance the project was advertised.

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 is the number of projects occurring in the same district within the following 360 days. 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 controls include the log of the engineer's estimate, the log of prior wins by the firm, log backlog, the number of opponents, the log number of items specified on the project, the number of working days, plus year, month and district dummy variables.

Standard errors corrected for clustering by contract are in parenthesis.

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

Table 12: 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.