CAN HIGH PRICES ENSURE PRODUCT QUALITY WHEN BUYERS DO NOT KNOW THE SELLERS' COST?

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The 1981 Klein-Leffler model of product quality does not explain why high-quality firms would dissipate the rents they earn from quality-assuring price premia, and it relies on consumers knowing the cost functions of firms. In the present article, consumers do not know any firm's cost of producing quality goods, so firms with a low cost of producing high quality engage in conspicuous spending to demonstrate they earn a profitable mark-up over cost. Complete rent dissipation does occur if such firms have the same cost of producing low-quality items as other firms that are worse at producing high quality. (*JEL* D2, D18, D82, L15)

I. INTRODUCTION

When consumers are unaware of product quality before they buy, producers can nonetheless be punished for providing low quality by losing repeat business. Klein and Leffler (1981) demonstrate that under fairly general conditions a price with a positive profit margin is needed to induce producers to deliver the promised quality level. If the profit margin were zero, the profit would be greater from low quality than from high, even if the customers were disappointed and none of them returned. Consequently, if a firm's price equaled its cost, repeat business would be a matter of indifference. A higher price, however, increases long-run profit more for firms that provide the promised quality because such firms benefit from the repeat business of satisfied customers. At a sufficiently high price, the profit from repeat business exceeds the profit from cheating on quality. At that price, firms will provide the promised quality level.[1]

Two points are of interest in the Klein-Leffler model. First, absent firm-specific capital expenditures, positive profit exists in a competitive market. Second, because consumers know the price is an incentive for high quality only if it generates sufficiently high profit, they must know the firm's production costs if a given price premium is to ensure high quality.

We address both points in this article. First, although it is sometimes thought that non-price competition will dissipate profits in the Klein-Leffler model, the model does not by itself have that implication. Positive profit will indeed persist in equilibrium, even with free entry, unless some new feature is added. Second, while the Klein-Leffler model assumes producers have identical costs, though they can choose different quality levels, we will add the possibility firms differ in their marginal costs of high quality in ways buyers cannot observe. Thus, we combine moral hazard and adverse selection in a product quality model. We

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1. Rasmusen (1989; 1994, 131–34) employs a game-theoretic approach to the Klein-Leffler model and notes the similarity of a quality-assuring price and an efficiency wage. In his model, profit is dissipated very simply by the assumption of a fixed entry cost. Enough firms enter that each has sales so small that operating profit barely compensates for the one-time entry cost. That is different from the signaling intuition of Klein and Leffler and of the present paper because signaling requires that consumers be aware of the entry cost, and that there be incomplete information for the entry cost to convey.

hope to accomplish two things: to explain how positive profits can persist in the original Klein-Leffler model and to show that adding adverse selection can result in profit dissipation. Let us explain further before setting out the model.

First, profit dissipation by non-price competition lies outside the Klein-Leffler model. In that model, information is complete: buyers know only one type of firm exists, but do not know product quality when they purchase a good.[2] Thus moral hazard is possible: firms may deliver quality that is less than what they promised. A price, P^*, above average cost, P_C, is necessary to induce firms to deliver the high level of quality they promise to consumers. Entry cannot eliminate the resulting profit, since additional output will drive price below the quality-assuring level of P^*. This is a surprising result: an industry known to earn positive profit, without collusion or conventional barriers to entry, and yet without expanded output or entry.[3]

Klein and Leffler suggest that non-price competition will dissipate this profit. They realize that non-price competition cannot reduce the operating margin by driving average cost per period up closer to price, but they suggest that some kind of fixed cost might absorb the profit:

> Competition to dissipate the economic profits earned by existing firms must therefore occur in nonprice dimensions...The competition involves firm-specific capital expenditures. [Klein and Leffler (1981, 626)]

Such thinking comes naturally to economists; we hold the maxim that "Markets abhor a profit" as dearly as physics does "Nature abhors a vacuum." Non-price competition would occur if each firm could increase profit via such behavior, even though the net effect of many firms doing it would dissipate profit. Such is the case with a cartel, where each cartel member can do better if it cheats on the collusive agreement, using secret price cuts or non-price competition that tends to drive profit to zero.[4]

Klein and Leffler offer a different justification for such spending. They argue that, when consumers are unsure of production costs, sunk capital expenditures such as advertising signal the magnitude of a firms' price premium, thereby assuring buyers that the price is high enough to induce high quality. They suggest that this provides a setting for Nelson's (1974) idea that firms engage in advertising to signal to consumers their incentive for repeat business. They also mention, however, Schmalensee's (1978) model, which showed that, in the original Nelson scenario, low-quality fly-by-night firms could profitably enter, advertise, sell for one period, and exit.

Our second point is that Klein and Leffler's intuition that profit-dissipating expenditures can signal a low cost of producing high quality is indeed correct. Formal modeling not only can show what is necessary for signaling to work but, in this setting, Nelson's idea can be rescued from Schmalensee's critique. We will show that, under incomplete information (adverse selection in addition to moral hazard), capital spending can allow low-cost firms to signal their cost. Under moral hazard alone, capital spending by firms has no value: spending does not increase a firm's profit, either by offering something of value to consumers (as a form of non-price competition) or by attracting buyers by revealing a firm's type.

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2. If buyers know quality when they purchase, the problem is one of full information.

3. More precisely, P^* must exceed not "average cost," but avoidable costs each period after the firm is established. Thus, if "average cost" is defined to include start-up costs, amortized over the lifetime of the firm, P^* does not necessarily exceed average cost. If "average cost" is defined to include the total costs of production in a given period divided by the quantity of production, however, while marginal cost is just the incremental cost of one more unit of output in that period, the key to the Klein-Leffler model is for P^* to exceed average cost, not marginal cost.

4. In his analysis of price and non-price competition, Stigler (1968) considers the case of a cartel. Empirical evidence in support of positive profit when entry is restricted is found in the taxicab "medallion" problem, where the license (the medallion) to operate an independent cab in New York City sold for about $17,000 in 1959 (Friedman [1962]) and about $30,000 in 1969 (Becker [1971]). Recently these licenses sold for over $200,000. Also, Breen (1977) found an average value of over $700,000 in 1971 for operating certificates for household movers subject to Interstate Commerce Commission regulation. In either case, presumably the sale price for an operating certificate reflects the discounted value of expected profit using the certificate. In these cases of regulated industries, capacity is restricted by government. Each firm maximizes profit, and no firm wishes to attract new customers, given capacity. In the Klein-Leffler model, new firms do not enter and existing firms do not expand capacity because greater output will reduce price below the level that assures product quality, in which case consumers would cease to purchase the product.

However, with the addition of adverse selection, so firms differ in cost and consumers are not aware of a firm's type, low cost firms do have an incentive to engage in conspicuous capital spending to reveal their type.

The outline of the remainder of this article is as follows. In the next section, a model of incomplete information is outlined. Before this model is fully analyzed in section V, results are presented in section III for the case with full information (i.e., when consumers can observe quality before they purchase), and in section IV for the case with complete information (i.e., with moral hazard but no adverse selection). Section VI contains concluding remarks.

II. THE MODEL

Consider a model similar to Klein and Leffler's, but in which some firms (Discount firms) have higher costs of producing high quality than other firms (Premium firms). Consumers cannot directly observe a firm's type. A firm charging a high price might be a Premium firm willing to deliver high quality, or it might be a fly-by-night Discount firm that intends to deliver low quality. Premium firms will have an incentive to distinguish themselves from Discount firms by investing in a signal. Either type of firm may invest in conspicuous spending, S, on items that involve sunk cost, but only the Premium firms will wish to do so.

The Model

The model is a repeated game between firms and customers. Note that the first two stages, (0) and (1), are not part of the repeated game, except that a new entrant at some point in the future would have to choose a level of conspicuous spending when it entered.

(0) Nature chooses some firms to be Premium firms, with marginal cost of high quality (H) and low quality (L) equal to c_{PH} and c_{PL}, respectively, and other firms to be Discount firms, with marginal costs of c_{DH} and c_{DL}. Each firm has the capacity to produce one unit of output per period, and there are enough firms that the entire population of consumers could be served by either type of firm.

(1) Each firm may choose a level, S, of conspicuous spending, if it has never chosen $S > 0$ before.

(2) Each firm chooses a price, P, for the unit it sells.

(3) Each firm chooses a quality, q, of either L or H, unobserved by consumers.

(4) Each consumer decides whether and where to buy.

(5) After one period, each consumer learns the quality of all units purchased.[5]

(6) The game returns to (1) and repeats forever.

Payoffs

All players use the discount rate r, and cash flows are at the ends of periods. A firm commits to production quality at the start of each period, with the cost incurred at the end of the period, but it need not incur the cost if no consumers wish to buy from it. Consumers pay the price and receive the consumption value at the end of the period. Consumers lie on the continuum from zero to infinity, indexed by their reservation price V for the one unit of a high-quality product of value $q = H$ they would purchase, and all consumers place zero value[6] on $q = L$. If the price is P, market demand for high-quality goods is $X(P)$, with $X' < 0$ and $X(c_{PH}) > 2$; i.e., market demand slopes down and is strong enough to support at least two Premium firms selling high quality.

Let us assume that:

(a) $c_{PL} < c_{PH}$ (Premium firms find low quality cheaper),

(b) $c_{DL} < c_{DH}$ (Discount firms find low quality cheaper),

(c) $c_{PH} < c_{DH}$ (Premium firms produce high quality more cheaply than Discount firms),

(d) $c_{PL} \leq c_{DL}$ (Discount firms do not produce low quality more cheaply than Premium firms), and

(e) $c_{DL} - c_{PL} \leq c_{DH} - c_{PH}$ (Premium firms do not have a larger cost advantage with low quality).

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5. If it takes longer than one period for consumers to learn quality, profit from low quality is higher, so the quality-assuring price would also be higher.

6. Assuming consumers place positive value on $q = L$ changes nothing as long as this value is less than the lowest cost of providing this quality, c_{PL}. Thus, with full information (i.e., sellers can observe quality before they purchase), no market would exist for low quality.

Discussion of Assumptions

We assume each firm can only produce up to one unit simply for convenience. This fixed capacity assumption allows a simple analysis of the difference between the complete and incomplete information cases. Assumptions (a) and (b) simply require that high quality is more costly than low quality for either type of firm. Assumption (c) requires that Premium firms have a lower cost of high quality than Discount firms. Assumption (d) allows Premium firms to have a lower cost of low quality than Discount firms, but does not rule out the case in which the cost of low quality is independent of firm type,[7] e.g., $c_{PL} = c_{DL} = 0$. Assumption (e) requires the cost advantage of Premium (versus Discount) firms be at least as large for high quality as for low quality. This assumption appears to be quite reasonable, and it guarantees that the quality-assuring price is lower for a Premium firm than for a Discount firm.

Klein and Leffler demonstrated the generality of the existence of a quality-assuring price. We do not disagree with this result, but we question the Klein-Leffler argument that profit will be dissipated in a world of complete information (i.e., a world with no adverse selection). Before developing the model of incomplete information, we consider two benchmark cases.

III. THE FULL INFORMATION CASE: QUALITY OBSERVABLE BEFORE PURCHASE

As a first benchmark, suppose consumers can observe quality before they purchase. Clearly each firm active in the market will produce one unit of high quality since consumers will not buy low quality. The price must be $P = c_{PH}$, since any higher price would create profit that would induce entry. Output will be $X(c_{PH})$, produced by $X(c_{PH})$ Premium firms.[8]

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7. It is also plausible that Discount firms have a lower cost of low quality than Premium firms do. In that case, however, signaling by conspicuous spending of S would fail to work. The price needed to deter Premium firms from producing low quality would be low enough that, if they had to expend the full amount of their future profit as a signal, S, at the time of entry, a Discount firm could enter, pay that same S, and make enough profit by its cheaper low-quality sales for one period to make entry profitable.

8. In all of the cases considered herein, there may be one firm that produces output less than one unit to ensure the market clears.

IV. THE COMPLETE INFORMATION CASE: JUST MORAL HAZARD

As a second benchmark, suppose all possible firms are Premium firms but consumers cannot observe quality before they purchase. This is the situation Klein and Leffler described.

If Discount firms do not exist, the problem is to induce Premium firms to set $q = H$. A premium firm that sets $q = H$ has present value of profit, π, equal to

$$(1) \qquad \pi_{premium}^{q=H} = (P - c_{PH})/r.$$

Note that π is defined as profit gross of any capital expenditures (considered in the next section). A firm that cheats and sets $q = L$ would be discovered after one period. Suppose such a firm would subsequently have zero sales. Profit from cheating is then

$$(2) \qquad \pi_{premium}^{q=L} = (P - c_{PL})/(1 + r).$$

Assuming consumers exist who will pay such a price, let P^* equal the quality-assuring price, that is, the price at which Premium firms are just willing to set $q = H$. Since $P^* > c_{PH}$, the market clears at the lower output of $X(P^*)$, and with fewer firms than under perfect information. The value of P^* is found by equating eqs. (1) and (2):

$$(3) \qquad P^* = (1 + r)c_{PH} - rc_{PL}.$$

If $P = P^*$, it follows that $\pi_{premium}^{q=H} = c_{PH} - c_{PL} > 0$. If there are no discount firms, Premium firms will earn positive profit.

More formally, what we have just described is the following Klein-Leffler Equilibrium.

Firms. A particular group of $X(P^*)$ of the potential Premium firms enters, chooses $S = 0$, produces high quality, and charges price P_* in the first period. A firm continues to do this in subsequent periods unless it has ever deviated by producing low quality or charging a price other than P^*, in which case it switches to always producing low quality and charging some price P. Unless some firm has thus deviated, no new entry occurs. If some firm does deviate, a new firm enters to replace it, adopting the strategy just described.

Consumers. Consumers buy randomly from the $X(P^*)$ firms that enter in equilibrium, except that, if any firm ever deviates, consumers never buy from that firm again, switching to the particular new entrant that replaces that firm.

Profit persists in this equilibrium. The lucky $X(P^*)$ firms that operate in equilibrium all earn positive profits, but no entrant would attract any customers, either matching the price (P^*) or charging a lower price. These firms earn a rent to the consumer belief that they will produce quality. How this belief [9] originates is beyond the scope of the model, but it is self-confirming; a firm expected to produce high quality will do so and will continue to do so.[10]

One way to extend the Klein-Leffler model is by adding assumptions on consumer beliefs. If, for example, consumers believe for non-economic psychological reasons that firms with high advertising expenditures will produce high quality, that belief will be self-fulfilling and could dissipate profits. Or suppose that consumers believe that firms that produced high quality in the past will produce high quality in the future as long as the price premium remains high enough. Then, as one referee suggested to us, there can be a race to enter the industry and capture those incumbent positions, a race which will dissipate profits in much the same way as a patent

race. We will not explore those assumptions on beliefs further here, but will instead look at how beliefs will arise endogenously from differences in production costs and signaling behavior.

V. THE INCOMPLETE INFORMATION CASE: MORAL HAZARD AND ADVERSE SELECTION

Now suppose both types of firms exist, Discount and Premium, so consumers cannot be sure which firms they face. The reputation equilibrium just described breaks down. As demonstrated below, Discount firms will not set $q = H$ if $P = P^*$. To assure that all firms set $q = H$, either (a) the price must be above P^* to induce Discount firms to set $q = H$, or (b) Premium firms must have some method of differentiating themselves from Discount firms to reveal their type.

Condition (a) could support an equilibrium that we will call the Inefficient Klein-Leffler Equilibrium. Suppose the price is

$$(4) \qquad P^{**} = (1 + r)c_{DH} - rc_{DL},$$

defined as the price high enough to support a reputation equilibrium with just Discount firms.[11] *A fortiori*, P^{**} is high enough to induce Premium firms to provide high quality.[12] However, market output will be smaller because of the higher price, so only $X(P^{**})$ firms will enter. The identity of the $X(P^{**})$ firms that consumers expect to produce high quality is arbitrary and can include any mix of Premium and Discount firms. We could even have an equilibrium consisting entirely of Discount firms, a curious result. Premium firms would not enter and undercut the price for the same reason as in the Pessimistic Equilibrium described in footnote ten: the entrants would be expected to produce low quality, and would attract no customers.[13]

9. In the next section, we demonstrate the possibility of a completely separating equilibrium in which Premium firms invest in conspicuous capital spending and discount firms do not. Tadelis (1999), Mailath and Samuelson (1999), and Hörner (1999) consider adverse selection models in which reputation is endogenous. In the first two papers, no completely separating equilibrium is possible, because consumers who received low quality would only marginally update their beliefs. Thus the incentive to maintain high quality disappears. Hörner demonstrates that, if consumers choose according to the beliefs they have about many firms, incentives to maintain high quality remain and a completely separating equilibrium can exist.

10. There are many other equilibria in this model, as is common in infinitely repeated games. The most notable is the following simple *Pessimistic Equilibrium* in which reputation does not work. *Firms*. No firms enter. If a firm did enter, it would produce low quality and charge some price P. *Consumers.* Consumers would not buy from any firm that entered. In the Pessimistic Equilibrium, consumer beliefs about product quality are pessimistic, and these beliefs are self-confirming. A firm that entered and claimed it was going to charge P^* and produce high quality would, rationally, not be believed. This is true despite the fact that, if consumers did believe the firm, and the firm expected them to believe it, the firm would then have incentive to produce high quality.

11. P^{**} is determined by equating the present value of profit from $q = L$ and from $q = H$ for a Discount firm.

12. Using P^{**} and P^* [eq. (3)], $P^{**} > P^*$ if $(1 + r)(c_{DH} - c_{PH}) > r(c_{DL} - c_{PL})$, which is true by Assumption (e) in Section II.

13. In fact, this equilibrium persists even in a model in which there is complete information and consumers know which firms are Premium. Knowing that a firm has low cost of producing high quality is not sufficient to induce consumers to buy from that firm, since consumers know that the firm could make even greater short-term profit with low quality. The successful firm is the one that consumers expect to produce high quality, not the firm

Condition (b) is required for Premium firms to differentiate themselves. If they can do this, and consumers expect Premium firms to produce high quality, then an efficient Reputation equilibrium can result. This signaling equilibrium, a concept first developed by Spence (1974), is as follows.

Firms. A particular $X(P^*)$ of the Premium firms enter, expend $S^* = (1 + r)c_{PH} - rc_{PL} - c_{DL}$ in initial conspicuous spending, and, in the first period, produce high quality and charge price $P^* = (1 + r)c_{PH} - rc_{PL}$. A firm continues to do this in subsequent periods, unless it has ever deviated by producing low quality or charging a price other than P^*, in which case it switches to always producing low quality and charging some price P. Discount firms never enter, but, if one did, it would choose $S = 0$ and produce low quality. Unless some firm has deviated, no new entry occurs. If some firm does deviate, a new firm enters to replace it, adopting the strategy just described.

Consumers. Consumers buy randomly from the $X(P^*)$ firms that enter in equilibrium, except, if any firm deviates in its choice of S, P, or q, consumers never buy from that firm, but buy from the entrant that replaces that firm.

Let us see why this is an equilibrium. First, Discount firms have no incentive to enter. Assume for simplicity an indifferent Discount firm will not enter and an indifferent Premium firm will enter. Discount firms that

simply plan to hit and run—that is to produce low quality until they are caught at the end of the first period—will not undertake such expenditure if $\pi_{discount}^{q=L} \leq S/(1 + r)$. Thus, using P^* and the fact that $\pi_{discount}^{q=L} = (P - c_{DL})/(1 + r)$, the minimum value of S, denoted by S^*, that will prevent entry by Discount firms is:

$$(5) \qquad S^* = (1 + r)c_{PH} - rc_{PL} - c_{DL}.$$

Given the equilibrium values of S^* and P^*, a Discount firm would earn zero profit and would not enter. If it produces high quality, a Premium firm entrant earns profit, net of S, of

$$(6) \qquad \begin{aligned} &\pi_{premium}^{q=H} - S^*/(1 + r) \\ &= (P^* - c_{PH} - S^*)/(1 + r) \\ &= (c_{DL} - c_{PL})/(1 + r). \end{aligned}$$

Note that Premium firms may earn positive profit (net of S) in equilibrium. If $c_{DL} > c_{PL}$, firms earn positive profit if $S = S^*$. In this case, there are multiple signaling equilibria: S may take on values in excess of S^*. If we use the *Intuitive Criterion* from Cho and Kreps (1987) as an equilibrium refinement, the only equilibrium to survive this refinement has $S = S^*$. This implies that some, but not all, profit is dissipated by the use of conspicuous capital spending by firms to signal their type.

If the cost of low quality is independent of firm type, however, so $c_{DL} = c_{PL}$ and the Premium firm's advantage is only in its lower cost of moving from low to high quality, then the equilibrium value of S is unique and completely dissipates profit. The smallest value of S that deters Discount firms from entering equals the largest value that induces Premium firms to enter. This is not accidental, and it has an intuitive explanation. Choose S^* to make a Discount firm indifferent between entering, paying S^*, and getting windfall profit from low quality for one period. Since the payoff from staying out is zero, S^* will exactly equal the value of the windfall profit from low quality. If Premium firms have the same marginal cost for low quality, S^* also equals the windfall profit to a Premium firm from entering, paying S^*, and taking the profit from one period of sales. However, the equilibrium price, P^*, is set so

that has low costs of producing high quality. Expectations are exogenous to the model, which requires only that they be consistent and self-confirming in any Nash equilibrium. Thus, if Firms 1 and 2 are Discount, and Firms 3 and 4 are Premium, the most intuitive equilibrium has consumers expecting Firms 1 and 2 to produce low quality, if they ever produce, and Firms 3 and 4 to produce high quality. However, an equally valid equilibrium has consumers expecting only Firm 4 to produce high quality, and a third valid equilibrium has consumers expecting only Firms 1 and 2 to produce high quality. This point about Nash equilibrium, though basic, is not generally understood. Many economists use implicit equilibrium refinements such as "Consumers expect identical firms to behave identically," or "Consumers expect a firm with a lower cost of producing high quality to be no less likely to produce high quality than any other firm that they expect to produce high quality." These may or may not be reasonable restrictions on consumer beliefs, but they go beyond well-accepted equilibrium concepts. Note, too, such expectations rely on consumers knowing firms' costs as well as firm's identities, a dubious assumption.

that the windfall profit to a Premium firm for one period equals the reputation profit from sales for many periods. Thus, if S^* equals the value of windfall profit, it also equals the value of the Premium firm's reputation profit, and there is complete profit dissipation.

Another corollary is that complete profit dissipation is the unique signaling equilibrium. We do not need to use a refinement argument such as the *Intuitive Criterion*, because the incentive-compatibility and self-selection constraints have already pinned S^* down to one value. Thus, this setting models the ideas of Nelson (1974) and Klein and Leffler (1981) that competitive firms in markets with asymmetric information completely dissipate their profit by conspicuous spending.[14]

VI. SUMMARY

In the preceding section, we showed that there exists a separating equilibrium in which Premium firms will enter and produce high quality because the price is high enough, but Discount firms will not enter and produce low quality because a one-time requirement of conspicuous spending on sunk, firm-specific items deters them. The quality-assuring price is found by equating the present value of profit for Premium firms from producing either low or high quality. The minimum level of conspicuous spending, S^*, that will induce a Discount firm *not* to match a Premium firm in this spending is found by equating the present value of profit for a Discount firm that intends to produce low quality with the present value of S^*. Thus, only if both types of firm have the same cost (and thus profit) for low quality does conspicuous spending tend to completely dissipate the profit earned by Premium firms when they provide the promised (high) quality.

Klein and Leffler (1981) demonstrated the important point that a price (P^*) in excess of the competitive, zero-profit price can induce firms to deliver the level of quality they promise consumers. They suggested that the resulting positive profit would be dissipated as firms competed via spending on sunk, capital items, but that argument is actually separate from their model. We have extended their model to show that profit dissipation can result when adverse selection is added to its moral hazard. When firms differ in their marginal costs of quality, profit is dissipated as they signal their cost to consumers. Thus, with the addition of adverse selection, the Klein-Leffler model indeed provides a justification for sunk capital spending and the dissipation of at least some of the positive profit from the quality-assuring price.

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14. As before, and as is usual in signaling models, other equilibria exist, including pooling equilibria in which Premium and Discount firms behave the same as each other. These include the Pessimistic Equilibrium (see footnote ten), in which no firm ever produces high quality, and equilibria in which the consumers' strategy is to ignore the conspicuous spending, S, in which case S fails to be a signal of Premium status and merely becomes a sign of odd, non-profit-maximizing behavior by a firm. The equilibrium we have focused on, however, shows how signaling by conspicuous spending can result in an equilibrium in which quality is high and is produced by the firms that can produce it at least cost.