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INFORMATIONAL PRODUCT DIFFERENTIATION AS A BARRIER TO ENTRY*

by

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ABSTRACT

In a market for experience goods, the products of an incumbent firm and a new entrant are informationally differentiated. A signalling model is analyzed, and it is shown that informational product differentiation can be a barrier to entry (even under "pro-entry" assumptions). Furthermore, when products are informationally differentiated, cost-based notions of predation are argued inappropriate.

1. Introduction

An experience good (Nelson (1970)) is a product whose quality becomes known among consumers only after the good has been tried or experienced; that is, an experience good is a product whose quality can not be determined by inspection. In a market for such goods, the products of an incumbent firm and an entering firm are informationally differentiated. Consumers may know the quality of the established product, but they often have no direct information about the quality of the entrant's product.

Bain (1956) was the first to argue that informational product differentiation can be a barrier to entry. After analyzing some twenty industries, he observed that consumers often continue to buy from established firms, even when new firms offer their products at discount prices. Bain, however, provided no real explanation of this behavior.

A tremendous amount of research, both in the economics and marketing literature, followed Bain's study.[1] Of particular importance is the work of Schmalensee (1982a). In his model, an incumbent whose product is generally known to be high quality competes with an entrant whose product quality is uncertain to consumers (perhaps high, perhaps low). The central conclusion of Schmalensee's essay is that this uncertainty may enable the incumbent to make a profit without encouraging the entry of an equally efficient, high quality entrant. In effect, entry is deterred because consumers desire insurance and will pay a premium for the incumbent's product.

As von Weizäcker (1980) has argued, it has perhaps become customary to think of a barrier to entry as an obstacle to competition which serves to preserve inefficiencies introduced by an incumbent firm. From this perspective, the Bain-Schmalensee thesis is that informational product differentiation is a barrier to entry, since, when such differentiation is present, the threat of entry may be insufficient to force the incumbent to price efficiently.[2]

In this paper, the Bain-Schmalensee thesis is extended in two important directions. The first extension involves the nature of the distortion introduced by the incumbent. In general, an incumbent can generate distortions in the market with its price and its quality. Bain and Schmalensee have emphasized the ability of an entrant to eliminate price distortions, when the actual quality of the entrant is identical to that of the incumbent. We consider the opposite problem. Specifically, a simple model is constructed in which quality type (but not price) is the source of inefficiency. An incumbent is known to have a low quality product, while consumers are uncertain as to whether the given entrant quality is high or low. The high quality product is assumed to generate more surplus in a full information world than the low quality product, and, in this sense, the high quality product is the relatively efficient product. The central question is then: Can the efficient (high quality) entrant "win" the market from the inefficient (low quality) incumbent? We will see that the answer to this question may be "no." That is, inefficiency in quality can persist in the presence of informational product differentiation, and so this form of differentiation can again be a barrier to entry.[3]

The second extension concerns the ability of consumers to use entrant price as a signal of entrant quality. In Schmalensee's model, consumers completely ignore price in forming their beliefs about quality. In contrast, we develop below a formal signalling model in which consumers draw rational inferences about the entrant's quality from the entrant's price.

Our fundamental results concern the existence of informational barriers to entry. We show that signalling equilibria exist in which a low quality, inefficient incumbent is able to prevent a high quality, efficient entrant from gaining positive market share! Furthermore, for some parameters, it is true in any signalling equilibrium that the high quality entrant is unable to immediately "win" the market; that is, for some parameters, the informational barrier is always present, to some degree.

As the entrant's quality is commonly known to be at least as good (and efficient) as the incumbent's, it may seem surprising that the entrant has difficulty gaining market share. The intuition is roughly as follows. Consumers initially do not know entrant quality, and they therefore will try the entrant's product only if a "reasonably" low price is charged. Assuming that high quality products are relatively costly to produce, the introductory prices which attract consumers to the entrant's store are often below the cost of high quality production. Thus, for a high quality entrant to gain market share, it may be necessary that an introductory phase be experienced during which losses are made.

When will the high quality entrant be willing to incur such losses? Clearly, these losses will be endured only if they are no larger than the future profits coming to the high quality entrant once consumers learn (through experience) the quality of its product. In turn, these future profits are measured by the extent to which the high quality entrant is more efficient than the incumbent. Thus, if the efficiency difference is "small," then the high quality product may never be sold. When such an informational entry barrier occurs, it is interesting to note that the incumbent retains market share without pricing below marginal cost.

On the other hand, if the high quality entrant is "very" efficient relative to the incumbent, then the future benefit to this entrant of early market share is great. In this case, the high quality entrant is in fact willing to undercut the incumbent's price, if necessary, in order to induce consumers to try the new product. A "very" efficient entrant, then, will in any equilibrium displace the incumbent. Informational barriers to entry do not impede "large" gains in efficiency.

We are also concerned with the definition of predatory behavior among firms whose products are informationally differentiated. In particular, we focus on the Areeda-Turner rule, which states that prices below marginal cost are predatory and should be discouraged. The analysis presented in this paper suggests that the rule has important exceptions; indeed, if we take the view that economic efficiency should be the sole objective of anti-trust law,[4] then the Areeda-Turner rule may prompt anti-trust enforcement at precisely the wrong time. When efficient entry is barred, the incumbent does not price below marginal cost and the Areeda-Turner rule has nothing to say. We would prefer a legal posture which made easier the entry of the efficient firm.[5] And, when the efficient entrant is able to gain market share, it may have done so with a price below its marginal cost. A blind application of the Areeda-Turner rule would in this case work against efficient entry.[6] In general, any cost-based notion of predation seems ill-equipped to deal with informationally differentiated products.

A final contribution of the paper is in the theory of promotional pricing. Bagwell and Riordan (1986) and Milgrom and Roberts (1986) have each developed signalling models in which the optimal price path for an experience good monopolist is characterized. We extend this work by analyzing the optimal price path for an experience good entrant in a market already inhabited by an incumbent. As discussed above, if the entrant is a high quality type, then successful entry requires a low introductory price (an introductory sale) followed by a higher price in the future.

We begin in Section II with a discussion of the model's basic assumptions. To strengthen our results, we make "pro-entry" assumptions. In Section III, we solve a static model. This model is then viewed as the second (and last) period of the general dynamic game, which is solved in Section IV. Sections III and IV may be of some technical interest, as they involve a rather unique signalling game: three sets of agents (the incumbent, the entrant, and the consumers) exist and one of these agents (the entrant) has private information. Finally, in section V, various extensions are discussed.

II. Basic Assumptions

We consider a product which is either high quality or low quality. Letting q index quality, we represent these possibilities with the symbols q^H and q^L. Consumers are not able to determine, by inspection, the quality level of a product. However, quality can be determined perfectly after the product has been consumed (experienced).

The game proceeds as follows. Initially, a single incumbent firm exists, and it is commonly known that the incumbent has a low quality product. Incumbent quality is exogenous and unalterable. Then, in period one, a single entrant appears. "Nature" determines (once and for all) the entrant's quality of product. It is commonly known that nature selects q^H with probability $\delta \in (0,1)$ and q^L with the complementary probability; however, the entrant is privately informed of nature's actual choice. The entrant then competes with the incumbent in period one and also in the future, which we summarize with a second period.

In any period, an individual consumer chooses between buying one unit of the product or zero units. If he does buy, then he must buy the whole unit from one firm only. Letting P represent price, we assume that each consumer has the same utility function, $V(P,q) = U(q) - P$, where $U(q^H) > U(q^L) > 0$. It is convenient to define $P^H \equiv U(q^H)$, $P^L \equiv U(q^L)$, and $P^r \equiv r \cdot U(q^H) + (1-r) \cdot U(q^L)$. These are, respectively, the reservation prices associated with a known high quality product, a known low quality product, and a product whose quality is high with probability r. Finally, we assume that M consumes live throughout the game.

Consumers are assumed able to communicate perfectly. Thus, if some consumers buy from the entrant in period one, then all consumers know the entrant's quality of product in period two. Clearly, under such an advantageous communication structure, the high quality entrant could always "win" the market by giving away a single unit of its product to a consumer in period one, and then having all consumers know its quality in period two. To avoid this trivialization of the problem, we assume that the entrant can not ration its product. An alternative assumption, under which the basic results hold, is that consumers do not communicate quality experience.[7]

There are no fixed or start-up costs. Firms have constant marginal (and average) costs with c^H and c^L being the respective marginal (and average) costs for high and low quality production. We assume $c^H > c^L > 0$. Since fixed (and sunk) costs are zero, the entrant can be modeled as always being "open for business." Put differently, the physical act of entry (acquiring a plant, store, etc.) is completely costless. The real issue is whether or not the entrant can gain market share. Notice that the entrant is in no way disadvantaged by entry costs or scale economies.

The social surplus attributable to a product is, in this model, quite simple to measure. The high quality product generates a surplus of $P^H - c^H$, while the surplus derived from a low quality product is $P^L - c^L$. Notice that the social surplus created by a product is a function of quality type but not price. We assume that the high quality product is relatively efficient ($P^H-c^H > P^L-c^L$) and that both products generate positive surplus ($P^L-c^L > 0$). The latter assumption is needed for a non-trivial entry problem.

So far, our assumptions have been decidedly "pro-entry." Consumers communicate quality experience freely, entry is free, returns to scale are constant, and the entrant's product is known to be a least as good as that of the incumbent. We next assume that consumers maximize instantaneous expected utility in each period. In other words, consumers use all available information to choose the purchasing action which maximizes current expected utility. We are therefore ignoring the incentive that consumers have to try the entrant's product in order to make more informed choices in the future.[8] This assumption of myopically rational consumers can work against the entrant. The assumption does, however, make the model much more tractable, and, in Section V, we argue that it is not central to any of the results of the paper.

Finally, it is important to assume that the incumbent and the consumers always have identical information about the entrant's quality type. If the incumbent had private information about the entrant's type, then consumers might attempt to use the incumbent's price as one signal of the entrant's quality of product. This multi-signal problem is best left for a future work.[9]

III. The Static Model and Its Welfare Properties

In this section, we analyze a completely static model in which the incumbent's product is of commonly known quality and the entrant's product may be of uncertain quality. The static equilibria derived here will ultimately correspond to the second (and final) period of the general dynamic equilibria (as argued in the next section). For this reason, the number two is subscribed to the sets and strategies below.

We consider two static games. In the first, the entrant has private information about its quality type. This is a game of incomplete information. In the second game, all information is commonly shared and so the game can be called a full information game. Both games are of substantial interest on their own terms; moreover, an understanding of these two static games will prove necessary in solving the general dynamic game.

Incomplete Information

In the following, it will be convenient to represent the incumbent as **I**, the entrant as **E**, and the high (low) quality entrant as **H**(**L**). Now, consider a single period or static game in which **I**'s quality of product is commonly known to be low and **E**'s quality of product is known only to **E**. Let $r \in (0,1)$ be the prior probability that **E** is **H** for the static game. That is, consumers and **I** believe, at the start of this game, that **E** is **H** with probability r. For the points to be made in this section, we can think of r as the probability that "nature" selects entrant quality, q^e, equal to q^H in the static game. r is assumed to be commonly known.

Let $Q^e \equiv \{q^L, q^H\}$ be the entrant quality set with element q^e. We define $\mathbf{P} \equiv [0,\infty)$ as the set of possible prices for each firm.

We can now define strategies and beliefs for the players. A strategy v_2^i for consumer $i \in \{1,2,...,M\}$ is defined by a mapping v_2^i: $(0,1)\times\mathbf{P}\times\mathbf{P} \to$ {buy from I, buy from **E**, don't buy}. The domain of this function includes the consumer's initial belief (r) about **E**'s quality type and the prices charged by **I** and **E**. Suppressing some notation, we write $v_2^i(P_2^I, P_2^e)$ for consumer i's strategy, where P_2^I and P_2^e represent arbitrary prices which **I** and **E**, respectively, might be observed charging. Define $v_2(P_2^I,P_2^e) \equiv \{v_2^1(P_2^I.P_2^e),\ldots,v_2^M(P_2^I,P_2^e)\}$.

Consumers are identical and we require them to share a common belief function. Let b_2: $(0,1)\times\mathbf{P} \to [0,1]$ be the posterior belief which updates the prior r with the observation of P_2^e. We will write $b_2(p_2^e)$ to denote this posterior probability that **E** is **H.**

I's price strategy is a mapping P_2^I: $(0,1) \to \mathbf{P}$. That is, **I** chooses its price given its belief (r) about **E**'s type. **I** and **E** are assumed to select price simultaneously. We use $P_2^I(q^L)$ represent **I**'s price strategy. Again, the variable r has been suppressed. It is common knowledge to all players that **I**'s product is of low quality; q^L is included in the representation of **I**'s strategy as a simple reminder.

The price strategies of **H** and L, respectively, are represented as $P_2^e(q^H)$ and $P_2^e(q^L)$. Both strategies map from $(0,1)\times Q^e$ into **P.**

Notice that we have restricted all players to use only pure strategies. It will often prove useful to eliminate dominated strategies, and we will do this freely. In a static game, this means $P_2^e(q^H) \geqslant c^H$, $P_2^e(q^L) \geqslant c^L$, and $P_2^I(q^L) \geqslant c^L$.

We can define $\pi_2^H(P_2^I,P_2^e)$ to be the profit that **H** gets when it charges P_2^e and when **I** charges P_2^I. $v_2(P_2^I,P_2^e)$ is, of course, implicit in this definition. $\pi_2^L(P_2^I,P_2^e)$ and $\pi_2^I(P_2^I,P_2^e)$ can be defined analogously.

Now, if an assessment $\{v_2(P_2^I,P_2^e);\ b_2(P_2^e);\ P_2^e(q^H);\ P_2^e(q^L);\ P_2^I(q^L)\}$ is to be an equilibrium for the static game beginning with the prior $r \in (0,1)$, then it is necessary that:

N1). $$P_2^I(q^L) \in \operatorname*{argmax}_{P_2^I} \quad r\cdot\pi_2^I\big(P_2^I,P_2^e(q^H)\big) + (1-r)\cdot\pi_2^I\big(P_2^I,P_2^e(q^L)\big).$$

N2). $P_2^e(q^H) \in \underset{P_2^e}{\operatorname{argmax}} \quad \pi_2^H\big(P_2^I(q^L), P_2^e\big)$

N3). $P_2^e(q^L) \in \underset{P_2^e}{\operatorname{argmax}} \quad \pi_2^L\big(P_2^I(q^L), P_2^e\big)$

It is also necessary that each consumer maximize expected utility, given his beliefs. $V(q^L,P_2^I)$, $b_2(P_2^e)\cdot V(q^H,P_2^e) + \big(1-b_2(P_2^e)\big)\cdot V(q^L,P_2^e)$, and 0 are, respectively, the expected utilities of buying from **I**, buying from **E**, and not buying. Thus, we have a fourth necessary condition for an equilibrium:

N4). For any (P_2^I,P_2^e), consumers pick the action corresponding to the maximum of the set $\{V(q^L,P_2^I),\ b_2(P_2^e)\cdot V(q^H,P_2^e) + \big(1-b_2(P_2^e)\big)\cdot V(q^L,P_2^e),\ 0\}$. If more than one maximum exists, each consumer does an action corresponding to one of the maximizers.

Finally, we must say something about beliefs

N5). The following three conditions must hold:

1). If $P_2^e(q^H) \neq P_2^e(q^L)$, then $b_2\big(P_2^e(q^H)\big) = 1$ and $b_2\big(P_2^e(q^L)\big) = 0$.
2). If $P_2^e(q^H) = P_2^e(q^L)$, then $b_2\big(P_2^e(q^H)\big) = r$.
3). $b_2(P_2^e) = 0$ for all $P_2^e \in [c^L,c^H)$.

The first two parts of N5 simply require beliefs to agree with Bayes' rule along the equilibrium path. If separation $\big(P_2^e(q^H) \neq P_2^e(q^L)\big)$ occurs, then price perfectly signals type, whereas if pooling occurs $\big(P_2^e(q^H) = P_2^e(q^L)\big)$, then price provides no information about type. Part 3 of N5 requires consumers to believe that dominated strategies are not played. $P_2^e \in [c^L,c^H)$

is dominated for **H**, but not for **L**, and so should be taken as an indication that **E** is **L**.[10]

We can now define an equilibrium for the static game beginning with the prior $r \in (0,1)$ as an assessment $\{v_2(P_2^I, P_2^e);\ b_2(P_2^e);\ P_2^e(q^H);\ P_2^e(q^L);\ P_2^I(q^L)\}$ satisfying N1 - N5.

This definition of a static equilibrium may seem familiar: A static equilibrium is simply a sequential equilibrium (Kreps-Wilson (1982a)) in which beliefs put zero weight on dominated strategies and are structurally consistent.[11]

In the below, we will say that a firm gets all (gets some) market share if all (some but not all) consumers buy from the firm. A firm is then said to get market share if it gets all or some market share. These definitions are clear when the firm is **H** or **L**. When we say that **I** gets all (no) market share, we mean that all (no) consumers buy from **I**, whether **E** is H or L.

We are now ready for our first proposition.

Proposition 1: Consider the static, incomplete information game with $r \in (0,1)$.

1). Separating static equilibria exist and are characterized by $P_2^I(q^L) = c^L = P_2^e(q^L)$, $P_2^e(q^H) = P^H - P^L + c^L$, no market share to **H**, and an arbitrary split of the market between **I** and **L**.

2). If $P^r - c^H \geqslant P^L - c^L$, then there exist pooling static equilibria in which **I** gets:

A). all or some market share; this class of equilibria is characterized by $P_2^I(q^L) = c^L$, $P_2^e(q^H) = P_2^e(q^L) = P^r - P^L + c^L$.

B). no market share; this class of equilibria is characterized by $c^L \leqslant P_2^I(q^L) \leqslant P_2^e(q^H)$, $c^H \leqslant P_2^e(q^H) \leqslant P^r - P^L + c^L$, and $P_2^e(q^H) = P_2^e(q^L)$.

3). If $P^L - c^L > P^r - c^H$, then pooling static equilibria do not exist.

This proposition gives a complete characterization of the static equilibria for the incomplete information game. The formal proof of Proposition 1 is contained in Appendix 1.

In thinking about this proposition, notice first that **H** can't separate and get market share. Intuitively, separation requires a financial sacrifice, and **H** is unwilling to make such a sacrifice since **H** has no future in which to recover its loss. Thus, in any static separating equilibrium, an informational barrier to entry exists. Note that separating equilibria always exist, and that only separating equilibria exist when $P^L - c^L > P^r - c^H$.

So, if **H** is to get market share, then **E** must pool. Proposition 1 indicates that $P^r - c^H \geqslant P^L - c^L$ is also necessary for **H** to get market share. The argument is intuitive. Since a pooling **E** gives higher expected quality than does **I**, **E** can price pool at a premium above **I**'s price. But, since prices below c^H are dominated for **H**, **E** can not credibly pool at prices below c^H. As **I** will price as low as c^L in order to save its market, it follows that **E** can pool and get market share only if the premium **E** can charge above c^L is sufficiently large to enable **E** to price above c^H. This premium is measured by $P^r - P^L$. Thus a pooling **E** can get market share only if $P^r - P^L + c^L \geqslant c^H$ or, equivalently, $P^r - c^H \geqslant P^L - c^L$. Notice that this condition is necessary, but not sufficient, for a pooling **E** to get market share. A more rigorous and complete description is provided in Appendix 1.

Since H can displace I in the static game only if $P^r - c^H \geqslant P^L - c^L$, it is important to ask what economic factors might cause this inequality to be met. A first point is that the inequality is more likely to be met the greater the chance that **E** is **H** (i.e., the higher is r). Thus, if a high quality product is known to be the likely outcome of R&D efforts, then it is possible that **H** could displace **I**. $P^r - c^H \geqslant P^L - c^L$ is also more likely to be true the greater is $P^H - c^H - P^L + c^L$. Thus, if the high quality product is "very" efficient relative to the low quality product (i.e., if $P^H - c^H \gg P^L - c^L$), then **H** has a chance of displacing **I**.

In general, inefficiencies are quite severe in the static model with incomplete information. In the next section, we see that giving **H** an extra period with which to work often (but not always) enables it to displace **I**. Before pursuing the dynamic model, however, we must first consider the static, full information model.

Full Information

Consider now the possibility that both **I**'s product and **E**'s product are of commonly known quality. Our static equilibrium concept is then simply a Nash equilibrium in prices (viz, N1 - N4 with r = 0 or 1, depending on whether $q^e = q^L$ or q^H, and $b_2(P_2^e) \equiv r$). Proposition 2 tells us the obvious: If firms play a static, full information game, then the efficient result obtains.

<u>Proposition 2</u>: Consider the static, full information game.

1). If $q^e = q^H$, then the unique static equilibrium is $P_2^I(q^L) = c^L$,

$P_2^e(q^H) = P^H - P^L + c^L$, with all market share going to **H**.

2). If $q^e = q^L$, then the unique static equilibrium is $P_2^I(q^L) = c^L = P_2^e(q^L)$, with **I** and **L** splitting the market arbitrarily.

The proof of Proposition 2 is not difficult and is left to the reader.

IV. The Dynamic Model and Its Welfare Properties

In this section, we roll time back one period and analyze the dynamic model which begins at the start of the first period. Thus, the dynamic game we investigate has two periods, an incumbent whose low quality type is commonly known, and an entrant whose quality of product is initially uncertain to consumers (high with probability δ, low with probability $1 - \delta$).

We will again use the sequential equilibrium concept. For clarity, we call a sequential equilibrium for the dynamic game a dynamic equilibrium. In what follows, we economize on notation and give an informal definition of a dynamic equilibrium. The reader interested in a more formal definition is encouraged to see Bagwell (1985) or Kreps-Wilson (1982a).

Sequential equilibria are to incomplete information games what subgame perfect equilibria (Selten (1965)) are to full information games. To get a subgame perfect equilibrium, one starts at the bottom of the tree and works up. A Nash equilibrium is then required for every subgame which appears along the way. In the same manner, we can start at the bottom of the tree for our dynamic game and use the fact that in a dynamic (sequential) equilibrium, second period behavior and beliefs can be identified with the static (sequential) equilibria of an appropriately selected static or second period game.

Before developing this point in greater detail, it will prove useful to define a first period posterior belief function $b_1(P_1^e)$. At the start of the first period, consumers and **I** believe that **E** is **H** with probability δ. **E** and **I** then simultaneously choose their first period prices (P_1^e and P_1^I, respectively). Consumers observe first period prices and revise their beliefs. $b_1(P_1^e)$ is this revised belief; after observing P_1^e, consumers believe that **E** is **H** with probability $b_1(P_1^e)$.

So, focus now on the second period. Suppose first that **E**'s product is tried in period one. Then, upon beginning the second period, all players are fully informed. We therefore require for a dynamic equilibrium that the static equilibria described in Proposition 2 characterize second period play when **E**'s product is tried in period one.

Suppose next that **E**'s product is not experienced by any consumer in the first period. Then, at the close of the first period, consumers and **I** believe that **E** is **H** with probability $b_1(P_1^e)$. Taking this probability to be a sufficient statistic for period one play, we can think of the second period as a static game of incomplete information (with $r = b_1(P_1^e)$).[12]

Two cases emerge. Suppose first that consumers and **I** have uncertainty in their beliefs; that is, suppose $b_1(P_1^e) \in (0,1)$. We then require for a dynamic equilibrium that the static equilibria described in Proposition 1 (with $r = b_1(p_1^e)$) characterize second period behavior.

The remaining case is that **E**'s product is not tried in period one and consumers and **I** are certain in their beliefs (i.e., $b_1(P_1^e) = 0$ or 1). The corresponding static game is an incomplete information game in which the prior r is zero or one. As is well known, this game need not behave the same as a complete information game in which entrant quality is known. One approach, adopted by Cramton (1985), Grossman and Perry (forthcoming), and Rubenstein

(1985), is to require that $b_2(P_2^e) \equiv 1(0)$ when $r = 1(0)$. Cramton calls such beliefs "passive," since the posterior belief is not responsive to new observations. The underlying idea is simple: If rational consumers are ever certain about something, then there should be nothing that could conceivable happen which would change their minds. We find this argument persuasive and employ the passive belief structure below.

To summarize, consumers enter the second period in one of three possible states. If they have tried **E**'s product, then Proposition 2 characaterizes second period play; if they have not tried **E**'s product and are uncertain in their beliefs $\left(r = b_1(P_1^e) \in (0,1)\right)$, then Proposition 1 characterizes second period play; and if they have not tried **E**'s product but are certain in their beliefs $\left(r = b_1(P_1^e) = 0 \text{ or } 1\right)$, then the restrictions implied by a passive belief structure characterize second period play.

We now proceed to discuss equilibrium conditions for first period strategies and beliefs. These terms can all be described in a manner precisely analogous to their second period counterparts:
v_1^i: $\{\delta\}\times\mathbf{P}\times\mathbf{P} \to$ {buy from **I**, buy from **E**, don't buy}, b_1: $\{\delta\}\times\mathbf{P} \to [0,1]$,
P_1^I: $\{\delta\} \to \mathbf{P}$, and P_1^e: $\{\delta\}\times Q^e \to \mathbf{P}$.

Consider first the consumers. As we are assuming that consumers maximize instantaneous expected utility, dynamic equilibrium conditions for $v_1(P_1^I,P_1^e)$ are exactly like those developed earlier for $v_2(P_2^I,P_2^e)$. (In N4, simply replace all subscript 2's with 1's.) Similarly we have an analogous condition for $b_1(P_1^e)$; namely, if equilibrium prices are $P_1^e(q^H)$ and $P_1^e(q^L)$, then $P_1^e(q^H) = P_1^e(q^L)$ implies $b_1\left(P_1^e(q^H)\right) = \delta$, and $P_1^e(q^H) \neq P_1^e(q^L)$ implies $b_1\left(P_1^e(q^H)\right) = 1$ and $b_1\left(P_1^e(q^L)\right) = 0$.

Consider next the firms. First period pricing strategies influence directly first period profits and indirectly second period profits. First period prices determine whether or not consumers experience the entrant's product (and what they believe if they don't). Consequently, these prices influence the state with which the second period begins and, thus, the second period profits of each firm.

Thus, the first period equilibrium pricing strategies, $P_1^I(q^L)$, $P_1^e(q^H)$, and $P_1^e(q^L)$, are selected to maximize first period profit plus a discounted second period profit, where each firm takes as given the equilibrium strategies of all other players. As in the static game, prices are selected simultaneously. I therefore chooses $P_1^I(q^L)$ knowing that $P_1^e(q^H)$ will be simultaneously picked with probability δ and $P_1^e(q^L)$ will be simultaneously selected with probability $1-\delta$. I then chooses $P_1^I(q^L)$ to maximize the expected value of its game profit.

With our equilibrium concept now understood, we are ready to state and prove propositions of importance to economists. In stating the results, a separating (pooling) dynamic equilibrium is understood to be a dynamic equilibrium in which $P_1^e(q^H) \neq P_1^e(q^L)$ $\left(P_1^e(q^H) = P_1^e(q^L)\right)$. Also, when we speak of a firm's market share, we will be referring to first period market share (unless otherwise stated).

We come now to our first proposition for the dynamic game.

Proposition 3: There exists no separating dynamic equilibrium.

The proof of this proposition is in Appendix 2. Intuitively, if a separating equilibrium were to exist, then all information would be revealed, and so I and L would find themselves in a very competitive relationship. In fact, $P_1^e(q^L) = P_1^I(q^L) = c^L$ (the usual Bertrand solution) would be necessary, and I and L would make zero game profit. Thus, if H is to separate and get market share, $P_1^e(q^H) < c^L$ is needed, lest **L** mimic **H**. But, since $P_1^I(q^L) = c^L$, there is no reason for **H** to price below c^L - a slight price raise, even if thought to signal low quality, would still attract the entire market. Hence, **H** can not separate with a price below c^L, since there always exists a slightly higher price that gives more profit.[13] Further, it can not be that **H** separates and gets no market share, since **L** could mimic **H**'s price in period one, enter period two believed to be **H**, and make a period two profit. Separating dynamic equilibria are thus impossible.

In light of Proposition 3, we need look only for pooling equilibria. The following assumption (discussed below) is important to the next proposition.

$$\text{A:}\quad (c^L-c^H)\cdot M + \alpha\cdot(P^H-P^L+c^L-c^H)\cdot M > \max[0,\alpha\cdot(P^\delta-P^L-c^L-c^H)\cdot M],$$

where $\alpha \in (0,1)$ is the discount factor.

Proposition 4: Suppose that A holds.

1). In any (pooling) dynamic equilibrium, **E** gets market share.

2). The only (pooling) dynamic equilibrium in which **I** gets some market share has $P_1^I(q^L) = c^L$, $P_1^e(q^H) = P_1^e(q^L) = P^\delta - P^L + c^L$.

3). The set of (pooling) dynamic equilibria in which **I** gets no market share is characterized by $c^L \leqslant P_1^I(q^L) \leqslant P_1^e(q^H)$, $c^L \leqslant P_1^e(q^H) \leqslant P^\delta - P^L + c^L$, and $P_1^e(q^H) = P_1^e(q^L)$.

Consider first part 1 of the proposition. We see here that the pooling **E** always gets market share when A holds. Thus, if **E** is **H**, then **I** is at least partially displaced in period one and **I** is completely displaced in period two (since communication is perfect). When A holds, inefficiency does not persist, and the informational entry barrier is not effective. Notice that A is more likely to hold the larger $P^H - c^H$ is relative to $P^L - c^L$. A "very" efficient entrant, then, can always overcome informational disadvantages.

A formal proof of part 1 is not difficult. Suppose to the contrary that a (pooling) dynamic equilibrium exists in which **E** gets no market share. What is the maximum profit that **H** could make in such an equilibrium? By assumption, **H** makes zero first period profit. Since first period prices are pooled, **H** enters period two with a product believed to be high quality with probability δ. Using Proposition 1 (with $r = \delta$), we see that **H** can at most make $\max[0, \alpha\cdot(P^\delta - P^L + c^L - c^H)\cdot M]$ discounted profit in an equilibrium of the described type. Notice also from Proposition 1 that **I** makes zero second period profit when **E** enters period two with $r = \delta$. Since **I** gets market share, it must therefore be that $P_1^I(q^L) \geqslant c^L$. The contradiction is now immediate. By charging a first period price of c^L (perhaps less ε), **H** could get all market share, even if it were initially thought to be **L.** **H** could then enter period two with a product of known quality and make a second period profit of $(P^H - P^L + c^L - c^H)\cdot M$ (see Proposition 2). Under assumption A, **H** would undertake this deviation, thereby destroying the putative pooling equilibrium. This proves part 1. The essential point is that a "very" efficient entrant is willing to undercut **I**, if such behavior is needed to gain market share.

Thus, when A holds, it must be that pooling occurs in period one and **E** gets market share. In parts 2 and 3 of Proposition 4, it is claimed that $P_1^e(q^H) = P_1^e(q^L) \leqslant P^\delta - P^L + c^L$ is also necessary for equilibrium when A holds. The argument is intuitive. If **E** pooled its first period price at $P_1^e(q^H) > P^\delta - P^L + c^L$, then **I** could make consumers indifferent with the price $P^L - P^\delta + P_1^e(q^H)$. Since this latter price exceeds c^L, **I** would charge $P^L - P^\delta + P_1^e(q^H) - \varepsilon$, which gives **I** all of the market, rather than allow **E** to get any of the market. But we know **E** must pool and get market share. It must therefore be that $P_1^e(q^H) = P_1^e(q^L) \leqslant P^\delta - P^L + c^L$. Put differently, since **E** must pool and get market share, it can not be that **E** pools at too high a price, lest **I** take the market at a profit. A more formal argument is given in Appendix 2, where parts 2 and 3 are proved.

Notice that when **E** gets all market share **E**'s first period price may be as low as c^L. (Under A, **H** is willing to charge c^L, and of course **L** will never go below c^L to attract business.) **H** may therefore be required to initially price below c^H in order to remove the inefficient incumbent. That is, efficient entry may come with an introductory price below marginal cost. Furthermore, if $P^\delta - P^L + c^L < c^H$ and A holds, then, in <u>any</u> equilibrium, **H** displaces **I** (immediately or eventually) and **H** introduces its product at a price below marginal cost. In short, an "unexpected" (small δ) but "very" efficient (A holds) product always wins the market from the inefficient incumbent, and it always does so with an introductory offer that is below marginal cost.

The behavior of **H** might, on the surface, appear predatory. After all, **H** comes into the market, prices below cost, wins the entire market from **I**, and then raises price.[14] But appearances are deceptive. **H**'s low introductory price is really an investment in information diffusion; equivalently, it is a form of insurance for consumers. Thus, as Demsetz (1982) has argued, when our notion of cost is expanded to include informational investments, **H** may in fact be pricing at or above its "true" cost. In any case, (production) cost-based definitions of predation are surely inappropriate for young firms in experience goods markets. Indeed, if **H** is "unexpected" and "very" efficient, then, in <u>any</u> equilibrium, successful and efficient entry occurs via a violation of the Areeda-Turner rule!

Given Proposition 4, we are led to wonder what happens when A fails. Does efficient entry still occur or does an informational barrier to entry emerge? If A fails, H can no longer assure itself market share with the threat of undercutting I, for this threat is no longer credible. This, in turn, means that distinctly new equilibria may appear when A fails. In fact, the next proposition shows that, if A fails, then there exists a dynamic equilibrium in which I gets all market share in both the first and second periods. Inefficiency persists because of informational product differentiation. Furthermore, I keeps all of the market without pricing below cost; that is, I blocks efficient entry without violating the Areeda-Turner rule!

Before stating Proposition 5, it is convenient to make a definition. Let P^* be the P that solves $(P-c^H)\cdot M + \alpha\cdot(P^H-P^L+c^L-c^H)\cdot M = 0$. Thus, if $P^* \geqslant c^L$, then A fails.

<u>Proposition 5</u>: Suppose $P^* \geqslant c^L$. Then there exists a (pooling) dynamic equilibrium in which I gets all market share in both the first and second periods. In this equilibrium, $P_1^I(q^L) = c^L$ and $P_1^e(q^H) = P_1^e(q^L) = P^\delta - P^L + c^L$.

In words, if H is relatively efficient, but not "very" efficient, then it may be that H never gets market share. THe guiding intuition is straightforward. Suppose that consumers believe that low, aggressive prices signal low quality. Then, if H is to get market share, it must actually undercut I's price. When $P^* \geqslant c^L$, I can pick its price low enough that the initial cost to H of establishing its quality (viz, pricing below $P_1^I(q^L)$) exceeds the future benefits of having known high quality.

The formal proof goes as follows. Specify as the static equilibrium (for any r) the separating equilibrium described in Proposition 1, with I getting all market share. Choose beliefs such that $b_1(P^\delta-P^L+c^L) = \delta$ and, for all

$P_1^e > c^L$, $b_1(P_1^e) \leqslant (P_1^e - c^L)/(P^H - P^L)$. Allow any beliefs for entrant prices at or below c^L. The line $b_1(P_1^e) = (P_1^e - c^L)/(P^H - P^L)$ is represented in Figure 1. Notice that a wide range of possible beliefs are allowed under this formulation. In particular, consumers are allowed to associate higher prices with higher qualities (i.e., b_1 can be an increasing function).

We claim now that the dynamic equilibrium described in Proposition 5 exists. To prove this, we need only to show that no player has incentive to deviate in period one. Consider first the consumers. Given their beliefs, they are indifferent between buying from **E** at $P^\delta - P^L + c^L$ and buying from **I** at c^L. Thus, an optimal response is to buy from **I**. (Such indifference is necessary for an equilibrium in which **I** gets all market share. If consumers strictly preferred **I** to the pooling **E**, then **I** would raise its price until consumers became indifferent.) Consider next **I**. There is clearly no reason for **I** to deviate. $P_1^I(q^L) < c^L$ causes negative game profit and $P_1^I(q^L) > c^L$ causes all market share to be lost and zero game profit to be made.

The more interesting players are **H** and **L**. Given the above belief structure, a deviant price above c^L will not gain market share. Thus, such a price generates zero first period profits and no second period profit. Consider then deviant prices at or below c^L. **L** makes zero second period profit when its type is known, so **L** has no incentive to charge c^L or less. Since $P^* \geqslant c^L$, **H** also will not price at or below c^L in order to attract business.[15] Thus, neither **H** nor **L** has incentive to deviate, and Proposition 5 is proved.

Proposition 5 shows that an equilibrium exists in which efficient entry is permanently barred. In Proposition 6, we find conditions under which, in <u>any</u> equilibrium, efficient entry is at least partially barred in the first period.

Proposition 6: Suppose $P^* > P^\delta - P^L + c^L$. Then in any dynamic equilibrium, I gets market share.

The proof is short. If I were to get no market share, then all market share would go to the pooling **E**, and so $P^\delta - P_1^e(q^H) \geq P^L - c^L$ would be necessary. But then $P_1^e(q^H) \leq P^\delta - P^L + c^L < P^*$ and, by the definition of P^*, **H** makes negative game profit. Thus, it must be that I gets market share.

Put differently, if **H** is "unexpected" and not "very" efficient, then in any dynamic equilibrium an informational barrier to entry exists, to some extent. Since $P^* > P^\delta - P^L + c^L$ implies $P^* > c^L$, we know that one such equilibrium which exists is the one described in Proposition 5, where **H** is permanently and completely barred from market share.

V. Extensions, Qualifications, and Summary

A basic point in the preceding analysis is that the beliefs of consumers matter. When consumers must form conjectures about the quality of the entrant's product, we can not conclude that free entry will remove inefficiencies or that prices below marginal cost are necessarily bad.

Since beliefs do matter, we are led to ask what it means to specify beliefs in a "plausible" way. We mention now that the beliefs used above satisfy three "plausibility" refinements that have been suggested in the literature. Namely, the beliefs underlying the above propositions satisfy the structural consistency requirement, put zero weight on dominated strategies, and generate equilibria which satisfy Kreps' (1984) "intuitive criterion."[16] It is also important to recall the following: From Proposition 4, an "unexpected" but "very" efficient **H** always wins the market, and it always does so by introducing its product at a price below marginal cost. Beliefs which could not support such behavior can be part of no equilibrium. Recall also that Proposition 6 states that all equilibria involve a barrier to entry to some extent, when **H** is "unexpected" and not "very" efficient. Again, beliefs unable to support such behavior can not be part of an equilibrium.

We claimed earlier that our assumptions are "pro-entry," with the possible exception of the assumption that consumers are myopically rational. Namely, it would seem that far-sighted consumers would have greater incentive to try **E**'s product (in order to gain information) and that **E** is therefore disadvantaged by the assumption that consumers behave in a myopically rational fashion. This point has some merit, but, as we argue below, the myopia assumption is not central to the basic gist of the paper.

Consider first the "myopic equilibria" described above in which **E** gets market share. Would the same equilibria survive if consumers were far-sighted? The only difference between far-sighted and myopic consumers is that the former group has an incentive to seek out information. But notice that since consumers communicate perfectly, information is a pure public good. This means that, given some consumers are buying from **E**, the rational thing for the individual consumer to do is maximize instantaneous expected utility. Thus, the "myopic equillbria" in which **E** gets market share are also "far-sighted equilibria." In these equilibria, myopia is rational and nothing is lost in assuming consumers behave in a myopically rational manner.

In the "myopic equilibrium" of Proposition 5, **E** gets no market share. In this case, the incentives of the myopic and far-sighted consumer differ, as the latter is more willing to buy from **E**. It seems clear, though, that the same result -- there exist dynamic equilibria in which **E** never gets market share -- would obtain if consumers were far-sighted ($P_1^e(q^H) = P_1^e(q^L)$ would presumably be slightly higher; otherwise, the argument would go through as before.)

We have assumed throughout that the entrant's quality type is known to be at least as good as that of the incumbent. This assumption was made in order to show that, even in this "pro-entry" case, a barrier to market share can exist. An interesting extension would be to allow for, say, three quality types. Suppose, for example, that the incumbent has a medium quality type, while the entrant's quality type is either high or low (with higher quality always more efficient). In this framework, the incumbent can make positive second period profit, provided consumers think (or know) that the entrant's quality type is low. Were the incumbent to know the entrant's quality type, we might then find the incumbent manipulating the information sets of consumers in a predatory way. In particular, the incumbent would have incentive to respond to high quality entry with a low price. This strategy lures consumers into the incumbent store and prevents then from learning about the entrant's type. Is there a notion of predation for this strategic blocking of the flow of information? Of course, if consumers were fully rational, they would recognize this price-cutting incentive, and they would use both the incumbent's price and the entrant's price in conjecturing the entrant's type. Can strategic information blocking occur with rational consumers? We avoid these issues by assuming a two-type model in which the incumbent knows no more about the entrant than do consumers. Clearly, much interesting work remains.

Footnotes

1 See, for example, Schmalensee (1979, 1982a, 1982b), Farrell (1986), and Dean (1969). In the marketing literature, see Porter (1980), Thomas (1985), and Yip (1982). See also the marketing research survey of Rao (1984) and the survey of related work in economics by Roberts (1985).

2 Indeed, Bain (p. 3) writes that barriers to entry can be assessed "by the advantages of established sellers in an industry over potential entrant sellers, those advantages being reflected in the extent to which established sellers can persistently raise their prices above a competitive level without attracting new firms to enter the industry."

3 Interestingly, in the model developed below, a welfare-maximizing social planner would remove the incumbent in favor of the entrant, even if the planner were informationally constrained to be ignorant of the entrant's actual quality. Thus, when an entry barrier occurs, the "market" outcome is inefficient relative to the "planned" outcome, whether or not the planner is assumed to know entrant quality.

4 See Bork (1978), pp. 7-8; Posner (1976), pp, 8-22; and Schmalensee (1979), p. 994. All three support this position.

5 One such standard is given by Posner (1976), who defines predatory pricing as "pricing at a level calculated to exclude from the market an equally or more efficient competitor" (p. 188). As Schmalensee (1979) has pointed out, however, Posner's standard may be difficult to implement.

6 Areeda and Turner (1975) are aware of this latter exception to their rule. Indeed, they acknowledge that beneficial entry may involve low promotional prices. The present paper formalizes this point and

illustrates when efficient entry necessarily involves a violation of the Areeda-Turner rule. See Areeda (1981) and Demsetz (1982) for more on "legitimate" versus predatory promotional pricing strategies. A relevant court case is Buffalo Courier-Express v. Buffalo Evening News. The court found there that the entrant's five-week giveaway strategy was not predatory. See also Lormar v. Kroger Co. and Utah Pie Co. v. Continental Baking Co.

7 If consumers did not communicate and if returns to scale were constant (as is assumed below), then, even if rationing were allowed, it would not be optimal. The no-communication model can be technically messy, however. In particular, consider the possibility that some consumers buy from the incumbent in period one and others buy from the entrant. Then, in period two, some consumers are informed of entrant quality and others aren't, and the resulting signalling game is quite complex: the latter group must guess the size of the former group in order to accurately use the entrant's second period price as a signal of quality. We avoid this complication by assuming perfect communication.

8 This assumption is admittedly at odds with the interesting work of Grossman, Kihlstrom, and Mirman (1977).

9 Implicitly, we are assuming that the incumbent can't buy the entrant's product and that consumers communicate their experiences to the incumbent. Presumably, the entrant would be worse off if its type were known to the incumbent.

10 For more on dominated strategies, see Milgrom and Roberts (1986). For applications of this refinement to specific games, see also Bagwell (forthcoming) and Kreps (1984).

11 Kreps and Ramey (forthcoming) have shown that structural consistency is

not always the same as the sequential equilibrium notion of consistency. For our purposes, it is sufficient to note that their counter example does not apply to our game.

12 The use of beliefs as sufficient statistics for past play is typically referred to as a "Markov" refinement. See Kreps and Wilson (1982b) for an original use of this refinement.

13 If the set of possible prices is finite, then a separating equilibrium may exist. In this equilibrium, $P_1^I(q^L) = c^L = P_1^e(q^L)$ and $P_1^e(q^H) = a$, where a is the largest price less than c^L. The existence of this equilibrium would change none of the qualitative results of the paper. Notice in particular that $a < c^H$ and that the separating equilibrium does not exist when assumption A (defined below) fails.

14 The concept of a predatory entrant is not foreign to the courts. See, e.g., Buffalo Courier-Express v. Buffalo Evening News and footnote 4 above.

15 H would price at c^L if only a few of the indifferent consumers would buy from it. Due to perfect communication, this would minimize first period loss and still give second period gain. Assume, then, that all indifferent consumers go to one firm or the other.

16 See Kreps (1984) for his criterion. For applications, see also Bagwell (forthcoming), Bagwell and Riordan (1986), and Milgrom and Roberts (1986).

Appendix 1

We prove here Proposition 1. We begin by considering separating equilibria.

Our first claim is that separating static equilibria can not exist in which **H** gets market share. Suppose to the contrary that **H** gets market share and that $P_2^e(q^H) \neq P_2^e(q^L)$. $P_2^e(q^H) \geqslant c^H > c^L$ necessary, and so it must be that **L** also gets market share (or **L** would mimic **H**). Thus, $P_2^I(q^L) \geqslant P_2^e(q^L)$ is required. Notice that $P_2^I(q^L) > P_2^e(q^L)$ is impossible: If $P_2^e(q^L) < P^L$, then **L** would increase its price, and, if $P_2^e(q^L) = P^L$, then **I** would undercut **L**. So, $P_2^I(q^L) = P_2^e(q^L)$ is necessary. But $P_2^I(q^L) = P_2^e(q^L) > c^L$ is impossible, since **I** or **L** would have incentive to cut price slightly in order to get the whole market. Hence, $P_2^I(q^L) = P_2^e(q^L) = c^L$. But then **L** makes zero profit and would mimic **H**.

Our second claim is that $P_2^I(q^L) = c^L$ is necessary for separation in the static game. Suppose instead that $P_2^I(q^L) > c^L$. Clearly, $P_2^e(q^L) \leqslant P_2^I(q^L)$ is necessary; otherwise, **L** would undercut **I**'s price. But $P_2^e(q^L) < P_2^I(q^L)$ and $P_2^e(q^L) = P_2^I(q^L) > c^L$ are impossible (see above). Thus, $P_2^e(q^L) = P_2^I(q^L) = c^L$, contradicting $P_2^I(q^L) > c^L$.

Third, notice that $P_2^e(q^L) = c^L$ is necessary for static separation; otherwise, **I** would increase price and hope that **E** is **L**.

Fourth, observe that $P_2^e(q^H) = P^H - P^L + c^L$ is necessary in a separating static equilibrium. Since **H** gets no market share, $P^L - c^L \geqslant P^H - P_2^e(q^H)$ is required. In fact, $P^L - c^L = P^H - P_2^e(q^H)$ is needed or I would increase its price (and hope that **E** is **H**). Thus, $P_2^e(q^L) = c^L = P_2^I(q^L)$, $P_2^e(q^H) = P^H - P^L + c^L$, and no market share to **H** are all necessary in a separating static equilibrium. Any split of the market between **I** and **L** is allowed. To show that these conditions are sufficient for an equilibrium, let $b_2(P_2^e) = 0$, for all $P_2^e \neq P^H - P^L + c^L$. Then it is easy to verify that no agent has incentive to deviate.

We turn our attention next to the possibility of pooling equilibria. Our first claim here is that, if a pooling equilibrium exists in which I gets some or all market share, then $P_2^I(q^L) = c^L$ and $P_2^e(q^H) = P_2^e(q^L) = P^r - P^L + c^L$. The proof is as follows. Suppose pooling occurs and I gets some or all market share. Then $P^L - P_2^I(q^L) \geq P^r - P_2^e(q^H)$ is necessary. In fact, $P^L - P_2^I(q^L) = P^r - P_2^e(q^H)$ is required; otherwise, I would increase price. $P_2^I(q^L) > c^L$ is impossible: I or L would have incentive to cut price slightly. Specifically, if I gets some market share at $P_2^I(q^L) > c^L$, then I would cut price slightly and get all market share. If I gets all market share at $P_2^I(q^L) > c^L$, then L would undercut I slightly and get all market share with $P_2^I(q^L) - \varepsilon > c^L$. Thus, $P_2^I(q^L) = c^L$ and so $P_2^e(q^H) = P_2^e(q^L) = P^r - P^L = c^L$ is necessary.

If $P^r - P^L + c^L \geq c^H$, then it is easy to verify that equilibria exist in which I gets some or all market share. Simply set $b_2(P^r - P^L + c^L) = r$ and $b_2(P_2^e) = 0$, for all $P_2^e \neq P^r - P^L + c^L$. Then no agent will deviate. If $P^r - P^L + c^L < c^H$, then static pooling equilibria in which I gets some or all market share can not exist, because H will not price below c^H.

Our second claim is that, if a pooling equilibrium exists in which I gets no market share, then $c^L \leq P_2^I(q^L) \leq P_2^e(q^H)$, $c^H \leq P_2^e(q^H) \leq P^r - P^L + c^L$, and $P_2^e(q^H) = P_2^e(q^L)$. $P_2^I(q^L) \leq P_2^e(q^H)$ is necessary to prevent L from raising its price, and $P_2^e(q^H) \leq P^r - P^L + c^L$ is necessary to prevent I from picking up profit with the price $c^L + \varepsilon$.

If $P^r - P^L + c^L \geq c^H$, these necessary conditions are sufficient for a static pooling equilibrium in which I gets no market share. Simply pick the usual pessimistic beliefs. If $P^r - P^L + c^L < c^H$, then static pooling equilibria in which **I** gets no market share can not exist, since **H** will not price below c^H.

Appendix 2

We prove here Proposition 3 and 4. We begin with the following lemma.

Lemma 1: In any dynamic equilibrium, **I** makes zero second period profit.

The proof is short. By Propositions 1 and 2, **I** makes zero second period profit if **E** pools in period one and gets no market share, and if **I**'s actual opponent gets market share. The "passive" belief structure is sufficient to guarantee zero second period profit to **I** in the remaining case, where **E** separates and **I**'s actual opponent gets no market share. This proves Lemma 1.

The following lemma will also prove useful.

Lemma 2: In any separating dynamic equilibrium, **L** makes zero game profit.

To prove this lemma, suppose a separating dynamic equilibrium exists. Consider period 2. If separation occurred in period one, then either **L** is now known to have a low quality product or **L** is now believed (r=0) to have a low quality product. In either case, **L** makes zero second period profit. Consider then period one. **L** can profit here only if it gets market share; thus, $P_1^I(q^L) \geqslant P_1^e(q^L) > c^L$ is necessary for **L** to profit when separation occurs. $P_1^e(q^L) < P_1^I(q^L)$ is certainly impossible: If $P_1^e(q^L) < P^L$, then **L** would increase price; whereas, if $P_1^e(q^L) = P^L$, then **I** gets no market share and (Lemma 1) makes no game profit, so **I** would undercut **L**. Thus, $P_1^I(q^L) = P_1^e(q^L) > c^L$ is required for **L** to profit when separation occurs. But this can't be, as either **I** or **L** would have incentive to cut price. Specifically, **L** would cut price slightly unless it got all market share, and, if **L** got all market share, **I** would cut price slightly (even if **I** were already getting market share when **E** is **H**). Thus, $P_1^I(q^L) = P_1^e(q^L) > c^L$ is impossible, which proves Lemma 2.

We can now prove Proposition 3. By Lemma 2, it can not be that a separating dynamic equilibrium exists in which 1) **H** gets market share with $P_1^e(q^H) > c^L$ or 2) **H** gets no market share. In the former case, **L** would mimic **H** for first period profits; whereas, in the latter case, **L** would mimic **H** in order to be believed (r=1) **H** so that second period profits could be made.

Thus, if a dynamic separating equilibrium is to exist, then $P_1^e(q^H) < c^L$ is necessary. Now, $P_1^I(q^L) \geqslant c^L$ is true in a dynamic separating equilibrium; otherwise, I would get market share when **E** is **L** and make negative game profit (by Lemma 1). Thus, $P_1^e(q^H) < c^L$ is impossible: **H** could raise price slightly and, regardless of what consumers believe the new price to signal, continue to get all market share. We therefore have a contradiction, and so Proposition 3 is proved.

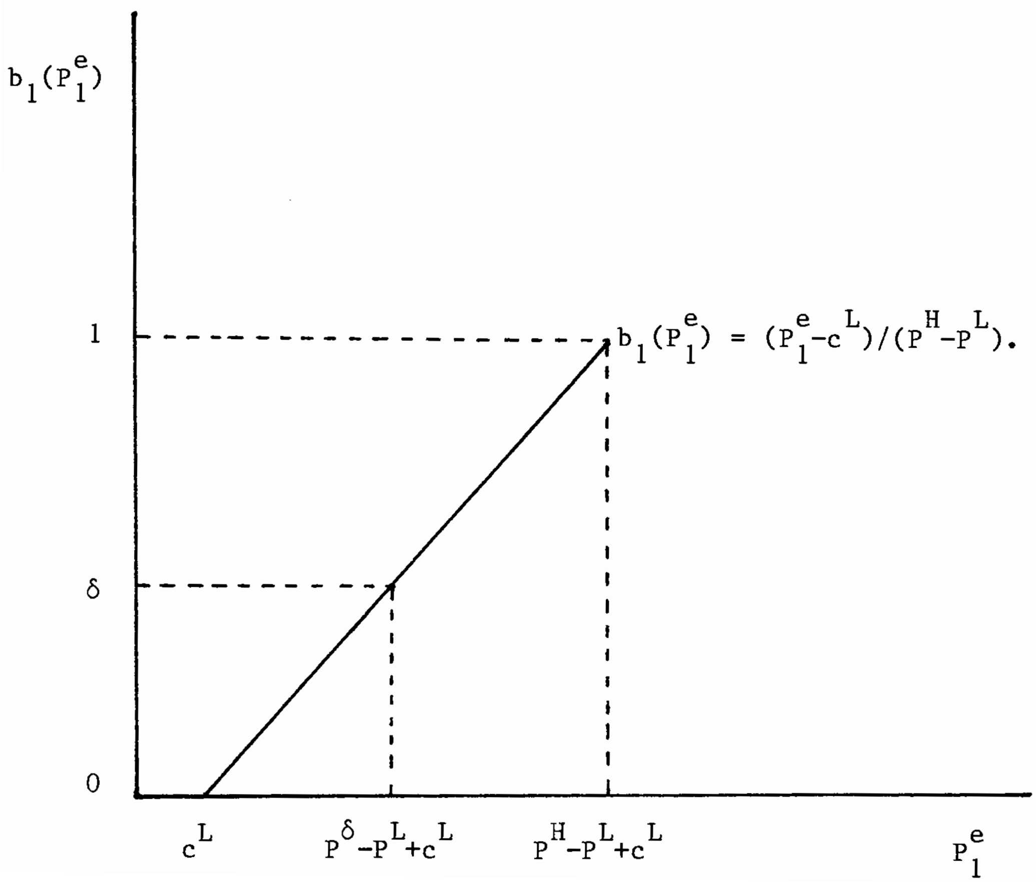
We prove next Proposition 4. Part 1 is proved in the text. Consider part 2. If I gets some market share, then $P^\delta - P_1^e(q^H) = P^L - P_1^I(q^L)$ is necessary. $P_1^I(q^L) \leqslant c^L$ is also necessary; for, if $P_1^I(q^L) > c^L$, then **I** would cut price slightly (use Propositions 1 and 2). $P_1^I(q^L) < c^L$ is of course not true. Thus, $P_1^I(q^L) = c^L$, and so $P_1^e(q^H) = P_1^e(q^L) = P^\delta - P^L + c^L$. These conditions are also sufficient for a dynamic equilibrium. Construct the usual pessimistic beliefs ($b_1(P_1^e) = 0$ if $P_1^e \neq P^\delta - P^L + c^L$ and $b_1(P_1^e) = \delta$ if

$P_1^e = P^\delta - P^L + c^L$). I clearly has no profitable deviation. If $P_1^e > c^L$ is announced, then consumers believe **E** to be **L** and buy from **I**. Such prices generate zero game profit for both **H** and **L**. The remaining deviant prices are $P_1^e \leqslant c^L$. But these prices are not attractive to either **H** or **L**. Notice that assumption A is important in guaranteeing that **H** makes positive profit in the desired equilibrium.

Moving on to part 3, if **I** gets no market share, then it is necessary that 1) $P^\delta - P_1^e(q^H) \geqslant P^L - c^L$ (or **I** would charge $c^L + \varepsilon$ and profit), 2) $P_1^I(q^L) \leqslant P_1^e(q^H)$ (or **L** would raise price slightly and keep all customers), and 3) $P_1^e(q^H) \geqslant c^L$ (or **L** would make negative game profit). Strictly speaking, $P_1^I(q^L) < c^L$ is possible. We make the (harmless) requirement that $P_1^I(q^L)$ be no less than c^L in the spirit of eliminating dominated strategies: Given $P_1^e(q^H) = P_1^e(q^L)$, **I** makes zero second period profit whether **E**'s product is tried or not (use Propositions 1 and 2), and so a first period price below cost makes possible a negative profit and does not make possible a positive profit.

We now show that these conditions are sufficient for the existence of a dynamic equilibrium in which **I** gets no market share. Construct the usual pessimistic beliefs: $b_1\left(P_1^e(q^H)\right) = \delta$ and $b_1(P_1^e) = 0$, for all $P_1^e \neq P_1^e(q^H)$. Would any player deviate? It is easy to argue that consumers are playing optimally. Consider **I**. Since $P_1^e(q^H) = P_1^e(q^L) \leqslant P^\delta - P^L + c^L$, **I** can get market share only by pricing below c^L. This is not a profitable deviation for **I** (see above). Finally, consider **E**. As **E** is getting all market share, an incentive does not exist for price cuts. Also, if **E** were to raise price, then consumers would believe **E** to be **L**, and they would all thus buy from **I** (since $P_1^I(q^L) \leqslant P_1^e(q^H)$). This leads to a static (second) period game with $r = 0$. Thus, neither **H** nor **L** will raise price. Notice that assumption A guarantees nonnegative profits. Proposition 4 is thus proved.

Figure 1



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