SOURCING FROM THE ENEMY: HORIZONTAL SUBCONTRACTING IN HIGHWAY PROCUREMENT

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Abstract

I empirically consider the effect of horizontal subcontracting on firm bidding strategies in California highway construction auctions. Subcontractors are hired by prime contractors prior to the auction, and the subcontractor may also be a competitor in the primary auction. While horizontal subcontracting may improve productive efficiency, it softens the horizontal subcontractor's bid strategy, since winning the auction may entail losing subcontracting business. I find that while each additional competitor supplied by the firm is estimated to increase its bid by 1.4 percent, the winning bid is uncorrelated with horizontal subcontracting. This points toward an efficiency motive for cross-supply.

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I INTRODUCTION

Settings where a firm's supplier is also a competitor in the downstream market are commonly observed.[1] In auctions for highway construction projects, for instance, prime contractors select subcontractors to complete a portion of the tasks on a project before the auction that determines the winner takes place. As a result, some firms bidding as prime contractors have also been hired by competing bidders as potential subcontractors. It is therefore possible for an auction participant to be either a prime contractor in the event of winning the auction, or could conceivably be a hired as a subcontractor for another firm in the event of losing. Such a firm, called a horizontal subcontractor, faces an opportunity cost of being the low bidder in the primary auction, since winning the primary auction entails losing subcontracting opportunities. This has the effect of softening competition in the primary auction.

Regulators have in the past struggled with the question of how to treat industries where horizontal subcontracting is important.[2] Despite the competition softening effect, horizontal subcontracting may be motivated by efficiency considerations, since the low cost supplier for a particular task may happen to be a competitor in the main auction. Spiegel [1993] highlights this tradeoff, suggesting that the efficiency rationale could be significant, and that horizontal subcontracting is potentially welfare enhancing as a result.

The goal of this paper is to estimate the relationship between horizontal subcontracting and bidding, and to establish the factors that lead horizontal subcontracting to arise. I also provide a series of facts about horizontal subcontracting in the highway construction industry, which is valuable in itself due to the scarcity of systematic empirical evidence regarding this phenomenon. I empirically examine horizontal subcontracting in auctions for California Department of Transportation (Caltrans) highway repair contracts. Bidders select subcontractors *ex ante*, and it is often observed that an auction participant will be listed as a subcontractor on an opponent's bid.

[1] An important paper in the theoretical literature, Spiegel [1993], cites several examples, such as the case of Mazda producing the Probe for Ford, while also selling its own sports car, the MX-6. Another example arises in the auto industry, where Toyota leases the right to use its hybrid technology to Ford. Also, telephone markets have been opened to competition by requiring incumbent firms to lease lines to potential entrants (see Sappington [2005]).

[2] In an example described by Baake et al [1999], the European Commission (EC) fined three Italian glass producers engaged in cross-supply for anticompetitive behavior. This decision was later overruled by the European Court of Justice, who claimed that the EC did not sufficiently prove that the cross-supply arrangement was evidence of collusion. In the case of telephone deregulation, Sappington [2005] explains that the FCC must decide how to regulate line pricing, which ideally would take into account the strategic effect of cross-supplies. The line price was set to limit the distortion of entrant's make-versus-buy decision, though this appears to have not taken into account the strategic affect of the line price on incumbent behavior.

In treating different auctions as separate markets, I will use variation in bids across auctions to estimate the effect of horizontal subcontracting on equilibrium prices.

I begin by writing a simple model of the subcontracting decision to motivate the empirical work. In this model, a project consists of two tasks, the second of which may be subcontracted or completed in-house. Consistent with institutional details, a firm chooses its subcontractor *ex ante*. The subcontractor is chosen in order to minimize cost, which may involve hiring a competing bidder. This model shows how a horizontal subcontractor has an incentive to bid less aggressively, since winning the auction entails losing surplus from subcontracting business. This opportunity cost enters into the firm's bid choice in the same manner as construction cost. Furthermore, the model predicts that auction participants with lower costs are more likely to be used be used as horizontal subcontractors.

In addition to generating testable implications, the model also serves to highlight an important empirical issue. Identifying the effect of horizontal subcontracting on a firm's bidding strategy is complicated by the fact that we should expect firms to choose the lowest cost subcontractor to complete a task. While theory predicts that being a horizontal subcontractor leads a firm to bid higher at a given cost due to the opportunity cost effect, being listed as a subcontractor is likely to indicate that a firm is particularly low cost on at least some dimension of the project. Actual construction cost is unobserved and potentially correlated with subcontractor status.[3]

The bid-level data reveals that firms bid 3.2 percent lower when serving as a horizontal subcontractor, which is consistent with the notion that lower cost bidders serve as subcontractors. There is evidence that firms with lower costs are used as horizontal subcontractors. A bidder is more likely to be a horizontal subcontractor when it is more experienced in providing items likely to be subcontracted out and when it is located close to the project. Furthermore, a large portion of the relationship between a firm's bid and being a horizontal subcontractor can be explained by firm fixed effects.

The level of detail in the auction data provides a solution to the identification problem. Caltrans specifies each item to be provided in the project, and firms when submitting their bids must place a unit price on each item. Moreover, some bidders list the exact items to be provided by each of their subcontractors. This unique information allows for a measure of the price charged for an item by

[3]A related issue will arise if a horizontal subcontractor has market power for the input it is providing, and thereby has the incentive and ability to raise its rivals cost through the pricing choice of the input. This will also lead to an apparent cost advantage for horizontal subcontractors.

the bidder, as well as the price charged for the same item by the firm to which it supplies the item. The strategic effect that we wish to capture is contained in the former measure but not the latter, while the horizontal subcontractor's cost is contained in both prices. I find that for each additional horizontal subcontracting opportunity, the price of an item in a firm's own bid rises by 1.4 percent relative to the price charged by the firms to which it provides the item as a subcontractor.

The effect of horizontal subcontracting on the winning bid is theoretically ambiguous. I find that the winning bid on auctions with a horizontal subcontracting relationship is virtually identical to those auctions without such a relationship. This suggests that softening downstream competition is unlikely to be the primary motive for horizontal subcontracting in this setting.

A number of theory papers have considered horizontal subcontracting relationships, as well as other conceptually similar arrangements where a supplier of a key input to a firm is also a downstream competitor. Spiegel [1993] analyzes a model of horizontal subcontracting, which has conflicting effects on welfare since it improves productive efficiency while at the same time softening competition. The paper finds that horizontal subcontracting improves welfare in the case of *ex ante* subcontracting, and may do so in the case of *ex post* subcontracting as well, provided the efficiency gains from production are sufficiently large. A related paper by Huff [2011] analyzes the effect of horizontal subcontracting on competition and welfare. Huff finds that horizontal subcontracting intensifies competition by lowering the cost of the subcontracting pair, but softens competition by raising the downstream opportunity cost of the firm serving as the subcontractor. The latter effect dominates when the firm serving as the subcontractor is stronger. Other related theory work includes Kamien et al [1989], who consider *ex post* subcontracting, and Gale et al [2000] who analyze sequential procurement where sellers can subcontract to one another.

Sappington [2005] studies line pricing in a deregulated telephone industry, where incumbent firms must offer to lease lines to potential entrants. The main result of the paper holds that the regulated line price is irrelevant for the make-versus-buy decision of entrants. The intuition for this result is similar to the bid softening effect of horizontal subcontracting. As the line price increases, competition from the incumbent is softened, since the incumbent's market share comes at the cost of lost opportunities to supply the entering telephone company.[4,5]

[4]Though not related to horizontal subcontracting per se, a similar line of reasoning applies to situations where a monopoly input supplier serves both a downstream firm and its competitor. Arya et al [2007] show that in such a case, the downstream firm may be willing to buy an input at a price above its in house cost of input provision in order to discourage the supplier from providing the input to the rival at favorable terms.

[5]Gayle and Weisman [2007] and Mandy [2009] show that the input price irrelevance result depends on the assumptions made regarding the nature of retail competition and demand.

A related type of horizontal relationship is the joint venture. This has been studied empirically in the context of auctions for off-shore oil drilling leases by Hendricks and Porter [1992]. Joint ventures, much like horizontal subcontracting, may improve efficiency though perhaps at the expense of lessening competition. The study of horizontal subcontracting presents an advantage from an empirical research standpoint, as it possible to draw inference regarding the competitive implications of the relationship by virtue of observing the prices of both firms.

Highway procurement data is now commonly used to answer a range of questions in auctions, contracting, the economics of organizations, and public economics, among others. Bajari and Lewis [2011a] examine the design of time incentives in procurement contracts. Bajari and Lewis (2011b) consider how firms adjust production decisions to unanticipated shocks. Bajari, Houghton, and Tadelis [2006] and Miller [2010] study the cost of incomplete contracts. Krasnokutskaya and Seim [2011] and Marion [2009] considers forms of affirmative action on government procurement costs.

This paper also relates to empirical literatures on the firm-supplier relationship and contracting issues in the supply chain. Kellogg [2011] shows that the relationship between oil producers and their drilling contractors become more productive as they work together more. Gil and Marion [2013] study subcontracting and and the use of future interactions to enforce informal contracts. Other examples of empirical work examining contracting issues between firms and suppliers include Monteverde and Teece[1982], Masten [1984], and Joskow [1987]. González et al [2000] consider the determinants of subcontracting in the construction industry.

The rest of the paper proceeds as follows. Section II describes a simple model of the subcontracting and bidding decisions that captures the main theoretical predictions regarding horizontal subcontracting. Section III describes the data and some key institutional details. Section IV describes the results regarding bidding behavior, and section V concludes.

II HORIZONTAL SUBCONTRACTING

In this section, I present a model that serves to motivate the empirical work, illustrating the opportunity cost effect of horizontal subcontracting and a couple of basic predictions regarding the types of firms that will typically be chosen. Consider $N + 1$ firms making entry and bidding decisions for an auction for a highway construction project. The project is comprised of two tasks, A and B. Firm i receives independent cost draws, c_i^A and c_i^B, capturing the cost of completing each task. The firm must complete the first task itself, but may subcontract task B. Prior to the auction, the firm selects a subcontractor for task B, or elects to complete the task itself. It subcontracts the task out if $c_i^B > c_{ij}^B$ for some j, where c_{ij}^B is the cost to contractor i of employing subcontractor j. This cost is comprised of two components, the direct cost of firm j completing the task c_j^B, and an IID contractor-subcontractor specific coordination cost, ξ_{ij}, so that $c_{ij}^B = c_j^B + \xi_{ij}$.[6] A firm's total cost of project completion can therefore be written as $C_i = c_i^A + min\{c_{ij}^B\}$, where $c_{ii}^B = c_i^B$. A potential entrant faces a fixed cost of entry, K. If a firm wishes to subcontract task B, it must select its subcontractor prior to bid submission.

A firm is allowed to both enter the auction as a bidder and also agree to serve as another bidder's subcontractor should it lose. Should firm i be selected as a subcontractor j, surplus is generated from the match equal to the cost reduction in using i rather than the next best alternative: $s_{ij} = min_k(c_i^B - c_k^B)$. Firm i and j split this surplus, with i receiving the portion λ. As shown by Rubinstein [1982], if the two firms engage in an alternating moves bargaining game, and each have identical discount rates, then $\lambda = 1/2$ will result. This approach is also taken by Gale et al [2000] to model the division of surplus from subcontracting.[7]

Define the set of participating bidders as Ω. If a firm loses the auction, its expected profits from its subcontracting agreements with other bidders are given by $\pi_i = \sum_{j \neq i} I(c_{ij}^B < c_{-ij}^B)\lambda s_{ij} Pr(b_j < b_{-j})$, which multiplies an indicator for firm i being the lowest cost supplier for firm j by the surplus it receives and the likelihood that j is the lowest bidder.

Expected profits conditional on entry are therefore given by

$$\Pi = (b_i - C_i)Pr(b_i < b_{-i}) + \pi_i(1 - Pr(b_i < b_{-i})), \tag{1}$$

which sums the expected profits from winning the auction with the expected subcontracting profits. Winning the auction represents an opportunity cost, since it results in giving up the expected surplus associated with subcontracting. This is seen clearly by rearranging (1), where the opportunity cost, π_i, enters in exactly the same way as usual construction cost:

$$\Pi = (b_i - C_i - \pi_i)Pr(b_i < b_{-i}) + \pi_i. \tag{2}$$

Using this model, we can derive predictions about the relationship between horizontal subcontracting and the bidding and entry decisions.

[6]Without this match-specific coordination cost, if a firm is chosen to subcontract for one firm, it would be chosen for all firms. This is clearly violated in the data, suggesting that it must be the case that the cost of using a given firm as a subcontractor varies across bidders.

[7]Since this negotiation occurs prior to the conduct of the auction, information regarding the task B cost of the hired firm is revealed. The model abstracts away from this, in that the hired firm does not price its subcontracting services strategically, anticipating the impact of this choice will have on its bidding strategy. The degree of independence between the costs on tasks one and two will limit the importance of informational leakage. The implications of this abstraction for the empirical work are discussed in Section II(iv)(b).

II(i) Bidding decision

An auction participant chooses its bid to maximize expected profits. Let $F(b)$ represent the distribution of the lowest opponents' bid. The firm's first-order condition is given by

$$b_i = C_i + \pi_i + \frac{1 - F(b_i)}{f(b_i)} + F(b_i)\frac{\partial \pi_i}{\partial b_i}. \tag{3}$$

Being a horizontal subcontractor affects the firms bid in two ways. First, the opportunity cost associated with lost subcontracting opportunities, π_i, enters linearly, acting just like the construction cost term C_i. Second, the expected value of the surplus from subcontracting changes as the bid rises, which is captured by the last term in (3). Conditional on losing, the higher bid submitted by the firm increases the expected cost of the auction winner. Therefore, under Nash bargaining, the expected value of π_i will increase in the bid. So both terms associated with horizontal subcontracting on the right-hand-side of (3) are positive. Horizontal subcontracting, therefore, tends to shift up a firm's bidding strategy.

In practice, two of the key elements of π, λ and s_{ij}, will not be observed directly. We only observe whether or not the firm is a horizontal subcontractor, and if so the number of contracts in the auction on which it appears. Denote the number of horizontal subcontracting relationships by h_i. As h_i rises, the opportunity cost will rise with it, since the likelihood that the firm supplies the eventual auction winner rises. This is further reinforced by the expected value of s_{ij} being positively correlated with h_i.

An identification problem arises, however, since C_i and π_i enter linearly in the bid function. Being a horizontal subcontractor likely indicates that the firm has a lower cost of completing task B than other firms in the market. Consider the indicator for i being chosen as the subcontractor of j, $I(c_{ij}^B < c_{-ij}^B)$. The likelihood that this is true is given by

$$Pr(c_{ij}^B < c_{-ij}^B) = Pr(\xi_{ij} < c_{-ij}^B - c_i^B) \tag{4}$$

which increases as the firm's cost of completion of task B falls. A lower value for task B cost, c_i^B, makes horizontal subcontracting more likely yet is associated with a lower bid since the firm's construction cost is lower. Therefore, bids may be positively or negatively correlated with horizontal subcontracting.

II(ii) Entry decision

The firm chooses to enter the auction if its profits from entry exceed its profits from not entering. The firm incurs an entry cost K if it chooses to bid as a primary contractor. Even if the firm does not bid as the primary contractor, it has positive expected profits from subcontracting (π_i). The firm will bid as a primary contractor if

$$(b_i - C_i - \pi_i)Pr(b_i < b_{-i}) > K. \tag{5}$$

Since the entry cost is fixed, and expected profits decline monotonically in cost, we can describe a cutoff value for cost, $\widetilde{C}$, inclusive of construction and opportunity cost, such that $(b - \widetilde{C})Pr(b_i < b_{-i}) = K$. If $c_i^A + min\{c_{ij}^B\} + \pi_i < \widetilde{C}$, the firm chooses to participate.

A subcontractor who chooses not to enter the bidding for the contract has the lowest cost of completion of task B, c_{ij}^B for at least one j, yet has a sufficiently high value of c_i^A to fail the entry condition. An entrant that is not a horizontal subcontractor has a favorable cost draw, though one that is not sufficiently low in any one dimension to warrant serving as a subcontractor. Conditional on an auction participant's overall cost, one with a higher variance of costs across different project components will be more likely to also serve as a subcontractor for a competitor.

II(iii) Comparison with literature

As with the model presented here, it is common in the literature for cost differences to motivate the use of horizontal subcontracting. In Spiegel [1994], firms engage in Cournot quantity competition downstream. Therefore, firms with identical cost structures will produce identical quantities, and even with strictly convex cost functions there will be no motivation for horizontal subcontracting. Asymmetric costs drive demand for subcontracting. In Kamien et al [1989], the firms engage in Bertrand competition, submitting unit-price bids to serve the entire downstream market. Convex costs of production then motivate subcontracting. Gale et al [2001] study sequential auctions for non-divisible goods, and convex costs give rise to the motivation for subcontracting. In Lewis and Sappington [1991], a downstream producer considers sourcing a key input from a more efficient firm. In this paper, one cost of subcontracting is that the supplier cannot be perfectly monitored and will only be hired if the efficiency gains are sufficient to outweigh the loss in control.

The existing literature differs somewhat in the timing of the subcontracting decision. Firms can form subcontracts either before or after the downstream production decision is made. Kamien et al [1989] assume *ex post* subcontracting. Similarly, in Gale et al [2001], in the event that one firm wins multiple auctions for supplying final goods, it can *ex post* subcontract the production of one of the units. Spiegel [1994] analyzes both *ex ante* and *ex post* subcontracting, and shows how efficiency and prices could differ in the two scenarios.

II(iv) Other considerations

II(iv)(a) Raising rivals' cost

As suggested by Salop and Scheffman [1983,1987], a firm with control over an input into production may find it desirable to gain market share in the downstream market by raising the cost of its rivals. This behavior here will be disciplined by competition in the market for the input that the horizontal subcontractor would provide to its competitor. However, it is possible that the firm has market power over the input, for instance by being (perhaps temporarily) the only available supplier of a specialty input to production.

Arya et al [2008] present a different version of the raising rival's cost scenario. In their model, under Bertrand price competition, a vertically integrated producer charges its downstream rival a high price for the input it produces. It does so to credibly commit to less aggressive retail price competition, due to the opportunity cost of gaining market share in the downstream market.

It is relatively simple to distinguish empirically the raising rival's cost story from the hypothesis that horizontal subcontracting softens bid strategies. In the raising rival's cost scenario, one expects the competitor's price to rise relative to the supplier, however the competition softening story predicts exactly the opposite – opportunity cost increases the horizontal subcontractor's bid relative to the firm to which it will supply.[8]

Moreover, the gap between the predictions of the two views grows as the number of firms to which the bidder cross-supplies grows. If the firm is listed by many competitors as a subcontractor, one would suspect it is more likely that the firm has market power over a particular input. Therefore, the condition needed to raising rival's cost is more likely to hold when the number of firms being served as a subcontractor is high. On the other hand, under the bid softening hypothesis, opportunity cost is greater when a firm is listed as a subcontractor on more bids.

[8] A second version of the raising rival's cost story in this setting is one where a bidder hires a downstream rival to serve as its subcontractor in order to raise the rival's cost via the opportunity cost effect. To the extent that this type of behavior is present, it will not alter the conclusions of the portion empirical work which tests for the opportunity cost effect.

II(iv)(b) Revealing information to competitors

By providing a competitor with a price quote for supplying an input, a bidder is revealing a portion of its costs. This suggests that the firm may strategically misprice subcontracting services to conceal its true cost. This mispricing could be lower if meant to discourage entry, or higher if meant to soften the competition of its rival. Given that we only observe the firm listed as a horizontal subcontractor if the competitor it will supply enters the auction, the latter is the more likely scenario. As with the raising rivals cost story, empirically this will be easily distinguished from the opportunity cost story, since the predicted effects go in opposite directions. In this case, overpricing to strategically withhold information increases the price of the subcontracted item relative to the firm's cost of provision. This tends to increase the rival's price relative to one's own. However, opportunity cost has the opposite effect, raising the horizontal subcontractor's price relative to its rivals.

A second way in which information is revealed to competitors is through the decision of the hiring firm. By employing a competitor as a subcontractor, the hiring firm provides a truncated signal of its cost for a portion of the project. However, it is not clear this sends a signal regarding the overall cost of project completion. This depends on the degree of correlation of cost across tasks. By participating in the auction despite needing to hire a subcontractor for a particular task, the hiring firm may feel it has lower costs on other portions of the project. The degree to which hiring a competitor is a signal of cost is an empirical question. In the data used in this paper, I find that firms employing a horizontal subcontractor submit bids that are on average 0.3 percent higher (SE=0.6) than other firms, and therefore I conclude that the hiring firm is not sending a strong signal regarding cost.

III CALTRANS HIGHWAY AUCTIONS

III(i) Institutional details

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 pre-qualified. This pre-qualification is based on the firm's equipment, training, licensing, and past work history. For each project, the engineer provides a list of the items required to complete the project and the quantities of each item.[9] See

[9] 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 discrepancies occur, a potentially costly renegotiation of contract terms is undertaken. (Bajari et al, 2006)

Appendix Table A1 for a list of commonly provided items. 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 multiplied by the quantity.

In its bid, the contractor must list each first-tier subcontractor, those whose work accounts for at least 0.5 percent of the contract value or $10,000, whichever is greater. Each subcontractor must be prequalified to do the listed work. During the sample considered in my data, at most 50 percent of a project may be subcontracted.[10] Subcontractors are selected prior to the auction. One factor that influences subcontracting are so-called specialty items. Unlike the typical item listed in a contract, the contractor must specifically be qualified to provide those items designated as specialty items, or must subcontract the provision of the items to a firm that is. Affirmative action is another important restriction regarding subcontracting that was in place through much of the period of the study. 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. In the observed set of contracts, the DBE goal ranges from 0 to 35 percent, and averages 9.4 percent for federally funded projects and, prior to the implementation of Proposition 209, 7.8 percent for state funded projects.

III(ii) Data

The data used in this study includes the universe of 5,342 road construction and repair auctions conducted by Caltrans between May 1996 and October 2005.[11] 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. Both winning and losing bids are observed. Caltrans assigns a unique identifier to each firm, so it is possible to track bidders across auctions. Using the winning bid and information on estimated project duration, I form a measure of the value of uncompleted projects, termed backlog. This variable reflects short-run capacity constraints, which have been found to be

[10] Specialty items are excluded from this calculation. In 2006, the minimum percentage completed by the contractor was reduced to 70 percent, though specialty items are now counted in this figure.

[11] 221 of these projects were ultimately not awarded. The counts of contracts, bids, and items cited in this section include these contracts, but they are dropped when estimating the regression specifications.

important in this industry (see Jofre-Bonet and Pesendorfer, 2003). In all, I observe 27,502 bids from 1,735 different firms, of which 805 win at least one contract.

Caltrans lists each of the items required to complete the contract, and provides an estimate of the quantity that will be needed of each item. Each bidder provides a unit price for each item, and the firm's total bid is the summation across items of price multiplied by quantity. The list of items and their quantities is observed, as well as the unit price placed on each item for all bidders. It is also observed if Caltrans has designated the item as a specialty item. In all, there are 186,836 item-level observations from winning bids, and 786,480 item observations from losing bids.[12]

Each firm provides in its bid a list of subcontractors to be used, as well as a short description of the work to be performed. This description in many cases actually lists the items to be provided by the subcontractor, making it possible in such cases to link the unit price of an item to the subcontractor that will provide the item. Of the 112,844 subcontractor observations, I observe the actual items that the subcontractor will provide in 10,033 cases, and 760 of these are provided by horizontal subcontractors (they are also bidders in the auction).[13] I assign unique identifiers to subcontractors based on firm name, allowing me to track subcontractors across auctions.[14]

Some bidders are also listed as subcontractors, either in other auctions or on competitors' bids within an auction. Based on firm name and city, I have connected firms across the bidder and subcontractor datasets. Of the 5342 contracts let by Caltrans, I have identified 605 that contain at least one horizontal subcontracting relationship, i.e. where a bidder intends to use a competing bidder in the auction as its subcontractor. Of the 27,502 bids submitted, 1189 are from firms who upon winning intend to use a competing bidder as a subcontractor, and 714 of the bids are submitted by firms who are listed as potential subcontractors by a competing bidder. This indicates that in some auctions, a given bidder may be listed as the subcontractor in multiple competing bids.

[Place Table I approximately here]

[12] Appendix table A1 lists examples of commonly observed items. This table also lists items that tend to represent a high fraction of the bid when they appear on a project, and those items that are most frequently observed to be supplied by subcontractors as a fraction of the number of times they are observed in the data. The latter two lists only consider items that are provided on more than five projects. Several items appear very few times, yet when they do they represent a large portion of project cost.

[13] The bidders that report the items to be subcontracted tend to have higher bids, are less likely to be located in the project county, use fewer subcontractors, and are observed winning fewer projects in the data. They are also more likely to use or be an horizontal subcontractor. Projects where the items subcontracted is observed for at least one bidder tend to have lower winning bids and fewer working days.

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

In Table I, I present summary statistics at the contract level. In column (1), I present information for all auctions in the data, while in columns (2) and (3) I separate auctions depending on whether a horizontal subcontracting relationship is observed in the auction. Eleven percent of auctions have at least one horizontal subcontractor. These contracts represent 9 percent of contract dollars awarded by the state. Excluding two projects over $1 billion, which are more than twice as big as the next biggest project, this figure is 14 percent. Horizontal subcontracting is seen in both successful and unsuccessful bids. In 3.4 percent of the auctions, or a little less than one-third of the auctions with a horizontal subcontracting relationship, the winner is listed on a competing firm's bid. In 2.7 percent of auctions, the winner uses a competing bidder as a subcontractor. The average winning bid in the data is $3.14 million. While the average winning bid for auctions with horizontal subcontracting is lower at $2.58 million, this is largely due to the two aforementioned unusually large projects that did not have a horizontal subcontracting relationship. Excluding these two contracts, the average winning bid on contracts without a horizontal subcontracting relationship was $2.69 million. The median auction with horizontal subcontracting was $0.68 million, similar to the median in the data as a whole of $0.60 million. A more telling figure is the average ratio of the winning bid to the engineer's estimate, called the relative bid. For the broader set of projects, this is 0.96, while auctions with at least one horizontal subcontract this is 0.91. As will be shown in subsequent empirical work, this is due to the fact that auctions with a horizontal subcontract have more bidders, which is likely to be simply a statistical artifact – with more bidders, the likelihood increases that at least one of them is also a subcontractor. Contracts where horizontal subcontracting is observed tend to have more items, particularly specialty items, listed in the contract specifications. This is not surprising, as these two variables are positively correlated with subcontracting demand. (see Gil and Marion, 2012)

[Place Table II approximately here]

In Table II, I present summary statistics at the bid level. In column (1), I present summary statistics for all bids, while in columns (2) and (3) I respectively report summary statistics for the sample of bids from firms that intend to use another bidder as a subcontractor and those that are listed as a subcontractor on a competing bid. Three percent of bidders are horizontal subcontractors, while four percent of bidders use a competing bidder as a subcontractor. Overall, the likelihood of a random bidder submitting a successful bid is 20 percent. This is considerably higher for bidders who are also listed as subcontractors, who win 26 percent of auctions they enter. This is over twice as high as the win rate for firms who use horizontal subcontractors, as

12 percent of their bids are successful. This is consistent with the notion that these firms are lower cost. Bidders that are horizontal subcontractors submit lower bids relative to the engineer's estimate compared to other firms, and the project is more likely to be located in the same county as the firm's headquarters, both facts consistent with lower costs. Horizontal subcontractors have a greater degree of backlog, perhaps because they are lower cost and win more auctions. The last three rows compare the size and geographic concentration of bidders who are horizontal subcontractors with other bidders. To measure size, I used the number of auction wins, and the total value of the firm's bid summed across all auctions won. Bidders that are horizontal subcontractors won more auctions, and have higher revenues, than firms generally and as compared to firms that use horizontal subcontractors. Despite the difference in firm size, there is little difference in geographic concentration between bidders that are horizontal subcontractors and other firms.

In Panel A of Table III, I provide some information comparing horizontal subcontractors with regular subcontractors. I infer the value of the subcontract based on the items to be provided by the subcontractor, the price of the item as listed in the bid, and the quantity of the item. This is only possible in those cases where I observe which items are to be provided by the subcontractor. The items provided by the average horizontal subcontractor represents 23.5 percent of the overall bid. This is compared to 6.1 percent for the average regular subcontractor. This suggests that horizontal subcontracting is likely to have a noticeable effect on the bidding strategy of a firm. The average horizontal subcontractor appears on 1.7 bids, slightly less than regular subcontractors. The horizontal subcontractor is less likely to appear on the winning bid, as 12.1 percent of horizontal subcontractors are in the winning bid compared to 19.7 percent of regular subcontractors. In Panel B, I compare the items provided by horizontal subcontractors with those provided by regular subcontractors. In general, regular subcontractors provide items that are more specialized and represent a smaller share of a project's cost. Of the items provided by horizontal subcontractors, 18 percent are specialty items compared with 53 percent of the items supplied by regular subcontractors. The typical item provided by horizontal subcontractors represents 5.7 percent of the bid, considerably higher than the 1.6 percent for the average item provided by regular subcontractors. Lastly, horizontally subcontracted items appear to be less commonly supplied – the average item provided by horizontal subcontractors appears on 619 contracts, compared to 830 contracts for regular subcontractors.

IV HORIZONTAL SUBCONTRACTING AND BIDDING

In this section, I estimate the relationship between bidding and horizontal subcontracting. I estimate bidding both as a function of whether the bidder is a horizontal subcontractor, and in a separate specification the number of competitors who list the firm as a subcontractor. This variable is meant to capture variation in opportunity cost along the intensive margin. As the horizontal subcontractor is listed on more bids of its opponents, the likelihood rises that it will have subcontracting business in the event of a loss in the primary auction. The sign of the relationship between bidding and horizontal subcontracting status, both on the extensive as well as the intensive margin, is theoretically ambiguous, as suggested by the model presented in section II. On the one hand, horizontal subcontracting raises the opportunity cost of winning the auction, thereby softening a bidder's strategy. On the other hand, firms serve as the subcontractor to a competitor only when they can complete a project task at a lower cost than other potential subcontractors, and the more competitors that are served may reflect a greater cost advantage. Therefore, estimates using both the extensive and intensive margin of horizontal subcontracting are likely subject to these two conflicting effects.

I go on to employ data on unit prices for items provided by horizontal subcontractors to separately identify the strategic effect of horizontal subcontracting from its association with bidder costs. I then consider how the effects on firm bids translates into differences in the winning bid between auctions with and without a horizontal subcontracting relationship.

IV(i) Bid-level data

I begin by estimating a regression of firm bids on an indicator for the bidder appearing as a horizontal subcontractor on a competing firm's bid. In a separate specification I consider the number of competing bids on which the firm is a subcontractor rather than the indicator for horizontal subcontractor. To account for differences in the characteristics of projects, the dependent variable is the relative bid of firm i on project k, $\widetilde{b}_{ik}$, which is the ratio of the firm's bid, b_{ik} to the engineer's estimate of project cost, e_k. The estimating equation is

$$\widetilde{b}_{ik} = \beta_0 + \beta_1 I(h_{ik} > 0) + BX_{ik} + \gamma_i + \epsilon_{ik} \tag{6}$$

where h_{ik} is the number of bids in auction k on which bidder i appears as a subcontractor, and γ_i is a firm fixed effect. Factors that might shift bids for a firm in an auction are captured by the vector of controls, X_{ik}, which captures year, season, number of working days, number of items to be provided on the contract, backlog, and firm proximity to the project, as measured by whether the firm is located in the project county.

[Place Table IV approximately here]

Table IV presents the results of estimating equation (6). In column 1, I include only basic contract-level covariates. The correlation between a firm's bid and its status as a horizontal subcontractor is significantly negative, both statistically and in magnitude. Horizontal subcontractors bid on average 6.2 percent less than firms who are not listed as a subcontractor on a competitor's bid. Much of this relationship is accounted for by the quality of firms employed as subcontractors. In the specification shown in column 2, I control for bidder fixed effects, and the estimated coefficient on the horizontal subcontractor indicator is reduced to -0.018. This suggests that firms employed as subcontractors by their competitors have lower costs on average.

The firm fixed effect captures the average firm bid, however the cost of a particular firm could vary over time as well. In column 3 I include additional covariates that are likely to contribute to firm costs on a particular project. These include the backlog of incomplete projects, which tends to increase costs due to short-run capacity constraints, and an indicator for the firm having a location in the project county.[15] This specification also includes controls for the firm's prior experience with the work required on the project. This includes the portion of items on the contract that the firm has provided as a prime contractor or subcontractor on another successful bid, as well as the portion of items requiring special expertise that the firm has provided as a subcontractor on other successful bids. The sign of the estimated coefficients on these variables are in the predicted direction, though firm location does not have a statistically significant effect. This is likely due to firms entering into bidding in a distant location only when there is some other factor yielding an offsetting cost advantage. Firms submit lower bids for projects comprised to a greater degree of items that the firm has provided on other projects, and this is true both for experience as a prime contractor and a subcontractor. Including the controls has little effect on the primary variable of interest. The coefficient on the horizontal subcontracting dummy variable is -0.019, virtually unchanged from previous specifications.

[15]The backlog variable is formed within the data and assumes that projects are completed in a straight line manner. The project start date and project working days are used to determine the project end date. I take the incomplete portion of each outstanding project multiplied by the value of the winning bid, and sum this across all projects incomplete as of the auction date.

A final consideration is that projects in which firms find it beneficial to utilize subcontractors may differ from those where firms wish to produce tasks themselves. While most of the variation in bids is captured by the engineer's estimate, there still may be other unobservable factors that are correlated with firm bids. For instance, the engineer's estimate may miss interactions between different elements in a project, or firms may recognize project difficulties not accounted for by the engineer. In column (4), I present estimates of a specification that includes contract fixed effects. The horizontal subcontracting coefficient is estimated to be -0.032 and statistically significant, which is larger in magnitude than the estimates that include only firm fixed effects. This suggests that horizontal subcontracting is more often observed in projects with higher costs. It is also worth noting that in this specification, firm location is a statistically significant determinant of bids. This indicates that within an auction firms located closer to the project bid lower than those firms located elsewhere.

I next examine the number of bids within an auction in which a bidder is listed as a subcontractor. This variation on the intensive margin imperfectly captures the size of the opportunity cost – increasing the number competing bids on which a bidder is listed increases the firm's likelihood of serving as a subcontractor in the event of losing the auction. This variable shares the same identification issues as the horizontal subcontractor indicator. The theoretical model suggests that as a firm's cost goes down, then more bidders will wish to hire that firm as a subcontractor. In columns (5)-(8) of Table IV, I present the same specifications as in the first four columns, but instead with the continuous measure of horizontal subcontracting as the independent variable of interest. A similar pattern of estimated coefficients emerges. I find that each additional horizontal subcontract is associated with a 2.6 percent lower bid. This estimate attenuates as firm attributes are included in the specification, indicating again that the majority of this effect is explained by firm productivity.

IV(ii) Item-level data

As discussed, the correlation between horizontal subcontracting and bids embeds both the cost effect (firms will use the lowest cost subcontractor), and the strategic effect (where horizontal subcontracting leads to an opportunity cost causing the firm to bid less aggressively). In this section, I attempt to separately identify the strategic effect by utilizing within-contract detail on the prices bidders place on items. Some bidders list the items to be provided by each of its subcontractors. When one of these subcontractors is also a bidder, it is possible to observe the price for the same item on both bids. In other words, I can observe a measure of the price charged by the same firm within the same auction, in one case acting as a subcontractor and in the other case acting as the prime contractor. Both prices should reflect the cost advantage of the horizontal subcontractor, while only the prime contractor price should include the opportunity cost.

To implement this empirically, I form a measure of the relative unit price for items that one bidder will provide to other competitors as a subcontractor.[16] This takes the log of the price charged as a bidder and subtracts the log of the average price charged as a subcontractor (via the bidders to which it subcontracts). Denote this relative price by $\widetilde{p}_{imk}$, where i and m denote the bidder who is a horizontal subcontractor and item, respectively. As before, k indexes the project. Appendix A2 provides an example from a particular contract of the item data and how it is used.

Since project award is determined by the total bid, and not the unit bids, it is important to establish how relevant the item prices are. Firms have an incentive to be accurate with item prices, since they are used to compensate for unexpected deviations from estimated quantities. On the other hand, a firm may try to game its bid by placing a higher unit price on items for which it anticipates an overrun.[17] It is worth noting that this incentive is the same for all firms with the same expectation of quantity deviations, suggesting the incentive to unbalance does not on average introduce a difference in the item prices across different bidders.

[Place Figure 1 approximately here]

In Figure 1, I plot the distribution of the relative unit bids observed in the data. The prices charged by the bidder and the bidders to which it subcontracts tend to be very similar. Almost half of the subcontracted prices are within 10 percent of the bidder prices. In all, 74 percent of the relative unit bids are between 0.7 and 1.1. Also in this figure is the distribution of the bidder's unit price for those same items relative to that of the bidders for which it doesn't subcontract, denoted by $\widetilde{p}_{-i}$. Two things are learned from comparing these distributions. First, the distribution of $\widetilde{p}_{-i}$ is more spread out than the distribution of $\widetilde{p}_{i}$, indicating that a firm's unit price is more similar to that of the bidders to which it subcontracts than it is to the other auction participants. Second, the unit price charged by horizontal subcontractors is lower relative to the firms they do

[16] In some instances, the description provided in the data of the work the subcontractor is to complete specifies the exact items to be provided, but only indicates that the listed subcontractor is to provide a portion of the item specified in the contract. Since it is unknown how much of the item is to be provided by the listed subcontractor, these cases have not been included.

[17] There are institutional constraints on this practice, as Caltrans checks bids for imbalances, and occasionally rejects bids it deems as imbalanced.

not subcontract to than to those they do. For instance, 43.3 percent of $\widetilde{p}_i$ observations are below 0.9 compared to 50.6 percent of $\widetilde{p}_{-i}$ observations.

To estimate the strategic effect of horizontal subcontracting on bids, I regress the relative unit bid on the number of bidders for which a firm subcontracts. The estimated specification is as follows:

$$\widetilde{p}_{imk} = \beta_0 + \beta_1 h_{ik} + BX_{imk} + \gamma_i + \epsilon_{imk}. \tag{7}$$

The dependent variable is the log unit price charged by bidder i for item m on project k minus the log average price charged for the same item by all the competing bidders to who it will supply the item. The variable of interest is h_{ik}, the number of competing bidders for which it is listed as subcontractor. It is important to note that with this empirical strategy, only variation along the intensive margin is available. The indicator for horizontal subcontracting is always one since attention is narrowed to only horizontal subcontracted items. As the horizontal subcontracting increases along the intensive margin, the opportunity cost of winning the auction grows, so the coefficient β_1 is predicted to be greater than zero.[18] A vector of bidder, auction, and item covariates, X_{imk}, is included to control for any factors such as project scale or item type that might alter the average gap in unit prices across bidders.

[Place Table V approximately here]

Table V presents the results of estimating equation (7). The results suggest that the price gap rises with each additional competitor for whom a bidder subcontracts. In column 1, I present the results from estimating off of the entire sample of horizontally subcontracted items. The point estimate of coefficient β_1 is 0.048, large in magnitude and statistically significant. One concern with this specification is the presence of large outliers of the dependent variable. As witnessed by the distribution of item prices plotted in Figure 1, it is sometimes the case that the firm charges substantially more or less for an item than the firms to which it subcontracts the same item. In subsequent columns I drop the top and bottom 5 percent of observations. Doing so yields qualitatively similar results, though a more plausible point estimate of β_1. The results of this estimation, shown in column 2, suggest that the unit price increases by 1.4 percent for each additional horizontal relationship.

[18] Note that selection into horizontal subcontracting is still an issue on the intensive margin, though taking the relative bid should net out this effect.

Another concern is that the average quality of firms subcontracted to may fall as h_{ik} increases. To account for this possibility, the specification shown in column 3 includes the average total bid relative to the engineer's estimate for bidders for whom the items to be subcontracted is observed. Doing so also accounts for the possibility that the firms who describe subcontractor work using item numbers differ from those that use a verbal description. The coefficient on this variable is small and insignificant, and the point estimate of β_1 is unaltered, lessening these concerns.

The specification shown in column 4 excludes "lump sum" items. These items are unique to the project and cannot be denominated in typical units of measure. One example would be the construction of a temporary building. It may be desirable to exclude these items, since they are not readily comparable across projects, and the incentives in setting unit prices are different from other items in the project. When these items are excluded from the estimation, the estimate of the effect of h_{ik} on the unit price gap is virtually unaltered.

Lastly, the specification shown in column 5 includes controls for the market power of the horizontal subcontractor. The degree of market power represents an unobserved variable that could be correlated with both the number of firms the horizontal subcontractor supplies as well as the item price deviation. I measure market power in three different ways. One is simply market thickness, as measured by the number of times the item appears in the project district in the data. Second is a measure of how concentrated provision of the item is across firms within the district. This is captured by an HHI measure, where a firm's market share for an item is the fraction of item appearances in a district that are provided by a firm. The squared market shares are then summed across firms in the district. The third measure is the share of item appearances in the district provided specifically by the horizontal subcontractor. The inclusion of these three measures of market power have no influence on the estimated parameter β_1.

IV(iii) Winning bids

I consider next the correlation between winning bids and the practice of horizontal subcontracting. Firms may enter into horizontal subcontracting arrangements in order to soften downstream price competition. On the other hand, employing a competitor as a supplier will reduce costs if supplier selection is motivated by efficiency.

[Place Table VI approximately here]

In Table VI, I present the results of estimating the correlation between the winning bid and whether the auction contains at least one cross-supply relationship. The dependent variable is the relative bid – the winning bid normalized by the engineer's estimate. An alternative approach to OLS would be some form of matching, such as nearest neighbor or kernel matching. The qualitative results are not sensitive to instead taking this approach. In column 1, I show the results of estimating a specification with no other covariates. Auctions with at least one horizontal subcontracting relationship have a 5.7 percent lower bid than auctions without such a relationship. This appears to be driven by the fact that horizontal subcontracting is more prevalent when there are more bidders. The specification shown in column 2 adds a control for the number of bidders, as well as the number of contract items and number of workdays. The coefficient estimate attenuates substantially with the inclusion of these variables, as the point estimate is now just -0.001 and statistically insignificant. The decline in the estimated coefficient between specifications 1 and 2 is largely due to the inclusion of the number of bidders, which affects both the likelihood of horizontal subcontracting and the winning bid.[19] In column 3, firm fixed effects are included to account for the possibility that auctions with a horizontal subcontractor see a stronger bidder winning the auction. The specification including fixed effects suggests just 0.1 percent difference between auctions with and without horizontal subcontracting. In column 4, I show the estimates of a specification controlling for the average number of subcontractors employed across bidders within the same contract. It is possible that subcontracting-intensive projects differ from projects that do not typically require subcontractors. Including this variable has virtually no impact on the coefficient of interest. In summary, though the results of section IV(ii) suggest that horizontal subcontracting softens the downstream bid strategies of the vertically integrated firm, this does not translate into a higher winning bid.

V CONCLUSION

In this paper, I examine horizontal subcontracting in the context of the California highway procurement market. The practice of horizontal subcontracting is often observed in procurement, as well as in several other industries where a firm supplies a downstream competitor with an input to production. Theoretically, this practice lessens competition, yet could reflect the most efficient way to organize production. I find support for both of these views. I find that a firm bids lower in auctions

[19]Given the importance of the bidders variable, specifications were also estimated where the number of bidders enters nonparameterically. This may be more appropriate since theory predicts a nonlinear relationship between the number of bidders and bidding strategies. The estimated coefficient on the horizontal subcontractor dummy variable changes little when the number of bidders is instead included in this fashion.

where it is a horizontal subcontractor. This is likely to represent these firms being cost advantaged, a notion that is supported by other markers of firm cost, such as proximity, which are favorable for horizontal subcontractors. I also find evidence consistent with firms bidding less aggressively as the opportunity cost of horizontal subcontracting grows. Despite this evidence of competition softening, the winning bid is virtually identical in auctions with a horizontal subcontracting relationship compared to auctions without such a relationship. Given the statistically non-existent effect on the market price, combined with the evidence suggesting that horizontal subcontracting is efficiency enhancing, the evidence presented in this paper suggests that restricting the practice of horizontal subcontracting could result in a reduction in surplus.

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Appendix 1

Table A1: Examples of items

Item description	Share of contracts with item	Median share of contract value	Fraction of bids subcontracting item
Panel A: Fifteen most common items			
1. Traffic control system	0.903	0.046	0.019
2. Construction area signs	0.890	0.007	0.061
3. Portable changeable message sign	0.472	0.011	0.025
4. Thermoplastic pavement marking	0.410	0.003	0.126
5. Roadway excavation	0.387	0.046	0.009
6. Mobilization	0.374	0.087	0.002
7. Clearing and grubbing	0.336	0.007	0.006
8. Water pollution control	0.315	0.005	0.002
9. Minor concrete (minor structure)	0.274	0.008	0.019
10. Pavement marker (reflective)	0.264	0.003	0.114
11. Temporary railing (type k)	0.261	0.022	0.013
12. Class 2 aggregate base	0.253	0.030	0.011
13. Pavement marker (non-reflective)	0.250	0.002	0.077
14. Paint traffic stripe (2-coat)	0.242	0.005	0.096
15. Place asphalt concrete (miscellaneous area)	0.238	0.003	0.032
Panel B: Fifteen most commonly subcontracted items			
1. Metal beam guard railing (element)	0.003	0.002	0.254
2. Object marker (type pb)	0.001	0.001	0.235
3. Lighting (location 5)	0.001	0.007	0.226
4. Pavement markings (tape)	0.009	0.007	0.223
5. Cable anchor assembly (breakaway type m)	0.002	0.003	0.222
6. Kilometer post marker	0.010	0.000	0.220
7. Modify lighting (location 2)	0.002	0.018	0.205
8. Pavement marker (reflective-recessed)	0.031	0.009	0.204
9. Remove roadside sign (timber pole)	0.003	0.000	0.197
10. 100 mm thermoplastic traffic stripe (broken 3.66 m - 0.92 m)	0.012	0.000	0.190
11. Flashing beacon and lighting	0.002	0.021	0.184
12. Lighting (location 4)	0.001	0.004	0.179
13. Pavement marker (retroreflective-recessed)	0.041	0.009	0.179
14. Reconstruct metal beam guard railing (2.1 m post)	0.004	0.005	0.176
15. Remove cable anchor assembly	0.005	0.002	0.172
Panel C: Fifteen items with highest median share of bid			
1. Building work	0.042	1.000	0.005
2. Establish existing planting	0.006	0.905	0.000
3. Asphalt concrete	0.007	0.645	0.000
4. Signal and lighting (city)	0.001	0.563	0.000
5. Rubberized asphalt concrete (type o)	0.006	0.561	0.019
6. Rubberized asphalt concrete (type g-asphalt rubber)	0.001	0.540	0.000
7. Rubberized asphalt concrete (type g)	0.022	0.513	0.010
8. High speed weigh-in-motion system	0.005	0.486	0.049
9. Rubberized asphalt concrete (type g-asphalt rubber)	0.001	0.480	0.036
10. Weigh-in-motion system	0.002	0.474	0.014
11. Asphalt concrete (open graded polymer modified)	0.006	0.470	0.015
12. Rubberized asphalt concrete (type g)	0.031	0.464	0.006
13. Rubberized asphalt concrete (type o)	0.004	0.416	0.000
14. Asphalt concrete	0.067	0.415	0.006
15. Signal and lighting	0.004	0.373	0.047

Panels B and C only include those items appearing on more than five contracts.

Appendix 2

Table A2 shows an example of the item price data available for a particular contract. In this auction, Parnum Paving is a bidder and is also listed as a subcontractor on the bids of Green Right o Way Constructors, Terraform Construction, and Steelhead Constructors Inc. The table shows the item prices for these four bidders. There are four other bidders in the auction not shown in this table.

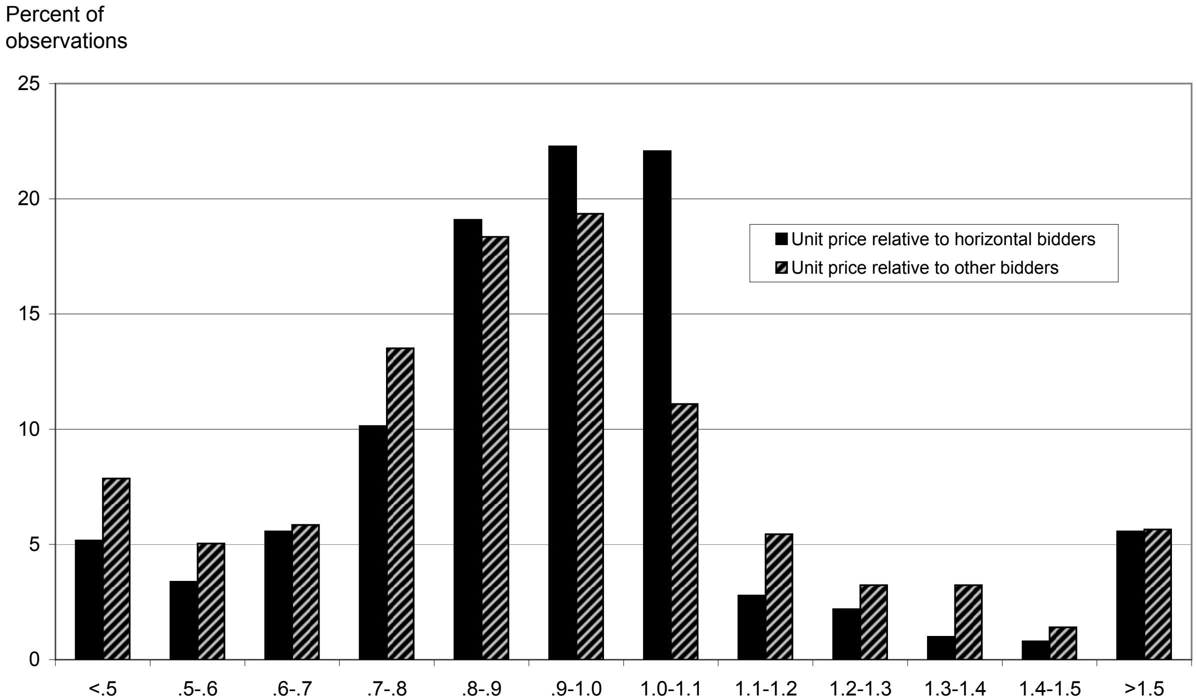
The table shows each item that will be required in the completion of the contract. Many items are comparable across contracts, in particular those listed in the units meters, square meters, and so forth. The first two items are in "lump sum" units, and these items tend to be idiosyncratic.

The table also lists the description of the subcontracting work that Parnum is to provide to each bidder. Terraform indicates that Parnum will provide items 17 through 21, but it is not possible to determine from the work descriptions exactly which items Parnum will supply to the other bidders. Steelhead indicates that Parnum will provide a *portion* of the items 17-21, while Green Right o Way only says that Parnum will provide "paving," which is not sufficient information to link to contract items. The average price for the items Parnum is to provide as a subcontractor in this example is therefore just the prices charge or items 17-21 by Terraform. The deviation between Parnum's price as a bidder and the subcontractor price, $\widetilde{p}_{ijk}$, is the log difference between Parnum's price and the average subcontractor price.

Table A2: Example of items in a contract with horizontal subcontracting

			Unit price					
				Subcontracted to [description of work below]:				
		Units	Parnum	Green Right o' Way [Paving]	Terraform [Items 17-21	Steelhead [Items 17-21] (partial)]	Avg. sub. price	$\widetilde{p}_{ijk}$
	Item							
1	Construction area signs	LS	3500	3500	2500	3000		
2	Traffic control system	LS	31000	59780	75000	43852		
3	Temporary traffic stripe (tape)	M	8	9.5	12.6	13		
4	Temporary pavement marking (tape)	M2	75	86.25	75	75		
5	Channelizer (surface mounted)	E	32	34.5	30	30		
6	Temporary railing (type k)	M	48	45	80	60		
7	Temporary crash cushion module	E	230	265	350	230		
8	Remove painted traffic stripe	M	4	4.75	2	2		
9	Reset milepost marker	E	50	500	50	100		
10	Reset roadside sign (two post)	E	300	500	350	200		
11	Roadway excavation	M3	22	10.5	21.25	20		
12	Ditch excavation	M3	40	35	20	30		
13	Imported borrow	M3	13	16	15	30		
14	Imported material (shoulder backing)	T	95	35	100	90		
15	Erosion control (type d)	M2	0.8	1	0.8	0.8		
16	Class 2 aggregate base	M3	52	42.75	50	55		
17	Asphalt concrete (type b)	T	66	75	***68***	70	68	-0.030
18	Paving asphalt (paint binder)	T	400	460	***400***	1000	400	0
19	Paving asphalt (binder-pavement reinforcing fabric)	T	200	115	***100***	500	100	0.69
20	Pavement reinforcing fabric	M2	4	4.6	***4***	4	4	0
21	Place asphalt concrete (miscellaneous area)	M2	8	9.2	***8***	8	8	0
22	Place asphalt concrete dike (type a)	M	18	32	16.5	17		
23	200 mm perforated steel pipe underdrain (1.63 mm thick)	M	152	210	100	175		
24	Permeable material (blanket)	M3	36	54	36	65		
25	Thermoplastic traffic stripe (sprayable)	M	4	4.6	4	4		
26	Pavement marker (reflective)	E	10	11.5	10	10		

Figure 1: Distribution of relative unit bids



This figure plots the distribution of the relative unit prices for goods that are horizontally subcontracted. The relative unit price takes a good that that the bidder supplies to its competitors, and divides the price it charges Caltrans in its own bid by the average price charged Caltrans for the same item by the bidders to which it supplies the item. The relative price to all other bidders is the unit price of those same items relative to the unit price of all other bidders (ones the firm has no subcontracting relationship with).

Table I: Auction-level summary statistics

	(1) All contracts	(2) No horizontal relationship	(3) With horizontal relationship
Horizontal relationship	0.11		
	(0.32)		
Winner is sub. on another bid	0.034		0.30
	(0.18)		(0.46)
Winner uses competitor as sub.	0.027		0.24
	(0.16)		(0.43)
Winning Bid	3.14 mill	3.21 mill	2.58 mill
	(26.7 mill)	(28.3 mill)	(5.94 mill)
Median winning bid	0.60 mill	0.59 mill	0.68 mill
Engineer's estimate	3.12 million	3.15 mill	2.9 mill
	(18.6 mill)	(19.7 mill)	(6.47 mill)
Median Estimate	0.63 mill	0.62 mill	0.75 mill
Relative Bid	0.96	0.96	0.91
	(0.23)	(0.23)	(0.19)
Number of items	35.13	34.53	40.26
	(38.64)	(38.68)	(38.05)
Number of s items	11.34	11.32	12.76
	(14.98)	(15.06)	(14.53)
Number of workdays	164.64	167.23	144.36
	(234.32)	(239.16)	(191.74)
Number of Bidders	5.16	4.94	6.91
	(2.83)	(2.72)	(3.00)
N	5342	4728	605

This table describes the summary statistics of nearly all contracts awarded by Caltrans from May 1996 through October of 2005. 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.

Table II: Bidder-level summary statistics

	(1) All firms	(2) Listed as hor. sub.	(3) Uses hor. sub
Horizontal sub	0.03		0.12
	(0.16)		(0.33)
Uses horizontal sub	0.04	0.21	
	(0.21)	(0.40)	
Win auction	0.20	0.26	0.12
	(0.40)	(0.44)	(0.33)
Relative bid	1.09	1.02	1.05
	(0.39)	(0.24)	(0.24)
Number of subs.	3.99	4.84	5.17
	(3.32)	(3.23)	(2.96)
Project in firm's county	0.30	0.34	0.28
	(0.46)	(0.47)	(0.45)
Log(1+backlog)	7.87	8.57	7.89
	(7.40)	(7.25)	(7.39)
Total number of wins	42.93	59.62	31.88
	(94.65)	(108.33)	(69.96)
Total revenue	$119 mill.	$146 mill	$88.5 mill
	(301)	(336)	(227)
HHI of firm's county concentration	0.345	0.331	0.313
	(.283)	(0.280	(0.266)
N	27502	714	1189

This table describes the summary statistics of nearly all contracts awarded by Caltrans from May 1996 through October of 2005. 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. Revenue is the sum of the firm's bid across all auctions won in the data.

Table III: Subcontracting summary statistics

	Horizontal subcontractor	Regular Subcontractor
Panel A: Horizontal subcontractors vs. regular subcontractors		
% of bid	0.235	0.061
	(0.160)	(0.094)
	[N=143]	[N=9,849]
# of bids appearing within auction	1.706	1.895
	(1.240)	(1.427)
	[N=670]	[N=51,886]
Appears on winning bid	0.121	0.197
	(0.326)	(.398)
	[N=1,149]	[N=100,090]
Panel B: Items provided by horizontal subcontractors versus regular subcontractors		
Specialty item	0.180	0.529
	(0.384)	(0.499)
Item's share of bid	0.057	0.016
	(0.093)	(0.041)
Item thickness	619.23	830.07
	(692.33)	(1103.25)
N	668	40,160

This table describes the summary statistics comparing horizontal subcontractors with regular subcontractors, and comparing the items provided by the two types of subcontractors. In Panel A, the first row reports the average percentage of the bid that is to be subcontracted to a particular subcontractor, as inferred from the item-level data. The sample here is restricted to those subcontractors for which we observe the items they are hired to provide. The # of bids appearing within auction is at the project-subcontractor level, and reflects that a subcontractor can be listed on multiple bids within the same auction. "Appears on winning bid" is the probability a subcontractor is listed in the bid of the winning firm. The means reported in Panel B are across items that are subcontracted. Item thickness is measured by the total number of times an item appears in the data..

Table IV: Horizontal subcontracting and bidding

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Horizontal sub	-0.062	-0.018	-0.019	-0.032				
	(0.010)***	(0.010)*	(0.010)*	(0.008)***				
Number of other bids hor. Sub.					-0.026	-0.006	-0.007	-0.005
					(0.005)***	(0.005)	(0.005)	(0.004)
Bidders	-0.008	-0.011	-0.011		-0.007	-0.011	-0.011	
	(0.001)***	(0.001)***	(0.001)***		(0.001)***	(0.001)***	(0.001)***	
Number of Items	-0.068	-0.017	-0.034		-0.068	-0.017	-0.034	
	(0.010)***	(0.012)	(0.012)***		(0.010)***	(0.012)	(0.012)***	
Log(working days)	0.012	-0.008	-0.011		0.012	-0.008	-0.011	
	(0.005)**	(0.005)	(0.005)**		(0.005)**	(0.005)	(0.005)**	
Log(1+backlog)			0.164	0.167			0.164	0.168
			(0.036)***	(0.030)***			(0.036)***	(0.030)***
In firm's county			-0.001	-0.011			-0.001	-0.012
			(0.005)	(0.004)***			(0.005)	(0.004)***
S items with sub experience/Tot items			-0.041	0.033			-0.042	0.027
			(0.103)	(0.090)			(0.103)	(0.090)
All items with sub experience/Tot items			-0.119	-0.155			-0.119	-0.156
			(0.050)**	(0.052)***			(0.050)**	(0.052)***
Items with prime experience/Tot items			-0.118	-0.051			-0.118	-0.051
			(0.017)***	(0.015)***			(0.017)***	(0.015)***
Firm effects		X	X	X	X	X	X	X
Contract effects				X				X
Observations	25864	25864	25714	25720	25864	25864	25714	25720
R-squared	0.02	0.50	0.50	0.82	0.02	0.50	0.50	0.82

The dependent variable is the firm's bid divided by the engineer's estimate. Each specification also controls for year and month dummies. S items are specialty items that the supplying firm must be qualified to provide. Items with experience are the number of items in the contract that the firm supplied on other successful bids. Each of the experience variables have been normalized by the total number of items specified in the contract. The number of items and the log backlog variables have been divided by 100 so that their coefficient estimates can be displayed.

Standard errors corrected for clustering by contract are in parenthesis.

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

Table V: Item price deviations between bidders and the firms they supply

	(1)	(2)	(3)	(4)	(5)
Number of bidders subcontracted to	0.048	0.014	0.013	0.012	0.014
	(0.016)***	(0.006)**	(0.006)**	(0.006)**	(0.006)**
Number of other bidders	0.011	0.004	0.004	0.006	0.007
	(0.008)	(0.004)	(0.004)	(0.004)	(0.004)*
Log(1+backlog)	-0.001	-0.005	-0.005	-0.005	-0.005
	(0.005)	(0.002)***	(0.002)***	(0.002)***	(0.002)***
Project workdays (X100)	-0.040	-0.017	-0.016	-0.023	-0.027
	(0.030)	(0.015)	(0.015)	(0.014)	(0.015)*
Log(estimate)	0.074	0.040	0.039	0.037	0.035
	(0.030)**	(0.013)***	(0.013)***	(0.012)***	(0.011)***
Number of items	-0.001	-0.002	-0.002	-0.002	-0.002
	(0.002)	(0.001)***	(0.001)***	(0.001)**	(0.001)***
Avg. relative bid			-0.013		
			(0.041)		
Item HHI in district					0.032
					(0.051)
Item appearances in district					-0.0004
					(0.0002)**
Share of appearances by firm					-0.065
					(0.052)
Drop outliers		X	X	X	X
Drop "lump-sum" items				X	X
Observations	532	478	476	457	457
R-squared	0.24	0.29	0.29	0.30	0.32

The dependent variable is the log of the firm's item price less the log of the average price of firms to which it supplies the same item in the same auction. Each specification also controls for year and month dummies. The average relative bid is the average total bid divided by the engineer's estimate taken across subcontractees where the price of the subcontracted item is observed. Item HHI in district is measures how concentrated the provision of the item is in the project district. The variable item appearances in district is the number of times the item appears in the project district. The share of these appearances where the firm in question is the prime contractor is the variable "share of appearances by firm."
Standard errors corrected for clustering by contract are in parenthesis.
*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.

Table VI: Auctions with horizontal subcontracting and the winning bid

	(1)	(2)	(3)	(4)
At least one horizontal sub.	-0.057	-0.001	0.001	0.0001
	(0.008)***	(0.008)	(0.009)	(0.009)
Bidders		-0.023	-0.024	-0.024
		(0.001)***	(0.001)***	(0.001)***
Number of items		0.017	0.040	0.025
		(0.008)**	(0.012)***	(0.016)
Log workdays		0.011	-0.001	-0.003
		(0.004)***	(0.006)	(0.006)
Mean number of subs.				0.003
				(0.002)
Firm effects			X	X
R-squared	0.01	0.15	0.41	0.41
Observations	5,104	5,104	5,104	5,104

The dependent variable is the winning bid divided by the engineer's estimate. Specifications 2, 3, and 4 also control for year and month dummies, the county of the project, and the funding source.
*,**,*** denote significance at the 90%, 95%, and 99% level, respectively.