Pooled Procurement under Cost Uncertainty*

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7 September 2023

Abstract

We examine the incentives to participate in pooled procurement when competing sellers face cost uncertainty. Our motivation for this study is the procurement of vaccines and other new drugs by countries with heterogeneous income and health sector development. Under supplier-independent, uncertain buyer-specific costs, pooled procurement reduces the expected price, when supplier participation is a given. However, pooled procurement reduces the incentives for suppliers to enter. Thus, when buyers are sufficiently asymmetric, "strong" buyers have little incentive to participate in a buyer group. If the asymmetry were more modest, though, both strong and "weak" buyers benefit from pooled procurement.

Keywords: Buyers group; pooled procurement; common values; cost uncertainty

*Thanks are due to Doh-Shin Jeon and David Sappington for their comments and suggestions on an earlier draft. The usual caveat applies.

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1 Introduction

This paper analyzes the incentives for buyers to procure as a group. Our research is motivated by observations in the context of sourcing vaccines and drugs in low and middle income countries (LMICs) that have received scant attention in the academic literature. We bring to center-stage two problems that, according to practitioners (see e.g., Nguyen 2022), characterize this context: the need to (i) provide suppliers with incentives to participate and (ii) guarantee that heterogeneous buyers benefit from joining the group.

We postulate a model where to participate in a procurement competition, suppliers must incur certain expenses—these encompass negotiation related activities in obtaining certification and, crucially, information about the uncertain cost of supplying to a particular buyer. We assume that such necessary expenses, along with the buyers' willingness to pay, are common knowledge but may vary across buyers. However, the cost of supplying each buyer, although common for all suppliers, is uncertain at the time of contracting. We show that, when asymmetries are small, both strong buyers (i.e., those characterized by low up-front expenses and high willingness to pay) and weak buyers benefit from joining the group. Indeed, pooling procurement via a group results in a lower price; for a strong buyer, though, it can simultaneously lead to less supplier participation. By contrast, weak buyers benefit from both a lower price and a higher supplier participation under pooled procurement. When asymmetries are large, however, strong buyers have little incentive to procure as a group because the lower price, conditional on the number of suppliers, is insufficient to counterbalance the lowered participation.

The main benefit to buyers from procuring as a group, i.e., the reduction in expected price, is a consequence of each supplier pooling two or more private signals (estimates) of costs, when they compete to supply the group. This pooling of risks reduces each supplier's uncertainty about the cost. As a by-product, such pooling reduces informational differentiation which is the source of rents. Indeed, compared to independent purchasing, the variation in the cost estimates is lower under pooled procurement, where each supplier pools its information about the costs of supplying each of the different buyers. Other things equal, this reduction in informational differentiation reduces suppliers' profits. As a consequence, the price (which is the sum of profit and the common cost) becomes lower. However, the reduced profitability may result in lowered participation. When buyers are heterogeneous, their relative attractiveness for potential suppliers is different; this in turn may render pooled procurement unattractive to the stronger buyers.

We claim that our main assumptions comprise a good representation of the problem at hand. Indeed, suppliers face important upfront costs to be able to compete for procurement contracts. For instance, in Mexico, several distinct institutions, such as IMSS and ISSSTE (see e.g., Chu and Rangan 2019 and Rangan et al. 2023) develop their own drug formulary, standards of care (that can vary significantly across institutions), and approval processes for formulary inclusion. Any drug company wishing to participate in the Mexican market has to make a case to the CSG's General Health Council—this involves the pharma company submitting dossiers to each institution and requesting an opportunity to argue for inclusion in the corresponding formulary. In a similar vein, the World Health Organization (WHO) publishes treatment guidelines and makes recommendations to health organizations on best practices. WHO uses a prequalification procedure to inspect and certify pharma companies for compliance with certain manufacturing practices; such certification serves to assure clinics that they are procuring medicines from suppliers who have met the WHO quality benchmarks.[1] These 'qualification' procedures impose non-trivial costs on sellers before even having a chance to participate in the subsequent procurement process.[2]

Our assumption of uncertain but common costs captures a relevant empirical regu-

[1] See http://who.int/teams/regulation-prequalification/overview accessed on 8/6/2023.

[2] Certification may also include additional costs. In 2014, when Egyptian authorities granted Gilead regulatory approval for its *Sovaldi* (a Hepatitis drug), the negotiated terms of the agreement stipulated "Gilead ... (to) provide support for medical education and training initiatives, including patient awareness and prevention campaigns" (see Rangan 2016)

larity, particularly when serving LMICs. While suppliers might have a good grasp of production cost, distribution-related costs are typically important and tend to be more buyer-specific (than being seller-specific). Note, however, that the information (i.e., the estimates) that different sellers have about that cost of supplying is private. In other words, suppliers operate in a common-values (costs) procurement environment.

Asymmetries among buyers are also crucial in explaining both the allure and the complexity of buyer groups. Indeed, some programs' success hinges on the pooling of purchases by countries that vary in their income levels. Such countries have quite different priorities and face very distinct opportunities under independent procurement (see e.g., Nguyen 2022, Yadav 2022). Thus, an often mentioned virtue of procuring via a group is that pooling purchases with richer buyers may help attract potential suppliers that otherwise may not be interested in dealing with the poorer buyers. Yet, an important question here is "what is the likely motivation of a rich buyer to participate in such a group?" Indeed, pooling their "attractiveness" with that of a weaker buyer may reduce participation for stronger buyers. We identify a possible answer to that question: in general, given a specific set of participating suppliers, pooled procurement reduces the expected price. As outlined earlier, we also identify the mechanism behind this effect.

Our results are consistent with conventional wisdom and also with empirical observations. Indeed, based on their synthesis of over 40 empirical studies from the healthcare domain, Parmaksiz et al. (2022) observe that buyer heterogeneity is an important factor in determining pooled procurement's success—if the individual buyers are too different, conflicts can arise, possibly collapsing the arrangement.

Apart from an exogenous change in buyers' bargaining power vis-a-vis suppliers, the literature has offered two main alternative explanations for the desirability of buyer groups. One has to do with the shape of suppliers' costs functions. If scale were linked to lower costs, size by itself may be sufficient to explain the common incentives for asymmetric buyers (see e.g., Inderst and Wey 2007, Jeon and Menicucci 2019). The second has to do with horizontal product differentiation and its impact on price competition. It is well understood that when buyers perceive competing products to be more similar, suppliers can sustain only lower margins leading to lower prices. By pooling buyers with horizontally different preferences over suppliers' offerings, a group serves to reduce product differentiation. The corresponding lower prices may compensate the buyers' imperfect match (with product characteristics) and therefore be attractive to asymmetric buyers (see e.g., Dana 2012, Chen and Li 2013).

We let bargaining power be endogenously determined in a market interaction, with the group's bargaining advantage only stemming from the buyers' commitment to procuring through the group. That is, the only bargaining power that a group offers its members is the mere existence of (and commitment to belong to) the group.[3] Also, we assume (to all effects) constant returns to scale, and abstract away any product differentiation across suppliers' products. Our results do not rely on a reduction of negotiation/participation expenses either, although this may well be an advantage of pooled procurement. Instead, our main insight is that pooled-procurement reduces the expected distance between suppliers' estimates of costs.[4] This may be thought of as a novel type of supplier differentiation. We posit that, for the problem at hand, this effect of pooled procurement is more important than product (horizontal) differentiation.

The rest of the paper is organized as follows. The next section characterizes the equilibrium behavior for the two procurement regimes. Section 3 compares equilibrium outcomes in the two regimes, both in the symmetric- and asymmetric-buyer cases. The last section concludes.

[3]Also in a context of procurement (but with private costs), Loertscher and Marx (2019) define "buyer power" as the ability to set reserve prices and discriminate among suppliers—i.e., design the trading mechanism.

[4]Although we assume no explicit information sharing among suppliers, a bidding process may be thought of as a mechanism that endogenously allows suppliers to condition on each other's information. In this sense, our result is consistent with the literature on this issue. For instance, Vives (1984) finds that the higher correlation of signals when information is shared by price setting competitors actually reduces their profit. This is in line with the effect of lower information differentiation that pooled procurement has in our setting.

2 The Model

Suppose two buyers, A and B, can each procure one unit of a good from either of two suppliers, S_1 and S_2. Buyer i's value, V_i, of the good is commonly known $\forall\, i = A, B$, and without loss of generality we assume $0 < V_A \leq V_B$. In this model, suppliers need to incur a cost, t, to (learn about the specific needs of and) deal with that buyer. For all $i = A, B$ and $j = 1, 2$, once this cost, t_i, is incurred, supplier j privately receives a signal $s_{i,j}$ about the common (for both suppliers) cost c_i of delivering the good to buyer i. We assume that c_i for $i = A, B$ are independent realizations of a random variable, with CDF F and PDF f, that takes positive values on $[0, 1]$, and $E[c_i] = \frac{1}{2}$, without loss of generality. Signals s_{i1} and s_{i2} are conditionally independent, for $i = A, B$, and distributed on $[0, 1]$ with a conditional CDF $G(\cdot | \, c_i)$ and a corresponding PDF $g(\cdot | \, c_i)$ that satisfies the monotone likelihood ratio property. Signals and costs are independent across buyers. We assume that $V_i \geq 1$, and $V_B - 1 \leq 2\,(V_A - 1)$. The latter guarantees that, under pooling, a monopolist supplier would always prefer to sell to both buyers at a price of V_A than selling only to buyer B at a price of V_B. Finally, we also assume that $V_i - \frac{1}{2} - t_i > 0$, for $i = 1, 2$. That is, we assume that a monopolist expects to make positive profit from buyer $i = A, B$.[5]

When more than one supplier participates (pays the cost t_i and gets a signal), we model the procurement negotiations as descending clock auctions. The "clock" points to continuously decreasing prices until one of the suppliers drops out. The remaining supplier wins the contract at a price shown on the clock. Alternatively, we could analyze negotiations as sealed-bid, second-price auctions (SPAs). In the case of only two suppliers, the above two protocols are strategically equivalent, and both are appropriate representations of a negotiation process where the buyer alternates in approaching the two suppliers seeking

[5] If this were not satisfied, then a viable buyer group would either imply a reduction in negotiation costs or a direct subsidy from a stronger buyer to a weaker one.

improvements upon the latest best-offer received.

Independent Procurement (IP)

The sequence of events here is as follows:

1. Suppliers decide, simultaneously and non-collusively, which buyers to deal with by incurring the corresponding participation costs.

2. Each supplier that incurs t_i for learning about buyer i, $i \in \{A, B\}$, (observes how many suppliers are present, and) participates in the negotiations for that buyer: each submits a sealed bid or, equivalently, decides at what price in the clock to drop out of the competition.

3. Trade occurs as determined by the negotiation protocol: the lowest bidding supplier delivers at the higher bid of the rival, and profits are made.

The following lemma (see Milgrom and Weber, 1982) characterizes equilibrium behavior in this auction when both suppliers negotiate with buyer i.

Lemma 1. *When both suppliers (denoted by $j = 1, 2$) compete for supplying to buyer $i = A, B$, a symmetric equilibrium (of the subgame) is characterized by*

$$b_i(s_{i,j}) \;=\; E\,[c_i \,|\, s_{i,j}, s_{i,j}]\,. \tag{1}$$

Given this result, it is straightforward to obtain the equilibrium decision with respect to entry; $\forall\, i = A, B$ we use $I_{i,j} = 1$ if supplier j competes for supplying to buyer i and $I_{i,j} = 0$ otherwise. For all $j, -j = 1, 2$, expecting the rival supplier $-j$ to enter the procurement process and obtain a signal for the cost of serving buyer i with probability p_i, supplier j's expected profit, Π_j, upon entry is given below.

$$\Pi_j(p_i|I_{i,j} = 1) \;=\; [1 - p_i]\left[V_i - \frac{1}{2}\right] + p_i\,\frac{\pi}{2} - t_i\,, \tag{2}$$

where π is the sellers' expected profit when both suppliers participate in the auction to sell to buyer i. To compute π, note that for the loser of the auction to have signal x, the competitor must have a lower signal z. That is, given c_i, x must be the first-order statistic of two independent realizations of the random variable with CDF G, and z must be the second order statistic. The probability density of the second (lowest) order statistic of the two realizations of the random variable with CDF $G(\cdot|\, c_i)$ is $2\, g(z|\, c_i)\, G(z|\, c_i)$. Thus, the expected price obtained by the winner is

$$Eb \equiv \int_0^1 \left[\int_0^1 2\, g(z|\, c_i)\, G(z|\, c_i)\, E\left[c_i \,|\, z, z\right] dz \right] dF(c). \tag{3}$$

Of course, in expectation (ex-ante), the cost of supplying is $\frac{1}{2}$. Therefore,

$$\pi = Eb - \frac{1}{2}\,. \tag{4}$$

Note that both Eb and π are independent of V_i. ($\Pi_j(p_i|I_j = 1)$ is not independent of V_i, of course: when only one supplier enters, the revenue is V_i.) Also, ex ante, that is, at the time of deciding whether to incur cost t_i or not, the probability that a supplier will become the winner in case both enter is $\frac{1}{2}$. Thus, because we assume that no participation means a profit $\Pi_j(p_i|I_j = 0) = 0$, and given (2) and (3), we obtain the following proposition.

Proposition 1. *In a symmetric equilibrium, if $t_i \leq \frac{\pi}{2}$, both suppliers enter the procurement process for buyer i; otherwise they enter with only a probability:*

$$p_i = \frac{V_i - t_i - \frac{1}{2}}{V_i - \frac{\pi}{2} - \frac{1}{2}}\,. \tag{5}$$

Proof. If $t_i \leq \frac{\pi}{2}$, and because $V_i - \frac{1}{2} - t_i > 0$ by assumption, given (2) we have $\Pi_j(p_i|I_{i,j} = 1) = [1 - p_i]\left[V_i - \frac{1}{2} - t_i\right] + p_i \left[\frac{\pi}{2} - t_i\right] > 0$ for any value of p_i (which is the probability that the rival enters). Consequently, given $\Pi_j(p_i|I_{i,j} = 0) = 0$, in equilibrium both sellers participate with probability 1. If $t_i > \frac{\pi}{2}$, then $\Pi_j(p_i = 1|I_{i,j} = 1) < 0$. Thus, in any symmetric (mixed-strategy) equilibrium $p_i < 1$. Solving for $\Pi_j(p_i|I_{i,j} = 1) = 0$, we obtain (5), so for that value of p_i for the rival, each supplier is indifferent about participating. Moreover, because $\Pi_j(p_i|I_{i,j} = 1)$ is monotone in p_i, (5) gives the only symmetric equilibrium probability of participation. ■

Buyer i makes a strictly positive surplus only when both suppliers participate. When $t_i \leq \frac{\pi}{2}$, this expected surplus is simply $[V_i - Eb] = \left[V_i - \pi - \frac{1}{2}\right]$. When $t_i > \frac{\pi}{2}$, however, buyer i's expected surplus under IP (denoted $CS_{i,IP}$) is:

$$CS_{i,IP} = p_i^2 \left[V_i - \pi - \frac{1}{2}\right] = \left[\frac{V_i - t_i - \frac{1}{2}}{V_i - \frac{\pi}{2} - \frac{1}{2}}\right]^2 \left[V_i - \pi - \frac{1}{2}\right]. \tag{6}$$

Pooled Procurement (PP)

Suppose buyers pool their purchases and commit to procure as a group. As before, we use the second-price auction as a format to compute equilibrium payoffs. Here, too, suppliers obtain signals when participating in the process: after incurring the cost[6] $2\,\bar{t}$, supplier j obtains a pair of signals, $(s_{A,j}, s_{B,j})$. We continue assuming the same signal structure as in the independent procurement setting. That is, we assume away any improvement (or the contrary) that the buyer group may allow in the supplier's information gathering, other than a possible change in the cost of that activity. Also, note that the best estimate of the cost of supplying a given buyer is as under IP and is independent of the cost for a different buyer.

Under PP, the focus is on the random variable $\mathbf{s}_j = s_{A,j} + s_{B,j}$. Conditional on c_1 and c_2, $\mathbf{s}_j$ has a positive PDF on $[0, 2]$, and CDF:

$$Q(\mathbf{s}_j|\, c_1, c_2) = \begin{cases} \int_0^{\mathbf{s}_j} g(z|\, c_1) G(\mathbf{s}_j - z|\, c_2) dz & \text{if } \mathbf{s}_j \leq 1, \\ 1 - \int_{\mathbf{s}_j - 1}^{1} g(z|\, c_1) \left[1 - G(\mathbf{s}_j - z|\, c_2)\right] dz & \text{if } \mathbf{s}_j \geq 1. \end{cases} \tag{7}$$

[6]Without loss of generality, $\bar{t}$ can be different from either t_A, t_B or both.

Let $q(\mathbf{s}_j | c_1, c_2)$ be the derivative of this function with respect to $\mathbf{s}_j$. Given that we are assuming $V_B - 1 \leq 2(V_A - 1)$, even if the competitor were to not enter, a supplier will not charge more than V_A as the group would not buy the second unit at such a price. In any case, when both suppliers compete, the suppliers' equilibrium behavior is analogous to that under IP (discussed in the previous subsection). First:

Lemma 2. *A symmetric equilibrium (of the subgame) when both suppliers compete for supplying the buyer group is characterized by*

$$b(\mathbf{s}_j) \;=\; E\left[c_1 + c_2 \,|\, \mathbf{s}_j, \mathbf{s}_j\right]. \tag{8}$$

Note that given the symmetry in costs and signals that we are assuming, $E\left[c_i \,|\, \mathbf{s}_j, \mathbf{s}_j\right] = \frac{1}{2}E\left[c_1 + c_2 \,|\, \mathbf{s}_j, \mathbf{s}_j\right]$ for $i = 1, 2$ and for any $\mathbf{s}_j$.[7] Next, $\forall\, j, -j = 1, 2$, expecting the rival supplier $-j$ to enter the procurement process with probability $\mathbf{p}$, supplier j's expected profit (denoted $\Pi_{j,PP}$) upon entry is:

$$\Pi_{j,PP}(\mathbf{p} \,|\, I_{i,j} = 1) \;=\; [1 - \mathbf{p}]\left[2\,V_A - 1\right] + \mathbf{p}\,\frac{\pi^{PP}}{2} \;-\; 2\,\bar{t}, \tag{9}$$

where, analogous to the IP setting,

$$\pi^{PP} = Eb^{PP} - 1, \tag{10}$$

and

$$Eb^{PP} \equiv \int_0^1 \int_0^1 \left[\int_0^2 2q(\mathbf{s}| \, x_1, x_2)Q(\mathbf{s}| \, x_1, x_2)E\left[c_1 + c_2 \,|\, \mathbf{s}, \mathbf{s}\right] d\mathbf{s}\right] f(x_1)f(x_2)dx_1dx_2 \tag{11}$$

is the expected price when both suppliers participate. Again, notice that both Eb^{PP} and

[7] Also, the random variable $c_1 + c_2$ has (marginal) CDF

$$\widehat{F}(\mathbf{c}) = \begin{cases} \int_0^1 f(z)F(\mathbf{c} - z)dz & \text{if } \mathbf{c} \leq 1, \\ 1 - \int_0^1 f(z)\left[1 - G(\mathbf{c} - z)\right] dz & \text{if } \mathbf{c} \geq 1. \end{cases}$$

From this CDF and the conditional of signals on $c_1 + c_2$ we can recover the join distribution of costs and signals.

π^{PP} are independent of V_A and V_B. As with Proposition 1 under IP, we obtain:

Proposition 2. *In a symmetric equilibrium, if* $\bar{t} \leq \frac{\pi^{PP}}{4}$, *both suppliers enter the procurement process for the buyer group; otherwise they enter with only a probability:*

$$\mathbf{p} = \frac{V_A - \bar{t} - \frac{1}{2}}{V_A - \frac{\pi^{PP}}{4} - \frac{1}{2}} . \tag{12}$$

We omit the proof of Proposition 2, which follows the same steps as that of Proposition 1. Here too, we compute the expected buyer surplus. When both suppliers participate with probability one, that is, when $\bar{t} \leq \frac{\pi^{PP}}{4}$, buyer i's expected surplus, $CS_{i,PP}$, is $\left[V_i - \frac{\pi^{PP}}{2} - \frac{1}{2}\right]$. When $\bar{t} > \frac{\pi^{PP}}{4}$, given (12) and the fact that only when both suppliers participate does buyer A obtain a positive expected surplus, we have:

$$CS_{A,PP} = \left[\frac{V_A - \bar{t} - \frac{1}{2}}{V_A - \frac{\pi^{PP}}{4} - \frac{1}{2}}\right]^2 \left[V_A - \frac{\pi^{PP}}{2} - \frac{1}{2}\right] . \tag{13}$$

However, if $V_B > V_A$, then buyer B obtains a positive surplus even if only one supplier participates. That is, buyer B obtains an extra $V_B - V_A$ surplus with probability $1 - (1 - \mathbf{p})^2$. Therefore,

$$CS_{B,PP} = CS_{A,PP} + \left(1 - \left[\frac{\bar{t} - \frac{\pi^{PP}}{4}}{V_A - \frac{\pi^{PP}}{4} - \frac{1}{2}}\right]^2\right)(V_B - V_A) . \tag{14}$$

3 IP versus PP

In this section, we consider two cases: one where the buyers are symmetric and the other where they are not. The first case will help illustrate the primary direct effect (on expected price in competition) of pooled procurement. This will follow from a comparison of Eb and Eb^{PP}, which as noted earlier are independent of V_A and V_B, whether or not the buyers are symmetric. The following lemma reports the outcome of this comparison, and will be used in both the cases.

Lemma 3. $Eb > \frac{1}{2} Eb^{PP}$.

Proof. Consider all four signal realizations, s_{ij}, $i = A, B$, $j = 1, 2$, such that $s_{A,1} + s_{B,1} = \mathbf{s}_1 > \mathbf{s}_2 = s_{A,2} + s_{B,2}$ for some values of $\mathbf{s}_1$ and $\mathbf{s}_2$. Note that

$$
\begin{aligned}
& E\left[b_{PP} \right| s_{A,1} + s_{B,1} = \mathbf{s}_1, s_{A,2} + s_{B,2} = \mathbf{s}_2] \\
&= E\left[E\left[c_A + c_B \,|\, s_{A,1} + s_{B,1} = \mathbf{s}_1, s_{A,2} + s_{B,2} = \mathbf{s}_1\right] \right| s_{A,1} + s_{B,1} = \mathbf{s}_1, s_{A,2} + s_{B,2} = \mathbf{s}_2] \\
&= E\left[E\left[c_A \,|\, s_{A,1}, s_{A,1}\right] + E\left[c_B \,|\, s_{B,1}, s_{B,1}\right] \right| s_{A,1} + s_{B,1} = \mathbf{s}_1, s_{A,2} + s_{B,2} = \mathbf{s}_2] \\
&< E\left[Eb_A + Eb_B \right| s_{A,1} + s_{B,1} = \mathbf{s}_1, s_{A,2} + s_{B,2} = \mathbf{s}_2], \qquad (15)
\end{aligned}
$$

where b_i represents the highest bid under IP for buyer i, and b_{PP} the highest bid under PP. The first equality follows from the equilibrium bidding obtained in Lemma 2. The second equality follows from s_{Aj} and s_{Bj} being independent of c_B and c_A respectively. The strict inequality follows from the fact that, even if $\mathbf{s}_1 > \mathbf{s}_2$, there is the possibility that $s_{A,2} > s_{A,1}$ (but then necessarily $s_{B,1} > s_{B,2}$) in which case,

$$
\begin{aligned}
b_A + b_B &= E\left[c_A \,|\, s_{A,2}, s_{A,2}\right] + E\left[c_B \,|\, s_{B,1}, s_{B,1}\right] \\
&> E\left[c_A \,|\, s_{A,1}, s_{A,1}\right] + E\left[c_B \,|\, s_{B,1}, s_{B,1}\right]. \qquad (16)
\end{aligned}
$$

(Analogously for the possibility that $s_{B,2} > s_{B,1}$.) The same conclusion is obtained even if $s_{A,1} + s_{B,1} = \mathbf{s}_1 > \mathbf{s}_2 = s_{A,2} + s_{B,2}$. Because the (marginal) distribution of signals is independent of the procurement protocol, this concludes the proof. ■

The above lemma is perhaps the most important insight of this paper. The simplest way to understand this result is by noticing that, as in standard SPA auctions to buy (or reverse auctions, as they are sometimes called), the price is determined by the larger of the two signals. If each signal is a combination (sum) of two sub-signals on two different random events, the larger signal may not be simply the combination (sum) of the larger realizations of the two sub-signals.

More generally, (for any number of sellers), the sum of two (not necessarily independent) signals puts more weight on central values of its range, as compared to the individual signals.[8] This reduces suppliers' information differentiation, which in turn lowers their profits. Indeed, profits accrue as a consequence of differentiated estimates of the cost (winner's curse duly taken into account), so competition becomes more fierce when the uncertainty about the cost of serving one buyer is pooled with the uncertainty about the cost of serving the other.[9] This seems akin to the well understood effect of buyer groups on product differentiation (for the group) when heterogeneous buyers pool their purchases. In our model, there is no product differentiation per se, as both suppliers are assumed to offer the same product. However, pooling cost-uncertainty for the two buyers lowers the "differentiation" in cost estimates of both suppliers, and in turn their ability to obtain information rents. That same effect explains why suppliers will be more reluctant to participate in pooled procurement.

Because lower prices mean lower expected profit after entry, the lower price in case of supplier competition under PP may come at the cost of lower participation and so the ensuing inability of appropriating any consumer surplus.[10] Indeed, comparing (5) with (12), Lemma 3 implies that $\mathbf{p} \leq p_i$, and when $\mathbf{p} < 1$, that is, when $\bar{t} > \frac{\pi^{PP}}{4}$, $\mathbf{p} < p_i$. These two effects of pooled procurement should be combined to establish its impact on buyers' surplus. Yet, when buyers are perfectly symmetric, the direct effect on the expected prices dominates the induced effect of a possible lowered level of participation.

[8] Indeed, for any two independent signals A and B with expectations μ_A and μ_B and standard deviations σ_A and σ_B, the variable $A+B$ has expectation $\mu_A + \mu_B$ and standard deviation $\sqrt{\sigma_A^2 + \sigma_B^2}$. But it is straightforward that

$$\frac{\sigma_A^2 + \sigma_B^2}{(\mu_A + \mu_B)^2} < \frac{\sigma_A^2}{\mu_A^2} + \frac{\sigma_B^2}{\mu_B^2}.$$

[9] In case of some positive correlation between these costs (i.e., their signals) the effect would be weaker, but it would still be present unless the correlation were perfect.

[10] Loertscher and Marx (2019) show that an increase in "buyer power"—i.e., the ability to commit to reserve prices and ex-post inefficient trade—may in fact favor entry of less—ex-ante—efficient suppliers. (In their case, the more efficient supplier is the result of a merger.) Of course, in our analysis all suppliers are equally efficient, and the group does not affect the buyers' bargaining power thus defined. Yet, this points to countervailing effects on entry for a buyer group which "also" raise buyer power.

Thus, when $V_A = V_B = V$ and $t_A = t_B = \bar{t} = t$ we have the following result.

Proposition 3. *In the symmetric case, buyers benefit from pooled procurement.*

Proof. Define the (continuous) function

$$S(x) = \begin{cases} \left[\frac{V-t-\frac{1}{2}}{V-\frac{x}{2}-\frac{1}{2}}\right]^2 \left[V - x - \frac{1}{2}\right] & \text{if } x < 2t \\ V - x - \frac{1}{2} & \text{if } x \geq 2t \end{cases}, \tag{17}$$

and note that its derivative with respect to x (everywhere other than at $x = 2t$, where it does not exist) is negative. From (6), (13) and (17), the buyer's surplus under IP and PP is $S(\pi)$ and $S(\frac{\pi^{PP}}{2})$, respectively, both with $t = t_A = t_B = \bar{t}$; then from Lemma 3 the proposition follows. ■

The most interesting case for us is that with asymmetric buyers, where B is a stronger buyer than A: i.e., $V_B > V_A$ and/or $t_B < t_A$. Note that the analysis in Section 2 was independent of symmetry. Therefore, (9) still defines the profits expected upon entry assuming that the rival enters with probability $\mathbf{p}$, and so Proposition 2 summarizes the entry decisions in a (supplier) symmetric equilibrium under pooled procurement.

Our case of interest is $t_B \leq \frac{\pi}{2} < t_A$, so that participation by suppliers is not an issue for the strong buyer, while it is for the weak buyer. We will restrict attention to this case. Accordingly, we have:

Proposition 4. *If* $\bar{t} = \frac{t_A+t_B}{2} \leq \frac{\pi^{PP}}{4}$*, then a buyer group increases participation for buyer A and is in the interest of both buyers.*

Proof. The increase in participation for A follows directly from comparing (5) and (12). Also, A's surplus under IP, given by (6), is lower than $V_A - Eb$, whereas under PP the surplus is $V_A - \frac{b^{PP}}{2}$, because $\mathbf{p} = 1$. Thus, from Lemma 3, A's surplus is higher under pooled procurement. Similarly, B's surplus under IP and PP is $V_B - Eb$ and $V_B - \frac{Eb^{PP}}{2}$, respectively, and so B's surplus is also higher under pooled procurement. ■

This is perhaps the scenario envisioned by proponents of pooled procurement as a way to foster supplier participation for weaker buyers. In our theory, the reduction in expected price (that comes from the suppliers' pooling of cost signals) is what attracts stronger buyers to group buying.

Of course, the reduction in expected profitability of dealing with the group may hinder supplier participation for otherwise attractive buyers, which is why pooled procurement may be problematic for stronger buyers. This trade-off is illustrated by the possible reduction in participation (and therefore on the intensity of competition) for the stronger buyer. Indeed, such is the case if $\bar{t} > \frac{\pi^{PP}}{4}$, so that $\mathbf{p} < 1$ and buyer B expects a surplus given by (14).

Let us begin with the case where $V_B = V_A = V$, so that the only asymmetry among buyers comes from the cost of participating in the respective negotiations. In this case, we note that the difference,

$$CS_{B,PP} - CS_{B,IP} = \left[\frac{V - \bar{t} - \frac{1}{2}}{V - \frac{\pi^{PP}}{4} - \frac{1}{2}}\right]^2 \left[V - \frac{\pi^{PP}}{2} - \frac{1}{2}\right] - \left[V - \pi - \frac{1}{2}\right], \tag{18}$$

is decreasing in $\bar{t}$. Moreover, because $\frac{\pi^{PP}}{2} < \pi$, the value of $\bar{t}$, that makes this difference equal to zero, is below $\frac{\pi^{PP}}{4}$. Thus, we conclude that:

Proposition 5. *When $V_B = V_A = V$, buyer A benefits from pooled procurement. Also, a buyer group always (weakly) reduces participation for buyer B, but there exists a cutoff $\bar{t}(V) > \frac{\pi^{PP}}{4}$ such that a buyer group increases surplus for buyer B if and only if $\bar{t} < \bar{t}(V)$.*

Proof. Note that in the symmetric case buyers benefited from pooled procurement. With $\bar{t} < t_A$, the probability of participation is (weakly) larger under PP than when $\bar{t} = t_A$, and therefore the difference between the surplus under PP and IP is larger now than with symmetry, and therefore is positive. Also, if $\bar{t}$ were below the value that makes (18) equal to zero, buyer B's surplus is higher under pooled procurement even though supplier participation is lower. ■

Thus, pooled procurement by asymmetric (in the cost of participation in their negotiations) buyers may still be in the interest of all, but a sufficiently large asymmetry erases the incentives of stronger buyers to participate, as the loss associated with lower entry outweighs the gains of a lower expected price.

Asymmetry in the valuation of buyers affects their incentives as well. B's surplus is increasing in V_B in any regime. However, when $t_B \leq \frac{\pi}{2}$ and $\bar{t} > \frac{\pi^{PP}}{4}$ as we are assuming, that surplus grows faster with V_B under IP than under PP. Indeed, with independent procurement, the derivative of buyer B's surplus with respect to V_B when $t_B \leq \frac{\pi}{2}$ (and so $p_B = 1$) is 1, but that derivative with $\bar{t} > \frac{\pi^{PP}}{4}$ (and so $\mathbf{p} < 1$) is only $1 - (1 - \mathbf{p})^2 < 1$. Thus,

Corollary 1. *Given a V_A, the larger the value of V_B, the larger is the threshold $\bar{t}(V)$ for $\bar{t}$ below which B benefits from a buyer group.*

Proof. Taking derivatives of $CS_{B,PP} - CS_{B,IP}$ with respect to V_B (and noting that $p_B = 1$ and $\mathbf{p}$ is independent of V_B) we obtain

$$\frac{\partial \left[CS_{B,PP} - CS_{B,IP}\right]}{\partial V_B} = (1 - \mathbf{p})^2 - 1 < 0 . \tag{19}$$

That is, the larger V_B over and above V_A, the lower the difference in $CS_{B,PP} - CS_{B,IP}$ for a given value of $\bar{t}$. Thus, the cutoff value of $\bar{t}(V)$ is decreasing in V_B. ■

Thus, it may be in the interest for both buyers to procure as a group, but only as long as the asymmetries along both dimensions, participation costs and willingness to pay, are not too large.

4 Conclusion

Our analysis is motivated by practitioners' observations in the procurement of medicines by LMICs (see[11] e.g., Nguyen 2022, Yadav 2022, Barton et al. 2022b). In such a setting, both academics and practitioners note that asymmetry of potential buyers ranks high in determining whether pooled procurement is viable and successful. An important issue to understand here is the likely motivation of a strong buyer to pool its purchases with a weaker buyer. Accordingly, we set out to understand the basic incentives to participate in pooled procurement.

We modeled the supply of a homogeneous product, with all risk-neutral players, and abstracted away from any shape-related issues of the (production) cost curves. In our setup, to engage in negotiations with a buyer, each supplier must incur an upfront expense. This expenditure also buys a signal on the cost that any supplier (if selected) would incur in order to supply to that buyer. Thus, we assume an unknown, common cost of supplying a buyer and private signals about the value of this cost.

When buyers pool their purchases, our results highlight that each supplier's (random) estimate of the pooled costs puts lower probability on extreme realizations than the estimates of the individual costs. This, in turn, results in a lowered price for the buyers. We are unaware of other research that makes this point; it is worth noting that this explanation is not contingent, for instance, on the group's stronger bargaining position (as argued by conventional wisdom), scale related issues, or other factors identified in the literature. A weak buyer who pools its purchases with those of a stronger buyer obtains more supplier participation, together with lower prices given participation. In this sense, our research supports the claim that pooled procurement is a way to enhance participation in the competition to supply weaker buyers. The flip side of this is that the stronger

[11] To get a broader perspective on the supply-chain related challenges in such markets, see e.g., Kraiselburd and Yadav (2013); Arinaminpathy et al. (2015); Kazaz et al. (2016); Gallien et al. (2017, 2021); and Karamshetty et al. (2022).

buyer suffers from a lower level of supplier participation. However, given the number of suppliers participating, the stronger buyer also benefits from a lower expected price. Thus, when the asymmetry is not too large, even the stronger buyer benefits from joining a buyer group.

Several issues are left out of our research that are important for the problem at hand. For one, we have abstracted from quality differentials (vertical differentiation) and the incentives to invest in quality. Also, group procurement has the potential to impact financial matters—e.g., those involving a buyer's ability to pay and the timing of a sponsor's release of funds—and the (un)predictability of demand. We hope to have contributed to understanding such issues by offering a simple model with which to tackle them.

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