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Auctions vs. Bargaining: An Empirical Analysis of Medical Device Procurement

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Abstract

We test recent theory on the benefits of auctions and bargaining as alternative procurement mechanisms using data on the procurement of medical devices by Italian hospitals. Theory suggests that auctions perform well when cost control is the key concern, but are less effective at producing the optimal mix of quality and price for complex products where quality is difficult to verify. Consistent with the theory, we find that auctions are used more often when the influence of financial staff relative to medical staff is high, when the marginal cost of increasing product quality is high, and when the marginal value of increasing quality is low.

JEL Classification: D44, I11, L14, L31

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1 Introduction

The procurement of sophisticated technology is an important issue for many organizations. Government military contracting is perhaps the most prominent example, but there are also many non-military examples. Boeing, Ford and many other large companies subcontract for key components, while rapid technological advance confronts hospitals with an ever-expanding array of new equipment options.[1] Most large corporations today face multimillion dollar decisions about the computing and information technology to install. In all of these cases, the organization must determine how to obtain the best product at the lowest price.

The procurement mechanism that has attracted the most attention from economists is the auction. Much theory has been developed in recent years exploring the performance of alternative auction structures. Relatively little of this work, however, has examined the choice between alternative procurement mechanisms, *e.g.* auctions versus bargaining. An exception is the recent work of Manelli and Vincent[**?**], who study the design of optimal procurement mechanisms when quality is unverifiable. They show that in such a setting, auctions provide high-powered incentives for price reduction at the expense of quality. Thus, bargaining sequentially with individual suppliers may yield the buyer greater net benefits than would an auction.[2]

In this paper, we examine data on the alternative procurement mechanisms used by hospitals, with the aim of understanding what motivates buyers to use different mechanisms. Within each hospital, the tradeoff between quality and price will depend on the number of potential suppliers, along with the marginal cost and marginal benefit of increasing quality. The benefit of quality improvement to the hospital, in turn, depends on which groups have decision-making authority, *e.g.* physicians (as proposed by Pauly and Redisch[**?**]) or hospital administrators (as proposed by Newhouse[**?**]).[3] We frame our analysis with a theoretical model inspired by the work of Manelli and Vincent[**?**], which generates testable hypotheses regarding the buyer's choice between an auction and a sequential bargaining

[1] For example, the *New York Times*[**?**, p. B6] reports that "[A]t New York University, the medical center has carved off neuro-oncology as its brightest attraction, investing $10 million alone in a rare Gamma knife that administers beams of gamma radiation without surgical incision to the brain."

[2] Bulow and Klemperer[**?**] also study the tradeoffs between auctions and negotiations, and show that under certain assumptions even a seller with all the bargaining power prefers an auction to a negotiation process. Their model is of limited relevance in the empirical setting we study, since it predicts—contrary to observed practice—that auctions will always be used.

[3] We focus on auctions and bargaining as alternative procurement mechanisms, although in principle hospitals could also vertically integrate into the production of medical inputs or sign long-term contracts with particular suppliers. We thank Jim Burgess for pointing out that the Veterans Administration in the United States has vertically integrated into the production of prosthetic devices in order to assure high-quality care for veterans.

process. We test these hypotheses using data from a unique new dataset of Italian hospitals. This dataset covers a variety of products, and includes data on the relative strength of medical staff and financial staff within each hospital. We find considerable support for the notion that auctions are used less often as product quality becomes more critical. In particular, auctions are used more often by hospitals where administrators have greater decision-making authority, and for products where the marginal value of quality is low and the cost of quality high.

The remainder of the paper is structured as follows. Section 2 presents the theoretical model. In section 3, we describe our data, and explain some of the characteristics of the Italian hospital system and the regulations governing its procurement practices.Section 4 presents our empirical model, while section 5 presents and discusses our results. Section 6 concludes.

2 A Theoretical Model

A hospital wishes to acquire a product whose quality q cannot be contracted upon directly. The hospital's valuation of the product is $V(q) = A + Bq$. If it pays a price P for the product its net utility is $U(q) = \alpha V(q) - (1-\alpha)P$, where $\alpha \in (0,1)$. The presence of α in the expression for net utility reflects the relative importance of quality and price to the hospital, which depends on the relative importance of physicians and cost managers within the decision-making process.[4]

There are S sellers who produce variants of the product. Seller s has quality $q_s \in [0,1]$, with cost $C(q) = Cq_s$ with $C \geq 1$. It is common knowledge that a given seller's quality can be regarded as a draw from a probability distribution $F(q)$ with density $f(q)$. For simplicity, we will assume that $F(q)$ is a uniform distribution on $[0,1]$.

The hospital can choose between two procurement mechanisms, an auction or a process of sequential negotiation with sellers. We discuss these in turn below.

2.1 Auction

If the hospital uses an auction, it will end up purchasing the cheapest but lowest-quality product, since quality cannot be contracted upon. Let $q_{min} = min_S q_s$ denote the lowest

[4]Chapter 8 of Phelps[?] provides an excellent discussion of the tension between medical staff and line management within a hospital. Phelps frames decision-making within the hospital as a political problem, where the various interests within the hospital—physicians, nurses, administrators, etc.—vie for influence in controlling the allocation of resources. For simplicity, we work with the reduced form of this political influence game, which we characterize as producing an objective function comprising a linear combination of quality of care and cost reduction.

quality on offer. Then the probability that q_{min} is greater than some value t is

$$Pr(q_{min} > t) = \int_t^1 \int_t^1 ... \int_t^1 f(q_1)f(q_2)...f(q_S)dq_1dq_2...dq_S \quad (1)$$

For a uniform distribution, (1) simplifies to $Pr(q_{min} > t) = (1-t)^S$. The probability that the lowest quality on offer is exactly t can then be obtained as

$$Pr(q_{min} = t) = -\frac{d}{dt}Pr(q_{min} > t) \quad (2)$$

For a uniform distribution, (2) simplifies to $Pr(q_{min} = t) = S(1-t)^{S-1}$. Let $\bar{q}_{min}$ be the expected value of the minimum quality on offer. Then for the uniform distribution we have

$$\bar{q}_{min} = \int_0^1 St(1-t)^{S-1}dt = \frac{1}{S+1}.$$

We know from the Revenue Equivalence Theorem that the net revenue to the seller (hence, the price paid by the buyer) is the same for any of the four most common forms of auctions: the English, Dutch, first-price sealed bid and second-price sealed-bid auctions.[5] Then we can solve for the expected price paid by the buyer as follows.

Lemma 1 *The expected price paid by the buyer in an auction is* $2C/(S+1)$.

Proof: McAfee and McMillan[**?**] show that the expected value of the second order statistic (which is equal to the expected price paid by the buyer) is

$$E(Price) = CS\int_0^1 \left[t + \frac{F(t)}{f(t)}\right][1-F(t)]^{S-1}f(t)dt.$$

For a uniform distribution on $[0,1]$ this reduces to

$$E(Price) = CS\int_0^1 2t[1-t]^{S-1}dt.$$

Integrating by parts yields the stated result. **Q.E.D.**

The buyer's expected utility from using an auction is

$$EU_A = \alpha V(\bar{q}_{min}) - (1-\alpha)E(Price).$$

Using the preceding calculations, we find that

$$EU_A = \alpha A + \frac{\alpha B - 2(1-\alpha)C}{S+1}. \quad (3)$$

[5] For a discussion of the Theorem, see McAfee and McMillan[**?**].

2.2 Sequential Offers

An alternative to using an auction for procurement is to bargain sequentially with potential suppliers. While there are many possible ways to implement this notion, we will consider a particular format for clarity. Suppose that the buyer views all suppliers as identical *ex ante*, and arranges them in a sequence arbitrarily. He then makes a take-it-or-leave-it offer of P to each supplier in turn. Supplier i will accept the offer if $Cq_i < P$.[6] The probability that the offer will be accepted by one of the sellers is $1 - [1 - F(P/C)]^S$. If q_i is drawn from a uniform distribution on $[0, 1]$ then the probability of acceptance becomes $1 - [1 - (P/C)]^S$.

The expected value to the buyer if the offer is accepted is $E\{\alpha V(q_i)|Cq_i \leq P\} - (1-\alpha)P$. If $V(q) = A + Bq$ then

$$\begin{aligned} E\{\alpha V(q_i)|Cq_i \leq P\} &= \alpha \int_0^{P/C} (A + Bq)dq \\ &= \frac{\alpha AP}{C} + \frac{\alpha BP^2}{2C^2}. \end{aligned}$$

Combining the above elements, we can write the buyer's expected utility from the sequential bargaining process as

$$EU_B = \left[1 - \left(1 - \frac{P}{C}\right)^S\right] \left[\frac{\alpha AP}{C} + \frac{\alpha BP^2}{2C^2} - (1 - \alpha)P\right]. \tag{4}$$

Let

$$\gamma \equiv \frac{\alpha A}{C} + \frac{\alpha BP}{C^2} - (1 - \alpha).$$

Then differentiating (4) yields

$$\frac{\partial EU_B}{\partial P} = \gamma + \left(1 - \frac{P}{C}\right)^{S-1} \left[\frac{S}{C}\left(\gamma P - \frac{\alpha BP^2}{2C^2}\right) - \gamma\left(1 - \frac{P}{C}\right)\right]. \tag{5}$$

Setting this equal to zero yields the buyer's first-order condition for an optimal P. Solving equation (5) analytically is a somewhat messy operation, and there is no guarantee that expected utility is concave in P.[7] When $P = C$, however—which is high enough to induce all suppliers to accept the offer—equation (5) becomes

$$\left.\frac{\partial EU_B}{\partial P}\right|_{P=C} = \gamma = \frac{\alpha V(1) - (1 - \alpha)C}{C}.$$

[6] Note that we can assume $P/C \leq 1$ since $C \geq 1$ and the buyer never need offer more than $P = C$ to ensure that the offer is accepted.

[7] We have conducted a variety of numerical simulations of the model, and in no case have we found an interior solution. Either the optimal offer price is $P = C$ or the buyer should not purchase at all.

Note that the numerator is simply the buyer's net utility of purchase when he buys from the seller with the highest cost. If buying from the highest-cost supplier is worthwhile, then expected utility is maximized by raising the offer price to $P = C$, thus ensuring that all suppliers are willing to sell. In fact, Manelli and Vincent[?] identify precisely a set of related conditions under which this simple mechanism is the optimal procurement mechanism. When $P = C$, the buyer's expected utility from the sequential offer mechanism is

$$EU_B = \left[\alpha A + \frac{\alpha B}{2} - (1-\alpha)C\right]. \tag{6}$$

2.3 Comparing Procurement Mechanisms

By integrating the results of the previous two subsections, it is possible to characterize when using an auction is preferable to a sequential bargaining process. Let $\Delta \equiv EU_A - EU_B$. Combining (3) and (6) reveals that

$$\Delta = -\frac{(S-1)}{2(S+1)}\left[\alpha B - 2(1-\alpha)C\right]. \tag{7}$$

For our empirical analysis, we are interested in how the relative benefits of auctions change as the parameters of (7) shift. These parameter shifts can readily be signed. For example, as the cost of quality C increases, we have

$$\frac{\partial \Delta}{\partial C} = (1-\alpha)\frac{S-1}{S+1} > 0,$$

indicating that auctions become more beneficial as the cost of quality rises. Conversely, as the benefit of quality B increases, we have

$$\frac{\partial \Delta}{\partial B} = -\frac{\alpha(S-1)}{2(S+1)} < 0,$$

indicating that auctions become less beneficial as the value of quality rises. As the relative of physicians within the hospital grows, we expect α to become larger, so we note that

$$\frac{\partial \Delta}{\partial \alpha} = -\frac{(S-1)}{2(S+1)}[B+2C] < 0,$$

indicating that auctions become less beneficial as physician influence increases. Finally, as the number of potential suppliers S increases, we find that

$$\frac{\partial \Delta}{\partial S} = -\frac{[\alpha B - 2(1-\alpha)C]}{(S+1)^2}.$$

Note that the sign of this expression is not affected by S, but is instead determined by the sign of $\alpha B - 2(1-\alpha)C$, which reflects the relative magnitudes of the benefits and costs of quality, along with the balance of power between physicians and administrators within the hospital. Changes in S simply affect the magnitude of the utility difference between the two procurement mechanisms. When the benefits of quality are high (low), *i.e.* $B > (<) 2(1-\alpha)/(\alpha C)$, then the value of the auction format is decreasing (increasing) in the number of potential suppliers.

Combining the foregoing results yields our testable hypotheses regarding the use of alternative procurement mechanisms:

Proposition 1 *Auctions are more likely to be used by hospitals for procurement (a) the higher is the marginal cost of higher quality, (b) the lower is the marginal value of higher quality, (c) the greater is the relative power of administrators within the hospital, (d) when the number of potential bidders is high and the marginal value of quality is low, and (e) when the number of potential bidders is low and the marginal value of quality is high.*

In the following sections, we describe our data, our estimation techniques, and our results.

3 The Data

We use a large database which is currently under development in Italy, under the coordination of the Ministry of Health. The database is supported by the Observatory of Prices and Technologies (OPT), a large research project funded by the Ministry of Health and carried out by the Research Center of Trieste. A sample of 30 hospitals participate in the project, by providing detailed data on their purchases to the central database and gaining free access to data provided by other hospitals. The project is managed through the Internet.

It may be useful to note that in the Italian system public hospitals are constituted as independent units, which must clear their balance sheet and demonstrate financial autonomy. Procurement decisions are entirely decentralized, so it is no surprise to observe rather large variations in prices charged for homogeneous products across the country (according to a survey conducted by the authors, the average dispersion is 26% of the minimum price observed). The construction of the database is a first step intended to reduce price dispersion and to increase the transparency of the market.

The project covers the following classes of procurement: equipment, pacemakers, angiographic catheters, prostheses, emodialysis filters, and X-ray film. Each class covers several groups, totaling 81. Groups define partially substitutable products (*e.g.* ecotomographs in the equipment class, bicameral pacemakers in the pacemaker class). Within groups, products are classified according to type and supplier identification, so that it is possible to make price comparisons of identical products procured at various hospitals.

The total number of price observations at present is 5,993 and is growing over time. An interesting feature of the project is that it allows refinements of econometric estimates as better data become available. Currently, price comparisons at the level of individual products can be carried out for 1,297 different products, accounting for 3,382 price observations. For each observation, the database includes the following data: price, purchasing hospital, size of the hospital (number of beds), size of purchasing lot, and type of procurement procedure (e.g auction, bargaining or hybrid forms). In addition, the class "equipment" also includes the number of participating suppliers.

We supplement the database with data derived from a mail questionnaire survey addressed to all hospitals participating in the OPT project. The purpose of the survey, which was carried out in collaboration with the Ministry of Health, was to complete the database with data on the organizational structure and procedures of the individual hospitals. All hospitals participating in the OPT project were addressed by fax and telephone. The total number of usable responses was 16. Consequently, in this paper we use a subset of data for which we have information on features of the purchasing hospital.

One of the interesting features of our hospital-specific information is that it gives the percentage of patients who travel from other regions of the country for health care at a given hospital. This measure provides valuable information regarding the general reputation for quality possessed by the hospital. We describe our use of this information in detail in section 4.2 below.

A key goal of the questionnaire was to determine the relative importance of different objectives within each hospital, *e.g.* quality enhancement versus cost containment. This information will allow us to determine how competition between groups within the hospital affects procurement decisions. We tried several different ways of approximating the relative importance of "technical" and "commercial" factors in hospital decisionmaking. The following data were included in the questionnaire:

- number of procurement areas for which there are two separate evaluations, technical and commercial (min 0, max 6) ;
- number of procurement areas for which technical evaluation is carried out before commercial evaluation (min 0, max 6);
- frequency of cases in which technical evaluation leads to the selection of only one alternative (0= never, 3= very frequently);
- frequency of cases in which commercial evaluation changes the ranking of products as defined by technical evaluation (0= never, 3= very frequently);
- percentage weight of price and quality in supplier selection.

For empirical purposes, we wished to construct a proxy variable for the importance of medical staff, relative to financial staff, within the hospital. After a variety of consistency tests on the questionnaire data, we decided to use the third measure. Other measures proved to be less useful, insofar as they showed modest variance. The first and second measures were highly correlated and exhibited very little variance. Surprisingly, the fifth measure was not very significant because in many cases a uniform rule is applied to all purchases, sometimes following a legal provision.

At this stage, we are able to use only part of the dataset described above. The product categories we study are equipment and prostheses. An overview of the data used is provided in Table 1. Clearly auctions were used much less frequently than bargaining, and the relative use of auctions was considerably higher for prostheses than for equipment.

Product Category	Product Group	Number of Procurements	Auctions	Bargainings
Equipment	Device for General Anesthesia	7	0	7
Equipment	Colonoscope	15	0	15
Equipment	Defibrillator	25	0	25
Equipment	Ultrasound Scanner	32	5	27
Equipment	Electrosurgical Unit	24	0	24
Equipment	Electrocardiograph	23	0	23
Equipment	Emodialyzer	17	0	17
Equipment	Esophagogastroduodenoscope	15	0	15
Equipment	Surgical Light	34	0	34
Equipment	Monitor for General Anesthesia	32	0	32
Equipment	IV Line Infusion Pump	29	1	28
Equipment	TV System for Endoscopy	14	0	14
Equipment	Pulmonary Ventilator	16	0	16
Equipment	Electroencephalograph	4	0	4
Equipment	Cold Light Source	11	0	11
Equipment	Blood Gas Analyzer	6	0	6
Equipment	CAT Scanner	4	1	3
Prostheses	Hip Prosthesis	553	142	411
Prostheses	Knee Prosthesis	230	58	172
Prostheses	Proximal Femur Prosthesis	2	0	2
TOTAL		1093	207	886

Table 1: Auctions vs. Bargaining by Product Group

Additional detail on the prices observed in our sample is presented in Table 2.[8] Equipment is, on average, considerably more expensive than prostheses.

Product Category	Product Group	Average Price (Total Sample)	Average Price (Auctions)	Average Price (Bargaining)
Equipment	Device for General Anesthesia	$28,243.70	$0.00	$28,243.70
Equipment	Colonoscope	$17,556.82	$0.00	$17,556.82
Equipment	Defibrillator	$5,780.13	$0.00	$5,780.13
Equipment	Ultrasound Scanner	$88,729.54	$84,583.52	$89,497.32
Equipment	Electrosurgical Unit	$7,889.17	$0.00	$7,889.17
Equipment	Electrocardiograph	$4,625.41	$0.00	$4,625.41
Equipment	Emodialyzer	$14,560.69	$0.00	$14,560.69
Equipment	Esophagogastroduodenoscope	$18,217.36	$0.00	$18,217.36
Equipment	Surgical Light	$8,179.76	$0.00	$8,179.76
Equipment	Monitor for General Anesthesia	$15,504.83	$0.00	$15,504.83
Equipment	IV Line Infusion Pump	$1,196.93	$1,098.90	$1,200.43
Equipment	TV System for Endoscopy	$16,819.98	$0.00	$16,819.98
Equipment	Pulmonary Ventilator	$17,548.96	$0.00	$17,548.96
Equipment	Electroencephalograph	$20,163.94	$0.00	$20,163.94
Equipment	Cold Light Source	$4,943.1	$0.00	$4,943.10
Equipment	Blood Gas Analyzer	$20,370.88	$0.00	$20,370.88
Equipment	CAT Scanner	$525,542.58	$671,346.15	$476,941.39
Prostheses	Hip Prosthesis	$646.38	$817.12	$587.39
Prostheses	Knee Prosthesis	$963.13	$1,139.31	$903.72
Prostheses	Proximal Femur Prosthesis	$164.84	$0.00	$164.84

Table 2: Auctions vs. Bargaining by Product Group

4 The Empirical Model

In section 2, we developed a stylized model of a hospital's choice between auctions and bargaining in the procurement process. The theoretical model provides important guidance on the prospective determinants of the procurement mechanism used, but the model is not capable of determining the relative importance of specific determinants. Moreover, the model employs a number of simplifying assumptions that are unlikely to hold precisely in an industry setting where institutional factors and imperfect information about product

[8]Italian lire have been converted to U.S. dollars at an exchange rate of 1820 lire to the dollar.

quality may have important effects. Accordingly, we now turn to the development of an empirical model that builds upon both the theoretical insights genenerated in section 2 and industry-specific factors likely to have affected the choice of procurement mechanism in our sample.

4.1 General Framework

In order to test the predictions of the theoretical model, we estimated a probit model in which the dependent variable AUCTION represents the binary choice between bargaining and an auction (with values 0 and 1, respectively). Our fundamental prediction is that, if the difference in expected benefits to the hospital between auction and bargaining is positive, then the hospital will use auctions to procure a given group of products. More precisely, we are interested in the relationship

$$\Delta_{ij} = \beta' x_{ij} + u_{ij}, \tag{8}$$

where Δ_{ij} is the net benefit of using an auction instead of bargaining, for the i^{th} hospital and the j^{th} product group, *beta* is a vector of coefficients, x_{ij} is a matrix of independent variables, and u_{ij} is an error term assumed to be $IN(0,1)$. Of course, the econometrician cannot observe Δ_{ij} directly. Instead we observe only the discrete choice between an auction and a bargaining process, *i.e.* we observe a dummy variable δ_{ij} defined by

$$\delta_{ij} = \begin{cases} 1 & \text{if } \Delta_{ij} > 0 \\ 0 & \text{otherwise} \end{cases} \tag{9}$$

It is this variable that we estimate with the probit.

Auctions are defined as procedures in which the purchaser must evaluate all offers simultaneously and allocate the purchase to a bidder according to a pre-specified rule. In the Italian administrative law system this covers sealed bid auctions ("asta pubblica") and restricted sealed bid auctions ("appalto concorso"), in which the list of invited suppliers is defined by the purchaser. The latter is clearly a hybrid form, since it shares with auctions the feature of sealed bid and with bargaining the feature of vendor list decisions. However, in practice the list of invited vendors is very large, so the dominant properties are those of auctions. Both procedures are subject to European Union legislation, imposing uniform rules of publicity and transparency for purchases beyond a threshold value (200,000 ECU).

Bargainings are defined as those negotiation procedures in which the purchasing entity observes bids separately and retains the right to refuse to allocate the bid until a certain price level is reached. In the Italian system, this definition applies to "trattativa privata," in which the purchasing entity defines the list of invited vendors and deals with them separately, and "privativa industriale", in which it negotiates with a small number of suppliers, retaining some type of intellectual property rights on relevant biomedical technologies.

It is worth noting that the model of section 2 imposes two assumptions that are unlikely to hold perfectly in our data sample. First, the theory assumes that product quality is unverifiable. In practice, however, buyers are likely to have at least some imperfectly verifiable information about the quality of alternative suppliers and the different products within a given supplier's product line. It is possible, for example, that a hospital might specify a set of performance indices that must be met by any bidder in a particular procurement. To the extent such performance indices can be precisely specified *ex ante*, auctions become relatively more attractive. Indeed, if the hospital can use such indices to eliminate low-quality products in a given category, it can combine the cost-reducing power of auctions with the ability to control quality as well.

A second issue is that the theory assumes that the buyer's marginal value of quality and the seller's marginal cost of quality are linear. This tends to lead to corner solutions in which the hospital's best strategy is either to pursue the highest quality possible or the lowest price possible. More complicated cost functions would allow for interior solutions where a hospital is very concerned with the tradeoff between price and quality at the margin. In such situations, bargaining is more likely to result in a price $P \in (0, C)$. Such a price may well reflect the buyer's valuation of quality as well as the cost of quality. Our price data suggest that such a phenomenon is part of our sample, since we observe considerable variation in purchase prices within a given equipment group, even within the purchases of a single hospital. We take these factors into consideration below when defining our independent variables.

4.2 Explanatory Variables

As mentioned above, our analysis focuses on the product categories of equipment (comprising 17 different product groups) and prostheses (comprising 3 different product groups), which cover a total of 1,093 observations. The number of auctions is 207, while bargaining procedures number 886. We will consider two slightly different empirical implementations of the model. Model I utilizes the full dataset, and employs a measure of potential bidders to measure the extent of supply side competition. Model II uses a subset of the sample for which we have data on the actual number of bidders in each procurement. This data is only available for the "equipment" product category, which restricts the size of our sample to 224 observations, of which 6 involve auctions and 218 involve bargaining.

Based on the model of section 2, our independent variables are defined as follows. The variable $POTBIDDERS$ is the total number of potential suppliers to a bid, as defined by the total number of suppliers observed in the database in a particular product group. (Alternatively, the variable *BIDDERS* is the total number of actual bidders in a given procurement.) The variable *MEDICAL STAFF* is the frequency of cases (on a scale from zero to one) in which technical evaluation leads to the selection of only one alternative. The variable *DPRO* is a dummy variable that takes on the value of one for observations on prostheses and zero for observations on medical equipment.

With regard to cost, the econometrician is unable to observe directly the marginal cost of increasing quality in each product group. As a proxy, we use the average price paid for items in each given product group for all procurements in the dataset. The average price for each item is then normalized by dividing by the average value for all product groups, yielding the variable *COST OF QUALITY*.

As in the case of cost, we are unable to observe directly the marginal value of increasing quality. Instead, we created a variable *VALUE OF QUALITY* which approximates the value of quality without being dependent on endogenous information for a given observation. The variable is constructed as follows. As discussed earlier, we collected information on the percentage of patients at a given hospital who come from other regions. This gives an indication of the overall quality of the hospital; presumably "good" hospitals weight quality more than price in their purchases. However, even for high-quality hospitals, the extent to which they weight quality relative to price may vary across products depending on the extent of product differentiation possible in a given product group. To capture this effect, we computed the ratio of the highest price observed in a given product group to the average price observed for all other products in the same group. We then ranked these ratios on a scale from one to twenty and normalized the ranking to an average value of one. Finally, we multiplied the normalized ranking times the percentage of patients from other regions to obtain *VALUE OF QUALITY*. The variable thus reflects both information specific to a particular hospital and information specific to a given product group.

Descriptive statistics for the full sample are presented in Table 3A.

Variable	Mean	Std. Dev.	Min.	Max.
AUCTION	.189	.392	0	1
POTENTIAL BIDDERS	25.742	12.001	4	40
COST OF QUALITY	1.000	4.531	0.021	86.070
VALUE OF QUALITY	1.000	1.653	0.064	18.338
MEDICAL STAFF	0.534	0.115	0.40	0.90
DPRO	.718	0.450	0	1
Number of observations	1,093			

Table 3A: Descriptive statistics for Equipment and Prosthetics Combined

As mentioned above, we also perform a second estimation that makes use of data on the actual number of bidders for each procurement. This data is only available for the "equipment" product category, which restricts the size of our sample to 224 observations, of which 6 involve auctions and 218 involve bargaining. The summary statistics for this subsample are presented in Table 3B. Compared to the entire sample, the subsample exhibits less frequent use of auctions, a relatively small number of actual bidders on average, and less variation in the importance of medical staff.[9]

Variable	Mean	Std. Dev.	Min.	Max.
AUCTION	0.0268	0.162	0	1
BIDDERS	4.246	4.686	1	50
COST OF QUALITY	1.000	2.423	0.050	25.208
VALUE OF QUALITY	1.000	1.047	0.033	7.996
MEDICAL STAFF	0.495	0.051	0.40	0.60
Number of observations	224			

Table 3B: Descriptive statistics for Equipment Only

5 Results

Our results for Models I and II are shown in Table 4. The first column of coefficients covers both product classes, using the number of potential bidders as an independent variable, while the second column presents coefficients for the class "equipment" only, making use of data on the actual number of bidders.

[9]Note that the definition of the potential bidders variable is such that it may be less than the number of actual bidders in a given procurement.

Table 4: Probit Analysis of Procurement Mechanisms
(Dependent Variable = 1 if an auction was used)

Variable	Model I (Equipment and Prosthetics)	Model II (Equipment Only)
CONSTANT	19.24443*** (4.307014)	-2.866833 (-0.679982)
POTBIDDERS	0.308456*** (-3.506419)	
BIDDERS		-0.211489 (-1.404963)
MEDICAL STAFF	−13.68113** (-2.480184)	2.712839 (0.352166)
COST OF QUALITY	0.208615*** (5.394638)	0.694735** (2.542793)
VALUE OF QUALITY	−4.744431*** (-6.163378)	−5.229061** (-2.056304)
DPRO	7.488859*** (2.889423)	
Number of observations	1,093	224

Note: t-statistics in parentheses

*** indicates significance at the 1% level

** indicates significance at the 5% level

* indicates significance at the 10% level

In general, the model provides considerable support for the theory. In the following, we discuss the results for individual variables and the extent to which they support the theory.

Number of potential bidders According to the model, the sign of the derivative of the difference between the expected utility of auctions and bargaining with respect to number of bidders, $\partial\Delta/\partial S$, may be positive or negative, depending on whether an auction or a bargaining process, respectively, is used. Since over 80% of our observations in the full sample (and over 97% of the observations used in Model II) involve the use of bargaining, we would expect the sign of the coefficient estimate to be negative in both models. This is indeed what we find with a high degree of statistical confidence in Model I. In Model II, the sign of *BIDDERS* is also negative, but it is only significant at the 16% level.

Importance of medical staff The derivative of the difference in expected utility, $\partial\Delta/\partial\alpha$, is negative, implying a negative expected sign in our model. In terms of our variable, the higher the frequency of selection of just one alternative, the higher the power and importance of medical staff. In Model I, the variable holds a negative coefficient which is statistically significant beyond the 2% level. In Model II, however, the coefficient is insignificant. This is not completely surprising, given the summary statistics in Table 3A. As can be seen there, our ability to estimate precisely the effects of *MEDSTAFF* in Model II is hampered by the lack of variability in our observations for this variable on the data subsample used in Model II.

Cost of quality Here the sign of the derivative $\partial\Delta/\partial C$ is always positive, implying a positive expected sign in the probit estimate. This is what we find, and the variable is significant beyond the 1% level in Model I and at the 1.2% level in Model II.

Value of quality The expected sign for value of quality, $\partial\Delta/\partial B$, is negative, which we find to be the case empirically. In Model I, this coefficient is significant beyond the 1% level, while in Model II it is significant beyond the 5% level.

Dummy for Prosthetics We did not have a sign prediction for the dummy variable *a priori*. The actual empirical coefficient in Model I is positive, and significant at the 1% level. This suggests that prosthetics is an area where problems of unverifiable quality may be relatively low.

Overall, our empirical results provide substantial support for the theoretical model. Auctions are used more often when medical staff are relatively weak compared to administrative staff, when the cost of increasing quality is high, when the value of increasing quality is low, and when the number of potential bidders is small. In Model I, all of the independent variables are of the predicted sign and highly significant. Model II uses the actual number of bidders in each procurement, but also has a smaller sample size, less variation in some of the independent variables, and a small percentage of auctions amongst its observations. It does not perform as well as Model I. Nevertheless the variables for cost and value of quality in Model II are of the correct sign and significant at the 5% level or better.

6 Conclusions

We have presented what we believe to be the first empirical study of an organization's choice between auctions and bargaining as alternative procurement mechanisms. Using data on the procurement practices of Italian hospitals, we find that auctions are used more often when medical staff are weak relative to financial staff, when the marginal value of product quality is low, and when the marginal cost of product quality is high. These findings are all consistent with the general and intuitive notion that auctions are less likely to be optimal procurement mechanisms when quality is important but difficult to verify.

It is well known that medical practice often varies substantially across hospitals and physicians, even within the same country, for identical health conditions.[10] In part, these practice variations are due to a paucity of available information allowing for comparative evaluations and development of "best practice" standards. We hope that our analysis will serve as a step toward helping to develop best practice standards for hospital procurement.

A number of further research questions remain. To begin with, it would be useful to apply our approach to other products to see if our results hold more broadly; this should be possible as our dataset expands. In addition, we have treated the procurement decision as a binary one between auctions and bargaining, but our data allow us to identify a range of hybrid mechanisms which could be studied with the use of a multinomial logit estimation, along the lines of Crocker and Masten's[**?**] study of price adjustment clauses in contracts. Furthermore, we have pricing data that can be used to explore the performance of the various mechanisms in more detail. It may also be possible to delve deeper into issues of internal hospital competition, by distinguishing products where quality is important to physicians (*e.g.* due to ease of use) from products where quality is important to patients or hospital staff. Likewise, a richer set of data on hospital characteristics might allow us to explore issues of physician self-selection across hospitals. These interesting issues await further research.

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