Procurement

ABSTRACT Firms and government agencies rely increasingly on goods and services procured from outside suppliers. How to assure desired quality at a minimal cost in the procurement is often challenging and warrants carefully-devised contracting policies. The current entry reviews several problems arising in procurement and policies designed to remedy them. (JEL numbers: C70, D44, D89, L24, O32)

Virtually all businesses, both public and private, rely on procurement of numerous goods and services, ranging from such routine jobs as food and custodial services to complex job of building high-tech fighter jets and high-speed train systems. Rapid progress of communication technologies — most notably the emergence of the Internet — has made outsourcing both cheaper and more efficient, thus altering the traditional boundaries of "make-or-buy" decisions by many firms and government agencies in favor of more outsourcing. Thus, designing efficient mechanisms for procuring goods and services has become ever more important.

Procurement of standardized parts and services is relatively straightforward as a competitive market or standard bidding would produce an efficient outcome. In many procurement settings, however, the quality and custom features of the procured job is an important concern that are often hard to specify and verify contractually. The present entry spells out some of these problems and the policies to address them.

Contractable Quality

When quality is verifiable, the terms of the contract can be made contingent on the quality of the good. If the cost associated with delivering the job is unobservable, it presents two problems. First, to ensure the supplier's participation may require paying more than the true cost, i.e., information rents to elicit the cost, so the quality level must be decided relative to the overall cost paid to the supplier. Second, the buyer must identify the supplier who can deliver the good at the minimal cost to her. We will sketch the method for finding the optimal mechanism that deals with these issues.

To begin, suppose a buyer derives utility of $v(q) - t$ when she procures a job of quality $q \in \mathbb{R}_+$ and pays $t \in \mathbb{R}_+$, where the gross surplus function, $v : \mathbb{R}_+ \mapsto \mathbb{R}_+$, is strictly increasing, differentiable and strictly concave. Suppose there are $n \geq 1$ potential suppliers. Supplier $i \in N := \{1, ..., n\}$ can deliver quality at unit cost of θ_i, which is drawn from $[\underline{\theta}, \overline{\theta}]$

according to the cumulative distribution function $F_i(\cdot)$. We assume that the distribution has a positive density f_i and that $\theta + \frac{F_i(\theta)}{f_i(\theta)}$ is nondecreasing in $\theta \in (\underline{\theta}, \overline{\theta})$ for all $i \in N$. A supplier i receives $t - \theta_i q$ from a contract that pays him t for delivering q.

If the suppliers' costs are observable, then the procurer's decision will be straightforward. She can pick the most efficient one, $i = \arg\min_{i \in N}\{\theta_i\}$, and have him deliver the job at cost, so she will pick the first-best quality, $q_i^{**}(\theta_i) \in \arg\max_{q \in \mathbb{R}_+} v(q) - \theta_i q$.

When the suppliers' costs are unobservable, it is not possible to procure at the actual cost, since suppliers can pretend to have higher than actual cost. Nor is it easy or necessarily desirable to pick the least cost supplier, as will be seen. To illustrate the optimal procurement decision, suppose first there is only one potential supplier, $n = 1$. By the revelation principle, there is no loss in restricting attention to a direct revelation contract that determines the quality and the payment, $\{(q_i(\theta), t_i(\theta))\}_{\theta \in \Theta}$, as a function of the cost reported by the supplier.

The optimal contract $(q_i^*(\cdot), t_i^*(\cdot))$ must solve

$$[P] \qquad \max_{q_i(\cdot), t_i(\cdot)} \int_{\underline{\theta}}^{\overline{\theta}} [v(q_i(\theta)) - t_i(\theta)] dF_i(\theta)$$

subject to

$$(IR) \qquad U_i(\theta) := t_i(\theta) - \theta q_i(\theta) \geq 0, \forall \theta \in [\underline{\theta}, \overline{\theta}],$$

$$(IC) \qquad U_i(\theta) \geq t_i(\tilde{\theta}) - \theta q_i(\tilde{\theta}), \forall \theta, \tilde{\theta} \in [\underline{\theta}, \overline{\theta}],$$

where (IR) and (IC) ensure, respectively, the supplier's participation and his incentive to report truthfully his type.

By the well-known method, (IR) and (IC) constraints can be simplified to a pair of conditions:

$$(M) \qquad q(\cdot) \text{ is nonincreasing.}$$

and

$$(Env) \qquad U_i(\theta) = \int_{\theta}^{\overline{\theta}} q(\tilde{\theta}) d\tilde{\theta},$$

or equivalently

$$(Env') \qquad t_i(\theta) = \theta q_i(\theta) + \int_{\theta}^{\overline{\theta}} q(\tilde{\theta}) d\tilde{\theta}.$$

The constraint (M) will be seen not to bind, so it can be ignored. Substituting (Env') into the objective function of $[P]$ and switching the order of expectations yield

$$\int_{\underline{\theta}}^{\overline{\theta}} [v(q_i(\theta)) - J_i(\theta)q_i(\theta)]dF_i(\theta),$$

where $J_i(\theta) := \theta + \frac{F_i(\theta)}{f_i(\theta)}$ is the so-called "virtual" cost. The additional cost $\frac{F_i(\theta)}{f_i(\theta)}$ reflects the additional rents that must be given away to the types more efficient than θ when its quality is raised marginally. To see this more intuitively, suppose the quality for type θ is raised by Δq toward the efficient level. Then, there is an efficiency gain (to be captured by the procurer) of $[v'(q) - \theta]\Delta q f(\theta)$. At the same time, the raising of quality enables each type $\theta' < \theta$ to command extra rents of Δq by mimicking (or choosing the contract intended for) type θ, so the same amount must be given to them to dissuade them from doing so. Since the measure of those types is $F(\theta)$, the marginal cost of quality increase is $F(\theta)\Delta q$. The optimal quality $q_i^*(\theta)$ balances these two marginal effects, so $v'(q) - \theta = \frac{F_i(\theta)}{f_i(\theta)}$ if $q_i^*(\theta) > 0$, or more generally

$$q_i^*(\theta) \in \arg\max_{q \in \mathbb{R}_+} [v(q) - J_i(\theta)q].$$

Clearly, $q_i^*(\theta) < q_i^{**}(\theta)$, for $\theta > \underline{\theta}$, whenever $q_i^{**}(\theta) > 0$. In other words, it is optimal for the buyer to choose less than the first-best quality. In particular, the buyer may not procure at all even though procuring is socially efficient, for instance when $\theta < v'(0) < J_i(\theta)$. In practice, the optimal procurement policy can be implemented by a *menu* of quality-transfer pairs, $(q_i^*(\theta), t_i(\theta))$, or by a *nonlinear pricing scheme* $\tau(q) := t_i(q_i^{*-1}(q))$.

Now suppose $n \geq 2$ so there are multiple candidate suppliers. The selection of the supplier, which can be studied using the same mechanism design approach (see Myerson (1981), Laffont and Tirole (1987), McAfee and McMillan (1987) and Riordan and Sappington (1987)), extends the above insight naturally. What ultimately matter to the buyer are suppliers' virtual costs, not their actual costs. Hence, the supplier with the lowest virtual cost, $i \in \arg\min_{j \in N}\{J_j(\theta_j)\}$, must be selected, and the selected supplier must choose the "downward distorted" quality level, $q_i^*(\theta)$. If supplier i has ex ante higher cost than j, say in terms of conditional stochastic dominance: $\frac{F_i}{f_i} < \frac{F_j}{f_j}$, then the optimal selection rule favors i. Favoring the "underdog" can be seen as a way of *handicapping* the top dog to make him compete more aggressively.

When the suppliers are ex ante symmetric, i.e., $F_i = F_j$ for $i \neq j$, then the optimal selection is also efficient, and the optimal procurement policy can be implemented by the so-called *scoring auction* (see Che (1993)). Specifically, there is a quasilinear scoring function,

$$S(q,t) := v(q) - \Delta(q) - t,$$

for some $\Delta(\cdot)$ increasing, that implements the optimal outcome if the suppliers are asked to make two-dimensional bids, (q,t), and the supplier who achieves the highest score according to $S(q,t)$ is selected to produce his proposed quality and receive his payment. The term $\Delta(q)$ serves as a penalty against "quality bid" so as to implement the downward distortion feature of the optimal contract. The scoring auction resembles the procedures used in the procurement of weapons, transportation, construction, and a multitude of other goods and services. *Quasilinear scoring auctions* are analytically tractable and can implement a broad range of outcomes, even when the quality is multidimensional (so q is a vector of attributes) and the suppliers may have heterogeneous costs with these attributes (Asker and Cantillon (2004)).[1]

In many procurement settings, the monetary expenditures are observable, but the inherent capabilities as well as their effort to reduce the cost may not be observable. In this case, how to reimburse the supplier's cost becomes an important issue. A *fixed-price contract* that pays the same price to the supplier regardless of his realized cost provides a strong incentive for cost reduction effort but requires the supplier to bear a large risk. By contrast, a *cost-plus contract*, which reimburses the supplier's cost fully, provides weak incentives for cost reduction effort but imposes no risk on the part of the supplier. McAfee and McMillan (1986) show a mixture of the two contract forms — i.e., a *partial reimbursement rule* — to optimally balance the tradeoffs between the cost reduction incentive, adverse selection and risk sharing. (Laffont and Tirole (1986) obtained a similar result without risk aversion of the agent.) Bajari and Tadelis (2001) focus on the tradeoff between the cost reduction incentive and ex post renegotiation inefficiencies, and study how the complexity of the procurement job affects the choice of contract form. They argue that fixed-price contracts are optimal for standard jobs, whereas cost-plus contracts are optimal for complex projects.

Uncontractable Quality

Often the quality enjoyed by the buyer is unobservable to the supplier delivering the good or unverifiable to the court, so it is difficult to contract on it ex ante. Book publish-

[1] A quasilinear scoring auction may not implement the optimal direct revelation mechanism for the buyer if the suppliers have multidimensional costs, but it does implement the socially efficient quality mix. See Asker and Cantillon (2005).

ing, advertising, film production, development of new (e.g., pharmaceutical) technologies, procurement of new weapons systems and hiring new talents all suffer from a difficulty with specifying the quality of the goods and services procured. While ex post signals about quality are often available after the good is procured (e.g., sale of a book, sale of an advertised product, etc.), the fixed cost associated with procurement may be so high that quality assurance is needed before full-scale production. We discuss several methods for assuring quality.

To illustrate, suppose a buyer values the good at q if a supplier makes an effort $c(q) = \frac{1}{2}q^2$. It would be ideal for the buyer to obtain the quality $q^* = 1$ at the price of $c(q^*) = \frac{1}{2}$. If quality is unverifiable, it would be difficult to specify contractually the level of quality: The buyer would argue that the quality provided is lower than specified, and the supplier would argue the opposite. In any case, the supplier would have little incentive to provide high quality, since there would be little reward for it.

A simple *option contract* can solve the problem of unverifiable quality. Suppose the buyer signs a contract that requires the supplier to pay a (nonrefundable) upfront fee of $q^* - c(q^*) = \frac{1}{2}$ to the buyer and gives the buyer an option either to accept the good at the price of $p = q^* = 1$ or to reject it at no penalty. If the supplier produces quality of q, then the buyer would receive $q - \frac{1}{2}$ from accepting the good and $\frac{1}{2}$ from rejecting the good. Hence, the buyer will purchase the good if and only if $q - \frac{1}{2} \geq \frac{1}{2}$, or the quality is at least $q^* = 1$. Knowing this, the supplier will produce $q^* = 1$. The supplier has the incentive to provide adequate quality since the buyer has an option to reject the good if the quality is not to his liking. These option contracts, known in such names as *purchase upon approval* and *delivery-contingent contracts*, are common in situations where quality assurance is important (Taylor (1993); Che and Hausch (1999)). For instance, advertising agencies must often develop acceptable pilot campaigns before they are paid in full; real estate agencies and other brokers are typically not paid until they find an acceptable match between buyers and sellers; book publishers often reserve the right to recover an advance in the event that they find the book unacceptable. The *up-or-out contracts* well-known for academic tenure and law partnerships is a form of an option contract, presumably motivated to deal with the "unverifiable quality" problem.

A problem with the above option contract is that it requires the supplier to pay an upfront fee, i.e., to buy in. Often, suppliers have limited liability or are liquidity constrained, which reduces the value of the option contract. In the above example, for instance, if the supplier cannot be induced to "buy-in," the buyer will receive zero net surplus.[2] This problem can be solved by a *pilot/research contest*, i.e., by having multiple suppliers compete for a reward. To be concrete, suppose the buyer invites two suppliers, each with the same technology described above, and suppose the buyer promises a fixed prize $P = \frac{8}{25}$ (which turns out to be the optimal level) for the supplier who offers the higher quality. It is then equilibrium behavior for each supplier to randomize quality over $[0, 4/5]$ according to the cdf, $F(q) = \frac{25}{16}q^2$, yielding a surplus of $\frac{8}{25}$ to the buyer.[3] *Fixed-prize contests* have been used for developing new innovations, some historically important, such as the Longitude technology and the steam engine design. But recent procurement contests have allowed suppliers some freedom in specifying their own rewards. For instance, most of the defense procurement competitions as well as grant competitions allow suppliers to adjust the size of their prizes and compete along that dimension as well. Such *auction contests* can be in fact justified, as a contest that allows suppliers to bid on their reward is optimal (see Che and Gale, 2003). Suppose the buyer in the example above lets suppliers bid prices for their innovations and then procures from the one offering the highest net surplus — the difference between the quality offered and payment demanded. This auction contest induces each supplier to randomize over q uniformly from $[0, 1]$ and to bid $\frac{1}{2}q$ for his prize, yielding a net expected surplus of $\frac{1}{3}(> \frac{8}{25})$ to the buyer.

The purpose of employing competition here is not to select a supplier efficiently (recall both suppliers are equally efficient ex ante), but rather to provide incentives for unverifiable quality. The buyer has an incentive to select the supplier that offers the best value (quality minus payment), and this option to select from suppliers — just like the option to reject in the option contract — creates incentives for effort by the suppliers, and assures the surplus for buyer even without supplier buy-in. Such incentives come at the expense of duplicative investment, however, since the buyer procures only from one supplier. This suggests that limiting the number of competitors — often to two — is optimal (see Che and Gale (2003), Taylor (1995), Fullerton and McAfee (1999)). If the quality of the innovation/good is stochastic, competition will serve the additional purpose of identifying an efficient supplier.

The nonverifiable quality problem can be overcome if the buyer procures the good

[2]This is attributable to the deterministic nature of quality. If quality is stochastic, the quality accepted will generally exceed the option price. Even with stochastic quality, however the option contract will be of limited value to the buyer if the suppliers cannot buy in.

[3]If the other supplier follows the randomization strategy, a given supplier receives a payoff of $F(q)P - c(q) = \frac{1}{2}q^2 - \frac{1}{2}q^2 = 0$, when choosing $q \in [0, 4/5]$, so randomizing according to F is a best response.

repeatedly. In such a situation, *a reputation*, more specifically, the promise of granting rents in exchange for an agreed-upon quality, combined with the threat of terminating a relationship for a sub par quality, can create the supplier's incentives for quality (Klein and Leffler (1981)). For instance, in the above example, the buyer and a supplier can make an implicit agreement such that the latter provides the quality of $q^* = 1$ in exchange for a payment $p \in (\frac{1}{2}, 1)$ from the former, as long as both honor the agreement; if one deviates unilaterally, both terminate the relationship. The threat of termination is credible, since it is a Nash equilibrium in each round for the supplier to provide zero quality and for the buyer to pay nothing. If nobody deviates, the buyer and the supplier would obtain $\frac{1-p}{1-\delta}$ and $\frac{p-0.5}{1-\delta}$, respectively, where $\delta \in [0, 1)$ is a common discount factor. The two parties can get at most 1 and p, respectively, from a unilateral deviation. If $\delta \geq \{p, \frac{1}{2p}\}$, then the first-best quality can be delivered.

So far, we have assumed that quality of procurement is observable to the buyer (albeit nonverifiable to the court). Often, the quality of good supplied may not be observable to the buyer at the time she procures from a supplier. Development of new weapons or transportation systems are subject to this problem, as the quality of new features are learned long after the procurement. If the buyer is unsure about the quality supplied, a standard auction based solely on price performances poorly (and unobservability of quality precludes the use of multidimensional competition such as scoring auctions). In such a case, it may be socially optimal for the buyer to bargain with one of the many potential suppliers, instead of inviting them to compete for a job. To illustrate, suppose there are 2 potential suppliers each with cost c drawn independently and uniformly from $[0, 1]$. A supplier with c can deliver a good with quality $v(c) = 3c$ to the buyer, so not only is the quality unknown to the buyer, but it is also positively correlated with the supplier's cost. In this case, competition based only on price will result in the selection of the low quality, with the buyer obtaining only $\frac{1}{3}$ in expectation. By contrast, if the buyer selects a supplier at random and makes a *take-it-or-leave-it offer* of price 1, that will be accepted, and the buyer will enjoy expected surplus of $\frac{1}{2}$. Notice that bargaining dominates competition also in social surplus (see Manelli and Vincent (1995)). Sole-source procurement may also dominate competitive bidding if the project is complex and requires frequent adaptations, which creates the need for ex post communication and negotiation (see Bajari, McMillan and Tadelis, 2004).

Procurement Irregularities

The difficulty with verifying quality may require a buyer to hire agents with special expertise to evaluate the proposals. This added bureaucracy can introduce agency costs to the procurement. In particular, there is a potential for the agents evaluating proposals to favor a certain supplier in exchange for a bribe or kickback. *Corruption* is a serious problem both in public and private procurement, particularly across national borders.[4] Burguet and Che (2003) analyze this problem via a scoring auction model where quality score is measured imperfectly and manipulable by the procurement agent in exchange for a bribe, and show that bribery competition — unlike standard auction competition — leads to allocational inefficiencies (see also Celentani and Ganuza (2002), Burguet and Perry (2002), Compte, Lambert and Verdier (2005)).

Another type of procurement irregularity is *collusion* among bidders in procurement competition. Bidding cartels in procurement auctions account for a significant portion of antitrust cases. McAfee and McMillan (1992) show that standard auctions are vulnerable to collusion but that the outcome will depend crucially on whether the cartel can exchange transfers: If the cartel members can exchange transfers, they can organize a "knock-out" auction to achieve an efficient allocation, whereas if transfers cannot be used (for fear of detection, say) a member will be chosen randomly to win without any competition, meaning that allocation will be inefficient. A subsequent work has shown that repeated interaction allows asymmetrically informed cartel members to sustain collusion via a "bid rotation" type scheme, and that the scheme can be refined to attain a degree of allocational efficiency (see Aoyagi (2003), Blume and Heidhues (2002) and Skrzypacz and Hopenhayn (2004), for example). To what extent inefficiencies result from procurement irregularities and how they can be remedied by procurement policies remain open questions.

YEON-KOO CHE, *Columbia University and University of Wisconsin*

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