

Sourcing from the Enemy: Horizontal Subcontracting in Highway Procurement

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Abstract

The practice of serving as a supplier to a firm that is also a competitor in the downstream market is frequently observed, though what gives rise to this practice, and its effects on market prices and efficiency, have not previously been explored empirically. In this paper, I consider these questions in the context of highway construction auctions, where a bidder is often chosen *ex ante* by a competitor in the same auction to be a subcontractor. In theory, while the practice may improve productive efficiency, serving as a horizontal subcontractor softens a firm's bid strategy, since gains in downstream market share come at the expense of lost subcontracting business. I find that auction participants bid 3.2 percent *lower* when listed as a subcontractor by a rival, reflecting that horizontal subcontractors are cost advantaged. To identify the effect of horizontal subcontracting on bid strategies from its correlation with firm costs, I use detailed item-level unit prices charged for the same items by the bidder and the firms to which it supplies those items. Each additional competitor supplied by the firm is estimated to increase its bid by 1.4 percent, consistent with horizontal subcontracting softening bid strategies. Despite this, the winning bid is virtually identical between auctions with and without horizontal subcontracting. This result, along with the characteristics of firms chosen as horizontal subcontractors, points toward an efficiency motive and away from a collusive explanation for cross-supply.

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1 Introduction

Settings where a firm's supplier is also a competitor in the downstream market are commonly observed.¹ Such horizontal subcontracting, or cross-supply, is likely to improve production cost if a firm is selecting the lowest cost supplier. However, an opportunity cost arises for the horizontal supplier, in that gains in market share in the downstream market come at the expense of lost supplying opportunities. This has the effect of softening competition in the downstream market. In light of these conflicting effects, regulators have in the past struggled with the question of how to treat industries where cross-supply is important.² Understanding what gives rise to this form of relationship, and how it effects efficiency and competition in the downstream market, is therefore highly relevant both from a practical/regulatory standpoint, as well as in understanding the vertical integration decision more broadly. No empirical work has examined these fundamental questions related to horizontal supplier relationships, and the goal of this paper is to fill this gap by estimating the effect of horizontal subcontracting on pricing, and to establish the factors that lead to horizontal supplier relationships arising in a market. I also will provide a series of facts about horizontal subcontracting in a particular industry, which is valuable in itself due to the lack of empirical work in this area.

I empirically examine horizontal subcontracting relationships in the context of auctions for California Department of Transportation (Caltrans) highway repair contracts. A firm must list in its bid the subcontractors it will employ should it win the auction, and it is often observed that an auction participant will be listed as a subcontractor on an opponent's bid. 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. In addition, I will utilize variation in project characteristics and how these interact with the characteristics of market participants, to establish drivers of horizontal subcontracting.

¹An 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).

²In 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.

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, and a greater dispersion of costs across project tasks, are more likely to be used as 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. Put another way, construction cost is unobserved and potentially correlated with subcontractor status.³

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, when describing the work to be provided by their subcontractors, will 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 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.

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, and suggests that horizontal subcontracting relationships may be efficiency enhancing. Much of this effect can be attributed to lower cost firms being used as horizontal subcontractors. These firms tend to be located in the project county, and much of the lower bid can be explained by firm

³A 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.

fixed effects. Examining the item level data reveals that the opportunity cost is tending to shift up firm bidding strategies. 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. While it is ambiguous what affect this should have on the winning bid, I find that the difference between the winning bid on auctions with a horizontal subcontracting relationship is virtually identical to those auctions without such a relationship. This calls into question a collusive motive for cross-supply in this setting.

Lastly, I turn to the question of what leads to horizontal subcontracting. I find that a bidder is more likely to be a subcontractor and supplies more competitors as the within-contract variability of its capabilities rises. This is consistent with a model of the subcontracting decision, which predicts that conditional on total cost, a firm that is particularly good at particular tasks will more likely be the lowest cost supplier of that good. The estimates suggest that this is true in a specification controlling for firm fixed effects, though the estimated effect of firm variance is virtually zero when firm fixed effects are excluded. This may imply that cost advantaged firms have invested in being generalists and are more likely to be used as subcontractors in those cases when when they happen to be productive on a particular task. Further light is shed on the role of capability variance when contract fixed effects are included. Some projects appear to be ones where firms are typically high variance, which seems to play the predominant role in the correlation between capability variance and subcontractor selection.

There are other signs that firms are motivated by productive efficiency when selecting a competitor as a subcontractor. 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. These results, together with the result that firms bid lower when a horizontal subcontractor, point toward productive efficiency as a primary motivation for horizontal subcontracting.

A number of theory papers have considered horizontal subcontracting relationships. 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. 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. 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. 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.

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. In the case of oil leases, the results of Hendricks and Porter indicate that joint bidding may help fringe oil companies enter the market by partnering with large firms. Large firms may benefit from partnering by spreading risk, sharing information, and reducing the number of competitors. However this is mitigated by several factors. First, by lowering lease prices the joint venture invites entry. Second, firms differ in the information they have about the oil contained in a lease, and by joint venturing a firm may allow a competitor entry into the market through information sharing where it would not have chosen to enter otherwise.

Horizontal subcontracting, though similar to a joint venturing relationship, differs in some important respects. Firms continue to compete in the downstream market under horizontal subcontracting. Combined with limits imposed by Caltrans on the degree of subcontracting, this limits the collusive implications of such a relationship. Second, the horizontal subcontracting relationship is often asymmetric. While one firm serves as the other's subcontractor should it lose the auction, the opposite is not true most of the time. Finally, the study of horizontal subcontracting presents an advantage from an empirical research standpoint, as it is possible to draw inference regarding the competitive implications of the relationship by virtue of observing both firm's prices in the downstream market.

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 (forthcoming) examine the design of time incentives in procurement contracts. Bajari, Houghton, and Tadelis (2006) and Miller (2010) study the cost of incomplete contracts. Marion (2009) considers the effect of affirmative action on government procurement costs. The latter two papers are notable in that they also make use of the item-level data used in the current study. Gil and Marion (2011) study subcontracting and the use of future interactions to enforce informal contracts.

This paper also relates to the empirical literature on the determinants of the make-versus-buy decision. A primary focus in this literature attempts to test theoretical predictions regarding

incomplete contracts and asset specificity on vertical integration decisions. Examples 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 2 describes a simple model of the subcontracting and bidding decisions that captures the main theoretical predictions regarding horizontal subcontracting. Section 3 describes the data and some key institutional details. Section 4 describes the results regarding bidding behavior, section 5 presents estimates of the determinants of horizontal subcontracting, and section 6 concludes.

2 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. Firms receive independent cost draws, c_i^1 and c_i^2 , capturing the cost of completing each task. The firm must complete the first task itself, but may subcontract task two, which it does if $c_i^2 > c_{ij}^2$ for some j , where c_{ij}^2 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^2 , and an IID contractor-subcontractor specific coordination cost, ζ_{ij} , so that $c_{ij}^2 = c_j^2 + \zeta_{ij}$.⁴ A firm's total cost of project completion can therefore be written as $C_i = c_i^1 + \min\{c_{ij}^2\}$, where $c_{ii}^2 = c_i^2$. A potential entrant faces a fixed cost of entry, K .

If a firm wishes to subcontract task two, it must select its subcontractor prior to bid submission.⁵ 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. Firm i earns surplus s_{ij} if it is employed as a subcontractor by firm j .⁶ Define the set of participating bidders as Ω . If a firm loses the auction, its expected profits from its

⁴Without 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.

⁵Spiegel (1994) analyzes both ex ante and ex post subcontracting, though I choose to describe ex ante subcontracting in order to match the sort observed in the data.

⁶For simplicity, this is defined as a fixed parameter, though in reality it is likely to be the outcome of a bargaining process. Note that it is irrelevant that the subcontractor is also a bidder in determining s_{ij} , since this price is only incurred after the bidding is concluded. The cost of the simplification is that it misses how the surplus might change as the cost of the subcontractor falls. For instance, a Nash bargaining solution might suggest that the subcontractor receives surplus equal to the difference between its cost and the cost of the next highest subcontractor. This effect is likely to be second-order however.

subcontracting agreements with other bidders are given by $\pi_i = \sum_{j \neq i} I(c_{ij}^2 < c_{-ij}^2) s_{ij} Pr(b_j < b_{-j})$, 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

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

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 this expression, where the opportunity cost, π_i , enters in exactly the same way as usual construction cost:

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

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

2.1 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

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

The opportunity cost associated with lost subcontracting opportunities enters linearly, acting just like the construction cost term C_i . As is usual, equilibrium bid functions in this model are monotone. Horizontal subcontracting, therefore, tends to shift up a firm's bidding strategy, and $\partial b_i / \partial \pi_i > 0$.

On the other hand, being a horizontal subcontractor likely indicates that the firm has a lower cost of completing task 2 than other firms in the market. Consider the indicator for i being chosen as the subcontractor of j , $I(c_{ij}^2 < c_{-ij}^2)$. The likelihood that this is true is given by

$$Pr(c_{ij}^2 < c_{-ij}^2) = Pr(\xi_{ij} < c_{-ij}^2 - c_i^2) \quad (4)$$

which increases as the firm's cost of completion of task 2 falls. A lower c_i^2 makes horizontal subcontracting more likely, yet is associated with a lower bid since it the firm's construction cost is lower. Therefore, bids may be positively or negatively correlated with horizontal subcontracting.

2.2 Entry decision

The firm chooses to enter the auction if its profits from entry exceed its profits from not entering. Taking into account the entry cost, K , and the expected profits from subcontracting π_i , which are earned if the firm does not enter, the firm's entry condition is given by:

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

Since the entry cost is fixed, and expected profits decline monotonically in cost, we can describe a cutoff value for cost, \tilde{C} , inclusive of construction and opportunity cost, such that $(b - \tilde{C})Pr(b_i < b_{-i}) = K$. If $c_i^1 + \min\{c_{ij}^2\} + \pi_i < \tilde{C}$, the firm chooses to participate.

A subcontractor who chooses to not to enter the bidding for the contract has the lowest cost of completion of task two, c_{ij}^2 for at least one j , yet has a sufficiently high value of c_i^1 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.

2.3 Other considerations

2.3.1 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 at least in the short run, for instance by being the only available supplier of a specialty input to production, even if only temporarily. This is a plausible scenario, however it is relatively simple to distinguish empirically 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.

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 it is listed as a subcontractor on more bids.

2.3.2 Revealing information to competitors

By providing a competitor with a quote for the price of supplying an input into the completion of the project, 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, as before the opportunity cost story predicts the opposite, as the opportunity cost is priced into one's own bid, raising it relative to one's rivals.

3 Caltrans highway auctions

3.1 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 prequalified. This prequalification 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.⁷ 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 first-tier subcontractor, those whose work accounts for at least 0.5 percent or \$10,000, whichever is greater, of the contract value. Each subcontractor must

⁷The 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)

be prequalified to do the listed work, and at most 40 percent of a project can be subcontracted. 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. 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. 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.

3.2 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 2005.⁸ 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 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. In the bid, 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.⁹ The

⁸221 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.

⁹The unit prices are used to adjust contractor compensation in the event that the realized quantity of an item differs from that estimated by Caltrans. This creates an incentive to manipulate the item prices, placing a higher price on those items that an overrun is expected. Caltrans attempts to curtail this behavior by reviewing the item prices and rejecting those bids it feels are unbalanced. Caltrans attempts to specify *ex ante* the relevant details of the work, when large deviations from project plans occur it often triggers a costly renegotiation process. (see Bajari et al, 2006)

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.

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 horizontal subcontractors (they are also bidders in the auction). I assign unique identifiers to subcontractors based on firm name, allowing me to track subcontractors across auctions.¹⁰

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.

In Table 1, 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. 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 one particularly large auction that did not have a subcontracting relationship. 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

¹⁰Due to many small permutations of spellings for the same firm, these were assigned by hand.

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 and more 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, 2011)

In Table 2, 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. Finally horizontal subcontractors have a greater degree of backlog, perhaps because they are lower cost and win more auctions.

4 Horizontal subcontracting and bidding

The sign of the relationship between bidding and horizontal subcontracting status is theoretically ambiguous, as suggested by the model presented in section 2. 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. In this section, I estimate the relationship between bidding and horizontal subcontracting, and I 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.

4.1 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. This variable is meant to capture variation in opportunity cost along the intensive margin. To account for differences in the characteristics of projects, the dependent variable is the relative bid of firm i on project k , \tilde{b}_{ik} , which is the ratio of the firm’s bid, b_{ik} and the engineer’s estimate of project cost, e_k . The estimating equation is

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

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.

Table 3 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 used 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. 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 uncompleted projects, which tends to raise costs due to short-run capacity constraints, and an indicator for the firm having a location in the project county. The sign of the estimated coefficients on these variables are in the predicted direction, though the location coefficient is insignificant. 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. The coefficient on the horizontal subcontracting dummy variable is -0.019, virtually unchanged from

previous specifications. This suggests that firms employed as subcontractors by their competitors have lower costs on average.

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 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, indicating 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 the firm loses 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 3, 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 a firm is associated with a 2.6 percent lower bid. This estimate is attenuated as firm attributes are included in the specification, indicating again that the majority of this effect is explained by firm productivity.

4.2 Item-level data

As discussed, the correlation between horizontal subcontracting and bids imbeds 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.¹¹ This takes the log of the price charged as 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 \tilde{p}_{ik} , where i and k denote the bidder who is a horizontal subcontractor and item, respectively. Appendix A1 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.¹² 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.

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 \tilde{p}_{-i} . Two things are learned from comparing these distributions. First, the distribution of \tilde{p}_{-i} is more spread out than the distribution of \tilde{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

¹¹In 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.

¹²There 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 \tilde{p}_i observations are below 0.9 compared to 50.6 percent of \tilde{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:

$$\tilde{p}_{ik} = \beta_0 + \beta_1 h_{ik} + BX_{ik} + \gamma_i + \epsilon_{ik}. \quad (7)$$

The dependent variable is the log unit price charged by bidder i for item j 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 horizontally 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. A vector of bidder, auction, and item covariates, X_{ijk} , 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.

Table 4 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.

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.

Lastly, 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.

4.3 Winning bids

I consider next the correlation between winning bids and the practice of horizontal subcontracting. In the absence of collusion, it is not clear whether higher or lower winning bids should prevail in auctions with a horizontal subcontracting relationship. The bidding strategy of the horizontal subcontractor is softened, yet its competitors benefit from using the low-cost supplier. If horizontal subcontracting merely facilitates collusion, however, the winning bid should clearly be higher in auctions with a horizontal relationship.

In Table 5, 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. 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 -0.004 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.¹³ Lastly, in column 3, firm fixed effects are included to

¹³Given the importance of the bidders variable, specifications were also estimated where the number of bidders enters nonparametrically. 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.

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. These results would seem to point away from a strong collusive motive for horizontal subcontracting.

5 Determinants of horizontal subcontracting

In this section, I consider the question of when horizontal subcontracting arrangements arise. The model presented in section 2 makes the obvious claim that a firm is employed as a subcontractor when the cost of employing the firm is less than producing the task in-house, as well as less than employing any other firm to produce the task.¹⁴ At the same time, a firm enters an auction when its overall project cost is below an entry threshold. A firm that is a horizontal subcontractor must have a cost low enough to enter the auction, and at the same time must be sufficiently productive at producing a particular task to be the lowest cost supplier of that task. Conditional on the average capability across tasks, the firm with a greater variance in capabilities should therefore be more likely to be used as a subcontractor.

This is tested by forming a measure capturing the variation of unit prices across items within a firm's bid. Unit prices vary considerably depending on the nature of the item, so I normalize the item price by dividing by its mean across all observations of that item in the data. The normalized item price could be typically high or low for a firm within a contract, so it is sensible to consider the coefficient of variation, $cv_{ik} = \sigma_{ik}/\mu_{ik}$. The specification to be estimated is

$$h_{ik} = \beta_0 + \beta_1 cv_{ik} + BX_{ik} + \gamma_i + \epsilon_{ik} \quad (8)$$

where h_{ik} is again the number of competitors that bidder i subcontracts for in auction k .¹⁵ The vector X_{ik} includes the number of bidders, which captures the fact that an auction with more bidders has more horizontal subcontracting opportunities. Another motivation for controlling for the number of bidders is that outsourcing decisions could depend on market competition, as suggested by Shy and Stenbecka (2005).

Table 6 presents the results. In column 1, I present the results with no controls. The effect of capability variance is of the anticipated sign, though statistically insignificant. On the other hand,

¹⁴While the model does not specifically address the cost of incomplete contracts, one can think of this being imbedded in the cost of employing a firm as a subcontractor.

¹⁵This captures variation on both the intensive and the extensive margin. Since the latter is responsible for most of the variation in h_{ik} , instead estimating a specification with an indicator for $h_{ik} > 0$ yields similar results.

as predicted, the relative bid is a significantly negative predictor of horizontal subcontracting. As the firm's costs rise, and consequently its bid, the likelihood that it is a low cost supplier for one of the items on the contract declines. This effect is nontrivial. A one standard deviation change in the relative bid is 0.39, and based on the coefficient estimate would lead to a twenty percent reduction in horizontal subcontracting relative to the mean of the dependent variable.

In column 2, I include firm fixed effects. Upon doing so, the estimated effect of the coefficient of variation is now positive and statistically significant. The difference in estimates between the specifications shown in columns (1) and (2) is telling. A firm may participate in many different auctions, some where its capabilities vary widely across project tasks and others where its capabilities are more uniform. For a particular firm, the fixed effects estimate indicate that it is more likely to serve as a horizontal subcontractor when its capabilities vary. However, firms whose capabilities are typically variable are not more likely to be horizontal subcontractors, as suggested by the specification without firm fixed effects.

In column 3, I include further auction and firm covariates. These covariates include auction characteristics that affect subcontractor demand generally, such as the time the project will take to complete, the number of different items to be provided, and the time of year. Also included are time varying firm characteristics that are likely to capture the attractiveness of firm as a subcontractor, such as the proximity of the firm to the project and the firm's backlog of uncompleted projects.

The *cv* coefficient is virtually unchanged when these covariates are included, and the sign of the estimated coefficients on the additional covariates generally are as expected. As the number of bidders rises, the firm serves more competitors as a horizontal subcontractor. This is consistent first with both more bidders being associated with more horizontal subcontracting opportunities and second with competition shifting up the demand for subcontractors generally. Geographic proximity is also relevant. A firm located within the project county is used more as a horizontal subcontractor. It is interesting that this has an independent effect from a firm's cost as captured by its bid. Local subcontractors may be easier to monitor, or in some way may have particularly low coordination cost compared with other possible subcontractors. Another significant determinant of horizontal subcontracting is the number of items listed in the contract, which is positively correlated with horizontal subcontracting. A greater number of items is likely to reflect both the number and breadth of tasks required to complete the project, both of which are expected to increase subcontracting demand. Lastly, despite the fact that project backlog is typically found to increase firm costs on the current project, it does not appear to significantly affect horizontal subcontracting.

It apparently operates solely through the firm's cost, which the specification controls for directly via the bid.

In the specification shown in column 4, a set of covariates reflecting the firm's experience providing items on the contract are included. These include the number of project items the firm has provided on other projects as a subcontractor, and similarly the number of items provided as the winning prime contractor on other projects. Importantly, I also include a measure of the firm's experience providing specialty items, which are the most likely to be subcontracting out and are a significant driver of subcontractor demand. (see Gil and Marion, 2011) A bidder's experience providing specialty items as a subcontractor has a substantial effect on its likelihood of being listed as a subcontractor by a competitor on the current project. The total number of items the firm has provided as a subcontractor is also positively influences its use as a horizontal subcontractor, though to a much lesser extent. Lastly, the specification shown in column 4 adds contract fixed effects to the regression. Interestingly, doing so makes the coefficient on the cv_{ik} variable small and statistically insignificant. This suggests that the within auction variation in the cv_{ik} variable is less important than the variation across auctions. A likely explanation is that some contracts have dissimilar tasks, where capabilities of the typical firm vary. In these situations, subcontractor demand will be higher than in those contracts where the typical firm is capable of performing all the tasks on the project.

6 Conclusion

In this paper, I examine an open empirical topic, the use of downstream competitors as suppliers, in the context of subcontracting in the California highway procurement market. While this practice lessens competition, it may also at the same time improve efficiency. I find that horizontal subcontracting does in fact soften the firm's bidding strategy, as each competing bidder listing it as a subcontractor increases its bid by 1.4 percent. I also provide evidence that further suggests that productive efficiency is the motivation for horizontal subcontracting. Conditional on overall bid, firm's with greater within contract variation in capabilities are more likely to serve as horizontal subcontractors.

A competing view with that presented in this paper is that firms use horizontal subcontracting to further collusion efforts. While this is difficult to rule out, the results in the paper do point to a substantial efficiency motive in the utilization of horizontal subcontractors. First, firms actually bid

lower when they are horizontal subcontractors, which itself makes collusion an unlikely explanation of the typical horizontal subcontracting situation. Furthermore, firm capabilities, location, and experience all contribute toward a firm being used as a subcontractor by a competing bidder. Most importantly, the winning bid is virtually the same on average in auctions where there is a horizontal subcontracting relationship compared with other auctions. These results all point toward productive efficiency improving due to horizontal subcontracting.

Though this paper considers why a firm subcontracts for others, it sets aside the question of why firms subcontract out certain tasks rather than producing them in house. In particular, why is it that a firm's capabilities vary? In this particular setting, one possible explanation is that investment in capital or know-how involves a fixed cost and is only incurred for capabilities that the firm expects to be in sufficient demand. A thinner market may lead to specialization. Another possibility is that firms have capacity constraints along several dimensions. While the firm may in general be capable of producing a task, it may temporarily be unable to produce the task itself due to commitments for other projects.

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Appendix

Table A1 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.

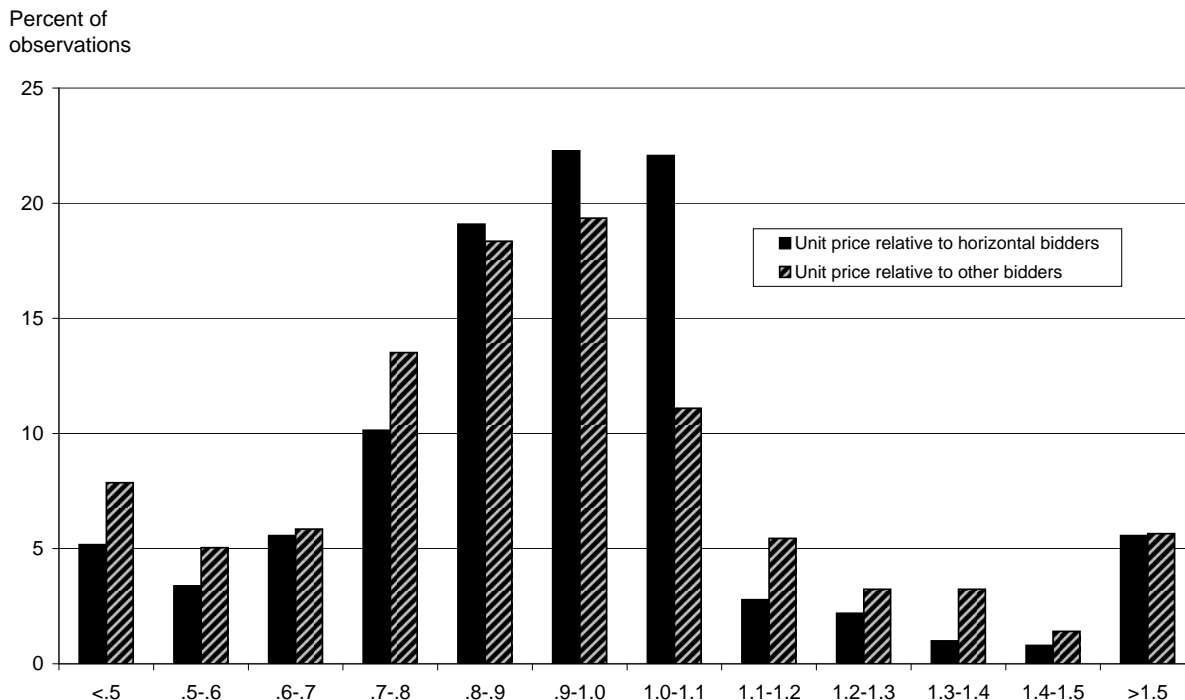
The table shows each item that will be required in the completion of the contract. Many items are comparable across contracts, in particular those listed in the units meters, square meters, and so forth. The first two items are in “lump sum” units, and these items tend to be idiosyncratic.

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, \tilde{p}_{ijk} , is the log difference between Parnum’s price and the average subcontractor price.

Table A1: 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	\hat{p}_{ijk}
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	52	55		
17	Asphalt concrete (type b)	T	66	75	68	70		
18	Paving asphalt (paint binder)	T	400	460	400	1000	68	-0.030
19	Paving asphalt (binder-pavement reinforcing fabric)	T	200	115	100	500	400	0
20	Pavement reinforcing fabric	M2	4	4.6	4	4	100	0.69
21	Place asphalt concrete (miscellaneous area)	M2	8	9.2	8	8	4	0
22	Place asphalt concrete dike (type a)	M	18	32	18.5	17	8	0
23	200 mm perforated steel pipe underdrain (1.63 mm thick)	M	152	210	100	175	100	
24	Permeable material (blanket)	M3	36	54	36	65	36	
25	Thermoplastic traffic stripe (sprayable)	M	4	4.6	4	4	4	
26	Pavement marker (reflective)	E	10	11.5	10	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 1: Auction-level summary statistics

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

	(1)	(2)	(3)
	All firms	Listed as hor. sub.	Uses hor. sub
Horizontal sub	0.03 (0.16)		0.12 (0.33)
Uses horizontal sub	0.04 (0.21)	0.21 (0.40)	
Win auction	0.20 (0.40)	0.26 (0.44)	0.12 (0.33)
Relative bid	1.09 (0.39)	1.02 (0.24)	1.05 (0.24)
Number of subs.	3.99 (3.32)	4.84 (3.23)	5.17 (2.96)
Project in firm's county	0.30 (0.46)	0.34 (0.47)	0.28 (0.45)
Log(1+backlog)	7.87 (7.40)	8.57 (7.25)	7.89 (7.39)
	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.

Table 3: Horizontal subcontracting and bidding

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

	(1)	(2)	(3)	(4)
Number of bidders subcontracted to	0.048 (0.016)***	0.014 (0.006)**	0.013 (0.006)**	0.012 (0.006)**
Number of other bidders	0.011 (0.008)	0.004 (0.004)	0.004 (0.004)	0.006 (0.004)
Log(1+backlog)	-0.001 (0.005)	-0.005 (0.002)***	-0.005 (0.002)***	-0.005 (0.002)***
Project workdays	-0.040 (0.030)	-0.017 (0.015)	-0.016 (0.015)	-0.023 (0.014)
Log(estimate)	0.074 (0.030)**	0.040 (0.013)***	0.039 (0.013)***	0.037 (0.012)***
Number of items	-0.001 (0.002)	-0.002 (0.001)***	-0.002 (0.001)***	-0.002 (0.001)**
Avg. relative bid			-0.013 (0.041)	
Drop outliers		X	X	X
Drop “lump-sum” items				X
Observations	532	478	476	457
R-squared	0.24	0.29	0.29	0.30

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.

Standard errors corrected for clustering by contract are in parenthesis.

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

Table 5: Auctions with horizontal subcontracting and the winning bid

	(1)	(2)	(3)
At least one horizontal sub.	-0.057 (0.008)***	-0.004 (0.008)	0.001 (0.009)
Bidders		-0.023 (0.001)***	-0.024 (0.001)***
Number of items		0.010 (0.008)	0.042 (0.012)***
Log workdays		0.005 (0.004)	-0.006 (0.005)
Firm effects			X
Observations	5120	5119	5119
R-squared	0.01	0.13	0.40

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

Table 6: Unit price variance and horizontal subcontracting

	(1)	(2)	(3)	(4)	(5)
CV of firm's unit prices	0.002 (0.004)	0.009 (0.004)**	0.007 (0.004)*	0.007 (0.004)*	-0.001 (0.007)
Total bid/Estimate	-0.023 (0.009)**	-0.012 (0.007)*	-0.010 (0.007)	-0.010 (0.007)	-0.013 (0.012)
Bidders	0.004 (0.001)***	0.009 (0.001)***	0.010 (0.001)***	0.010 (0.001)***	
Number of items			0.056 (0.009)***	0.029 (0.012)**	
Log(workdays)			0.001 (0.001)	0.001 (0.001)	
Log(1+backlog)			0.004 (0.053)	0.001 (0.053)	-0.010 (0.078)
In firm's county			0.022 (0.007)***	0.022 (0.007)***	0.030 (0.008)***
S Items with sub. experience				0.031 (0.014)**	0.049 (0.021)**
Items with sub. experience				0.009 (0.004)*	0.008 (0.007)
Items with prime experience				0.032 (0.024)	-0.022 (0.040)
Firm effects		X	X	X	X
Year, month effects			X	X	
Contract effects					X
Observations	25020	25020	24871	24871	24876
R-squared	0.00	0.12	0.13	0.13	0.29

The dependent variable is the number of competing bids on which the firm is listed as a subcontractor. The CV of firm's unit prices is the coefficient of variation of the unit prices across items in a firm's bid, where the unit price of an item has been normalized by its mean across all observations of the item in the data. S items are specialty items, where the firm supplying the item must be specifically qualified to provide. The variable "Items with subcontracting experience" counts the number of items the firm has provided as a subcontractor on other successful bids. "S Items with sub. experience" and "Items with prime experience" are similarly defined. The number of items, number of workdays, log backlog, and prime experience 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.