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HIGH AND DECLINING PRICES SIGNAL PRODUCT QUALITY*

by

Kyle Bagwell
Northwestern University

and

Michael Riordan
Boston University

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I. Introduction

The marketing literature has produced various evidence on price-quality relationships. Numerous experimental studies show that consumers infer a higher quality from a higher price (Monroe and Petroshius, 1981). This inference is consistent with the findings of several case studies. Such diverse products as fountain pen ink and car wax (Gabor and Granger, 1965) and vodka, skis, and television sets (Buzzell, Nourse, Matthews, and Levitt, 1972) have been successfully introduced at high prices to connote high quality. A variety of empirical data is also available. Analyses of *Consumer Reports* data yield positive price-quality rank-order correlations for many products, and particularly for consumer durables (Gerstner, 1985; Tellis and Wernerfelt, 1987). Moreover, a recent longitudinal analysis of *Consumer Reports* data for consumer durables indicates declining trends in (a) real prices, (b) price differentials between competing brands, and (c) the rank-order correlation between price and quality (Curry and Riecz, 1988).

These "stylized facts" are consistent with two important features of markets. First, firms signal high-quality, new products with prices that are above full-information, profit-maximizing prices. Second, over time, as information about the product diffuses, this price distortion lessens or vanishes entirely.

We demonstrate the logic and robustness of this argument in several equilibrium models of behavior by consumers and firms. The models have different assumptions about consumer information. However, all of the models possess intuitively plausible equilibria in which higher quality products are introduced at higher prices that decline over time.

Our essential argument is outlined as follows. Consider a market in which a firm introduces a new product possessing some innovative feature of uncertain quality. Some consumers can ascertain the quality, while others cannot, but all understand that a higher quality product is more costly to produce. The most efficient way for the firm to signal a high quality is to charge a price too high to be profitable if the product were in fact of lower quality. This high-price strategy is potentially successful for two reasons. First, the consequent loss of sales volume is less damaging to a higher-cost product. Second, a lower quality product would lose more sales from informed consumers by charging a high price. Understanding this, uninformed consumers rationally infer a higher quality from the higher price.

However, as consumers gain experience with the product and information about its quality diffuses, the portion of uninformed consumers in the market declines. Consequently, it becomes even more costly for the firm to falsely signal a higher quality to the uninformed. The firm can efficiently signal a higher quality with a smaller price distortion. Thus, a high and declining price path identifies a high-quality product.

A positive correlation between price and quality follows because higher quality products are more costly to produce, so that signaling distorts upward the price of newly introduced high-quality products. As information diffuses, signaling distortions diminish and the prices of newer products converge downward to those of older products of corresponding quality. An associated weakening of the correlation between price and quality can then be explained by measurement errors in the data. Thus, the theory appears consistent with the stylized facts.

Our conclusion that high-quality products have a downward sloping price profile differs from that of previous theoretical contributions to the economics literature. For example, Shapiro (1983) shows that a monopolist charges a high and declining price if consumers optimistically overestimate product quality, and a low introductory price if consumers pessimistically underestimate product quality. However, these conclusions depend on an assumption that consumers have adaptive expectations about product quality with no possibility of price signaling.

Milgrom and Roberts (1986) focus on the introductory phase of a nondurable product's life and argue that prices will rise over time as repeat buyers learn about their own preferences. Their analysis is similar to ours in that they also recognize the potential for high prices to signal high (expected) quality due to cost effects.[1] However, we abstract from short-run experimental-buying effects and focus on the long-run trends associated with the signaling of product quality.

In a dynamic model of consumer learning, Judd and Riordan (1987) show that high-quality prices tend to rise after the introductory period. This is because signaling does not occur until after consumers have gained experience with the product, which follows from an assumption of cost parity for different quality products. Moreover, they conjecture that, for multiperiod extensions, price would eventually decline as consumers gain further experience.

Conlisk, Gerstner, and Sobel (1984) and Stokey (1981) have argued for a declining price path for a durable good of known quality. This path represents the firm's attempt to "skim" the market of buyers. Lazear (1986) also predicts a declining price path, under the assumption that the firm is unsure of the size of its demand and consumers know quality. While these theories are complementary to ours, they do not provide direct insight into the relationships between price and quality described above.

Finally, our distinction between informed and uninformed consumers is reminiscent of a related literature on product selection in which some consumers observe quality while others do not. In this context, Chan and Leland (1982), Cooper and Ross (1984, 1985), Farrell (1980), and Wolinsky (1983) argue that the presence of informed consumers enables high prices to signal high-quality choices. While our work is related, we take quality to be exogenous and also analyze the role of production costs in establishing high prices as signals. Indeed, we find that high prices can signal high quality even if all consumers are uninformed. Informed consumers are not necessary for the signaling of a given quality, but they do determine the size of the signaling distortion.

The paper is organized in four sections. Our basic results are developed in a static context in section 2. A variety of multiperiod extensions are analyzed in section 3. Sections 2 and 3 may be of methodological interest. The "intuitive criterion" of Cho and Kreps (1987) is actively employed in each section, and the criterion is applied in section 3 to dynamic signaling games with the possibility of multiple dimensions of private information. Section 4 then concludes.

II. Basic Model

Consider a one-period consumer market in which a firm has introduced a new product with a novel feature of uncertain quality. For simplicity, assume that quality is either high or low; $q \in \{H, L\}$.

The production technology is common knowledge. The average cost of a high-quality product is constant and equal to $c > 0$, while low-quality production cost is normalized to zero.

There are a large number of potential consumers of the new product, approximated by a continuum of mass M (Judd, 1985), each with a potential demand for one unit. Consumers have a common reservation price, $P^L > 0$, for a low-quality product. On the other hand, consumers have heterogeneous reservation prices for a high-quality product, uniformly distributed between P^L and $(1 + P^L)$. The uniform distribution is convenient because it generates a linear demand for a high-quality product.

A fraction of consumers are informed about product quality, while remaining consumers believe that quality is high with probability r. This prior belief is common knowledge. Let X denote the ratio of informed to uninformed consumers.

At the beginning of the period, the firm and informed consumers observe the true quality of the product. The firm then sets a price P, and uninformed consumers update their beliefs about product quality on the basis of this signal. Let $b = b(P)$ be the uninformed consumers' posterior belief that quality is high when the price is P. Consumers are assumed to mak purchase decisions which maximize expected utility (i.e., the expected reservation price minus P), given beliefs. This process generates an informed demand curve in which a fraction, $1 + P^L - P$, of informed consumers buy when $P \in [P^L, 1 + P^L]$ and $q = H$, and an uninformed demand curve, characterized by a fraction, $1 + (P^L - P)/b$, of uninformed consumers buying when $P \in [P^L, b + P^L]$ and quality is believed to be high with probability b. With these demand curves and our assumptions on cost technologies, the profit of a firm with quality q and price P facing uninformed consumers with belief b, denoted $\pi(q, b, P)$, is straightforward to define explicitly. We assume that the objective of the firm is to maximize profits.

These actions and objectives define an extensive form game of incomplete information with multiple sequential equilibria (Kreps and Wilson, 1982). A sequential equilibrium requires that the firm and consumers act in a sequentially rational fashion, and that uninformed consumers update beliefs using Bayes' rule on the equilibrium path. As usual, we distinguish between separating equilibria (in which high- and low- quality firms choose different prices), and pooling equilibria. However, we do restrict attention to pure strategy equilibria.

We select plausible equilibria by imposing the Intuitive Criterion (Cho and Kreps, 1987). Consider an equilibrium in which the firm earns profits of $\pi(H)$ and $\pi(L)$ for high- and low-quality products, respectively. Then the equilibrium satisfies the Intuitive Criterion if there does *not* exist a price P' such that: (a) $\pi(H, 1, P') > \pi(H)$, and (b) $\pi(L, 1, P') < \pi(L)$. Intuitively, if such a price P' did exist, then uninformed consumers should believe that only a high-quality firm would change P', which by (a) causes the equilibrium to fail.[2]

Letting $P(q)$ denote the equilibrium price charged by a type q firm, we now state our first two lemmas, which are almost obvious.

Lemma 1: In any equilibrium, $P(q) \geq P^L$ for $q \in \{H, L\}$.

Proof: $\pi(q, b(P), P)$ is strictly increasing in P, for all $q \in \{H, L\}$ and all functions $b(\cdot)$, when $P < P^L$. Thus, were P(q) less than P^L, the type q firm could increase its price slightly and increase profits.

Lemma 2: In any separating equilibrium, $P(H) > P^L$ and $P(L) = P^L$.

Proof: A low-quality firm earns zero profits in a sequential equilibrium if $P(L) > P^L$ and positive profits if $P(L) = P^L$. Therefore, the result follows from Lemma 1.

In a separating equilibrium, the low-quality firm charges P^L and the high-quality firm charges some higher price. Moreover, it must be that $\pi(L, 0, P^L) > \pi(L, 1, P(H))$; otherwise, the low-quality firm would mimic its high-quality counterpart. We are thus led to consider the set

$$\{P \mid \pi(L, 0, P^L) = \pi(L, 1, P)\} \quad .$$

This equation has an upper and lower root,

$$\overline{P}(X) = \tfrac{1}{2}\cdot(1 + P^L) + [\tfrac{1}{4}\cdot(1 + P^L)^2 - P^L\cdot(1 + X)]^{\frac{1}{2}}$$

and

$$\underline{P}(X) = \tfrac{1}{2}\cdot(1 + P^L) - [\tfrac{1}{4}\cdot(1 + P^L)^2 - P^L\cdot(1 + X)]^{\frac{1}{2}} \quad ,$$

expressed as functions of X.

We assume that $1 > P^L$ and represent $\overline{P}(X)$ and $\underline{P}(X)$ by the upper and lower boundaries of the parabola in Figure 1.[3] These equations have no solution for values of $X > \overline{X}$. For $X \leq \overline{X}$, any price inside the parabola, $P \in [\underline{P}(X), \overline{P}(X)]$, satisfies $\pi(L, 0, P^L) < \pi(L, 1, P)$; the low-quality firm would mimic any such price. This leads immediately to the following lemma.

[**Figure 1: Separating Prices**]

Lemma 3: If $X < \bar{X}$, then in any separating equilibrium, either $P(H) \geq \bar{P}(X)$ or $P(H) \leq \underline{P}(X)$.

It is important to understand the parabola in Figure 1. By mimicking a high-quality price $P(H) > P^L$, the low-quality firm both gains and loses. It gains because it tricks uninformed consumers into buying at a high price, but it loses because informed consumers refuse to buy at that price. The gains outweigh the losses for prices inside the parabola; for these prices the low-quality firm finds mimicry profitable.

As the ratio of informed to uninformed (X) rises, it becomes increasingly costly for the low-quality firm to mimic its high-quality counterpart. For this reason, the parabola narrows about $\frac{1}{2}\cdot(1 + P^L)$, the maximizer of $\pi(L, 1, P)$. For X above $\bar{X}$, the low-quality firm refuses to even mimic $\frac{1}{2}\cdot(1 + P^L)$.

The high-quality firm's full information monopoly price is $P^H \equiv \frac{1}{2}\cdot(1 + P^L + c)$, the maximizer of $\pi(H, 1, P)$. If $P^H > \bar{P}(X)$, then the low-quality firm would be unwilling to mimic the high-quality firm's favorite price. In this case, the natural separating equilibrium has $P(H) = P^H$ and $P(L) = P^L$. The more interesting case emerges when $P^H < 1$, or equivalently $P^L + c < 1$, and separation is costly for the high-quality firm. We thus assume henceforth that $P^H < 1$.

The following theorem established necessary conditions for a separating equilibrium satisfying the Intuitive Criterion.

Theorem 1: $P(H) = \max\{\overline{P}(X), P^H\}$ and $P(L) = P^L$ are the only separating equilibrium prices satisfying the Intuitive Criterion.

Proof: Lemma 2 implies $P(L) = P^L$, so suppose $P(H) \neq \max\{\overline{P}(X), P^H\}$ and consider figure 2. X^H satisfies $\overline{P}(X^H) = P^H$. For $X > X^H$, the Intuitive Criterion fails by setting $P' = P^H$. For $X \leq X^H$, Lemma 3 rules out $P(H) \in (\underline{P}(X), \overline{P}(X))$. Moreover, the Intuitive Criterion fails for $P' \in (\overline{P}(X), P(H))$ if $P(H) > \overline{P}(X)$, and for $P' \in (P(H), \underline{P}(X))$ if $P(H) < \underline{P}(X)$. This leaves the possibility that $P(H) = \underline{P}(X)$, but it is straightforward to show that $c > 0$ implies $\pi(H, 1, \overline{P}(X)) > \pi(H, 1, \underline{P}(X))$, from which it follows that $P' = \overline{P}(X) + \epsilon$ violates the Intuitive Criterion for sufficiently small ϵ.

As an immediate corollary of Theorem 1, we find that a supra-monopoly price is charged if the ratio of informed to uninformed consumers is small.

Corollary 1: If X is sufficiently small, $P(H) = \overline{P}(X) > P^H$ and $P(L) = P^L$ are the only separating equilibrium prices satisfying the Intuitive Criterion.

[**Figure 2: Equilibrium Separation Prices**]

Figure 2 illustrates the prices charged in a separating equilibrium satisfying the Intuitive Criterion (the parabola is the same as in Fgure 1). It may seem surprising that a high-quality firm separates with $\overline{P}(X)$ instead of a lower price $\underline{P}(X)$, when X is small. However, a simple intuition underlies this result. Because high-quality production is costly ($c > 0$), the full-information monopoly price P^H is closer to $\overline{P}(X)$ than to $\underline{P}(X)$. Put differently, the high price is the efficient means of separation because the forgone profit from a lost customer is less for the high-quality firm (Milgrom and Roberts, 1986). Thus the high-quality firm prefers to separate with the high price.

So far we have characterized necessary conditions for a separating equilibrium. We now turn to existence.

Separation can occur only if the high-quality firm chooses not to monopolize informed consumers at the expense of losing uninformed consumers. Such a deviation is potentially attractive only if $X < X^H$ and so $P(H) = \overline{P}(X) > P^H$. Prices which might then increase high-quality profit must be inside the parabola and thus must also be prices which could increase low-quality profit. The Intuitive Criterion does not restrict beliefs for such prices, and at worst a deviation in this range could induce the belief of certain low quality. The high-quality firm will thus charge the price $P(H) = \overline{P}(X)$ when $X < X^H$ in a separating equilibrium if and only if $\pi(H, 1, \overline{P}(X)) > \pi(H, 0, P^H)$. Setting $\pi(H, 1, P) = \pi(H, 0, P^H)$ when $X < X^H$ defines a "no-defect" root,

$$P^{\dagger}(X) = P^H + \frac{1}{2}(1 + P^L - c)(1 + X)^{-\frac{1}{2}} \quad ,$$

which begins at $(1 + P^L)$ for $X = 0$ and asymptotically declines to P^H, as shown in Figure 3. The high-quality firm has no incentive to defect if and only if $P(H) \leq P^{\dagger}(X)$. Since "intuitive" beliefs can entail $b(P') = 0$ for all $P' \in (\underline{P}(X), \overline{P}(X))$, it is easily established that the low-quality firm is also unwilling to defect from the proposed separating equilibrium. We thus have the following existence theorem.

[Figure 3: "No-Defect" Prices]

<u>Theorem 2</u>: A separating equilibrium satisfying the Intuitive Criterion exists if and only if $X \geq \overline{X}$ or if $X < \overline{X}$ and

$$\Delta(X) \equiv P^{\dagger}(X) - \overline{P}(X) \geq 0 \quad .$$

Two observations are in order, which we state below as corollaries. First, a separating equilibrium always exists if the ratio of informed to uninformed consumers is small because $\Delta(0) \equiv P^L > 0$. Second, it can be shown numerically that a separating equilibrium exists for any value of X unless P^L and c are small; Figure 4 illustrates parameter values for which separating equilibria fail to exist for some intermediate X.

<u>Corollary 2</u>: A separating equilibrium satisfying the Intuitive Criterion exists if X is sufficiently small.

<u>Corollary 3</u>: A separating equilibrium satisfying the Intuitive Criterion exists if P^L or c are sufficiently large.

[Figure 4: Parameter Values Supporting Separation]

We next turn to pooling equilibria. The following theorem establishes that, if the percentage of informed consumers is sufficiently small, then the only equilibrium satisfying the Intuitive Criterion is a separating equilibrium. In other words, when the market is very uninformed, there always exists a high price at which the high-quality firm can profitably distinguish itself.

Theorem 3: If X is sufficiently small, then no pooling equilibrium satisfies the Intuitive Criterion.

Proof: We prove the result for $X = 0$; the result follows for X close to 0 by continuity. Let $Q(P, b) \equiv [1 - (P - P^L)/b]M$ denote the quantity of sales at a price P when consumers believe high quality with probability b. In a pooling equilibrium, $P(H) = P(L) = P*$, and $b(P*) = r$. The high- and low-quality firms earn profits $\pi(H) \equiv (P* - c)\cdot Q(P*, r)$ and $\pi(L) \equiv P*\cdot Q(P*, r)$, respectively. Clearly $1 + r > P* \geq \max\{P^L, c\}$; otherwise one or the other type of firm would defect. Thus $\pi(L) > \pi(H) \geq 0$. Since $P*\cdot Q(P*, 1) > \pi(L)$, there exists $P'' > P*$ such that $\pi(L, 1, P'') \equiv P''\cdot Q(P'', 1) = \pi(L)$ and $\pi(H, 1, P'') = \pi(H) + c\cdot[Q(P*, r) - Q(P'', 1)] > \pi(H)$. Moreover, $P\cdot Q(P, 1)$ is decreasing in P at P''. Therefore, $P' \equiv P'' + \epsilon$ violates the Intuitive Criterion for $\epsilon > 0$ sufficiently small.

Pooling is therefore impossible if X is sufficiently small. Similarly, if the market is sufficiently well informed that X is large, then pooling is impossible to maintain, as each firm type prefers to deviate and monopolize informed consumers. For example, if $X \geq \bar{X}$ (see Figure 1), then pooling is clearly impossible, because the low-quality firm would not select $P > P^L$ even if it were then believed to certainly have a high-quality product. The critical X beyond which pooling is impossible is actually smaller than $\bar{X}$, since pooling only generates the belief $b(P(L)) = r$. This point is stated in the following theorem, as is the related point that pooling is impossible when consumers' prior belief of high quality is pessimistic and correspondingly the profits from pooling are low.[4]

Theorem 4: If $r \le \max\{P^L, c - P^L\}$ or $X \ge (r - P^L)^2/4rP^L$, then no pooling equilibrium exists satisfying the Intuitive Criterion.

Proof: By Lemma 1, pooling can never occur at $P < P^L$. Moreover, since $1 > P^L$, pooling at $P = P^L$ violates the Intuitive Criterion as the high-quality firm would deviate to $\overline{P}(X)$. A necessary condition for pooling at P is $\pi(L, r, P) \ge \pi(L, 0, P^L)$. Suppose pooling occurs at $P > P^L \ge r$. Let $M/(1 + X)$ denote the stock of uninformed consumers and let $\epsilon \equiv P - P^L > 0$. Then $\pi(L, r, P) = \pi(L, 0, P^L) - [\epsilon(P^L - r)/r + \epsilon^2/r]M/(1 + X) < \pi(L, 0, P^L)$, a contradiction. Suppose next that pooling occurs when $r \le c - P^L$. Pooling at P requires $P \ge c$ and $P < r + P^L$ (lest the low-quality firm deviate to P^L), which is contradictory. Finally, suppose $r > \max\{P^L, c - P^L\}$. Then it is easy to show that $X \ge (r - P^L)^2/4rP^L$ implies that at $P > P^L$, $\pi(L, r, P) \le \pi(L, r, (r + P^L)/2) < \pi(L, 0, P^L)$, a contradiction.

Finally, if r is big and X is intermediate, pooling equilibria satisfying the Intuitive Criterion may exist. The possible prices for such equilibria are easily restricted. First, pooling at or below P^L is inconsistent with the Intuitive Criterion, as argued in the proof of Theorem 4. Second, given that pooling must occur above P^L, the pooling price must certainly be inside the parabola, or the low-quality firm would deviate to P^L. In fact, since pooling only gives the belief $b(P(L)) = r$, a tighter bound can found. Setting $\pi(L, r, P) = \pi(L, 0, P^L)$ gives the prices at which the low-quality firm is just willing to pool. The corresponding roots are

$$\overline{P}_r(X) = \frac{1}{2}(r + P^L) + [\frac{1}{4}(r + P^L)^2 - rP^L(1 + X)]^{1/2}$$

$$\underline{P}_r(X) = \frac{1}{2}(r + P^L) - [\frac{1}{4}(r + P^L)^2 - rP^L(1 + X)]^{1/2} .$$

As shown in Figure 5, a "pooling parabola" is thus defined, which is inside of the initial (separating) parabola. The pooling parabola is drawn under the assumption that $r > P^L$ and is not defined for $X \geq (r - P^L)^2/4rP^L$, as suggested by Theorem 4. Any price outside of the pooling parabola has $\pi(L, r, P) < \pi(L, 0, P^L)$ and therefore cannot be supported as a pooling equilibrium. We thus have the following theorem.

[**Figure 5: The Pooling Parabola**]

Theorem 5: In any pooling equilibrium satisfying the Intuitive Criterion, $\underline{P}_r(X) \leq P(H) = P(L) \leq \overline{P}_r(X)$.

Therefore, if an intuitive pooling equilibrium does exist, then r must be large, X must be intermediate, and the pooling price must be lower than the intuitive separating price for high quality.

III. Multiperiod Extensions

A. Interpreting the Static Results

We begin by offering a multiperiod interpretation of the static results of the previous section. Suppose that the market evolves in two periods. In the introductory period, the market is poorly informed about the characteristics of the product; the ratio of informed to uninformed consumers (X_1) is close to zero. Over time, information about the product diffuses through published quality reviews (e.g. *Consumer Reports*). Thus, during the mature phase of the market, the ratio of informed to uninformed (X_2) is larger.

A high-quality product ($q = H$) will be introduced at a price that is distorted above the full information monopoly price (Corollary 1 and Theorem 3). As information diffuses, it becomes easier to signal high quality, and the size of this distortion is reduced. If X_2 is sufficiently large, then a lower price signals high quality during the mature period (Theorem 4). For intermediate values of X_2, pooling might occur during the mature phase; however, even a pooling price must be below the introductory price (Theorem 5). Therefore, high-quality products exhibit high and declining prices in either case.

A low-quality product, on the other hand, is introduced and remains at a low price P^L if X_1 is small and X_2 is large (Theorem 1, 3, and 4). If instead X_1 is small and X_2 is in an intermediate range, then the product is introduced at a low price, but might rise to a higher pooling price in the mature phase (Theorems 1 and 5). However, this possibility is unlikely to be observed, because pooling can occur only if the prior probability of low quality is small (Theorem 4). Therefore, we conclude that on average prices will tend to fall as the market evolves.

In summary, our results appear consistent with the stylized facts for consumer durables (see the Introduction). Consider a reasonably well-defined product category, such as microwave ovens or color TVs. Over time, quality improvements lead to the introduction of new products, but information about the value of these improvements diffuses gradually. New, higher quality products are introduced at higher prices resulting in a positive rank-order correlation between price and quality. As consumers gain information about new products, prices on average decline over time, since it becomes easier or unnecessary to signal quality, and price differentials narrow.

Finally, a weakened correlation between price and quality might be explained by measurement errors in the data. To understand this point, suppose that price and quality were perfectly rank-order correlated, but that price differentials narrowed over time. Suppose further that prices and quality were measured with error, and that this measurement error was IID over time. Then the measured rank-order correlation between price and quality would tend to decline.

This interpretation of our static results can be formalized in a two-period extensive form game under the following assumptions. First, the populations of consumers in each of the two periods are distinct. That is, a consumer enters the market at the beginning of one or the other period, either makes a purchase or doesn't, and then leaves the market at the end of that period. In other words, we are taking a long-run view of the evolution of the market.

Second, upon entering the market, consumers only observe the current price. Specifically, consumers in the mature phase do not know what price was charged by the firm in the introductory phase. They do, however, know the date, i.e., whether they are in the introductory or mature phase. (We relax these assumptions below.) As new consumers are ignorant of past prices, we refer to this model as the *ignorant consumer model*.

Finally, information diffusion is independent of market activity. During the introductory phase most consumers cannot distinguish a high-quality product prior to consumption, although some small fraction might be able to do so, say through inspection, because of some related expertise. During the mature phase, a new population has better information about product quality, because of the availability of published quality reviews. However, the ratio of informed to uninformed in the mature period is independent of the quantity of sales in the first period.

Under these assumptions the multiperiod model decomposes into a sequence of one-period models, with our results of the previous section applying to each period. The fundamental dynamic variable is the ratio of informed to uninformed consumers, X_t, which by assumption declines over time (Bagwell and Riordan, 1986).

The assumption that information diffusion is independent of market activity might be important for our basic conclusion that high and declining prices signal product quality. Suppose instead that the number of informed consumers during the mature phase depended on the number of introductory sales. This might be the case if word-of-mouth communication about personal experience was an important mechanism for information diffusion. In this case, high prices which discourage sales become a less attractive method of signaling high quality. The high-quality firm might instead prefer to signal with a low price, in which case price would tend to rise over time.

However, word-of-mouth communication is not a particularly good method of information diffusion for many products. For example, for many durable products (e.g., smoke alarm detectors), it is difficult to determine quality even after purchase. For such products, quality reviews, or the advice of experts, are a much more important source of information diffusion.

Further, word-of-mouth communication may be a very noisy source of information if there is an idiosyncratic component to consumer tastes. For example, knowing that my neighbor likes his new microwave oven may not be a very good indicator that I will like it. On the other hand, knowing that 90 percent of consumers like it is much more informative. Published quality reviews, such as those in *Consumer Reports*, accomplish this information aggregation. It is easy to extend our model to introduce an idiosyncratic taste component (Milgrom and Roberts, 1986).[5]

We conclude that our independence assumption is consistent with a long-run view of markets, in which the primary source of information diffusion is published quality reviews. This seems particularly pertinent for explaining stylized facts based on data published in *Consumer Reports*. It is plausible that the availability of published quality reviews is independent of first-period pricing.

We turn now to a relaxation of some other assumptions about consumer information.

B. Confused Consumers

In the above-described ignorant consumer model, consumers know the age of the firm but do not know past prices. This is tantamount to assuming that each consumer knows the ratio of informed to uninformed consumers prevailing at any date. This is clearly an extreme assumption, as it seems reasonable that consumers might also be incompletely informed about the demand side of the market. We address this issue in a very simple way by assuming that consumers in any period observe only the current price and not the age of the firm. We continue to assume that some fraction of consumers are informed about quality in each period. As consumers are confused about the date, we refer to this model as the *confused consumer model.*

An important novelty of the confused consumer model is that the firm now has two dimensions of private information: the quality of its product, and the prevailing ratio of informed to uninformed consumers. Consequently, the price set by the firm potentially signals information about both. Uninformed consumers will thus attempt to update their beliefs about both unknown variables.

Formally, we model this situation as a two-period extensive form game with the following structure. At any period t, the ratio of informed to uninformed consumers is actually X_t. The firm knows this ratio as well as the quality of its product and chooses a price, $P_t(q)$. Uninformed consumers at any date do not observe quality and also do not know whether they are in period one or two. Thus, an uninformed consumer knows that $q \in \{H, L\}$ and $X \in \{X_1, X_2\}$, where H, L, X_1 and X_2 are all commonly known values and $X_2 > X_1$, but he does not know the actual realizations of q and X. Upon observing a price P, an uninformed consumer forms a (stationary) belief b(P), representing the likelihood of high quality. In a sequential equilibrium, the belief of uninformed consumers must agree with Bayes' rule for prices which could occur (for some quality and date) in equilibrium.[6]

The Intuitive Criterion can be usefully employed in this environment. A sequential equilibrium fails the Intuitive Criterion if there exists an out-of-equilibrium price P′ such that (a) $\pi(H, 1, P') > \pi_t(H)$ for some t, and

(b) $\pi_t(L, 1, P') < \pi_t(L,$ for all t, where $\pi_t(q)$ are equilibrium profits at date t for quality q, with $t \in \{1, 2\}$ and $q \in \{H, L\}$. Intuitively, if there exists an out-of-equilibrium price which is profitable for a high-quality firm at some date when uninformed consumers believe it to be high quality, but which is never profitable for a low-quality firm no matter what uninformed consumers believe, then uninformed consumers must believe high quality at that price. In effect, the firm makes an implicit speech as to quality *and* date with the selection of the price P'.

We will continue to interpret the first period as an introductory phase in which X_1 is close to zero and the second period as a mature phase with X_2 large. Our main result is that the high-quality firm will separate with a high price in period one, and the prices of both types of firm will decline. This equilibrium exhibits intertemporal pooling, in that the young, low-quality firm mimics the price of the mature, high-quality firm. Thus, the general implications of the ignorant consumer model also are true in the confused consumer model.

<u>Theorem 6</u>: In the confused consumer model, if X_1 is sufficiently small, then in any equilibrium satisfying the Intuitive Criterion, $P_1(H) \geq P_2(H)$, $P_1(H) \in (P^H, \bar{P}(X_1)]$, $b(P_1(H)) = 1$, and $P_1(L) \geq P_2(L)$. If in addition X_2 is sufficiently large, then $P_1(H) > P_2(H)$ and $P_1(L) = P_2(H) > P_2(L) = P^L$.

The theorem has a simple intuition. (A formal proof is in the Appendix.) The declining path of prices follows from the assumption that the number of informed consumers increases through time. As the market becomes more informed, distortions away from complete-information monopoly prices become more costly. Thus, a rising price profile is not an optimal strategy for a firm, since it entails greater distortions when the market is more informed. The firm would be better off, for example, to reverse the order of its two prices. The assumption that the number of informed consumers is initially small is not important in ruling out rising price profiles, but does ensure that the introductory high-quality price separates; the logic is similar to that for Theorem 3.

It is interesting to note that the initial high-quality price in the confused consumer model is never higher, and indeed may be lower, than the corresponding price in the ignorant consumer model, when X_1 is small. Since the introductory period is when the low-quality firm has the greatest incentive to mimic, the price $\overline{P}(X_1)$ is sufficient to separate even when consumers are confused as to the date. Furthermore, an introductory price strictly below $\overline{P}(X_1)$ may separate when consumers are confused, because the low-quality firm initially earns a larger profit by mimicking the mature, high-quality price than by charging P^L.

C. Hindsighted Consumers

We close this section by considering another alternative assumption, that consumers observe both the age of the firm and the entire history of prices; we call this model the *hindsighted consumer model*. We think this a strong assumption e.g., past prices are not typically reported in *Consumer Reports*.

In this model, uninformed consumers in period one observe a first-period price P_1 and attempt to infer quality, while uninformed consumers in period two base their beliefs on a pair of prices, P_1 and P_2. Sequential equilibrium then requires that the beliefs of an uninformed consumer be consistent with

Bayes' rule for any price, or pair of prices, that could occur in equilibrium. The sequential equilibria of the ignorant consumer model are also equilibria of this model, but have the property that consumers always ignore past prices in forming beliefs about product quality. However, there also exist other equilibria in which period two consumers base their quality beliefs at least partially on period one price.

Cho (1987) has generalized the Intuitive Criterion to multiperiod settings such as this. However, as Cho (1987, p. 1385) notes, this refinement is often very weak, and this is true in our model as well. The problem is as follows. In order to test their out-of-equilibrium beliefs, period one consumers ask: (a) Is the deviation *ever* profitable for a high-quality firm; (b) Is the deviation *never* profitable for a low-quality firm? In the hindsighted consumer model, the answers to these questions for period one consumers depend on expectations about period two market activity. Unfortunately, the Intuitive Criterion hardly restricts these expectations, so that the answer to (b) is usually negative. Many, if not most, period one prices could increase low-quality profit if favorably interpreted by period two consumers.[7]

Nevertheless, there do exist plausible sequential equilibria--other than those of the ignorant consumer model--that are consistent with the stylized facts. One interesting class of equilibria has all signaling in period one, with firms separating at their complete-information prices (P^H and P^L) in period two. Within this class of equilibria, the Intuitive Criterion selects a unique equilibrium; the arguments are similar to those in Section 2. Separation in period one requires the high-quality price to be distorted above

P^H. Moreover, it is easy to show that unless the period two market is very informed ($X_2 \geq X^H$), this distortion is greater than in the ignorant consumer model ($P_1(H) > \bar{P}(X_1)$).

One interpretation of this equilibrium is that period one consumers form a precise belief about product quality based on the period one price and communicate this reputation to period two consumers by word of mouth. This is equivalent to assuming that beliefs are passive (Cramton, 1985; Rubinstein, 1985), i.e., once posterior beliefs become degenerate, consumers ignore any new information. An alternative interpretation is that first period consumers are cautious in their beliefs, refusing to believe that quality is high unless the price is unprofitable for the low-quality firm, no matter how future consumers behave.

It is also plausible, however, that period two consumers remain receptive to new information after learning the period one price. This view is consistent with the notion that mature phase consumers receive two signals, and are not directly concerned with the order in which they arrive. Given this orientation, a particularly focal equilibrium is that which is the Pareto dominant separating equilibrium for the firm. To find this equilibrium, we solve the program:

$$\max_{\{P_1, P_2\}} \quad \pi_1(H, 1, P_1) + \delta\pi_2(H, 1, P_2)$$

$$\text{s.b.} \quad \pi_1(L, 1, P_1) \leq \pi_1(L, 0, P^L) \quad \text{and}$$

$$\pi_1(L, 1, P_1) + \delta\pi_2(L, 1, P_2) \leq \pi_1(L, 0, P^L) + \delta\pi_2(L, 0, P^L) \quad ,$$

where δ is a common discount factor. The above constraints generate the set of high-quality prices that could arise in a separating equilibrium. When consumers have hindsight, separation requires that the low-quality firm prefers not to mimic the high-quality firm during the introductory phase or during both phases. Since the low-quality price is always P^L in any separating equilibrium, the prices solving this program are the high-quality prices in the Pareto dominant separating equilibrium.

Our fundamental result is that the Pareto dominant separating equilibrium is characterized by high and declining high-quality prices, while low-quality prices are constant at P^L. The price dynamics for the hindsighted consumer model are again qualitatively the same as for the ignorant consumer model. In each case, the high-quality price begins high and then declines as the number of informed consumers increases and signaling becomes easier.

Theorem 7: In the hindsighted consumer model, the Pareto dominant separating equilibrium is characterized by $P_1(H) \geq \overline{P}(X_1)$, $P_2(H) = P^H$ if $X_2 \geq X^H$, $P_2(H) \in [P^H, \overline{P}(X_2)]$ if $X_2 < X^H$, and $P_1(L) = P_2(L) = P^L$.

The proof of Theorem 7 is in the Appendix.

It is interesting to compare the Pareto dominant separating equilibrium for the hindsighted consumer model with the separating path in the ignorant consumer model. Numerical calculations reveal that the two paths agree if P^L is large. However, if P^L is small and X_2 is not too large, the hindsighted model equilibrium has $P_1(H) > \overline{P}(X_1)$ and $P_2(H) < \overline{P}(X_2)$. Here, the high-quality firm "front loads" the signaling process, by signaling strongly in the introductory phase and then profit taking in the mature phase.

More generally, since the ignorant consumer equilibrium is not always the hindsighted consumer equilibrium, the high-quality firm has a clear incentive to ensure that past price information is available to uninformed consumers. By equipping consumers with hindsight, the high-quality firm may be able to generate a more profitable equilibrium. This point is reminiscent of work by Bernheim and Whinston (1987), who argue that firms may seek multimarket contact so as to pool incentive constraints. Analogously, we find that a high-quality firm may want consumers to observe its past pricing decisions so as to pool its "no-mimic" constraints through time.[8]

In concluding this section, we note that a general theme seems to arise from a comparison of the ignorant, confused, and hindsighted consumer models. In the focal separating equilibria of these models, the initial high-quality price is at least as high in the hindsighted as in the ignorant consumer model, and is at least as high in the ignorant as the confused consumer model. In effect, the more information consumers have about the initial period, the more difficult and the more important it is for the high-quality firm to signal strongly in that period. Since signaling involves high prices, the initial high-quality price is highest when consumers have hindsight and lowest when they are confused.

IV. Conclusions

A high-quality good will be introduced at a high price that is lowered over time toward the full-information monopoly price. The high introductory price signals high quality, because a high-cost firm is more willing to restrict sales volume than is a low-cost firm. Furthermore, a low-quality firm loses greater sales volume from a high price, since informed consumers refuse to buy at such a price. As information about product quality diffuses and more consumers become more informed, it therefore becomes easier for a high-quality firm to signal its quality. High-quality prices thus decline as the market matures.

Our prediction of high and declining prices is consistent with the stylized facts of the marketing literature.[9] In particular, our model provides an explanation for the declining trends in consumer durables of real prices, price differentials between competing brands, and the rank-order correlation between price and quality.

The prediction is robust to a variety of assumptions about consumer information. Whether or not uninformed consumers know past prices and firm age, intuitively plausible equilibria exist in which high-quality products have high and declining prices.

Our model relies on many special features that can be relaxed. For example, linear demands and costs are not crucial for our conclusions. The two-period framework is also easily extended into a many-period setting.

Many interesting extensions do remain. It would be intriguing to study an explicit model of word-of-mouth communication. Further work might also involve classifying products by the level of consumer information, so as to see if the high-quality price in the introductory phase tends to be higher when consumers are more informed about past prices and firm age.

Appendix

I. **Proof of Theorem 6**: Observe first that $P_t(H) > P^L$ and $P_t(L) \geq P^L$. $P_t(q) < P^L$ is impossible in equilibrium, as $P_t(q) = P^L$ earns greater profit always. Also, $P_t(H) = P^L$ is inconsistent with the Intuitive Criterion, because $\pi_t\left(H, 1, \bar{P}(X_1)\right) - \pi_t\left(H, b(P^L), P^L\right) > 0$ and $\pi_t\left(L, 1, \bar{P}(X_1)\right) \leq \pi_t\left(L, b(P^L), P^L\right) \leq \pi_t(L)$.

Next, X_1 small implies $b\left(P_1(H)\right) = 1$. For suppose $b\left(P_1(H)\right) < 1$. From the proof of Theorem 3, there exists $P'' > P_1(H)$ such that $\pi_t(L, 1, P'') = \pi_t\left(L, b(P_1(H)), P_1(H)\right) \leq \pi_t(L)$ and $\pi_1(H) = \pi_1\left(H, b(P_1(H)), P_1(H)\right) < \pi_1(H, 1, P'')$. $P' = P'' + \epsilon$ with $\epsilon > 0$ and small, then violates the Intuitive Criterion.

Given $b\left(P_1(H)\right) = 1$, $P_1(H) \in \left(P^H, \bar{P}(X_1)\right]$ follows. To see this, note $P_1(H) = P^H$ induces $P_2(H) = P^H$ and thus $P_1(L) = P^H$, which contradicts $b\left(P_1(H)\right) = 1$. Further, $P_1(H) < P^H$ violates the Intuitive Criterion. For if $P_1(H) \in \left[(1+P^L)/2, P^H\right)$, then $P' = P_1(H) + \epsilon$, for $\epsilon > 0$ and small, violates the Intuitive Criterion. On the other hand, if $P_1(H) < (1+P^L)/2$, then as in the proof of Theorem 1, $P'' > P^H$ can be found for which $\pi_t(L, 1, P'') = \pi_t\left(L, 1, P_1(H)\right) \leq \pi_t(L)$ and $\pi_1(H, 1, P'') > \pi_1\left(H, 1, P_1(H)\right) = \pi_1(H)$. $P' = P'' + \epsilon$ then violates the Intuitive Criterion. Finally, $P_1(H) > \bar{P}(X_1)$ is also inconsistent with the Intuitive Criterion, as can be seen by setting $P' = P_1(H) - \epsilon$.

$P_1(H) \geq P_2(H)$ is straightforward to establish. Otherwise, since $b\left(P_1(H)\right) = 1$ and $P_1(H) > P^H$, $\pi_2(H) = \pi_2\left(H, b(P_2(H)), P_2(H)\right) < \pi_2\left(H, 1, P_1(H)\right)$, and so the high-quality firm would do better to select $P_1(H)$ in period two as well.

Consider next $P_t(L)$. Clearly, $P_t(L) = P^L$ or $P_t(L) = P_2(H)$ at any t. $P_1(L) = P^L$ and $P_2(L) = P_2(H)$ is impossible, since $\pi_2\big(L, b(P_2(H)), P_2(H)\big) \geq \pi_2\big(L, b(P^L), P^L\big)$ implies $\pi_1\big(L, b(P_2(H)), P_2(H)\big) > \pi_1(L, 0, P^L)$, contradicting $P_1(L) = P^L$. Hence, $P_1(L) \geq P_2(L) \geq P^L$.

We now impose the additional assumption that X_2 is sufficiently large, taken here to mean $X_2 > \bar{X}$ and $P^{\dagger}(X_2) < \bar{P}(X_1)$. $X_2 > \bar{X}$ implies $P_2(L) = P^L$, while $P^{\dagger}(X_2) < \bar{P}(X_1)$ can be shown to imply $P_2(H) \in \big(\underline{P}(X_1), \bar{P}(X_1)\big)$. The latter result gives $P_1(L) = P_2(H)$. Since $b\big(P_1(H)\big) = 1$ and $P_2(H) > P^L$, we thus have $P_1(H) > P_2(H) = P_1(L) > P_2(L) = P^L$.

II. **<u>Proof of Theorem 7</u>**: Separation requires $P_1(H) \geq \bar{P}(X_1)$ or $P_1(H) \leq \underline{P}(X_1)$, lest the low-quality firm mimic initially. Familiar arguments establish that $P_1(H) \leq \underline{P}(X_1)$ is impossible, since $P' \geq \bar{P}(X_1)$ defined by $\pi_1\big(L, 1, P_1(H)\big) = \pi_1(L, 1, P')$ gives $\pi_1\big(H, 1, P_1(H)\big) < \pi_1(H, 1, P')$. Thus, $P_1(H) \geq \bar{P}(X_1)$.

Observe next that $P_2(H) = P^H$ if $P^H \geq \bar{P}(X_2)$, since if the high-quality firm separated initially, then $P_2(H) = P^H$ maintains separation and maximizes profit. If instead $\bar{P}(X_2) > P^H$, then $P_2(H) \in [P^H, \bar{P}(X_2)]$ must be true. $P_2(H) > \bar{P}(X_2)$ is impossible, since the high-quality firm could lower $P_2(H)$ without attracting mimicry. Also, $P_2(H) \in \big[(1+P^L)/2, P^H\big)$ is impossible, as a slight price raise increases $\pi_2(H, 1, P_1)$ and decreases $\pi_2(L, 1, P_1)$. Finally, $P_2(H) < (1+P^L)/2$ cannot occur, since the high-quality firm could separate more profitably with $P' > (1+P^L)/2$ defined by $\pi_2\big(L, 1, P_2(H)\big) = \pi_2(L, 1, P')$.

References

Bagwell, K. and M. Riordan (1986), "Equilibrium Price Dynamics for an Experience Good," Northwestern D.P. 705.

Bernheim, D. and M. Whinston (1987), "Multimarket Contact and Collusive Behavior," mimeograph.

Buzzell, R., R. Nourse, J. Matthews, and T. Levitt (1972), *Marketing: A Contemporary Analysis*, McGraw-Hill, Inc.

Chan, Y. S. and H. Leland (1982), "Prices and Qualities in Markets with Costly Information," *Review of Economic Studies*, pp. 499-516.

Cho, I. K. (1987), "A Refinement of Sequential Equilibrium," *Econometrica* 55, pp. 1367-1390.

Cho, I. K. and D. Kreps (1987), "Signaling Games and Stable Equilibria," *The Quarterly Journal of Economics* 102, pp. 179-221.

Conlisk, J., E. Gerstner, and J. Sobel (1984), "Cyclic Pricing by a Durable Goods Monopolist," *The Quarterly Journal of Economics* 99, pp. 489-505.

Cooper, R. and T. Ross (1984), "Prices, Product Qualities and Asymmetric Information: The Competitive Case," *Review of Economic Studies*, pp. 197-208.

Cooper, R. and T. Ross (1985), "Monopoly Provision of Product Quality with Uninformed Buyers," *International Journal of Industrial Organization* 3, pp. 439-449.

Curry, D. and P. Riesz (1988), "Prices and Price/Quality Relationships: A Longitudinal Analysis," *Journal of Marketing* 52, pp. 36-51.

Farrell, J. (1980), *Prices as Signals of Quality*, Ph.D. dissertation, Brasenose College, Oxford.

Fertig, D. (1988), *Advertising as a Signal of Quality*, Ph.D. dissertation, Northwestern University.

Gabor, A. and C. Granger (1965), "The Pricing of New Products," *Scientific Business* 3, pp. 141-150.

Gerstner, E. (1985), "Do Higher Prices Signal Higher Quality?" *Journal of Marketing Research* 22, pp. 209-215.

Judd, K. (1985), "The Law of Large Numbers with a Continuum of IID Random Variables," *Journal of Economic Theory* 35, pp. 19-25.

Judd, K. and M. Riordan (1987), "Price and Quality Determination in a New Product Monopoly," mimeograph.

Kohlberg, E. and J. Mertens (1986), "On the Strategic Stability of Equilibria," *Econometrica* 54, pp. 1003-1038.

Kreps, D. and R. Wilson (1982), "Sequential Equilibria," *Econometrica* 50, pp. 863-894.

Lazear, E. (1986), "Retail Pricing and Clearance Sales," *American Economic Review* 76, pp. 14-32.

Milgrom, P. and J. Roberts (1986), "Price and Advertising Signals of Product Quality," *Journal of Political Economy* 94, pp. 796-821.

Monroe, K. and S. Petroshius (1981), "Buyers' Perceptions of Price: An Update of the Evidence," in *Perspectives in Consumer Behavior*, Harold H. Harsajian and Thomas S. Robertson (eds.), Glenview, Illinois: Scott, Foresman, pp. 43-55.

Ramey, G. (1986), "Moral Hazard, Signaling, and Product Quality," mimeograph.

Shapiro, C. (1983), "Optimal Pricing of Experience Goods," *Bell Journal of Economics*, pp. 497-507.

Stokey, N. (1981), "Rational Expectations and Durable Goods Pricing," *Bell Journal of Economics*, pp. 112-128.

Tellis, G. and B. Wernerfelt (1987), "Competitive Price and Quality Under Asymmetric Information," *Marketing Science* 6, pp. 240-253.

Wolinsky, A. (1983), "Prices as Signals of Product Quality," *Review of Economic Studies*, pp. 647-658.

Zeithaml, V. (1988), "Consumer Perceptions of Price, Quality and Value: A Means-End Model and Synthesis of Evidence," *Journal of Marketing* 52, pp. 2-22.

Notes

1. Independent of our own work, Fertig (1988) and Ramey (1986) have constructed models in which high prices are used to signal high quality, when high quality is more costly to produce than low quality. Fertig and Ramey analyze static, continuum-type models, whereas we refine multiperiod, two-type models and thus offer predictions about the path of prices.

2. We use the Intuitive Criterion throughout to restrict the class of equilibria. A weaker refinement is to eliminate dominated strategies (Kohlberg and Mertens, 1986 and Milgrom and Roberts, 1986). This refinement is sufficient for all of our results for separating equilibria and some of our work on pooling equilibria. The Intuitive Criterion is necessary, however, for Theorems 3 and 6.

3. If $P^L \geq 1$, then for $\epsilon = P - P^L > 0$, $\pi(L, 1, P) = \pi(L, 0, P^L) - [P^L X + \epsilon(P^L - 1) + \epsilon^2]M/(1+X) < \pi(L, 0, P^L)$, so that a low-quality firm's marginal revenue for a price increase above P^L is negative no matter how beliefs adjust. Thus, if $P^L \geq 1$, then mimicry is never profitable for the low-quality firm and the problem degenerates. The following can be shown: If $P^L \geq 1 + c > 1$, then the unique equilibrium has $P(H) = P(L) = P^L$; while if $1 + c \geq P^L \geq 1$, then the unique equilibrium has $P(L) = P^L$ and $P(H) = (1 + P^L + c)/2 \equiv P^H$. $P^L < 1$ is thus the interesting case.

4. By Theorems 2, 3, and 4 and Corollary 2, pure strategy, sequential equilibria satisfying the Intuitive Criterion might not exist if r is small and X is in an intermediate range. There do, however, exist equilibria satisfying the Intuitive Criterion in which the high-quality firm selects a price $P(H) > P^L$, the low-quality firm mixes between $P(H)$ and P^L with weights λ and $1 - \lambda$, and uninformed consumers believe high quality with probability b, where $P(H)$, λ, and b satisfy $b = r/[r + (1-r)\lambda]$, $\pi(H, b, P(H)) = \pi(H, 0, P^H)$, and $\pi(L, b, P(H)) = \pi(L, 0, P^L)$.

5. The assumption that initial sales volume influences the future information state is in fact problematic, even if quality is non-idiosyncratic and easily evaluated after experience. In particular, in a separating equilibrium, each current consumer believes he knows quality whether or not he chooses to buy. Word-of-mouth communication then affects the rate of diffusion only if a consumer who knows quality communicates more effectively than does a consumer who believes himself to know quality.

6. The specific nature of the consumer arrival process will determine the consumers' priors over dates. It is perhaps easiest to imagine that the process treats consumers anonymously, pulling out a certain fraction in period one and the remainder in period two, in which case consumers have common priors over dates (Bagwell and Riordan, 1986). The consumers' priors over dates will affect beliefs as to quality only for prices which would be charged

at different dates by the high-and low-quality firms. In any event, Theorem 6 below characterizes the necessary characteristics of equilibrium and is independent of the details of the arrival process.

7. This difficulty with the Intuitive Criterion also arises in a static model, if, for example, there are two sets of signal receivers and one set observes only one signal while the other set observes two signals. It is difficult to persuade members the former set that an equilibrium dominated action has been taken, since they do not observe the entire action.

8. This conclusion must be qualified somewhat, given our discussion of refinements: while hindsight does create a more profitable separating equilibrium, it also makes more difficult the process by which a high-quality firm "escapes" from an unprofitable equilibrium.

9. It should be noted, however, that at least some of our "stylized facts" are in fact controversial (Zeithaml, 1988).

Separating Prices

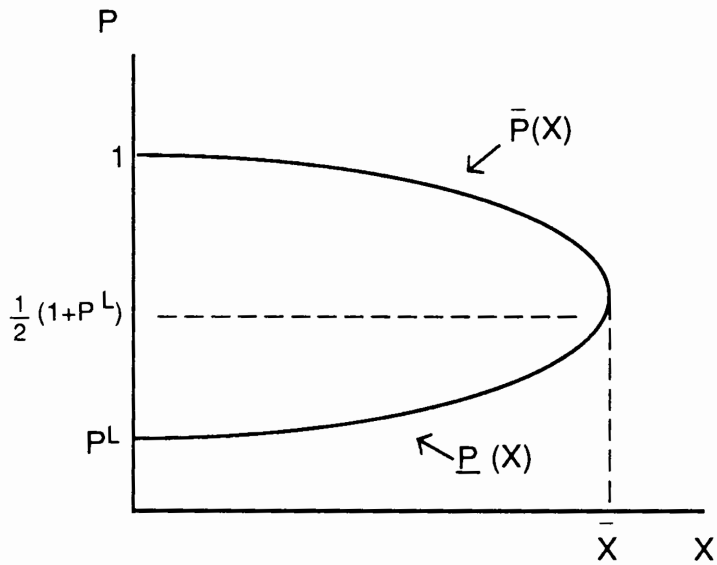

Figure 1

Equilibrium Separating Prices

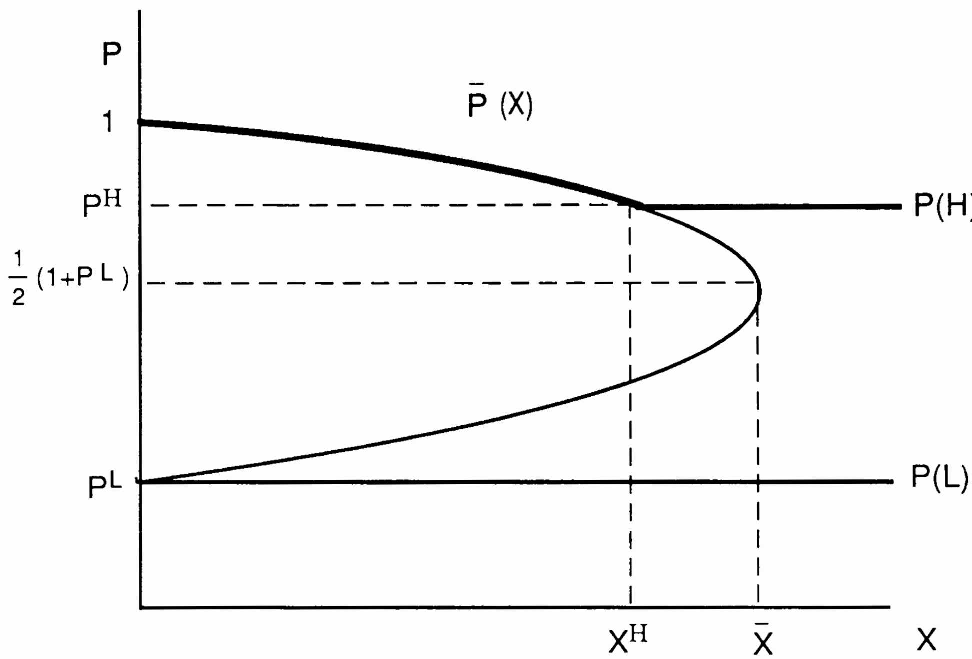

Figure 2

"No-Defect" Prices

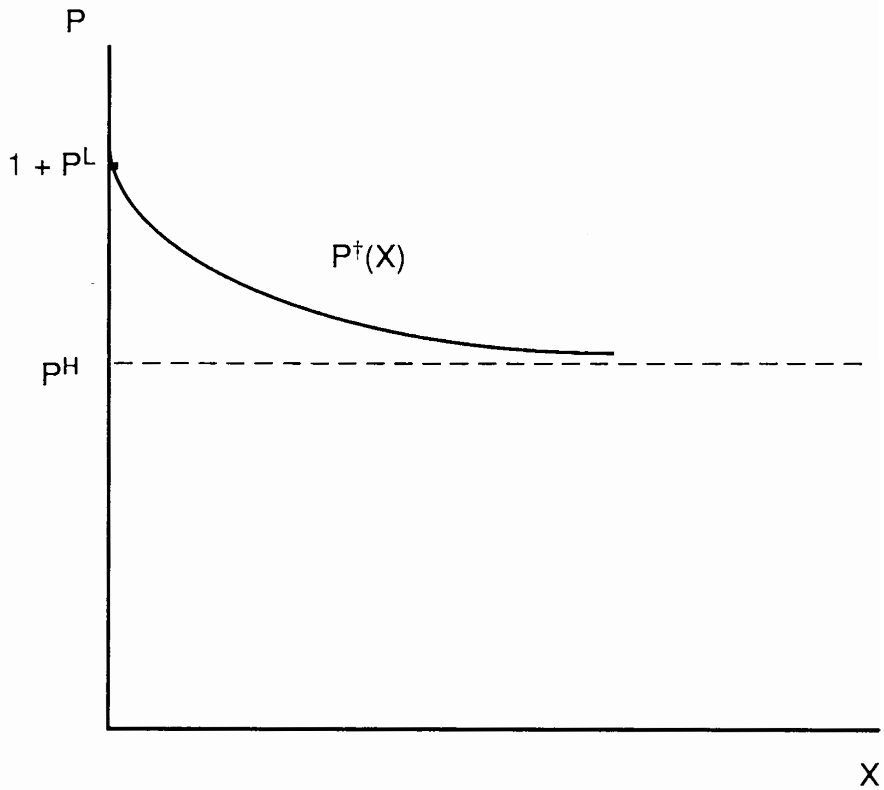

Figure 3

Parameter Values Supporting Separation

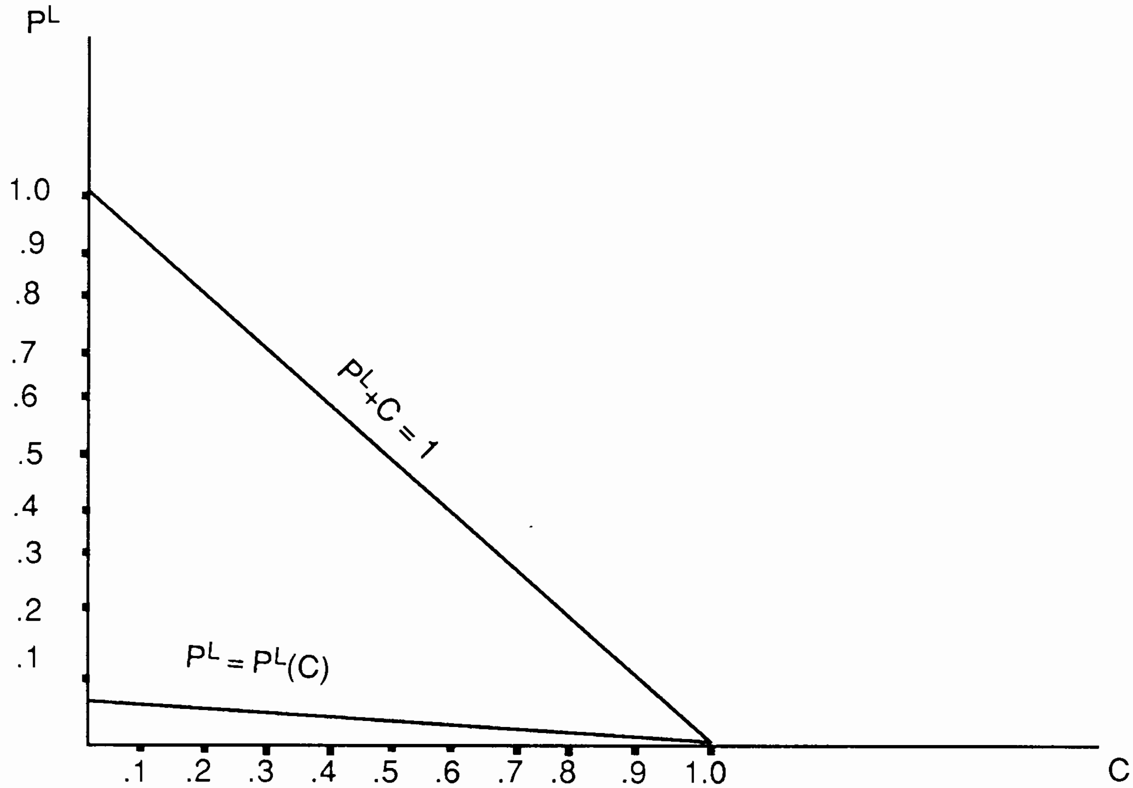

Figure 4

For $\{P^L, C\}$ such that $P^L > P^L(C)$, a unique separating equilibrium satisfying the Intuitive Criterion exists. If instead $P^L < P^L(C)$, a separating equilibrium may fail to exist for intermediate values of X.

The Pooling Parabola

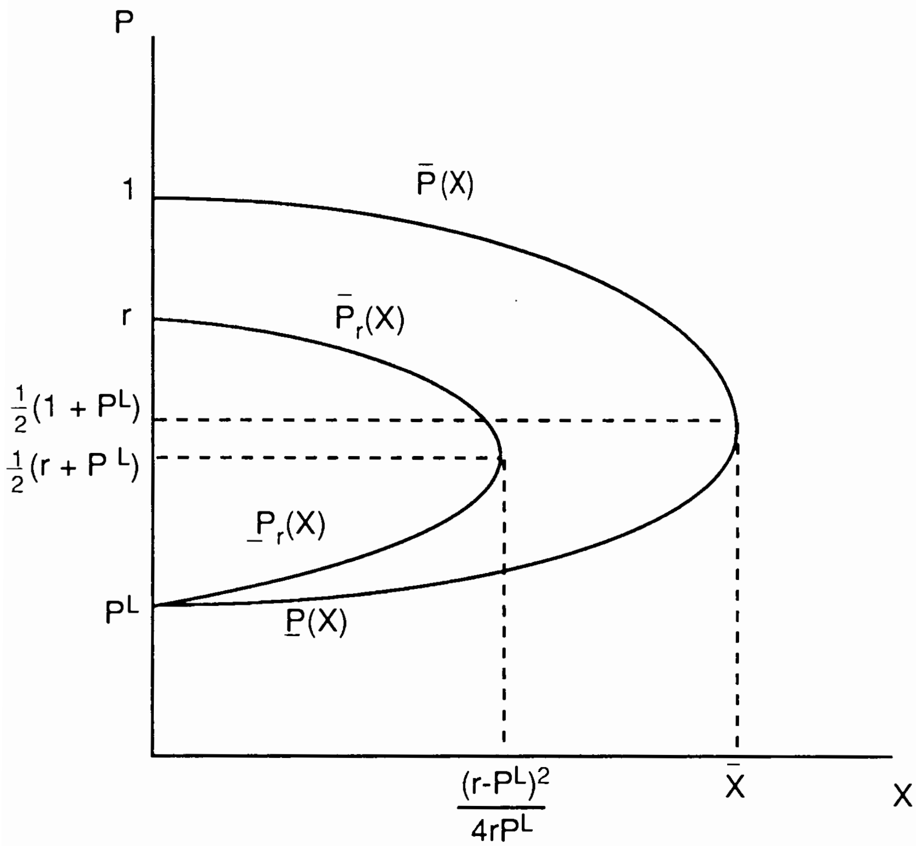

Figure 5