

**Supplying Information to  
Facilitate Price Discrimination**

by

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**ABSTRACT**

We examine the incentive of a seller to allow potential buyers to acquire private information about their tastes for the seller's product. Improved private information for buyers enables the seller to segment the market and charge higher prices to high-value buyers. However, improved information can also provide rents to buyers. In a variety of settings, this tradeoff is optimally resolved at one of two extremes: either buyers are supplied with the best available knowledge of their tastes, or no information is supplied by the seller.

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## 1. Introduction.

Price discrimination is common in practice, and has received careful study in the economics literature. (Phlips (1983), Tirole (1988, chapter 3) and Varian (1989) provide excellent surveys.) Some analyses of price discrimination assume the variation in consumer tastes is known to both buyers and suppliers (see, for example, Oren et al. (1982) and Schmalensee (1982)). Other analyses assume buyers have private knowledge of their tastes for the suppliers' products (see, for example, Gabszewicz et al. (1986), Maskin and Riley (1984), and Mussa and Rosen (1978)). In all of these analyses, the information structure is taken to be exogenous. In particular, the analyses do not account for the possibility that a supplier might control the amount of information about her product that is available to potential buyers.

In practice, suppliers often have considerable control over what is known about their products. This is particularly true of new, complex industrial and commercial products.<sup>2</sup> By sponsoring training seminars and demonstrations for distributors, or by facilitating hands-on experimentation, for example, a supplier can help inform buyers about the uses and potential profitability of purchasing her goods or services. To illustrate, energy management and communication consultants often provide free detailed demonstrations and on-site appraisals to allow potential commercial customers to better assess the likely value of the services they might purchase.<sup>3</sup> In addition, brokerage houses that market complex financial securities routinely assist potential buyers and underwriters with seminars and reports to help them determine whether the securities are well suited for their idiosyncratic needs.<sup>4</sup>

In deciding how much to allow potential buyers to learn about their tastes for a supplier's product, a monopoly supplier faces a fundamental tradeoff. By endowing buyers with very

precise knowledge of their tastes for a supplier's product, the supplier can create extra surplus by improving the match between buyers' preferences and their consumption patterns.<sup>5</sup> Through price discrimination, the supplier can capture some of the surplus; but she will generally have to yield some of the surplus to the privately-informed buyers. On the other hand, if she provides little or no information to consumers about their idiosyncratic valuations for a product, a supplier may be able to extract nearly all the surplus of the "average" buyer. But there is less surplus to extract when consumption patterns are not finely tailored to true preferences.

The modest goal of this research is to begin to analyze some of the factors that influence this tradeoff for suppliers. As the ensuing findings make clear, general conclusions are difficult to come by in this line of inquiry, in part because there is considerable latitude in defining better information. In some settings, though, sharp conclusions can be drawn. Our main contribution (in section 3) is to identify some plausible settings where the monopoly supplier always finds it most profitable either to endow buyers with the best available information or to provide no new information. We also explain (in section 4) why the supplier may prefer intermediate information structures more generally.

Our analysis proceeds as follows. In section 2 a very simple, stylized environment is explored to illustrate some key elements of the supplier's calculus. Section 3 presents our main results, analyzing a more general setting in which the aforementioned supplier preference for extreme information structures prevails. Section 4 considers an alternative setting in which the supplier prefers intermediate information structures for buyers. Extensions of our analysis are discussed in section 5. There we consider the effects of competition among suppliers, and

suggest other factors that may influence information supply in market settings.

Before proceeding, we briefly review related works in the literature. Adams and Yellin (1977) demonstrate that a monopoly supplier may be able to use advertising to better extract surplus from consumers. In contrast to the (costless) "information" in our model, the (costly) "advertising" in their model always raises buyers' expected valuations of the supplier's product. Their analysis of price discrimination is also limited to the setting where the supplier and all buyers have perfect knowledge of buyers' preferences.

Clay, Sibley, and Srinagesh (CSS) (1992)'s focus on private information for consumers more closely parallels our focus. CSS examine whether a profit maximizing firm will prefer to have customers commit to a payment structure before or after uncertainty about their demand is resolved. The authors show that under certain conditions, the firm will prefer to contract with customers before the uncertainty is resolved, provided the magnitude of the uncertainty is sufficiently small.

Our formal model is an agency model with an endogenous information structure. In a related model, Sobel (1983) asks whether a principal prefers her risk-averse agent to share the principal's imperfect knowledge of the state of the world, or to know the state perfectly. Perfect knowledge of the state reduces the agent's production costs, but also increases required payments to the agent. Sobel finds that with a binary outcome space, a risk-neutral principal always prefers an informed agent to an uninformed one. With a risk-averse principal or many possible outcomes, either ranking can emerge. Aside from differences in how information affects the production technology and in the agent's aversion to risk, our approach differs from Sobel's in

that we examine more general information structures, and allow "agents" to be partially informed.

A more recent paper in the agency literature is that of Cremer and Khalil (CK) (1992).<sup>6</sup> CK allow the risk-neutral agent to acquire a signal about the true state of nature either before or after the principal proposes a contract. This information is not socially valuable because (in contrast to our analysis) the agent always becomes perfectly informed before acting. Thus, better information only increases the agent's rents, explaining CK's focus on how the principal can best mitigate the agent's incentive to acquire the information.<sup>7</sup>

Finally, we should point out that our analysis is quite distinct from the disclosure literature (e.g., Matthews and Postlewaite (1985)).<sup>8</sup> In that literature, the concern is with private testing and learning by the supplier and with public pre-sale disclosure of the supplier's findings. In our model, the supplier affects the opportunities of buyers to collect private information about their idiosyncratic preferences for the supplier's product. The supplier has no private information in our model.

## **2. A Binary Setting.**

To provide some preliminary feel for the monopoly supplier's calculus, consider the following very simple and very special setting. Suppose each buyer will purchase exactly one unit of the supplier's product if his expected valuation of the product exceeds the price of the product.<sup>9</sup> Otherwise, the buyer purchases none of the product. A buyer's actual valuation is either high ( $\theta_2$ ) or low ( $\theta_1$ ). The two realizations are initially thought to be equally likely by all buyers, so without additional information, each of the  $n$  potential buyers has the same expected

valuation,  $\theta^m = \frac{1}{2} [\theta_1 + \theta_2]$ .

Before buyers decide whether to purchase the product, the seller can (costlessly) provide additional private information to them that may alter their expected valuation. This additional information may arise, for example, from actual experimentation with the product (as when automobile dealers permit test drives or magazine publishers provide free samples), or from supplier-sponsored demonstrations and seminars designed to answer questions and provide detailed information about a complex product (such as new security offerings or new computing services). For simplicity, we abstract from any costs the supplier might incur in providing information to potential buyers, and from any costs potential buyers might incur in acquiring this information.

We model the buyer's private information here as the realization of one of two equally-likely signals,  $s_1$  or  $s_2$ . A signal provides information about the product's value or desirability. The accuracy of the signal is denoted by  $\gamma \in [0,1]$ . A more accurate signal is associated with better information in the sense of Blackwell (1951). Intuitively, a buyer's assessment of his valuation for any given signal is less precise or more garbled the smaller is  $\gamma$ . Formally,  $p(\theta_i | s_i; \gamma) = 1/2 + \gamma/2$ , and  $p(\theta_j | s_i; \gamma) = 1/2 - \gamma/2$ , for  $i, j = 1,2$ ,  $i \neq j$ , where  $p(\theta_j | s_i; \gamma)$  is the conditional probability that a buyer's true valuation is  $\theta_j$  after signal  $s_i$  of accuracy  $\gamma$  is observed. Thus, after observing the high signal ( $s_2$ ), for example, the buyer revises upward his expected valuation for the product, and more so the more accurate the signal. We assume the supplier chooses  $\gamma$  by deciding how much information to provide to potential buyers.

After the supplier chooses  $\gamma$  and her choice becomes known publicly, each buyer observes his private signal, and updates his assessment of his valuation,  $\theta$ . Then, after the supplier sets a unit price for her product, each buyer decides whether to purchase one unit of the product. Once final demand becomes known, the supplier produces to satisfy demand, with each unit produced at constant marginal cost,  $c$ . We assume  $c < \theta^m$  to ensure the supplier could secure strictly positive profit without providing any private information to potential buyers (i.e., by setting  $\gamma = 0$ ).

Notice that if the supplier chooses  $\gamma > 0$ , she endows potential buyers with asymmetric valuations of her product. Consequently, the supplier can set a price above the mean valuation,  $\theta^m$ , and some buyers (those who observe signal  $s_2$ ) will still purchase the product. Thus, by endowing potential buyers with private information, the supplier creates opportunities for "targeting" or "market segmentation", i.e., selling to subsets of the population at prices above the average valuation.<sup>10</sup> Of course, when she sets  $\gamma > 0$ , the supplier also forfeits the ability to sell to all potential buyers at their average valuation. With  $\gamma > 0$ , those buyers who observe  $s_1$  reduce their expected valuation of the product, and thus will not pay  $\theta^m$ . Selling to a broad versus a segmented market is the essential tradeoff the supplier faces in choosing  $\gamma$ .

The supplier's maximum expected profit in this binary setting as a function of the accuracy of the buyers' private information is readily shown to be:

$$\Pi^B(\gamma) = n [\theta^m - c - \gamma[\theta_2 - \theta_1]] \quad \text{for } \gamma \in [0, \hat{\gamma}], \text{ and}$$

$$\Pi^B(\gamma) = \frac{n}{2} [\theta^m - c + \gamma[\theta_2 - \theta_1]] \quad \text{for } \gamma \in (\hat{\gamma}, 1],$$

$$\text{where } \hat{\gamma} = \text{minimum} \left\{ \frac{2}{3} \cdot \frac{\theta^m - c}{\theta_2 - \theta_1}, 1 \right\}.$$

Notice that the supplier's expected profit declines as each buyer's private signal becomes more accurate in the range where these signals are not very accurate (i.e., when  $\gamma \leq \hat{\gamma}$ ). (See Figure 1). In this range, observation of the more favorable signal ( $s_2$ ) does not raise a buyer's expected valuation sufficiently to make it profitable for the supplier to sell to only this group of buyers. The supplier prefers to set the highest price that induces all  $n$  buyers to purchase the product. This price falls as  $\gamma$  increases because the more accurate the signal, the lower the expected valuation of potential buyers who receive the less favorable  $s_1$  signal. Consequently, the supplier's expected profit declines with  $\gamma$  in this range.

The supplier's expected profit may also increase as buyers' information about the product improves. When the expected valuation of buyers differs sufficiently according to their private information (in the range where  $\gamma \in (\hat{\gamma}, 1]$ ) and when the supplier's profit margin from selling to all  $n$  buyers at price  $\theta^m$  is sufficiently small, the supplier will prefer to sell to only those buyers with high expected valuations. In this range, the more accurate their private information, the higher the expected valuation of the buyers who observe the more favorable signal,  $s_2$ . Consequently, the supplier's expected profit increases with  $\gamma$  for  $\gamma \in (\hat{\gamma}, 1)$ . Therefore, as Figure 1 illustrates, the supplier will either: (i) provide no private information and sell one unit to each of the  $n$  buyers at price  $\theta^m$ ; or (ii) supply perfect information to all potential buyers, and sell one unit at price  $\theta_2$  to each of the buyers who observe signal  $s_2$ . It is straightforward to verify that the former (respectively, the latter) alternative will be preferred when  $c < \theta_1$  (respectively,  $\theta_1 > c$ ).<sup>11</sup>

Clearly, there are a variety of strong assumptions that contribute to this result. The

linear updating of beliefs about two equally-likely valuations is important. So, too, is the "0-1" demand structure, which even precludes second-degree price discrimination in this setting. In section 3, though, we show that the supplier's decision to supply either perfect information or no information persists in certain more general environments.

### 3. More General Settings.

In this section, we present our main findings. We show that the supplier will continue to supply potential buyers with either perfect information or no information in certain settings where each buyer's taste for the supplier's product can take on a continuum of values, and where buyers' demand functions are continuous functions of the product's price. The key requirement is that a buyer's private signal be informative about his true valuation with some probability ( $\gamma$ ) and uninformative with the complementary probability. Thus,  $\gamma$  might represent the fraction of buyers who receive relevant pre-sale information from the supplier, whereas  $1 - \gamma$  represents the fraction of potential buyers who discern no new information about their valuation of the product from the supplier's advertising and sales demonstrations.

To analyze such settings formally, let  $U(Q, \theta) - P$  represent the utility of a buyer with taste parameter  $\theta$  who pays  $P$  dollars for  $Q$  units of the supplier's product. The higher is  $\theta$ , the more utility the buyer receives from the product, so  $U_\theta(\cdot) > 0$ . Utility is also an increasing, concave function of the number of units consumed, so  $U_Q(\cdot) > 0$  and  $U_{QQ}(\cdot) < 0$ .  $\theta$  can take on any value in the interval  $[\underline{\theta}, \bar{\theta}]$ . In part to abstract from a supplier's incentives to target the most heavily represented buyer types, we assume all values of  $\theta$  are equally likely. Thus,  $\theta$  follows a uniform distribution on  $[\underline{\theta}, \bar{\theta}]$ .<sup>12</sup>

Buyers are initially uncertain of their taste parameter,  $\theta$ . By allowing potential buyers to experiment with the product or by sponsoring some other information programs, the supplier can improve a potential buyer's knowledge of  $\theta$ . Formally, we assume the supplier can choose  $\gamma \in [0,1]$ , which is the probability that any particular buyer receives an informative signal,  $s \in [\underline{s}, \bar{s}]$ , about  $\theta$ .<sup>13</sup> Having observed informative signal  $s$ , the buyer's updated beliefs about his taste parameter are represented by the conditional distribution function  $H(\theta|s)$ . We assume  $H_s(\theta|s) \leq 0$  for all  $\theta \in [\underline{\theta}, \bar{\theta}]$ , with strict inequality for some  $\theta$ . In words, higher realizations of the signal  $s$  are associated with higher realizations of the taste parameter  $\theta$  in the sense of first order stochastic dominance.  $G(s)$  will denote the marginal distribution function for the informative signal.

If the buyer receives no signal, or if the observed signal is uninformative (which will be the case with probability  $1-\gamma$ ), the buyer's beliefs about his taste parameter are unchanged, and so are reflected in the uniform prior,  $F(\theta) = \frac{\theta - \underline{\theta}}{\bar{\theta} - \underline{\theta}}$ . Initially, we assume the buyer can discern perfectly whether the signal he has observed is informative or uninformative. We will denote by  $s_0$  the uninformative signal. As in the binary setting, the supplier first chooses  $\gamma$ . Each of the  $n$  buyers then observes a private signal and learns whether the signal is informative or uninformative. The supplier then specifies a menu of quantities and corresponding total payments  $\{Q(s), P(s)\}$ . Next, each buyer selects his most preferred consumption-payment pair. The supplier then satisfies total demand, again at constant marginal cost  $c$ , and collects the requisite payments from the buyers.

Formally, the seller's problem [P-I] is:<sup>14</sup>

$$\text{Maximize}_{\gamma, Q(\cdot), P(\cdot)} \quad n\gamma \int_{\underline{s}}^{\bar{s}} [P(s) - cQ(s)] dG(s) + n[1-\gamma][P(s_o) - cQ(s_o)]$$

subject to,  $\forall s, \hat{s} \in \{[\underline{s}, \bar{s}], s_o\}$ :

$$u(s|s) \geq 0 \quad ; \text{ and}$$

$$u(s|s) \geq u(\hat{s}|s),$$

where

$$u(\hat{s}|s) \equiv \int_{\underline{\theta}}^{\bar{\theta}} U(Q(\hat{s}), \theta) dH(\theta|s) - P(\hat{s}) \quad \text{for } s \in [\underline{s}, \bar{s}], \text{ and } \hat{s} \in [\underline{s}, \bar{s}], s_o ; \text{ and}$$

$$u(\hat{s}|s_o) \equiv \int_{\underline{\theta}}^{\bar{\theta}} U(Q(\hat{s}), \theta) dF(\theta) - P(\hat{s}) \quad \text{for } \hat{s} \in \{[\underline{s}, \bar{s}], s_o\}.$$

As noted above, the supplier maximizes her expected profit in this setting either by ensuring the buyers' private signals are always informative or never informative. Formally, letting  $\Pi^I(\gamma)$  denote the supplier's maximum expected profit given  $\gamma$  in this setting, we have:

**Proposition 1.**<sup>15</sup>  $\Pi^I(\gamma) \leq \text{maximum} \{ \Pi^I(0), \Pi^I(1) \} \quad \forall \gamma \in [0,1].$

**Proof.** Let  $\tilde{\Pi}(\gamma)$  denote the maximum expected profit for the supplier given  $\gamma$  in the benchmark problem where both the buyer and supplier learn whether the buyer's private signal is informative or uninformative. Then:

$$\begin{aligned}
\Pi^I(\gamma) &\leq \tilde{\Pi}(\gamma) \\
&= \gamma \tilde{\Pi}(1) + [1-\gamma] \tilde{\Pi}(0) \\
&= \gamma \Pi^I(1) + [1-\gamma] \Pi^I(0) \\
&\leq \text{maximum} \{ \Pi^I(0), \Pi^I(1) \} .
\end{aligned}$$

The first inequality follows from the extra information available to the supplier in the benchmark problem. The first equality holds because in the benchmark problem the supplier faces buyers with conditional beliefs given by  $H(\theta|s)$  with probability  $\gamma$  and by  $F(\theta)$  with probability  $1-\gamma$ . The last equality holds because the solutions to [P-I] and the benchmark problem coincide in the extreme cases where  $\gamma = 0$  or  $\gamma = 1$ . ■

Before providing an explanation of Proposition 1, it should be noted that the finding also holds in the setting where buyers are not certain whether the signal they observe privately is informative or uninformative. For example, certain information about a new financial security may be relevant under current market conditions, but may be irrelevant under the conditions that ultimately prevail. Thus, unable to forecast market conditions perfectly, the buyer cannot be certain whether the information he receives is informative or uninformative about his ultimate tastes,  $\theta$ . To state our findings for this setting formally, let [P-U] denote the supplier's counterpart to problem [P-I] when the buyers are not certain whether the signal they observe privately is informative or uninformative. (Problem [P-U] is stated formally in the Appendix.) Also let  $\Pi^U(\gamma)$  denote the supplier's maximum expected profit in this setting when the signal she provides is informative with probability  $\gamma$  and uninformative with probability  $1-\gamma$ . Then we have:

**Proposition 2.**  $\Pi^U(\gamma)$  is a convex function of  $\gamma$ , so  $\Pi^U(\gamma) \leq \text{maximum} \{ \Pi^U(0), \Pi^U(1) \}$   
 $\forall \gamma \in [0,1]$ .

The proof of Proposition 2 is in the Appendix. Notice that when the buyer's private signal,  $s \in [\underline{s}, \bar{s}]$ , may be either informative or uninformative, it is necessary to specify a marginal distribution for the informative signal,  $G(s)$ , and a marginal distribution for the uninformative signal,  $G^o(s)$ . To ensure the realization of the signal itself provides no information about the supplier's choice of  $\gamma$ , the formulation of [P-U] presumes  $G(s) = G^o(s)$   
 $\forall s$ .

In this setting, it is also possible to determine how the supplier's expected profit varies as the buyers' private information improves slightly (i.e., as  $\gamma$  increases above 0). As Proposition 3 reports, such slight improvement is detrimental to the supplier, just as in the binary setting. (The proof of Proposition 3 is in the Appendix.) The slight improvement in information for buyers is not sufficient to make targeting profitable for the supplier. However, it does reduce the price that buyers who observe the smallest realizations of the signal are willing to pay for the product. Thus, the supplier loses from a slight improvement in the buyers' information whenever she can earn strictly positive expected profit if buyers have only their initial beliefs about  $\theta$  (i.e., whenever condition (C1) holds).<sup>16</sup>

$$(C1) \quad \int_{\underline{\theta}}^{\bar{\theta}} U_Q(0, \theta) dF(\theta) > c.$$

**Proposition 3.**  $\Pi^{U'}(\gamma) |_{\gamma=0} \leq 0$ , with strict inequality if (C1) holds.

The supplier's preference for extreme information structures in these settings stems from considerations similar to those identified in the binary setting of section 2. There are two basic consequences of an increase in  $\gamma$ . First, there is a "high signal" effect that is beneficial for the supplier. Those buyers who observe high realizations of the signal are more certain that their taste for the product ( $\theta$ ) is high, and thus are willing to pay more for the product. Second, there is a "low signal" effect that is detrimental to the supplier. Buyers who observe low realizations of  $s$  are more certain that their taste for the product is low, and so are not willing to pay as much for the product. The supplier's anticipated gains from increasing  $\gamma$  due to the high signal effect are proportional to the quantity demanded by buyers who observe the high realizations of  $s$ . The corresponding losses due to the low signal effect are proportional to the demand of buyers who observe the low realizations of  $s$ . Most importantly, the more accurate the private information of buyers, the greater (respectively, the smaller) the equilibrium purchases by buyers who observe the high (respectively, the low) realizations of  $s$ . Consequently, as  $\gamma$  increases, the marginal expected gains from the high signal effect increase and the marginal expected losses from the low signal effect decrease. This results in the identified preference for extreme information structures.

What remains is to explore the supplier's choice between the two extreme information structures. The degree of buyer heterogeneity and the level of production costs both influence the supplier's preference for informing buyers. To explore the role of buyer heterogeneity, notice that the supplier can extract the entire expected consumers' surplus of the "average" buyer if she provides no private information to buyers. However, she cannot tailor purchase patterns to the innately asymmetric tastes of buyers. By providing the best available information to

buyers, the supplier can effect such tailoring and can capture some of the resulting increase in surplus through price discrimination. However, buyers generally command some rents from their superior knowledge of their tastes. In general, when buyers' demands are sufficiently sensitive to individual tastes ( $\theta$ ), the large potential increase in total surplus from tailoring purchase patterns to tastes (the analogue of targeting in the binary setting) outweighs the rents privately informed buyers can command.

To illustrate this effect, consider the following two simple examples. In the first example, each buyer consumes at most one unit of the product. Buyers differ according to a parameter,  $\theta$ , which is distributed uniformly on the interval  $[\underline{\theta}, \bar{\theta}]$ . The utility a buyer of type  $\theta$  derives from a unit of the good is  $u(P, \theta) = \hat{v} + d[E(\theta) - \hat{\theta}] - P$ .  $P$  is the unit price of the good,  $\hat{v} > 0$  is the valuation of the "average buyer",  $d$  is a parameter reflecting consumer diversity, and  $E(\theta) - \hat{\theta}$  is the perceived difference between a particular buyer and the average buyer. When no information is provided,  $E(\theta) = \hat{\theta}$  and all buyers perceive they are the same. When perfect information is provided,  $E(\theta) = \theta$ , and higher values of  $d$  correspond to greater diversity between buyers of different types. For simplicity we assume production is costless, so it is profitable to sell to the "average customer". Straightforward calculations reveal that the supplier's expected profit as a function of  $d$  (denoted  $\Pi(d)$ ) is such that  $\Pi(1) \begin{matrix} \geq \\ \leq \end{matrix} \Pi(0)$  as  $d \begin{matrix} \geq \\ \leq \end{matrix} \hat{d}$ , for some  $\hat{d} > 0$ . (See the Appendix for details.) When it is optimal to provide perfect information, the supplier serves only those buyers with high valuations, and charges them a high price. This strategy is the most profitable strategy in this setting when buyers are sufficiently diverse.

In the second example illustrating the importance of buyer diversity, we suppose  $U(Q, \theta) = \frac{\theta}{\delta} Q^\delta \quad \forall Q \geq 0$ , where  $\delta < 1$  and  $\delta \neq 0$ . Here,  $\varepsilon \equiv \frac{1}{1-\delta}$  is the buyer's elasticity of demand, and  $\theta$  is a multiplicative factor representing the intensity of a buyer's demand. Also suppose the informative signal reveals the exact realization of  $\theta$  (i.e.,  $H(\theta|s) = 0 \quad \forall \theta < s$  and  $H(\theta|s) = 1 \quad \forall \theta \geq s$ ). The foregoing arguments suggest the supplier will prefer to: (i) endow buyers with perfect knowledge of their tastes when their demand is sufficiently elastic; and (ii) provide no additional information to buyers when their demand is sufficiently inelastic. Tedious calculations and simulations reveal this is precisely the case:  $\Pi^U(1) > \Pi^U(0)$  when  $\delta \in (0,1)$ , and  $\Pi^U(0) > \Pi^U(1)$  when  $\delta < 0$ .<sup>17,18</sup>

Now consider the influence of the level of production costs on the supplier's choice of information structure. The key observation is that when marginal production costs are sufficiently high, the profit earned by serving the "average customer" will be too small. Consequently, the supplier will prefer to target those buyers with the highest valuations, charging them a high price after providing detailed product information. This intuition is confirmed by examining a third example, which is a slight variation of the first example presented above. Again, let  $u(P, \theta) = \hat{v} + d[E(\theta) - \hat{\theta}] - P$  denote the utility of a buyer of type  $\theta$ . Now, fix the parameter  $d$ , but allow the unit cost of production ( $c$ ) to vary. Straightforward calculations reveal that there exists a critical cost level  $\tilde{c} \in (\underline{\theta}, \hat{\theta})$  such that  $\Pi(1) \begin{cases} \geq \\ \leq \end{cases} \Pi(0)$  as  $c \begin{cases} \geq \\ \leq \end{cases} \tilde{c}$ . In words, it is profitable to fully inform potential buyers when and only when unit production costs are sufficiently high. Notice that  $\tilde{c} < \hat{\theta}$ , so the seller may

prefer to segment the market and serve only those buyers with high valuations even when the "average buyer" is willing to pay more than the cost of supplying the product.<sup>19</sup>

It is important to note that in all three of these examples, a Pareto improving allocation of resources results when the seller provides complete information to potential buyers. Buyers, like the supplier, are better off when the supplier provides complete information because all fully-informed buyers are ensured of nonnegative utility, not simply the nonnegative expected utility they receive when they are uninformed about  $\theta$ .

The first two examples suggest that higher prices and greater dissemination of information in such forms as advertising and product demonstration will be more likely the more diverse are consumers' tastes for the product. In practice, this relationship may be difficult to test because it is difficult to observe and rank the inherent diversity of consumers across different products. Furthermore, an identification problem arises because diversity of tastes among consumers may itself be influenced by the amount and type of information disseminated by suppliers.

The testable implication of the third example is more clear. The finding suggests sellers of high-cost items will provide more information about the product and charge higher prices, thereby attracting only those buyers with particularly high valuations. Exclusive and expensive department stores like Nordstrom's seem to follow this strategy. Such stores have a reputation for devoting time to their customers, carefully explaining the characteristics and uses of the products they carry. These stores also tend to carry more expensive items that the average consumer cannot afford to buy.

#### 4. Preferred Intermediate Information Structures.

As noted above, the finding that the supplier will prefer either to endow buyers with the best available information or to provide no private information is not completely general. In this section, we explain briefly why a monopoly supplier may prefer intermediate information structures in some settings.

To describe the essential intuition most readily, consider the simple setting where each of  $n$  potential buyers purchases either one unit of the supplier's product (e.g., an automobile) or none, and where each buyer's true valuation of the product can take on one of three possible values,  $\theta \in \{\theta_1, \theta_2, \theta_3\}$ . For simplicity, we also assume all three values are equally likely for all buyers, and the intermediate valuation is simply the average of the extremes, i.e.,  $\theta_2 = \frac{1}{2}[\theta_1 + \theta_3]$ . Any improvement in buyers' information about  $\theta$  arrives in the form of a signal  $s \in \{s_1, s_2, s_3\}$ . (The signal might be generated by a cursory examination or a test drive of the automobile.) We maintain the timing of the binary setting, and continue to let  $c$  represent the supplier's constant marginal cost of production.

The key difference between this trinary environment and the binary setting of section 2 is the type of Blackwell rankings of information structures that are admitted. Initial improvements in a buyer's information about his valuation of the product (perhaps due to a cursory examination of the car) permit a better assessment of whether the buyer has the lowest possible valuation  $\theta_1$  (e.g., the car is too small). Improving buyers' information along these lines enables the supplier to target the higher-valuation buyers, excluding the lowest-valuation buyers. Subsequent improvements in information (perhaps from lengthy test drives) tell buyers

whether they are more likely to have the highest or the intermediate valuation of the product (e.g., whether the car's performance is just slightly better or substantially better than the performance of the car the potential buyer currently drives). The supplier who wishes to sell to all buyers with intermediate or higher valuations will not favor such improvements in information, because the improved information simply reduces the price a targeted group of buyers is willing to pay. Consequently, the supplier in such an environment will prefer the intermediate information structure, where buyers know for sure whether they have the lowest possible valuation, but have no better knowledge of whether their true valuation is  $\theta_2$  or  $\theta_3$ .

To demonstrate this effect formally, let  $p(\theta_i | s_j; \gamma)$  denote the conditional probability that a buyer's valuation is  $\theta_i$  after he observes the signal  $s_j$  of accuracy  $\gamma$ . For  $\gamma \in [0, \frac{1}{3}]$ ,  $p(\theta_2 | s_j; \gamma) = p(\theta_3 | s_j; \gamma) = \frac{1}{3} + \frac{\gamma}{2}$  and  $p(\theta_1 | s_j; \gamma) = \frac{1}{3} - \gamma$  for  $j = 2, 3$ . Also,  $p(\theta_2 | s_1; \gamma) = p(\theta_3 | s_1; \gamma) = \frac{1}{3} - \frac{\gamma}{2}$ , and  $p(\theta_1 | s_1; \gamma) = \frac{1}{3} + \gamma$ .

In words, after observing one of the two highest signals ( $s_2$  or  $s_3$ ), a buyer revises upward (respectively, downward) the probability that his valuation is either  $\theta_2$  or  $\theta_3$  (respectively,  $\theta_1$ ). The revision is more pronounced the more accurate the signal (i.e., the greater is  $\gamma$ ).<sup>20</sup> The buyer who observes signal  $s_1$  becomes more certain that he has the lowest valuation,  $\theta_1$ . When the accuracy of the signal increases to  $\frac{1}{3}$ , the buyer who sees signal  $s_1$  is certain that his valuation is  $\theta_1$  (e.g., the car is definitely too small). The buyer who sees signal  $s_2$  or  $s_3$  assigns equal probability ( $\frac{1}{2}$ ) to his valuation being  $\theta_2$  or  $\theta_3$ .

Further increases in the accuracy of the private signal provide better information about

whether the buyer's true valuation of the product is  $\theta_2$  or  $\theta_3$ . For  $\gamma \in [\frac{1}{3}, 1]$ ,  
 $p(\theta_i | s_i; \gamma) = \frac{1}{2} + \frac{\gamma}{2}$  for  $i = 2, 3$ , and  $p(\theta_i | s_j; \gamma) = \frac{1}{2} - \frac{\gamma}{2}$  for  $j \neq i$ ,  $i, j = 2, 3$ .  
 Also,  $p(\theta_1 | s_1; \gamma) = 1$  and  $p(\theta_i | s_1; \gamma) = 0$  for  $i = 2, 3$ .<sup>21</sup> As noted above, the  
 supplier will not favor increases in  $\gamma$  above  $\frac{1}{3}$  if it is most profitable to induce all buyers who  
 see either of the two highest signals to purchase the product. This will be the supplier's most  
 profitable strategy when the marginal cost of production is less than the intermediate buyer  
 valuation,  $\theta_2$ . Thus, provided the supplier also finds it profitable to exclude the lowest-valuation  
 buyers from the market (which will be the case when the marginal cost of production exceeds  
 this lowest valuation), the supplier will prefer the intermediate information structure where  $\gamma =$   
 $\frac{1}{3}$ . This conclusion is recorded formally in Proposition 4, whose proof is in the Appendix. In  
 the statement of Proposition 4,  $\Pi^T(\gamma)$  denotes the supplier's maximum expected profit for given  
 $\gamma$  in this trinary environment.

**Proposition 4.**  $\Pi^T(\frac{1}{3}) > \text{maximum} \{ \Pi^T(0), \Pi^T(1) \}$  if and only if  $c \in (\theta_1, \theta_2)$ .

It should be apparent that the basic conclusion in Proposition 4 will hold in many other  
 settings.<sup>22</sup> The supplier's choice among information structures will depend critically upon  
 exactly what buyers learn as their information improves. Better private information for buyers  
 can either systematically increase or decrease a supplier's expected profit, or it can increase this  
 profit over some ranges and decrease profit over other ranges. Blackwell rankings of  
 information structures do not preclude any of these possibilities.

## 5. Conclusions and Extensions.

The existing price discrimination literature takes as given buyers' information about product characteristics. Here, we have identified some factors that may influence the amount of information a monopolist will provide to her customers. We have shown how better consumer information about the attributes of a product can allow a supplier to charge higher prices to buyers with higher valuations, thereby segmenting the market. We found that market segmentation tends to be most profitable when consumers are heterogeneous and production costs are high. In our model, Pareto improvements arise when sellers voluntarily provide information to buyers, since buyers can better tailor their purchases to their tastes. Our analysis revealed that the seller's preference for providing private information to potential buyers is sensitive to how improvements in information are modelled.

We do not view our analysis as the final word on the supply of product information in market settings. Rather, we see our work as a modest extension of some early work in the area (e.g., Adams and Yellin (1977)) and, more importantly, as a contribution to the agency literature where the information structure is endogenous. Clearly, our model is special in many ways, so our results should be interpreted with care. Some of the more important extensions of our analysis are discussed in closing.

First, competition among suppliers can affect information flows to buyers. To briefly illustrate some of the key effects of competition, consider a modified version of the first example in section 3 where two symmetric producers (A and B) are located along a straight line in product space at extreme positions ( $\underline{\theta}$  and  $\bar{\theta}$ , respectively). A buyer's most preferred product

type is given by  $\theta$ , where each of the  $n$  buyer's  $\theta$  is drawn (independently) from a uniform distribution on the interval  $[\underline{\theta}, \bar{\theta}]$ . A buyer of type  $\theta$  who purchases one unit from supplier A (respectively, buyer B) receives utility  $u(\theta, P_A | A) = \hat{v} + \tilde{d}[\hat{\theta} - \theta] - P_A$  (respectively,  $u(\theta, P_B | B) = \hat{v} + \tilde{d}[\theta - \hat{\theta}] - P_B$ ). Here,  $\hat{v}$  is the average (or generic) valuation each buyer attaches to the products of firms A and B,  $\tilde{d}$  is the perceived degree of product differentiation,  $\hat{\theta}$  is the average buyer type, and  $P_i$  is the price charged by seller  $i$ .

If production costs are zero, both producers will set price equal to  $\tilde{d}$  in any pure strategy price-setting equilibrium, and earn profit  $\frac{\tilde{d}n}{2}$ . If potential buyers are completely uninformed about their relative valuations of the two products or if there is no product differentiation (so  $\tilde{d} = 0$ ), a Bertrand equilibrium will result in which neither supplier makes positive profit. Consequently, there is an incentive for each supplier to provide buyers with information, and to differentiate her product from that of her competitor. Increases in  $\tilde{d}$  enable producers to earn strictly positive profit when buyers are aware of their preferences (i.e., know  $\theta$ ). Notice, though, that in this setting the information provided by one supplier can provide information to consumers about the other product as well. If information is costly to provide (a possibility that we have ignored to this point), there will be an incentive for each producer to rely on the other to supply information to the market. This public good characteristic of information can cause producers to collectively supply less than the profit maximizing amount of information to potential buyers.

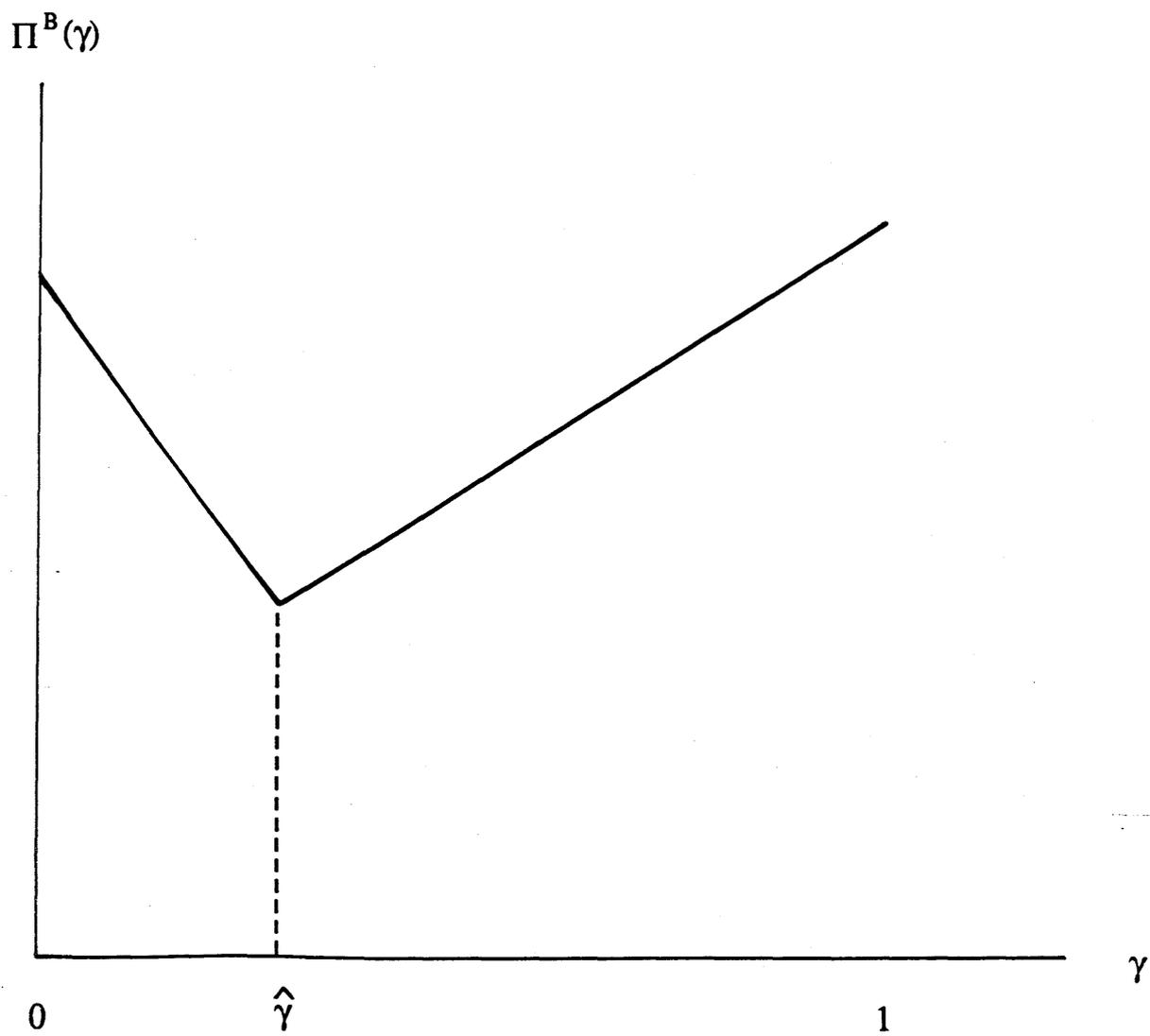
Second, costs of providing information will likely affect information dissemination in several other ways. If information costs are convex, it may no longer be optimal for suppliers to choose extreme information structures, even for the settings examined in sections 2 and 3. There is also the issue of whether buyers or suppliers (or both) should provide information. Economies of scale in collecting and transmitting information may make it less expensive for suppliers to provide information. However, when suppliers have incentives to distort information, buyers may seek other information sources.

Third, production costs may be reduced through learning by doing. Suppliers of new products may wish to serve the entire market in early periods of the product cycle in order to reduce future production costs, thereby moving rapidly down their learning curves. Our analysis suggests that if a monopoly supplier sells to the entire market, she may limit the information she supplies, thereby ensuring she can charge the maximum amount the "average customer" is willing to pay. Of course, our analysis would require modification if buyers learn more about product characteristics over time by consuming the product.

Finally, consumer protection statutes and policies can influence information dissemination by a supplier. If a monopolist chooses to serve the entire market, she could provide no information and charge the price that extracts each customer's expected surplus. After the purchase, though, some customers may be disappointed if they discover their realized surplus to be unexpectedly low. When buyers are guaranteed the right to return unwanted purchases, a supplier's strategy of selling to the entire market at the price the "average buyer" is (initially) willing to pay will not be feasible. Notice that multiproduct monopolists might voluntarily adopt

a "no questions asked" return policy to avoid the possibility of consumer dissatisfaction with one product adversely affecting sales of other products. These and related extensions of our model await future research.

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**Figure 1.** Expected Profit in the Binary Setting.

## FOOTNOTES

1. We are grateful to the National Science Foundation for financial support. We wish to thank an anonymous referee, Peter Cramton, Jacques Cremer, Mark Flannery, Ed Green, David Levine, Albert Ma, Preston McAfee, Tom Palfrey, Gary Ramey, Jennifer Reinganum, Richard Romano, Tom Ross, Steve Shugan, Jean Tirole, Bart Weitz, Ralph Winter and other seminar participants at Barcelona, Cal Tech, U. C. Davis, Florida, Penn, Toronto, and Toulouse for helpful comments. This paper is based in part on an earlier draft entitled "Should Principals Inform Agents?: Information Management in Agency Problems".
2. For an interesting overview of this issue, see Webster (1984).
3. Furthermore, financial planners often sponsor introductory seminars to allow potential clients to better assess how valuable the planner's services might be to them. Similarly, lawyers, architects, orthodontists, and other professionals commonly provide free initial consultations, in part to inform prospective clients about their competence and expertise. Of course, in practice, these seminars and consultations may be motivated in part by competitive considerations. Our analysis focuses on the case of a monopoly supplier. The effects of competition among suppliers is discussed briefly in section 5.
4. See Kuhn (1988) and Badih and Madan (1991).
5. We abstract from the possibility that suppliers might attempt to deceive potential buyers about the characteristics or value of their products.

6. Craswell (1988) examines the design of legal rules to motivate an agent to acquire the socially optimal amount of valuable planning information.
7. Crocker and Snow (1992) are also concerned with the question of how much information should be supplied to "agents". In their model, the cost of improved information is the resources agents waste in signalling to the marketplace the private information they receive about their abilities. The analyses of Riordan and Sappington (1987) and Ma (1987) also consider the optimal supply of information in a principal-agent setting. In their models, though, an exogenous amount of information is always supplied; the question addressed is whether the principal or the agent should receive this information.
8. Our analysis is also distinct from the search literature (as surveyed, for example, in Varian (1989)). In that literature, buyers are assumed to know product characteristics, but may be uninformed about prices. In our model, all prices are known, but buyers are uncertain about product characteristics that affect their idiosyncratic preferences, unless suppliers provide this information.
9. If a buyer is a final consumer, his valuation can be thought of as the level of utility derived from the product. If the buyer employs the product as an input for production, his valuation can be viewed as the increase in expected profit from employing the input.
10. Pricing strategies of this form are described in Webster (1984, Chapters 4 and 7). Notice that if buyers had downward sloping demand curves, the supplier could practice second-degree price discrimination once buyers learn their asymmetric valuations. Second-degree

price discrimination is considered formally in section 3.

11. To understand why the relationship between the supplier's marginal cost of production and the lowest buyer valuation ( $\theta_1$ ) influences the supplier's decision on information dissemination, consider the following hypothetical setting (suggested to us by a referee). Suppose any information a buyer receives about his preferences is observed publicly. When perfect information about preferences is revealed in this setting, the supplier can practice perfect price discrimination, and so acts to maximize total surplus. When surplus maximization entails selling to all buyers (i.e., when  $c < \theta$  for all valuations,  $\theta$ ), the supplier's expected profit is the same whether perfect information or no information is supplied to buyers. This is because the expected sales price is the same in both cases, given that all buyers have the same *ex ante* (and thus expected *ex post*) valuation of the supplier's product. In contrast, if surplus maximization requires that some fully-informed buyers not receive the product (because  $c > \theta$  for some  $\theta$ ), the fully-informed supplier will prefer to endow potential buyers with perfect knowledge of their preferences. The perfect price discrimination that results provides higher total surplus, and thus greater profit for the suppliers.

In the binary setting analyzed here (with private buyer information), exclusion of the low-valuation ( $\theta_1$ ) buyer enables the supplier to practice perfect price discrimination on the remaining population of buyers (since they all have the same valuation,  $\theta_2$ ). Hence, the supplier's preference for supplying perfect information when  $c > \theta_1$  is explained. Furthermore, since the supplier is indifferent between providing perfect public information and no information when  $c < \theta_1$ , she will prefer to supply no information to buyers when

any information is observed privately by buyers, making perfect price discrimination impossible.

12. The main conclusions of this section hold even if the distribution of  $\theta$  is not uniform. The uniform assumption is useful because it facilitates a convenient parameterization of information structures that are better in the sense of Blackwell (1951).
13. Notice that the supplier can't selectively inform certain types of potential buyers, since  $\gamma$  is independent of  $\theta$ . This possibility is an interesting topic for future research.
14. The I in [P-I] refers to the fact that buyers are informed as to whether the signal they observe privately is informative or uninformative.
15. A special case of Proposition 1 is reported in Lewis and Sappington (1991).
16. This finding is reminiscent of the conclusion drawn by Radner and Stiglitz (1984) in a setting where there is only one strategic player. Radner and Stiglitz treat the cost of better information as an exogenous parameter. In our model, the cost of improved information is endogenous, arising from the equilibrium costs of selling to buyers. Singh (1985) abstracts from cost considerations, but finds in a moral hazard model that the marginal value to the principal of imperfect information about the agent's effort level is zero at the point of no information.
17. Standard techniques reveal that for  $\theta = z\bar{\theta}$ ,  $\Pi^U(1) \begin{matrix} > \\ \equiv \\ < \end{matrix} \Pi^U(0)$  as

$\frac{1 - (2z - 1)^{\frac{2-\delta}{1-\delta}}}{1 - z} [1 - \gamma] / [2 - \gamma] \stackrel{\geq}{\leq} \left[ \frac{1+z}{2} \right]^{\frac{1}{1-\delta}}$ . To ensure equilibrium purchase levels

are positive  $\forall \theta \in [\underline{\theta}, \bar{\theta}]$ , we require  $z \in (.5, 1)$ . Therefore, for  $\delta < 0$ ,  $\left( \frac{1+z}{2} \right)^{\frac{1}{1-\delta}} < 1$ ,

$\frac{1-\delta}{2-\delta} > \frac{1}{2}$ , and  $(2z-1)^{\frac{2-\delta}{1-\delta}} < 2z - 1$ . Together these facts reveal that

$\Pi^U(0) > \Pi^U(1) \quad \forall \delta < 0$ . Next, letting  $\rho = \underline{\theta} / \bar{\theta}$ , simulations that allow  $\rho$  to vary

between .5 and .9 in increments of .1 reveal  $\Pi^U(1) > \Pi^U(0)$  for values of  $\delta$  that vary

between .1 and .9 in increments of .1.

18. The rankings are stated for the case where the buyers are uncertain whether the signal they observe is informative or uninformative. Of course, these rankings also hold when buyers do not face this uncertainty since only the extreme information structures are being compared.
19. Adams and Yellin (1977) draw similar conclusions in their analysis of advertising.
20. It is straightforward to verify that with all three valuations equally likely *ex ante*, increases in  $\gamma \in [0, \frac{1}{3}]$  represent better information in the sense of Blackwell (1951).
21. Again, it is straightforward to verify that increases in  $\gamma \in [\frac{1}{3}, 1]$  represent better information in the sense of Blackwell (1951).
22. It can also be shown that if  $c = \theta_2$  in this trinary setting, then  $\Pi^{T'}(\gamma)|_{\gamma=0} > 0$ . In words, slight improvements in the initial information of buyers will increase the supplier's

expected profit when the marginal cost of production is equal to the expected valuation of uninformed buyers. The improved information enables the supplier to sell to (only) those buyers who observe the  $s_2$  and  $s_3$  signals at a price that exceeds the marginal cost of production. Thus, slight improvements in buyers' information are not always detrimental to the supplier.

23. To prove this conclusion formally, let  $t(s|\theta)$  denote the conditional probability of the informative signal. Note that  $g^0(s)$ , the conditional density of the uninformative signal, is independent of  $\theta$ . Given our assumptions, Bayes formula reveals that  $h(\theta|s, \gamma)$ , the conditional distribution of  $\theta$  given signal  $s$  of accuracy  $\gamma$ , is given by:

$$\begin{aligned} h(\theta|s, \gamma) &= [\gamma t(s|\theta) + (1-\gamma)g^0(s)]f(\theta) / \left[ \gamma \int_{\underline{\theta}}^{\bar{\theta}} [t(s|\theta) + (1-\gamma)g^0(s)] dF(\theta) \right] \\ &= [\gamma t(s|\theta) + (1-\gamma)g^0(s)]f(\theta) / [\gamma g(s) + (1-\gamma)g^0(s)] \\ &= [\gamma t(s|\theta) + (1-\gamma)g(s)]f(\theta) / g(s) \\ &= \gamma h(\theta|s) + (1-\gamma)f(\theta), \end{aligned}$$

where  $f(\cdot)$ ,  $g(\cdot)$  and  $g^0(\cdot)$  denote the density functions associated, respectively, with the distribution functions  $F(\cdot)$ ,  $G(\cdot)$  and  $G^0(\cdot)$ .

## APPENDIX

In the setting of section 3 where the buyers are generally uncertain as to whether their private signals are informative or uninformative, the conditional distribution for a given signal  $s$  of accuracy  $\gamma$  is  $\gamma H(\theta|s) + [1-\gamma]F(\theta)$ .<sup>23</sup> Thus, the supplier's problem, [P-U] is:

$$\text{Maximize}_{Q(s), T(s), \gamma} \int_{\underline{s}}^{\bar{s}} [P(s) - cQ(s)] dG(s) \quad (\text{A1})$$

subject to  $\forall s, \hat{s} \in [\underline{s}, \bar{s}]$ :

$$\bar{u}(s; s, \gamma) \geq 0, \text{ and} \quad (\text{A2})$$

$$\bar{u}(s; s, \gamma) \geq \bar{u}(\hat{s}; s, \gamma), \quad (\text{A3})$$

where

$$\bar{u}(\hat{s}; s, \gamma) \equiv \int_{\underline{\theta}}^{\bar{\theta}} U(Q(\hat{s}), \theta) [\gamma dH(\theta|s) + (1-\gamma)dF(\theta)] - P(\hat{s}). \quad (\text{A4})$$

### Proof of Proposition 2.

Using standard techniques (e.g., Baron and Myerson (1982)), it is straightforward to verify that at an interior solution to [P-U], the individual rationality constraints (A2) bind only for  $\underline{s}$ . Furthermore, the local incentive compatibility constraints (A3) require a buyer's equilibrium expected utility to be

A2

$$\bar{u}(s; \gamma) \equiv \bar{u}(s; s, \gamma) = \gamma \int_{\underline{s}}^s \int_{\underline{\theta}}^{\bar{\theta}} U(Q(\bar{s}), \theta) dH_s(\theta | \bar{s}) d\bar{s}. \quad (\text{A5})$$

Now, let  $\Pi^u(\gamma; Q(s))$  denote the maximum expected profit for the supplier who chooses accuracy  $\gamma$  and implements the incentive compatible quantity schedule  $Q(s)$ . Using (A5) and integration by parts in (A1), it can be verified that

$$\begin{aligned} \Pi^u(\gamma; Q(s)) &= \gamma \int_{\underline{s}}^{\bar{s}} \int_{\underline{\theta}}^{\bar{\theta}} [U(Q(s), \theta) - c Q(s)] \left[ dH(\theta | s) + dH_s(\theta | s) \frac{1-G(s)}{g(s)} \right] dG(s) \\ &\quad + [1 - \gamma] \int_{\underline{s}}^{\bar{s}} \int_{\underline{\theta}}^{\bar{\theta}} [U(Q(s), \theta) - c Q(s)] dF(\theta) dG(s). \end{aligned} \quad (\text{A6})$$

Now let  $\gamma'' = \alpha\gamma + [1 - \alpha]\gamma'$ , where  $\alpha \in (0, 1)$ . Then because (A6) is linear in  $\gamma$ ,

$$\Pi^u(\gamma''; Q(s)) = \alpha \Pi^u(\gamma; Q(s)) + [1 - \alpha] \Pi^u(\gamma'; Q(s)). \quad (\text{A7})$$

Also let  $Q(s|\gamma)$  denote the quantity schedule that maximizes the right hand side of the expression in (A6). Then;

$$\begin{aligned} \Pi^u(\gamma'') &= \alpha \Pi^u(\gamma; Q(s|\gamma'')) + [1 - \alpha] \Pi^u(\gamma'; Q(s|\gamma'')) \\ &\leq \alpha \Pi^u(\gamma; Q(s|\gamma)) + [1 - \alpha] \Pi^u(\gamma'; Q(s|\gamma')) \\ &= \alpha \Pi^u(\gamma) + [1 - \alpha] \Pi^u(\gamma'). \end{aligned} \quad (\text{A8})$$

The first equality in (A8) follows from (A7). The inequality follows from the definition of  $Q(s|\gamma)$ . The last equality follows from the definition of  $\Pi^u(\gamma)$ . ■

**Proof of Proposition 3.**

From (A6), the envelope theorem provides:

$$\Pi^u(\gamma) = \int_{\underline{s}}^{\bar{s}} \int_{\underline{\theta}}^{\bar{\theta}} [U(Q(s), \theta) - cQ(s)] \left[ dH(\theta | s) - dF(\theta) + dH_s(\theta | s) \frac{1-G(s)}{g(s)} \right] dG(s).$$

Therefore, since  $Q(s) = Q_0$ , a constant,  $\forall s \in [\underline{s}, \bar{s}]$  in the solution to [P-U] when  $\gamma=0$  is optimal,

$$\Pi^u(\gamma)|_{\gamma=0} = \int_{\underline{s}}^{\bar{s}} \int_{\underline{\theta}}^{\bar{\theta}} [U(Q_0, \theta) - cQ_0] dH_s(\theta | s) \frac{1-G(s)}{g(s)} dG(s) \leq 0. \quad (\text{A9})$$

The right hand side of (A9) will be strictly negative when (C1) holds. ■

**Proof of Proposition 4.**

It is straightforward to verify that

$$\Pi^T(0) = n[\theta_2 - c] \quad \text{and} \quad \Pi^T(1/3) = \frac{2}{3} n \left[ \frac{1}{2}(\theta_2 + \theta_3) - c \right] \quad (\text{A10})$$

whenever it is optimal for the supplier to sell only to those buyers with valuations  $\theta \in \{\theta_2, \theta_3\}$

when  $\gamma=1/3$ . A comparison of the two expressions in (A10) reveals  $\Pi^T(1/3) \geq \Pi^T(0)$  as  $c \geq \theta_1$ .

Furthermore, with  $c > \theta_1$ ,  $\Pi^T(1) = \frac{n}{3}[\theta_3 - c]$ . It then follows immediately that

$\Pi^T(1/3) \geq \Pi^T(1)$  as  $\theta_2 \geq c$ . ■

**Analysis of Example 1.**

When the supplier provides no information, she charges price  $P = \hat{v}$  and earns profit  $\Pi(0) = n\hat{v}$ . When the monopolist provides complete information and charges price  $P$ , she attracts all buyers of type  $\theta \geq \theta(P)$ , where  $\theta(P)$  satisfies  $u(\theta(P), P) = 0$  or  $\theta(P) = \frac{(P - \hat{v})}{d} + \hat{\theta}$ .

With zero production costs, the supplier chooses  $P$  to maximize  $\Pi(1) = \frac{nP(\bar{\theta} - \theta(P))}{(\bar{\theta} - \theta)}$ .

Assuming an interior solution (with  $\theta(P) \in (\underline{\theta}, \bar{\theta})$ ), the profit maximizing  $P$  is  $P = \frac{\hat{v}}{2} + \frac{d}{4}$ ,

and profits are  $\Pi(1) = \frac{nP^2}{d}$ . Comparing  $\Pi(0)$  and  $\Pi(1)$ , it is immediate that there exists a

$\hat{d} > 0$  such that  $\Pi(1) \gtrsim \Pi(0)$  as  $d \gtrsim \hat{d}$ . ■

**Analysis of Example 3.**

This analysis closely parallels the analysis of Example 1, and so is omitted.

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