"PRICE FORMATION AND PRODUCT DESIGN THROUGH BIDDING"

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N° 88 / 09

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Director of Publication :

Charles WYPLOSZ, Associate Dean
for Research and Development

Printed at INSEAD,
Fontainebleau, France

PRICE FORMATION AND PRODUCT DESIGN

THROUGH BIDDING[a]

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Abstract: We compare an auction where bids have two dimensions, quality and price, with a first-price sealed-bid auction for a fixed-quality product. Multi-dimensional bidding, or letting the bidders decide upon both the product's quality and price, yields a higher utility to the auctioneer provided his preference structure is common knowledge. On the other hand, multi-dimensional bidding might not be so good for the auctioneer whose utility function is unknown to the bidders, because each of them may find a niche where a large portion of the auctioneer's surplus is captured in the event of winning.

Keywords: Auctions, multi-dimensional bidding, optimal product diversity, standards.

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a. This paper is derived from Chapter 1 of my Doctoral dissertation. My acknowledgements to Professors Richard J. Gilbert, of UC Berkeley, Paul R. Milgrom, of Stanford, Joel S. Demski and Peter C. Cramton, of Yale; the first for introducing me to his pioneering work on this topic, and all of them for leading me into fruitful directions. Any shortcomings should be imputed only to me.

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1. Introduction

Competitive bidding might arise on two occasions: when a seller faces many bidders, or when a buyer faces many sellers. The literature usually focuses on the former case, where bids are prices, and treats the latter as a trivial symmetric case with bids being also scalars. This ignores the important fact that a buyer facing many sellers is usually offered <u>many products</u> of <u>various qualities</u>; therefore, she is likely to get more information than just a cost estimate. When many sellers are involved in competitive bidding, their bids are likely to be multi-dimensional.

In defense procurement for instance, the government considers bids that include, in order of importance, a performance description of the future weapon, a development schedule and time delivery, <u>and</u> an estimated total cost (Rich and Dews (1986)). Although they have indeed many components, these bids are usually not exhaustive, for the project is very complex and presents many uncertainties. The bids must also respect some more or less stringent quality standards and product requirements.

These observations raise a number of interesting issues. What role do bidding rules and their generated prices play in the development of a new good? How are the setting and meaning of prices changed when the agents are allowed to interact through additional channels? Should product design and price formation be simultaneous or sequential processes? Should a procurement agency let the sellers specify both quality and price, or should it rather impose some quality standards, making the sellers compete on price only? To what extent does the sellers' knowledge of the agency's preferences influence the relative performance of a given procurement rule? In this essay, we attempt to answer these questions. Our findings can be summarized as follows:

i) when the buyer's exact preferences are common knowledge among the sellers, a procurement rule where sellers bid both on quality and price brings a higher expected utility to the buyer than one where sellers are constrained to deliver a fixed quality and compete on the basis of price only;

ii) the last assertion is not true, however, if the sellers' knowledge of the buyer's utility is noisy.

Our next section is devoted to presenting the model that drives these propositions. Our model is consistent with Gilbert's (1977) formulation. Both of us consider the case of several bidders competing for the sale of a complex product to a consumer whose preferences may be uncertain. In both formulations, production and utility functions are similar (strictly quasi-concave). However, while both of us examine a bidding process where bids are two-dimensional, we also here formally compare such a process with one where bids are scalars. Hence, in this essay we emphasize the dimension of bids as a crucial decision variable for whoever sets up a bidding process. The simplicity of our model is a bit surprising given that, as far as we know, multi-dimensional bidding has not yet been fully analyzed in the literature, for tractability reasons.

We state, prove and discuss our results in the third and fourth section. The upshot is that *a procurement agency should somehow express clearly what it likes, either by promoting some quality standards, or by revealing its whole preference structure to the potential contractors*; otherwise, each seller will look for a niche in the spectrum of possible products where he can most easily capture a good part of the consumer's surplus.

Our analysis of multi-dimensional bidding has ramifications for various subjects: optimal product diversity (Lancaster (1975)), spatial competition (Hotelling (1929), Osborne and Pitchik (1987)), multi-dimensional signalling (Wilson (1985), Milgrom and Roberts (1986)), procurement (McAfee and Macmillan (1986)), standards (Farrell and Saloner (1985; 1986), Katz and Shapiro (1985)), and measurement costs (Barzel (1982)). Some of these links will be sketched in our fifth and last section.

2. The Model

In the theoretical or experimental analysis of economic institutions, models usually have two segments: an institution (some abstract description of a rule for allocating ressources) and an environment (a set of assumptions about the agents' characteristics). A rigorous comparison of allocation mechanisms is made by amending the institutional part while keeping the same environment. We want to perform such an analysis here. Let us then present our model, starting with the institutional variants and finishing with the environment.

2.1 Institutions

In the bidding situations that shall be encountered below, bids b are allowed to have two dimensions: a quality index $q \in \mathbf{R}_+$, and a price $p \in R_+$. We may sometimes write concisely $b = (q,p)$ in R_+^2.[1] A larger q should be interpreted as a higher quality. Let us now consider three particular bidding rules.

- Lowest-Cost Bidding for a Standardized Product (LCS):

Under this rule, a quality requirement or standard q^* is first established by the buyer. She then offers a contract to the bidder who makes the lowest-cost proposal for producing a good of quality q^*.

- First-Preferred Offer Bidding (FPO):

Such a rule requires two-dimensional bids. A bidder wins the sale when he announces the product description (q,p) that best satisfies the buyer. He then has to produce a good that agrees with the description he proposed.

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1 R_+ denotes the set of non-negative real numbers. $R_+^2 = R_+ \times R_+$ is the non-negative orthant of the plane R^2.

- Second-Preferred Offer Bidding (<u>SPO</u>), or Procurement with Technology Transfer:

This rule is a formulation of Vickrey's (1961) second-price sealed-bid auction with multi-dimensional bids. The winning bidder makes the proposal (q,p) that most pleases the buyer. However, he must only deliver a product that conforms with the <u>second</u> most appealing offer ($\bar{q},\bar{p}$).

The SPO rule could model some procurement situations where the winning agent is required to achieve a technology that is transferred to him from a competitor.

Now that the bidding rules we want to compare have been described, let us introduce the environment in which they will operate.

2.2 <u>Environment</u>

We suppose there are a fixed number $n > 1$ of risk-neutral bidders or sellers. Each bidder has a linear profit function $p-cq$, where the marginal cost of quality c is a privately known characteristic. The parameters c are independently uniformly distributed on the open interval (0,1).[2]

Let us now consider the buyer. We shall assume her preferences can be represented by a utility function that shows no income

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2 We assume a uniform distribution on (0,1) in order to lighten the exposition. It is straightforward, however, to derive our results when the marginal costs of quality are independently uniformly distributed on (a,b), $0 \leq a < b$.

effect, nonsatiation and **decreasing** marginal satisfaction for quality. Formally, we shall write this utility function at $(q,p) \in R_+^2$ as $V(q)-p$; where $V(0) = 0$, $V'(0) = +\infty$, $V'(\infty) = 0$ and $V''(q) < 0$. Note that our setting allows utility functions that smoothly emphasize some specific quality level, meaning the buyer would most enjoy a particular kind of good for its compatibility, say, or other "network externalities"[3]. Two useful lemmas will be deduced from the general properties of the function $V(\cdot)$.

2.2.1 Lemma: On R_+, the function $V(V'^{-1}(x)) - xV'^{-1}(x)$ is

i) decreasing;

ii) convex.

PROOF:

At $x \geq 0$, the first-order derivative of the function is

$$\frac{V'(V'^{-1}(x))}{V''(V'^{-1}(x))} - \frac{x}{V''(V'^{-1}(x))} - V'^{-1}(x) = - V'^{-1}(x) < 0 .$$

This demonstrates i). To prove ii), just note that the second derivative of the function at $x \geq 0$ is

$$\frac{-1}{V''(V'^{-1}(x))} > 0 .$$

□

Note that in proving part ii) of the assertion, we also showed that $V'^{-1}(\cdot)$ was a monotone decreasing function on R_+.

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3 Some good examples of network externalities and the advantages of standardization are presented in Kindleberger (1983).

2.2.2 Lemma: Take $\alpha > 0$. The function $V(V'^{-1}(\cdot)) - \alpha V'^{-1}(\cdot)$ attains its global maximum at α.

PROOF:

The first-order derivative of the function at a point x is

$$\frac{x - \alpha}{V''(V'^{-1}(x))} .$$

One can now see that the function is increasing at $x < \alpha$, stationary at $x = \alpha$, and decreasing at $x > \alpha$. This proves the lemma. □

With the above lemmas, we are now equipped to established some interesting results.

3. Some Propositions against Standards

In this section, we will assume that the environment stated in section 2.2, in particular the buyer's utility $V(q)-p$ at any $(q,p) \in R^2_+$, is common knowledge among the sellers. As we will see, this assumption implies that setting standards instead of allowing the sellers to specify the product is an inferior policy for a procurement agency. Let us start our analysis with the LCS bidding rule.

3.1 Let competition among the sellers be allowed over the price only: they all must produce a good of quality q, say. In this case, a seller incurs a total cost cq that is distributed uniformly on (0,q).

Suppose each bidder proposes **a price** $p(cq)$ that increases with his private cost cq. Then a bidder wins provided he has the lowest total cost; by independence, his probability of winning is $(1-cq/q)^{n-1}$. Hence, given that he makes a profit $p(cq)-cq$ if he gets the sale and 0 if he does not, his expected benefit is given by

$$(p(cq)-cq)(1-cq/q)^{n-1}.$$

At a Nash equilibrium, the bidding function $p(\cdot)$ must satisfy

i) $p'(cq) = (n-1)\dfrac{(p(cq)-cq)/q}{(1-cq/q)}$: a seller with private cost cq maximizes his expected benefit by proposing $p(cq)$;

ii) $p(q) = q$: a seller with the highest cost just hopes to recover this cost, for it cannot ask a higher price than q to the buyer.

One can check that the function $p(\cdot)$ given by

$$p(cq) = [c+(1-c)/n]q \equiv b(c)q$$

satisfies these conditions. The function $b(\cdot)$ so defined satisfies in turn the differential equation with initial condition

(1) $$b'(c) = (b(c)-c)(n-1)/(1-c) \quad , \; b(1) = 1,$$

which characterizes the symmetric increasing equilibrium strategy of the first-price sealed-bid auction in this environment (Vickrey (1961)).

The buyer's expected price for a product with quality q can now be computed to be

$$(\#\ \text{sellers})[\textbf{Average payment} \text{ to each seller}]$$
$$= n\int_0^1 b(c)q(1-c)^{n-1}dc$$
$$= 2q/(n+1).$$

A rational buyer would pick the quality standard q^* that maximizes her expected utility

(2) $$V(q) - 2q/(n+1).$$

Taking the first-order conditions for a maximum of (2) yields

(3) $$q^* = V'^{-1}(2/(n+1))$$

and the expected level of utility

(4) $$V(V'^{-1}(2/(n+1))) - \frac{2}{n+1}V'^{-1}(2/(n+1)).$$

This expected utility level depends on the quality standard q^*, which is linked to the <u>expected</u> minimum cost $1/(n+1)$ through equation (3). First-order efficiency, however, requires that q^* correspond to the <u>realized</u> minimum cost. Although efficiency in this sense remains unachievable due to informational asymmetry, the criterion suggests, nevertheless, that the quality parameter should perhaps be set by the bidder with lowest cost. We shall now see that the first-preferred offer bidding rule indeed yields more efficient outcomes.

3.2 In the FPO bidding rule, it is up to the sellers to specify both the quality and the price. Let us assume, reasonably enough, that two bidders having an identical cost parameter c will make the same quality-price proposal $(\underline{q}(c),\underline{p}(c))$ leading to the same net satisfaction $\underline{V}$; in other words, sellers adopt a symmetric strategy. An equilibrium in such a strategy is computed below by backward reasoning. Figure 1 illustrates the sequence of steps.

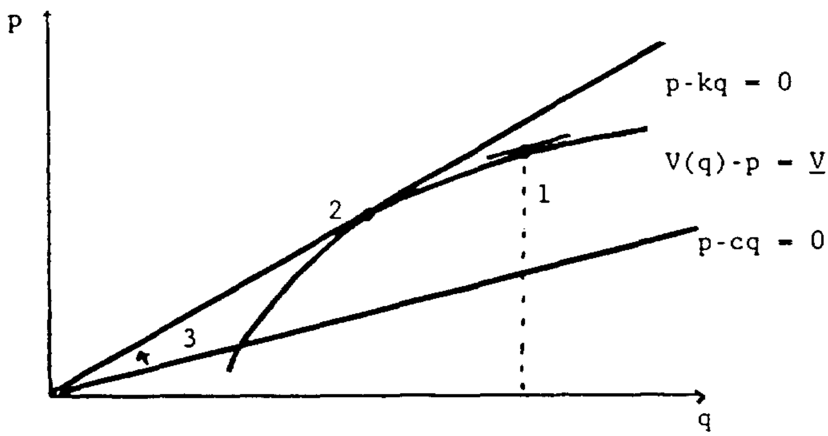

figure 1: steps for computing the equilibrium strategy in FPO.

step 1: The bid ($\underline{q}$(c),$\underline{p}$(c)) should maximize the seller's profit provided the buyer achieves a given level of satisfaction $\underline{V}$. Formally,

$$(\underline{q}(c),\underline{p}(c)) = \arg\max_{p,q}\ p-cq$$
$$\text{subject to: } V(q)-p \geq \underline{V}.$$

step 2: The proposed utility level $\underline{V}$, which determines the probability of winning, should be the highest degree of satisfaction the buyer could achieve if the seller reveals a marginal cost k for quality and gets no profit; i.e.

$$\underline{V} = \max V(q)-p$$

$$s/t \quad p - kq = 0.$$

From these two steps, it is now possible to write the bid quality and price of a seller with cost parameter c: they are respectively $\underline{q}(c) = V'^{-1}(c)$ from step 1,

$\underline{p}(c) = V(\underline{q}(c)) - \underline{V}$ from step 1

$= kV'^{-1}(k) + [V(V'^{-1}(c)) - V(V'^{-1}(k))]$ from step 2.

Moreover, from step 2, the buyer gets a satisfaction level

$$\underline{V} = V(V'^{-1}(k)) - kV'^{-1}(k).$$

<u>step 3</u>: A bidder must now pick a k that best shades his true cost parameter c. Let us suppose this k is an increasing function of c. Clearly then, by lemma 2.2.1i, the bidder with the lowest cost will offer the highest satisfaction level to the buyer and will therefore get the sale. Thus, the expected profit of a bidder with private cost c is

[Benefit from selling](Probability of getting the sale)

(5) $$= [V(V'^{-1}(c)) - V(V'^{-1}(k(\underline{c}))) + k(\underline{c})V'^{-1}(k(\underline{c})) - cV'^{-1}(c)](1-\underline{c})^{n-1}.$$

The function $k(\cdot)$ is an equilibrium shaded marginal cost if the above expression is maximized at $\underline{c} = c$. The first-order conditions for optimizing (5) lead to the following characterization of $k(\cdot)$:

(6) $$k'(c) = \frac{(n-1)[V(V'^{-1}(c)) - V(V'^{-1}(k(c))) + k(c)V'^{-1}(k(c)) - cV'^{-1}(c)]}{V'^{-1}(k(c))(1-c)},$$

$$k(1) = 1 .$$

We can now deduce from step 3 that the shading parameter

$k(c)$ is never greater than the bidded marginal cost $b(c)$ of LCS.

3.2.1 Lemma: $k(\cdot) < b(\cdot)$ on $(0,1)$.

PROOF:

Equation (6) can be reduced to

$$k'(c) = \frac{(n-1)(k(c)-c)}{(1-c)} + \frac{(n-1)[V(V'^{-1}(c)) - cV'^{-1}(c) - V(V'^{-1}(k(c))) + cV'^{-1}(k(c))]}{(1-c)\ V'^{-1}(k(c))}.$$

If $k(c) \geq b(c)$ at some $c \in (0,1)$, then $k'(\cdot) > b'(\cdot)$ on $(c,1)$ by lemma 2.2.2 and the last equation. So the difference between $k(\cdot)$ and $b(\cdot)$ is positive and increasing on $(c,1)$. But $k(1) = b(1)$. This contradiction establishes the lemma. □

An analogous result was obtained recently by Hansen (1986). In his model, the variable q may also be fixed or may depend on the price level. However, q is interpreted as the demanded quantity of the product and is never set up by the sellers.

Lemma 3.2.1 was a preview for the main result of this section, that we shall now state and prove.

3.2.2 Theorem: The buyer gets a higher expected utility from the first-preferred-offer bidding than from the lowest-cost bidding for a standardized product.

PROOF:

Let P_1 be the expectation operator with respect to the nth-order statistic of the **uniform distribution** on (0,1); i.e. P_1 is the expectation operator with respect to the random variable $c = \min[z_1,\dots,z_n]$, where z_i obeys to a uniform distribution law on (0,1). Note that the density of the nth-order statistic in this context is $n(1-z_i)^{n-1}$.

Now the buyer's expected utility from FPO is given by

$$P_1\ V(V'^{-1}(k(c)))-k(c)V'^{-1}(k(c))$$

$$= \int_0^1 [V(V'^{-1}(k(c))-k(c)V'^{-1}(k(c))]n(1-c)^{n-1}dc$$

$$> V(V'^{-1}(P_1\ k(c))) - (P_1\ k(c))V'^{-1}(P_1\ k(c))$$

by lemma 2.2.1 ii) and Jensen's inequality

$$> V(V'^{-1}(P_1\ b(c))) - (P_1\ b(c))V'^{-1}(P_1\ b(c))$$

by lemma 2.2.1 i) and lemma 3.2.1

$$= V(V'^{-1}(2/(n+1))) - \frac{2}{(n+1)} V'^{-1}(2/(n+1)),$$

and the last expression is precisely the buyer's expected utility from LCS. □

This theorem establishes that a buyer whose utility is known by the sellers would dislike rigid quality standards that reduce the spectrum of possible products to a single definite one. Therefore, one may infer that if standards are promoted by a third party (e.g. the government) but have to be enforced by the buyer (e.g. the army), they might very well not be fulfilled. A procurement agency might do better by ignoring third-party standards, provided its preferences are common knowledge.

One more argument **against** standards will be brought up in the next section.

3.3 Let us consider the second-preferred offer bidding rule. In the present environment, it is not hard to see that a seller with marginal cost c who is confronted with such a rule would make a proposal $(\bar{q},\bar{p}) = \alpha$ that

(7) $$\text{maximizes} \quad V(q) - p$$
$$\text{subject to:} \quad p - cq = 0;$$

Figure 2 might help understand why this is so.

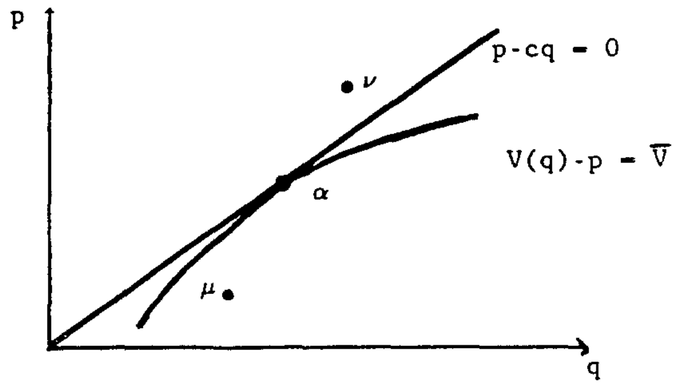

figure 2: Equilibrium and alternative bids in SPO.

Again, the analogy with Vickrey's (1961) second-price-sealed-bid auction is clear. By proposing $(q_1,p_1) = \nu$ where $p_1 - cq_1 > 0$, instead of α, a bidder with parameter c does not change his benefits if he already loses; his benefits are also unaffected if he still wins, but he might let go some profitable sales; so his overall expected profit decreases. Similarly, a bid $\mu = (q_2, p_2)$, where $p_2 - cq_2 < 0$, diminishes the expected profit of a bidder with parameter c, for if it leaves his benefits unchanged when he already wins, it might also turn into a commitment to deliver an unprofitable product.

Hence, bidding $\alpha = (\bar{q}, \bar{p})$ is a dominant strategy for a seller with private parameter c. Solving (7) by elementary calculus yields

$$\bar{q}(c) = V'^{-1}(c) \ , \ \bar{p}(c) = cV'^{-1}(c).$$

Therefore, a bidder with parameter c makes a proposal that brings the buyer's satisfaction up to

$$V(V'^{-1}(c)) - cV'^{-1}(c).$$

By lemma 2.2.1i, the bidder with the lowest marginal cost for quality will get the sale. He will bring, however, a good that corresponds to the buyer's second most-preferred bid. Thus, the buyer's expected utility from SPO can be written as

$$\int_0^1 [V(V'^{-1}(c)) - cV'^{-1}(c)] n(n-1)c(1-c)^{n-2} \, dc = P_2 \ V(V'^{-1}(c)) - cV'^{-1}(c),$$

where P_2 denote the expectation operator, and $n(n-1)c(1-c)^{n-2}$ the density, with respect to the (n-1)th-order statistic of the uniform law on (0,1).

It cannot be determined in the present context whether a buyer seeking her highest expected utility would generally organize bidding under a SPO rule or a FPO rule.[4] But the superiority of the

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[4] Intuitively, FPO should be better, since it yields more efficient quality choices and the resulting surplus gains are shared.

SPO bidding rule over the LCS one will now be established.

3.3.1 Theorem: The buyer's expected utility is higher in the second-preferred-offer bidding than in the lowest-cost bidding for a standardized product.

PROOF:

Just note that

$$P_2 V(V'^{-1}(c))-cV'^{-1}(c) > V(V'^{-1}(P_2 c))-(P_2 c)V'^{-1}(P_2 c)$$

by lemma 2.2.1ii and Jensen's inequality

$$= V(V'^{-1}(2/(n+1))) - \frac{2}{n+1} V'^{-1}(2/(n+1)),$$

which is precisely the expected utility from the LCS rule. □

The above theorems should explain why, sometimes, procurement agencies are not so worried about *ex ante* quality requirements. Frequently however, some standards are promoted and enforced. We made here the extreme assumption that the buyer's whole preference structure be known to the sellers. As we will now see, relaxing this assumption can make standards a good choice.

4. The Return of Standards

Let us assume that, except for the buyer's utility function, the environment described in section 2.2 is common knowledge among the sellers and the buyer. The buyer's preference structure shall be uncertain to the buyer herself and its only common knowledge feature shall be a set of possible utility functions, containing the true one, with a probability distribution on that set. This new assumption could model many situations, like defense procurement or franchise bidding, where product complexity and communication costs do not allow bidders to know or forecast the buyer's preference structure with absolute precision.[5] In this context, we will now illustrate how standards can benefit the buyer by enhancing competition among bidders.

4.1 To simplify, let there be only two sellers and assume the distribution of their marginal cost is degenerate at $c \in (0,1)$. For these sellers, the buyer's utility shall be either

$$V_1(q)-p \quad \text{with probability } 0 < \alpha < 1,$$

or

$$V_2(q)-p \quad \text{with probability } (1-\alpha).$$

As before, the functions $V_i(\cdot)$, $i = 1,2$, are such that $V_i(0) = 0$, $V_i'(0) = \infty$, $V_i'(\infty) = 0$ and $V_i''(q) < 0$. The utility functions $V_1(\cdot)-p$, $V_2(\cdot)-p$ will now also represent preference orderings that are mutually exclusive: there will exist a quality-price pair (p_o,q_o) different from (0,0) such that

$$V_1(q_o)-p_o = V_2(q_o)-p_o = 0.$$

In this setting, it is possible to exhibit preference and

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5 A good analysis and critique of franchise bidding can be found in Williamson (1985), chapter 10.

belief structures that yield multi-dimensional bidding equilibria where sellers, although identical, find niches within the buyer's utility and capture all the buyer's surplus.

4.1.1 <u>Proposition</u>: Suppose that

i) $\alpha(V_1(V_1'^{-1}(c))-cV_1'^{-1}(c)) = (1-\alpha)(V_2(V_2'^{-1}(c))-cV_2'^{-1}(c))$

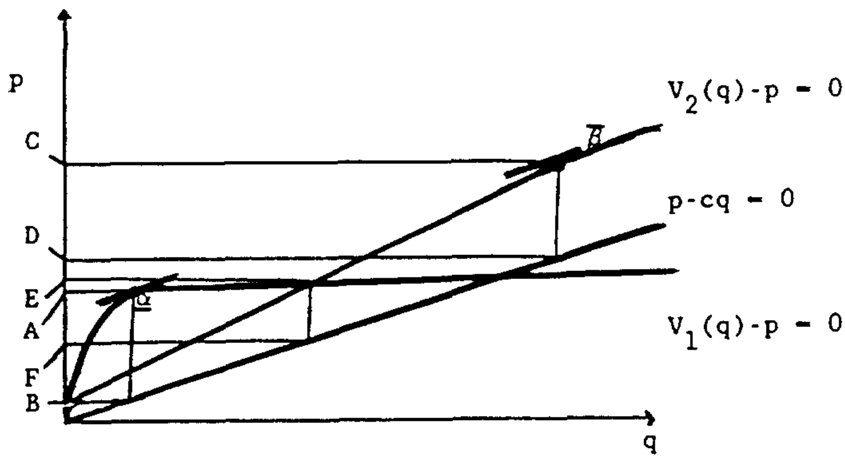
and ii) $\alpha(V_1(V_1'^{-1}(c))-cV_1'^{-1}(c)) \geq V_1(q_o) - cq_o$. The multi-dimensional bids

$$(V_1'^{-1}(c), V_1(V_1'^{-1}(c))) \text{ and } (V_2'^{-1}(c), V_2(V_2'^{-1}(c)))$$

constitute a Nash equilibrium in the first-preferred offer bidding. At this equilibrium, the seller's utility level is zero.

PROOF:

Without loss of generality, let $\alpha = 1/2$ and consider figure 3, where both assumption i) and ii) are verified. Assumption i) just says that $\alpha(AB) = (1-\alpha)(CD)$ and assumption ii) that $\alpha(AB) \geq (EF)$. One can see immediately that the points $\underline{\alpha}$ and $\bar{\beta}$ constitute an equilibrium of the type asserted by the proposition. □



<u>figure 3</u>: the niche problem.

4.1.2 This situation, however, is a consequence of the special sellers' beliefs assumed in i) and ii). A wise buyer could break these assumptions by announcing some quality requirements that would change the subjective probability α to her advantage. For instance, if the buyer's true utility function is $V_1(q)-p$ and she can drive α up to 1 (this is equivalent to imposing standard quality $q^* = V_1'^{-1}(c)$), i) and ii) will be suppressed, both sellers will offer a product of quality q^* and competition will bring the price down to cq^*. The buyer's satisfaction will be maximized at $V(q^*)-cq^*$.

Hence, when a buyer's preference structure is unknown or cannot be directly communicated to potential sellers, imposing requirements on procurement bids, in the sense of reducing their dimension, may significantly improve the buyer's position.

4.2 Gilbert (1977) also made the statement that complexity of products or services may sometimes be an obstacle to the good performance of franchise bidding.[6]

> Additional profits arise if participants in the bidding process perceive the decision-maker's preferences as uncertain. Clearly, this should motivate the contracting agency to give an acurate statement of preferences. (Gilbert (1977): p. 17)

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6 In the tenth chapter of his book, Williamson (1985) also articulates a critique of franchise bidding along these lines.

He assumed, however, that bidders were not identical. So his model supported a warning against multi-dimensional bidding that is somehow weaker than the one coming from our example.

5. Epilogue

In this chapter, we examined the advantages of allowing multi-dimensional bids versus reducing the bids' dimension by promoting quality standards. We showed that a buyer would prefer one bidding rule to the other depending on the common knowledge information sellers have about her utility function:

- when the buyer's whole preference structure is common knowledge, asking for multi-dimensional bids is more appealing;

- when the buyer's utility is private or uncertain, enforcing standards may increase her satisfaction.

This essay can be seen as an another attempt in trying to analyze standards promotion, optimal product diversity and price formation. Its originality comes for the fact that it bears on a bidding model (or a game with incomplete information) while most other studies rely on oligopoly theory (or deterministic games). The advantages of our approach, at least to understand better the formation of prices, have been clearly stated in a recent paper by Hansen (1986):

> "What is particularly nice about auction theory is that it requires an equilibrium in the process of disequilibrium: actual prices may never be Nash equilibrium prices, but the strategies of firms used to determine those disequilibrium prices are equilibrium strategies... Oligopoly models focus upon an equilibrium with unchanging prices and disregard the process whereby those

prices are determined.

Thus, auction models of price formation should illustrate better the notion of Walrasian "tatonnements" (see Walker (1987)). We believe also that auction theory should be more appropriate than classical oligopoly theory in studying the development of high-tech products, where advances in research constantly impose the revision of previous decisions.

Admittedly, the study of multi-dimensional bidding and the policy issues it involves needs to be refined; for instance, examining situations where bids are costly (Samuelson (1985)) or bidders have different degrees of risk aversion (Cox, Smith and Walker (1982)) would provide a better grasp at "real-life" procurement rules. The connections between our present analysis and other fields of information economics also have to be clarified and developed.

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