Incumbents and the Diffusion of Information on Demand

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Abstract

This work discloses the conditions under which a well-established firm may skew the playing field to its advantage by deferring entry to future periods in a multi-period game, where two firms – an incumbent and an entrant - compete for consumers. It is assumed that the novice entrant firm lacks information about both the consumer reservation price for the low-quality product and the techniques required to produce the high-quality product (both already known to the incumbent).

The paper explores how successful market entry derives both from a firm's own capacity to utilize superior technology as well as in overriding its rival's ability to create information barriers to entry. Moreover, we illustrate how the incumbent might manipulate the playing field, while competing with potential entrants, by increasing the price *above* the monopoly price.

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1 Introduction

In many markets, entrants regularly confront firmly established incumbents. For example, it is worth recalling that in 1975 a small company called Microsoft was a newcomer to a market indisputably dominated at the time by IBM. Among the several factors affecting the competitive arena, entrants are hindered by the incumbent's superior management know-how. We can identify this know-how differential also at the level of world markets. With globalization many goods are available across newly created world markets, with the Southern Hemisphere noticeably benefiting from this development. And yet the same trend has presented new challenges for the domestic industries of the South, not least of which the facility of strong foreign corporations in exploiting advanced technology. Firms in the South are meeting these difficulties very slowly, mainly by gradually assimilating new technologies. Northern Hemisphere deep-rooted management know-how, including a keen perception of market forces continue to be a qualitative hurdle as the South poises itself in competition against the international veteran players .

The Economist has made it clear how crucial such know-how is to the success of a firm. In the car industry, for example, "the trick is to manage the flow of such products [new cars] so that offerings in the marketplace always remain reasonably fresh, without wasting profits on excessive investment in updates or re-design. If a car company gets this aspect of the product cycle wrong, it soon suffers." But can this knowledge sufficiently tilt the playing field to the incumbent's advantage to impede competition, at least in the short run?

This paper seeks to shed some light on this advantage (which is modeled here as "superior information on demand") and to demonstrate how first rate management know-how leads the established firms to throw up information barriers to entry. The paper, then, illustrates what impact, if any, this practice is having on entry deterrence.

In exploring the above issues, we shall assume a market for low- and high-quality products in which firms compete in prices. One firm, the entrant, does not have complete information on consumers' preferences, whereas the other, the incumbent, does. In particular the incumbent has private information about the consumer's reservation price for the low-quality product, and it is producing the high-quality product. The entrant, on the other hand, produces the low-quality product, and, after learning by doing, it can also produce the high-quality product, if it wishes to do so. Specifically, the entrant needs to make a sale – that is, price the low-quality product at or below the consumer reservation price for the low-quality product. Then, after it makes a sale, it can produce the high-quality product from the next period on. If however the entrant has not made a sale in the current period, it must sell the low-quality product in the next period. In other words, the entrant suffers an information deficit about both the consumer reservation price for the low-quality product and the techniques required to produce the high-quality product. The entrant also has a capacity constraint, if it produces the high-quality product. This ensures that both firms will make strictly positive profits when selling a homogenous, i.e., high-quality, product.

The interactions of the firms are modeled via a multi-period signaling game with a finite horizon in which, in each period, the incumbent sets the price for the high-quality product. The entrant, upon observing the price set by the incumbent for the high-quality, sets the price in the low-quality market. The paper also focuses on a perfect sequential equilibrium, in which consumers do not make mistakes. The latter assumption implies that if an entrant does not make a sale in the current period, it knows with certainty that the reservation value lies below the price for the low-quality product just charged.

The paper argues that an incumbent firm may hinder an entrant's ability to learn, and thus deter entry (by at least one period); in other words, our study points out that firms' ability to enter markets for differentiated goods is a function of not only a firm's ability to handle superior technology but also a rival firm's ability to create information obstacles to entry. More specifically, if both the reservation price and the capacity constraint are low enough, and the firms are patient enough, entry is deferred by at least one period.

Note first, that when there is asymmetry of information on demand – i.e., when the entrant is not informed about the consumer reservation price for the low-quality product – an incumbent who is deterring entry should price higher than when it is maximizing its current profits. The reason: Entry is deterred when the entrant does not make a sale, and the entrant's action is positively correlated with the incumbent's action in a perfect sequential equilibrium. Moreover, the incumbent gains from deterring entry if the discount factor is high enough – that is, if the incumbent is patient enough. The reason is that the cost of deterring entry lowers current-period profits, whereas the benefit gained by deterring entry is that of securing a higher stream of profits in the future. This is because later in the game, the entrant is able to compete in the high-quality market.

Then, since the entrant does not upgrade from a low- to a high-quality product when the consumer reservation price is high (since there is a capacity constraint on the amount the entrant can produce in the high-quality market, when the reservation price is high the entrant's profits will be greater if it produces the low-quality product), the incumbent accommodates entry. In other words, if the reservation value for the low-quality is high, then the incumbent signals this information to the entrant. In this case, the entrant does better by vertically differentiating and by producing the low-quality product; this holds true even after it has attained the required know-how to produce the high-quality product. When however the consumer reservation price is low, the entrant will earn low profit as a low-quality producer, and so the entrant will instead elect to produce the high-quality product once it has made a sale and developed sufficient know-how. In addition, the lower the cost to the entrant of pricing too high and not making a sale in the current period, the higher is the price it then sets in equilibrium for the low-quality product. This cost goes lower as the discount rate goes higher and as the capacity constraint goes lower. Thus, when the reservation value is low, the incumbent wants the entrant to "over-price" so that the entrant won't make a sale. Entry into the high-quality market will then be delayed by at least a period. Thus the incumbent pools when the reservation value is low, thereby concealing the true reservation value.

Summarizing the factors outlined above, we can state that the incumbent will decide to defer entry if (i) the consumer reservation price is low, (ii) the discount rate is sufficiently high, and (iii) the capacity constraint is sufficiently small. Moreover, since consumers do not make mistakes, if an entrant does not make a sale in the current period then it knows with certainty that the low-quality reservation price is below the current-period price and is thus better informed from the next period on. This property of the game implies that all information becomes known within a finite number of periods, as long as the horizon is long enough.

The remainder of this paper is organized as follows. Section 2 surveys the literature. Section 3 sets up the economic structure. Section 4 comments on the refinement used to derive a focal equilibrium. The multi-period equilibria is derived in Section 6. Some discussion and concluding remarks are offered in Section 7. All proofs are deferred to the Appendix.

2 Related Literature

Previous work has modeled entry-deterrence due to private information on the cost of production (e.g., Bagwell [2]), on consumers' knowledge of the quality of the good produced (e.g., Schmalensee [33]), and on the entrant's financial constraint (e.g., Bolton and Scharfstein [8]). By contrast, this work focuses on the asymmetry of information between two firms when only one of them is informed about consumer preferences. Furthermore, the paper brings an additional circumstance to the product-differentiation advantage of a well-established firm, thereby supplementing the three offered by Bain [6]. In particular it suggests that superior information on demand makes possible a temporary exclusion of entrants.

In deriving the cost associated with information barriers raised up against an infant industry, this paper complements Bagwell [3], Bagwell and Staiger [5], and Grossman and Horn [18], in the sense that such information barriers stem from incomplete information on consumers' preferences as opposed to on the quality of the good produced. The paper also complements the literature on predatory behavior (e.g., Milgrom and Roberts [29] and Kreps and Wilson [25]), in that a long-run player–the informed firm–tries to skew the playing field while competing with potential entrants, by increasing the price above the monopoly price (as opposed to decreasing the price below marginal cost, as implied by predatory behavior). Moreover, this paper shows how information barriers can harm an economy, since in the short run domestic prices may be higher then the monopoly profits.

The paper also complements those works in the literature that combine a signaling model with predatory behavior, among these being Fudenberg and Tirole [14], Riordan [30], Roberts [31], and Saloner [32], by combining a signaling model with asymmetric information on demand and assuming markets with differentiated products. Riordan [30] modeled uncertainty about demand, whereas Roberts [31] assumed incomplete information on demand in a two-period game. Both authors focused on homogeneous products. The other two papers focused on the cost side (Saloner [32] and Fudenberg and Tirole [14]). Moreover, Saloner [32] examined strategic pricing in a duopoly, in anticipation of a takeover of one by the other.

The current model draws upon the work of Bagwell and Riordan [4], who gave a rationale for high and declining prices in markets with differentiated products. See also Schmalensee [33], who showed the advantage of a pioneering firm in a reputation model. As opposed to both of those papers, the current paper assumes that consumers are informed about the product quality and that one firm does not have complete information on consumers' preferences.

3 The Economic Structure

There are T periods when it is assumed that there are many potential consumers, this being approximated by a continuum of mass M (Judd [23]), with each consumer having a potential demand of one unit. Following Bagwell and Riordan [4], it is assumed that consumers have a common reservation price, $r > 0$, for the low-quality product. On the other hand they have heterogeneous reservation prices for the high-quality product, which are uniformly distributed between r and $1 + r$. Differently from Bagwell and Riordan [4], however, two firms exist, as opposed to one, and r is not known to the potential entrant. Only the distribution characteristics are common knowledge; in other words, $\Pr(r_i) > 0$ is known for all $r_i \in \Gamma \equiv \{r_1, \ldots, r_N \mid \underline{r} \equiv r_N < \ldots < r_1 \equiv \overline{r}\}$, where $\Delta \equiv |r_{i+1} - r_i|$ for $i \in \{1, \ldots, N-1\}$ and where N denotes the number of elements in Γ such that $N < T$. The private information on the reservation price, i.e. r, is known to the potential entrant only after the latter has successfully entered the market; that is, only after the entrant has made a sale. Beliefs are formed using Baye's rule when possible, where $b_t(r|h)$ denotes the posterior belief at time t that, given the history h, the true value of the consumer reservation price for the low-quality product is r.

A consumer purchases a high-quality product that costs p_H, iff $(v - p_H) \geq (r - p_L)$ and $(v - p_H) \geq 0$, where the price of the low-quality product is denoted p_L and the consumer's reservation price for the high-quality product is v. Note that $(v - p_H)$ is the benefit if a consumer purchases a high-quality product, while $(r - p_L)$ is the benefit if he purchases a low-quality product. Hence, a consumer will purchase a high-quality product if $v \geq p_H$ and if $v \geq r + p_H - p_L$, with this implying that a fraction of consumers, $\int_{\max\{p_H, r+p_H-p_L\}}^{1+r} dx = 1 + r - \max\{p_H, r + p_H - p_L\}$, purchase the high-quality product. Therefore, when $p_L \leq r$, a fraction of consumers $\int_{p_L}^{p_H} dx = \max\{p_H, r + p_H - p_L\} - r$ purchase the low-quality product.

The firms' cost-sides are modeled next, where I denotes the incumbent and E the potential entrant. Let c_q denote a constant unit cost of production, q the quality of the product produced, L low quality and H high quality–such that $0 = c_L < c_H < 1$. It is assumed that if a firm has never produced either a low- or a high-quality product, then there is a fixed cost of producing a high-quality product, $\overline{F}$, which is very high. This cost-structure captures the notion that quality is costly, and that experience is essential.

Profits for firm i, $i \in \{E, I\}$, in period t are $\pi_t^i(\mathbf{p_t}, \mathbf{q_t}, r) = \left[p_t^i - c_q\right] D_t^i(\mathbf{p_t}, \mathbf{q_t}, r)$. Let $\mathbf{p_t} \equiv \left(p_t^I, p_t^E\right)$, $\mathbf{q_t} \equiv \left(H, q_t^E\right)$ and $\frac{\vartheta^2 \pi_t^i}{\vartheta {p_t^i}^2} < 0$. (Note that $q_t^I \equiv H$.) $D_t^i(\mathbf{p_t}, \mathbf{q_t}, r)$ denotes the demand that firm i faces in period t. p_t^i and q_t^i denote the price and quantity, respectively, set by firm i in period t. Also, by referring to "the incumbent of type r," we are implicitly saying that the value of the reservation price of the low-quality product, which is known to the incumbent, is r.

It is assumed that the potential entrant has a capacity constraint, $\alpha_H M$, if it produces the high-quality product, and that the quotas of the constrained firm are distributed by using the efficient-rationing rule where $0 < \alpha_H < \overline{\alpha} = \frac{1-c_H}{4}$ is assumed. This ensures that, when both firms produce high-quality products, it is optimal to play pure strategies.[1] (Note that the efficient-rationing rule maximizes expected consumer surplus.) The constraint is needed to ensure that both firms will make strictly positive profits when selling a homogenous, i.e., high-quality, product.

[1]Note that $\frac{1-c_H}{4}M$ is the Cournot outcome one arrives at when both firms produce the high-quality product, if both firms are symmetric and if $r = 0$. Note also that if α_H is too big, then the equilibrium strategies may be mixed strategies.

4 Refinements

This work takes the view that an off-equilibrium message is a special kind of signal, and that the incumbent should take into account the fact that a disequilibrium move could have a particular effect on the entrant's beliefs about the true value of r. This interpretation of beliefs is sometimes referred to as *forward induction* (see Banks and Sobel [7], Grossman and Perry [19], Kohlberg and Mertens [24], and Mailath, Okuno-Fujiwara and Postlewaite [28]). In other words, "when an off-equilibrium-path information set is reached, the player on the move in this information-set should not suppose that it was reached by mistake and then use the equilibrium strategies to go backward on the tree as in backward induction. Instead, the player should take into account what could have happened, but did not, in forming his beliefs about the nodes in the information-set and about what is likely to happen next."[2] This class of refinements underlies the off-equilibrium notion of the iterated deletion of weakly dominated strategies. Furthermore, the assumption that players do not make mistakes is extended to the consumers, as will be modeled in Section 6.

More specifically, the refinement used follows Grossman and Perry [19]; in other words, the paper focuses on perfect sequential equilibria (PSE). The idea of the proposed refinement is that the entrant, finding itself at an information-set that should not have been reached during the play of the game, should "try to interpret the move as a signal by an incumbent." Then a given sequential equilibrium is tested, as follows. For each information-set which is not on the equilibrium-path, the entrant hypothesizes that the move was made by some subset of types of the incumbent and *revises* its prior according to Bayes' rule, conditional upon the incumbent being within the specified subset of types. If this best response, given these beliefs, is preferred by precisely the prespecified subset of types, then the sequential equilibrium fails the test.

[2] Fudenberg and Tirole [15].

5 Single-Period Game

In the single-period game with complete-information firms interact only once, and the consumer reservation price, i.e. r, is common knowledge. By assumption the incumbent produces the high-quality product. On the other hand the entrant produces the low-quality product, since $\bar{F}$ is sufficiently high. Furthermore, an incumbent sets the price in the high-quality market when the price of its product is observed by an entrant, which subsequently enters the market and sets the price for the low-quality market. It can then be shown, while focusing on the sub-game perfect equilibrium (SPE), that the incumbent's best response is to accommodate entry.

Changing the information structure, such that only the incumbent is informed of the consumer valuation, does not alter the outcome of the game when focusing on PSE.[3] The reason: The incumbent's short-run profits are maximized if it accommodates entry and plays the equilibrium actions of the complete-information game, since this strategy minimizes the cost attributed to competition. That cost stems from the positive correlation between the entrant's and the incumbent's prices, given the entrant's best-response function $p^E = \min\left\{\frac{p^I}{2}, r\right\}$. In other words, if an incumbent of type r were to raise its price slightly to equal that of an incumbent of type $r + \Delta$, then the entrant would price higher. But the incumbent could have raised p^I and elicited a higher p^E in the complete-information game, too, and did not. To summarize: The entrant's response is fundamentally driven by p^I, so long as $p^E \leq \frac{p^I}{2}$.

As we shall discover in the following section, however, extending the game to multiple periods with asymmetric information does improve the incumbent's ability to compete; in other words, it heightens its ability to raise information barriers to entry (by affecting the entrants beliefs) and thereby skew the playing field to its advantage.

[3]This claim is derived in Hochman [22]

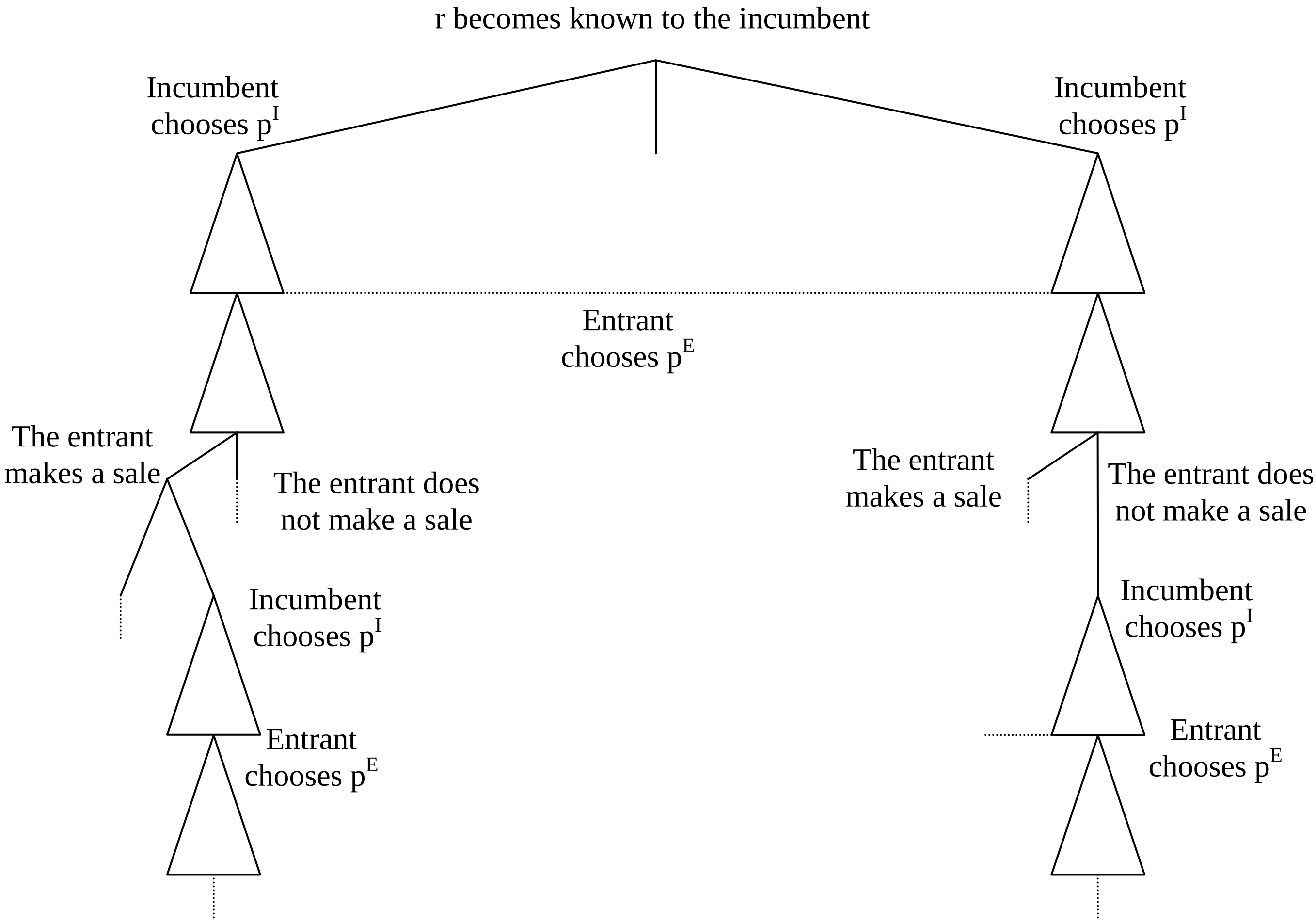

Figure 1: **Timing of the Game**

6 A Multi-Period Game

In period 0, "nature" chooses r, at which point it is revealed only to the incumbent (see Fig. 1). In period t, for $t = 1, 2 \ldots$, the incumbent chooses the price p_t^I; the entrant chooses the quality, q_t^E, and the price, p_t^E, of its product. Then sales are made such that the period payoffs are derived. It is assumed that the same entrant tries to enter the market in each period. One can also assume, however, that in every period a new entrant tries to enter the market until one of them has made a sale. The latter interpretation can be used to point out the important role being played by "fly-by-night" firms, with respect to the information they supply to a potential entrant.

Let us begin by defining the game formally. Denote as H_t the set of possible histories of moves taken by the firms from period 1 up to but not including period t, and let $h_t \in H_t$. In such a case an updating rule $g(.)$ is a mapping which for *each* h_t maps the set of probability distribution to itself. Thus if, just before p_t^I was observed, the entrant held beliefs b_{t-1}, it will hold beliefs $g\left(h_t, p_t^I; b_{t-1}\right) \in \wp$ after p_t^I has been observed where $\wp$ is the set of probability-distributions on Γ. Then, given the updating rule and the prior at time zero b_0, $g(.)$ can be used to compute the beliefs of the entrant at each of its node-belief pairs.

Before we define a credible updating rule, the pure metastrategies for the entrant and the incumbent must be defined. For the entrant, the metastrategy is a sequence defined on t such that

$$p_t^E : H_t \times \wp \rightarrow R_+ \qquad\qquad t = 1, 2, \ldots,$$

where $p_t^E\left(h_t, p_t^I, b\right)$ gives the response at time t after the entrant has observed history $< h_t$, $p_t^I >$ and has arrived at belief b about the incumbent's type. On the other hand, an incumbent of type $r \in \Gamma$ chooses a strategy that is a sequence defined on t such that

$$p_t^I : H_t \rightarrow R_+ \qquad\qquad t = 1, 2, \ldots,$$

where $p_t^I(h_t)$ gives the message sent at time t after history h_t has occurred.

Before we can derive the unique PSE, however, some formal definitions are required; these are in fact direct extensions of Grossman and Perry [19].

Definition 6.1 *Metastrategy*

Let $\sigma^E = \left\{p_t^E\right\}_{t=1}^T$ *denote the entrant's metastrategy, and let* $\sigma_r^I = \left\{p_t^I\right\}_{t=1}^T$ *denote the strategy of an incumbent of type* $r \in \Gamma$.

Definition 6.2 then helps us to broaden the definition of a credible updating rule as defined in Grossman and Perry [19], such that a degenerate belief with a support that does not include the true value of r is not possible as part of an equilibrium belief-function that encounters a deviant price. Also, let Φ_t denote the support of b_t.

Definition 6.2 *Beliefs Are Consistent with Consumer Behavior*

$g\left(h_t, p_t^I; b_{t-1}\right)$ *is said to be consistent with consumer behavior when the following conditions hold:*

1. h_t *implies that the entrant made a sale in period* $t-1$*:* $\Phi_t \equiv r^*$ *where* r^* *is the true value of* r*.*

2. h_t *implies that the entrant did not make a sale in period* $t-1$*. Then,*

$$\Phi_t = \left\langle \begin{array}{ll} \text{support of } b_{t-1} & \text{if support of } b_{t-1} \bigcap \text{ support of } \left(r < p_{t-1}^E\right) \neq \emptyset \\ \text{support of } \left(r < p_{t-1}^E\right) & \text{otherwise} \end{array} \right. .$$

Note that by saying "support of $\left(r < p_{t-1}^E\right)$" we are implying that the support includes all the values of r such that $r < p_{t-1}^E$. Note also that condition 1 implies that once a sale is made all information becomes common knowledge; in other words, consumers do not make mistakes in the game.

The stream of payoffs for the incumbent of type r is given by

$$v^I\left(\sigma_r^I, \sigma^E, r\right) = \sum_{t=1}^T \delta^{t-1} \pi_t^I(.),$$

and the entrant's payoff is

$$v^E\left(\sigma_r^I, \sigma^E, r\right) = \sum_{t=1}^T \delta^{t-1} \pi_t^E(.).$$

Next, a credible updating rule is defined for the multi-period game. If $K \subset \Gamma$ and $\Pr(K) > 0$, then b_k can be defined as the conditional distribution of type r, given that $r \in K$. Note that $\Pr(r) > 0$ iff $r \in \Phi$.

Then, given $\hat{\sigma}^I$, $\hat{\sigma}^E$, a node-belief $\left(h_t, p_t^I, b\right)$, and a set $K \subset \Gamma$ such that $\Pr(K) > 0$, we are able to say that K supports the updating rule $g\left(h_t, p_t^I; b_{t-1}\right)$ if for all $r \in K$ there exists a $\sigma_r^I(h_t)$ such that

$$v^I\left(\sigma_r^I, \hat{\sigma}^E\left(h_t, p_t^I(h_t), b_k\right), r\right) \geq v^I\left(\hat{\sigma}^I, \hat{\sigma}^E, r\right),$$

and if for all $r \in \{\Gamma - K\} \cap \Phi_t$,

$$v^I\left(\sigma_r^I, \hat{\sigma}^E\left(h_t, p_t^I\left(h_t\right), b_k\right), r\right) < v^I\left(\hat{\sigma}^I, \hat{\sigma}^E, r\right)$$

for all $\sigma_r^I\left(h_t\right)$.

Definition 6.3 *Credible Updating Rule*

The updating rule is credible at $\left(h_t, p_t^I, b\right)$, relative to σ^I and σ^E, if the following conditions hold:

1. *The support of $g\left(h_t, p_t^I; b\right)$ is in Φ_t.*
2. *There exists a $K \subset \Gamma$ that supports $g\left(h_t, p_t^I; b\right)$; if so, then $g\left(h_t, p_t^I; b\right) = b_k$.*
3. *$g\left(h_t, p_t^I; b\right)$ satisfies Bayes' rule, when $< h_t, p_t^I >$ is an outcome of σ^{I*} and σ^{E*} for some r.*

Condition 1 extends the notion of "credible belief" as defined in Grossman and Perry [19], since it does not allow the entrant to maintain its beliefs if they are degenerate and if their support does not include the true value of r.

Note that the incumbent knows r, whereas the entrant computes its expected payoffs $Ev^E\left(\sigma_r^I, \sigma^E, r\right)$, on the basis of its information about σ^I. Then let $\widehat{h}_t \equiv \left\langle h_t, p_t^I \right\rangle$, and let $p^E\left(\widehat{h}_t\right) \equiv \left\{p_i^E\right\}_{i=1}^T$ be the specification of the entrant's actions at each successor of $\widehat{h}_t$, as well as a specification of what the entrant has done along predecessors of $\widehat{h}_t$, such that the entrant solves

$$\max_{p^E\left(\widehat{h}_t\right)} Ev^E\left(\sigma_r^I, p^E\left(\widehat{h}_t\right), r|\widehat{h}_t\right),$$

where the posterior belief b is used.

Definition 6.4 *Sequentially Perfect*

Let $p^{E*}\left(\widehat{h}_t, \sigma_r^I, b\right)$ *be the* $\left\{p_i^E\right\}_{i=t}^T$ *that solves the entrant's maximization problem, and call it a best response to* σ_r^I *at* $\widehat{h}_t$, *b. If* p_t^{E*} *is the first element of* $p^{E*}\left(\widehat{h}_t, \sigma_r^I, b\right)$, *and if* $\sigma_t^{E*}\left(\widehat{h}_t, p_t^I, b\right) = p_t^{E*}$, *then* σ^{E*} *is sequentially perfect at* $\widehat{h}_t$ *for belief b. Thus,* σ^{E*} *is sequentially perfect if it is sequentially perfect at each and every history-belief pair.*

Let $p^I(h_t) \equiv \left\{p_i^I\right\}_{i=1}^T$ *be a specification of an incumbent of type r's action in every successor of* h_t*; note as well that* p_i^I *is required to be equal to the corresponding predecessor in* h_t *for* $i < t$*. Then* $\sigma_r^{I*}(h_t)$ *is sequentially perfect at* h_t *if* $\sigma_r^{I*}(h_t) \in \underset{p^I(h_t)}{argmax}\ v^I\left(p^I(h_t), \sigma^E, r|h_t\right)$.

Finally, a PSE for the multi-period game is defined.

Definition 6.5 *Perfect Sequential Equilibrium*

Taken jointly, an updating rule $g(.)$ *and metastrategies* $\left\{\sigma_r^{I*}\right\}_r$ *and* σ^{E*} *form a perfect sequential equilibrium iff*

1. $\left\{\sigma_r^{I*}\right\}_r$ *and* σ^{E*} *are sequentially perfect.*
2. *g is credible for all* $\left(h_t, p_t^I, b\right)$.

When $T \to \infty$ the set of equilibria is too big to provide us with any real insight into the significant impact that information barriers have on competition in markets for differentiated products. The reason is that when firms are patient enough, any one-period gain from deviation is outweighed by even a small loss in profits in every future period.[4] For this reason we turn now to a game having a finite horizon, i.e. $T < \infty$, and focusing on PSE. These assumptions will allow us to focus on a unique equilibrium, i.e., on a focal equilibrium.

6.1 General Properties of the Equilibria

Before we derive the PSE in the next subsection, some general properties of a sequential-equilibria profile are derived. We do so, however, while focusing on stationary strategies and

[4] For more on repeated games with an infinite horizon see Friedman [12], Fudenberg and Maskin [13], and Fudenberg and Tirole [15].

assuming that consumers do not make mistakes; in other words, if the entrant did not make a sale in period t, then it knows with certainty that $r < p_t^E$.[5] In what follows, $\widehat{t}$ denotes the time at which r is revealed to the entrant.

Lemma 1

If the entrant makes a sale in period $\widehat{t}$ and if $\underline{r} \leq r < \Psi$, then it produces the high-quality product in period t' for all $t' > \widehat{t}$, where $\Psi \equiv \frac{1}{4}\left[\alpha_H + \sqrt{\alpha_H\left(-7\alpha_H + 8\left(1 - c_H\right)\right)}\right]$.

Proof. This result can be derived by comparing the entrants profits from producing either the low- or the high-quality product, while assuming that r is common knowledge. ■

Thus, the entrant does not upgrade its product from low- to high-quality if the reservation price of the low-quality product is high enough. Note that the lower is the marginal cost of producing the high-quality product – i.e., c_H – and the larger is the capacity constraint – i.e., α_H – the larger is Ψ.

When we say, in what follows, that "the entrant believes the incumbent is in $[r_l, r_h]$," this means that the beliefs of the entrant are described by the conditional distribution of r', given that $r' \in [r_l, r_h]$ and that $r_l \leq r_h$. Lemma 2 follows directly from the assumption that consumers do not make mistakes.

Lemma 2 *Successive Skimming in a Pooling Equilibrium*

In a pooling equilibrium, and at any period t, if the entrant believes the incumbent is in $[r_l, r_h]$ in period $t-1$, and the entrant did not make a sale in period $t-1$, then in period t the entrant believes the incumbent is in $[r_l, r'_h]$, where $r'_h < r_h$.

Moreover, if in period $t' \leq t$ an entrant has priced its product at $p_{t'}^E$ and has made a sale, then an entrant that prices at $p_t^E < p_{t'}^E$ will enter the market with probability 1. To prove the latter, notice that since the entrant at t' did make a sale, $p_{t'}^E \leq r$.

[5] With respect to the importance of stationarity in dynamic programming, see Stokey and Lucas [34].

Next it is shown that r becomes common knowledge in a finite number of steps. This result, when it is taken along with the notion of metastrategies, greatly simplifies the derivation of the PSE.

Lemma 3

There exists a $T^* \leq N < \infty$ such that with probability 1 in all equilibria, r becomes common knowledge on or before T^*.

This follows from Lemma 2, since the number of elements in Γ, N, is finite, and since consumers do not make mistakes.

To summarize: Suppose that the entrant has beliefs $[r_l, r_h]$, in period $t \leq T^*$. If then, on the equilibrium path, the entrant's action is below the true value of r, r becomes common knowledge and the game becomes one of complete information. If on the other hand the entrant does not make a sale in period t, it updates its beliefs such that the support becomes $[r_l, p_t^E)$, where $p_t^E \leq r_h$. This repetition continues for at most T^* periods, after which r becomes common knowledge and the game continues as one of complete information. Furthermore, when the true value of r is common knowledge, the entrant produces the high-quality product if the incumbent is of type $r < \Psi$.

Now we shall begin to look more closely at a PSE, and therefore focus on a focal equilibrium in the multi-period game.

6.2 The PSE of the Multi-Period Game

Before we can derive the PSE, some additional notation has to be introduced. Let

$$A_t \equiv \{r \mid r \in \Phi_t\}$$

denote the set of realizations of r such that if $r \in A_t$ then an incumbent chooses the price p^I; and let

$$a_t \equiv \{\ \max\ r \mid r \in A_t\}.$$

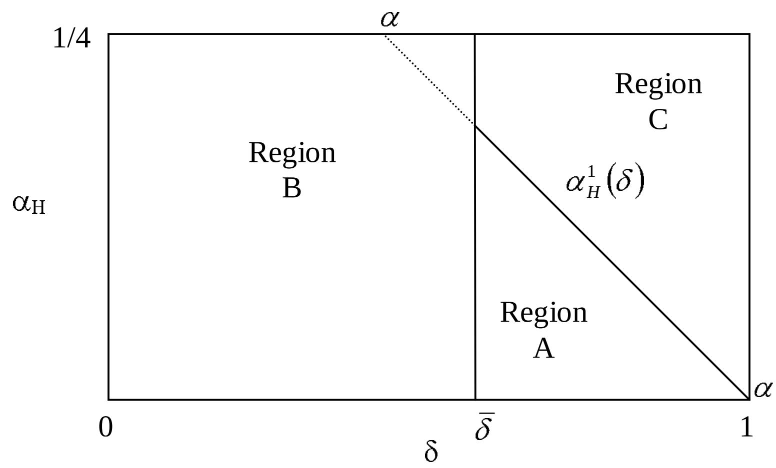

Figure 2: Characterizing the Incentives to Deter Entry

Next the PSE is derived.

Theorem 1

There exist $\overline{\delta}$ such that for all $\delta > \overline{\delta}$, $T > T(\delta)$, and all $\alpha_H < \alpha_H(\delta, T(\delta))$ a unique[6] *PSE exists such that, when $r < \Psi$, entry is delayed to period $t > 1$.*

Theorem 1 (depicted in Fig. 2) shows us that for values of δ and α_H localized somewhere in region A, entry is delayed; it also says that for a given δ we can always choose T, such that for $\alpha_H < \alpha_H(\delta, T(\delta)) \equiv \alpha_H^1(\delta)$, entry is delayed. Furthermore the curve $\alpha_H^1(\delta)$, which is denoted $\alpha\alpha$ in Fig. 2, is determined by the entrant's stream of profits; $\overline{\delta}$ on the other hand, is determined by the incumbents profits.

If the proposed search-strategy is not optimal for the entrant, such that the entrant's expected stream of profits swells when it prices lower than implied by Theorem 1, private information on the consumer reservation price is not sufficient for us to observe entry deterrence (region C in Fig. 2). In other words if, given δ, the capacity constraint is too big, the entrant prefers to price lower than implied by Theorem 1 since the expected cost of "under-pricing" today is smaller than the expected loss from entering the high-quality market later in the game. In

[6]By "uniqueness" we mean that the equilibrium outcome is unique. It may be that there is another equilibrium, in which the actions off the equilibrium path are different. Yet the on-equilibrium-path prices are the same as in the proposed equilibrium.

other words the entrant is willing to obtain lower profits today (to price lower than implied by the theorem) in order to secure higher profit-stream in the future. This in turn implies that it is optimal for the incumbent to accommodate entry, and to avoid incurring a cost by pricing higher than the monopoly price.

If, on the other hand, firms are very impatient, then both the entrant and the incumbent will want to maximize their current-period profits at the expense of future profit. In other words, if $\delta < \overline{\delta}$ then the incumbent will signal the true value of r and accommodate entry. This third case is denoted as region B in Fig. 2. Note that the incumbent accommodates entry in regions B and C, whereas it defers entry (by at least one period) in region A.

Let it be noted that if an entrant does not make a sale in the current period, it can always make a sale in the future, when it is better informed about r and hence knows with certainty that $r < p_t^E$. Note also that the cost to the entrant of not making a sale in the current period is lower, given a higher δ and a lower α_H. Furthermore, the incumbent gains from deterring entry if it is patient enough, since the increase in future payoffs from delaying entry is sufficiently high. (Remember too that the incumbent's current-period profits are maximized, if it accommodates entry.) Thus it can be seen, given the conditions stated in Theorem 1, that the incumbent gains from pooling with higher types and from pricing higher than the monopoly price, since under such conditions the entrant will "over-price" and not make a sale in the current period. Finally, note that if the consumer reservation price is high enough, the entrant will prefer to vertically differentiate itself and to produce the low-quality product, even once it has gained the required knowhow to produce the high-quality product.

These results inevitably bring to mind the Coasian Dynamics, these having been derived by Coase [10][7] for a monopoly selling a durable good:

1. *Skimming Property.* The higher the reservation price of the low-quality product, the earlier the entrant makes a sale. (In the case of a monopoly selling a durable good, the Coasian Dynamics imply that higher-valuation-type buyers buy earlier, since they are more impatient to consume.)

[7] See also Gul et al. [20].

2. *Monotonicity of Prices.* The equilibrium path exhibits a weakly decreasing sequence of prices until all information has become common knowledge. (This property also exists for a monopoly that sells durable goods, although, as pointed out in Fudenberg and Tirole [15], a stationary assumption may be needed.)

7 Discussion and Concluding Remarks

This work has attempted to shed some light on the ability of an informed firm to throw up information barriers against the entry of an uninformed firm. Moreover, this paper has been able to use a rational-expectation model to show that an informed firm can affect the learning of an uninformed firm, by influencing the entrant's belief updating. Put differently, this work points to the way an informed agent can prevent (for at least one period) an information-deficient firm from acquiring sufficient information to make a sale. The following two examples exemplify this conclusion. The first utilizes derived intuition to explain the long delay of firms from the South from penetrating international markets. The second example is of retail firms.

7.1 Product Cycle

The conclusion that, an incumbent possessing superior knowledge on demand can utilize this information asymmetry to skew the playing field to its advantage, is important for our understanding of the product cycle.[8] Since it affects the number of periods until the product is exported by firms from the South. In other words, it supplements the existing theory on the product cycle by pointing out that firms from the South lack not only the superior technology, but also the information, to produce the high-quality products. This asymmetric information on demand may be exploited by established firms from the North to prolong the learning pe-

[8]Raymond Vernon [35], in attempting to explain patterns of international trade, observed a circular phenomenon with respect to the composition of trade between countries in the world market. Advanced countries, which have the ability and the competence to innovate, high income levels, and mass consumption, become the initial exporters of goods. Nonetheless they lose their exports, initially to developing countries and subsequently to less developed ones, and eventually become importers of these goods. This patterns of international trade is commonly referred to as *the product cycle.*

riod required for the new entrants to produce the high-quality product. This helps explain the long duration these new entrants experience in penetrating international markets, as pointed out by the following quote:

> Between 1945 and 1980, the World Bank reckons, economic integration was concentrated among rich countries. Since 1980 that has changed. Manufactured goods rose from 25 percent of poor-country exports in 1980 to more than 80 percent in 1998. This integration was concentrated in two dozen countries including China, India and Mexico that are home to 3 billion people.[9]

In sum, the present paper supplements the existing literature on product cycles, which has chiefly focused on R&D and on technology transfer (e.g., Brezis et al. [9], Findlay [11], Grossman and Helpman [16] [17], Krugman [26], and Vernon [35],) and on property rights (Helpman [21] and Antras [1]). It does so by showing that all one really needs to observe a product cycle going on between the North and the South is asymmetric information on demand.

7.2 Retail Companies

The ability of an incumbent firm to deter entry, and thus the entrant's ability to learn about the consumer valuation of its good, implies the existence of an interesting strategy on the part of retail companies entering a low-quality market, where a high-quality market exists. Lazear [27] showed us that "the ability to sell products over time allows richer strategies for two reasons. First, if the good does not sell during the first period, the seller still has a chance of selling it during the next period. Second, the outcome of the first period provides the second-period seller with additional information."[10] The current paper predicts that an entrant will price its product higher than predicted by Lazear, given that a third effect, the competition effect, exists. Since the entrant's price in a PSE is non-decreasing in the incumbent's price which is non-decreasing in the consumer valuation, the incumbent has an incentive to signal a higher consumer valuation than the true valuation, if the incumbent is seeking to deter entry.

[9] "Going Global," *The Economist*, December 6, 2001.

[10] Lazear [27], p. 15.

Therefore, the proposed theory implies a link to the theory of retail firms. Lazear showed that a retail firm (seller) sets a higher price in a two-period than in a one-period game. Similarly, in the current setting the entrant prices its product higher than in the static game. Furthermore, this work complements Lazear and identifies a third effect, a competition effect. This third effect raises the retail firm's price further than predicted by Lazear, if the incumbent is seeking to deter entry. This follows from Theorem 1.

7.3 Future Work

This work has focused on competition in markets for differentiated products, and has looked closely at the incumbent's incentives to throw up information barriers to entry. A natural extension would be to assume that the entrant is financially constrained, with respect to purchasing capacity. Such an extension could help us to better understand the cost of "fly-by-night" firms, if we were to add an initial setup cost for the entrant. Another extension would be to allow for more than one potential entrant at any given time, and then to see how competition for entry was affecting the firms' behavior.

8 Appendix

Proof of Theorem 1 In what follows, let $\widetilde{p}^I(r)$ denote the complete information best response action of an incumbent of type r.

First, note that if $r > \Psi$, then the true value of r is revealed in period 1, since delaying entry imposes an unnecessary cost on the incumbent. (When $r > \Psi$, the entrant does not want to upgrade to a high-quality product.) Then, an incumbent of type r', where $r' < \Psi$, does not profit from mimicking an incumbent of type r'', where $r'' > \Psi$. The reason: $\pi^I\left(p_t^I(\Psi), ., q^E = L, r'\right) > \pi^I\left(\widetilde{p}_t^I(r''), ., q^E = L, r'\right)$. Furthermore, since consumers do not make mistakes, if an incumbent of type r' plays $p_1^I(r'')$ in period 1, in period 2 the entrant knows with probability 1 that $r < \Psi$. Therefore, in any pooling equilibrium, $r \leq \Psi$ and $A_1 \subseteq \{r_N, \ldots, \Psi\}$.

It is then shown that an incumbent of type r, for $r \in A_t$, will mimic the action played by an incumbent of a higher type and deter entry, if the entrant prices "high enough."

Claim 1

There exist $\overline{\delta}$ *such that for* $\delta > \overline{\delta}$*, and* $r < \Psi$*, an incumbent of type* $r \in A_t$ *best response is* $p_t^I(r) = \widetilde{p}^I(a_t)$*, if* $p_t^E\left(\widetilde{p}^I(r)\right) = r$*.*

The claim can be derived from comparing the incumbent's profits from playing $\widetilde{p}^I(a_t)$ to playing $\widetilde{p}^I(r')$ where $r' < a_t$ and assuming $p_t^E\left(\widetilde{p}^I(r)\right) = r$.

In other words, an incumbent of type r, for $r \in A_t$, will prefer to defer entry to the future if δ is high enough.

If δ and T are large enough, and if α_H is small enough, the entrant's best response is $p_t^E\left(\widetilde{p}^I(a_t)\right) = a_t$.

Claim 2

There exist $\overline{\delta}$ *such that for all* $\delta > \overline{\delta}$*,* $T > T(\delta)$*, and all* $\alpha_H < \alpha_H(\delta, T(\delta))$*, the entrant's best response is* $p_t^E\left(p_t^I(r)\right) = r$*.*

This claim can be derived from comparing the entrants expected profits from playing a_t to playing $r < a_t$, while noting that within a finite time r becomes common knowledge (Lemma 3). Furthermore, given δ, choose T large enough such that payoffs at the end of the horizon are sufficiently small. And, given δ and T, pick α_H sufficiently small such that the expected loss from guessing too high r is small enough.

To summarize: We know from Claim 2 that there exist $\delta > \overline{\delta}$, $T(\delta)$, and $\alpha_H(\delta, T(\delta))$, such that $p_t^E\left(\widetilde{p}^I(r)\right) = r$ is the entrant's best-response. It then follows from Claim 1 that the incumbent's best-response action in period t, i.e., p_t^{I*}, is

$$p_t^{I*} = \langle \begin{array}{ll} \widetilde{p}^I(a_t) & \text{if } r \leq \Psi \\ \widetilde{p}^I(r) & \text{if } r > \Psi \end{array} .$$

Next, we prove by induction that the equilibrium is unique.

Claim 3

In period t, if $a_t = r$ then $p_t^I(r) = \widetilde{p}^I(a_t)$.

The reason: Beliefs are credible, and the incumbent's current-period profits are maximized if $p_t^I(r) = \widetilde{p}^I(a_t)$.

Claim 4

If $\delta > \overline{\delta}$, $T > T(\delta)$, and $\alpha_H \leq \alpha_H(\delta, T(\delta))$, then an incumbent of type r, where $r < a_t$, will mimic the action played by an incumbent of type a_t.

Claim 3 showed us that an incumbent of type a_t plays $\widetilde{p}^I(a_t)$. Claim 1 can then be used to show that an incumbent of type r, such that $r < a_t$, gains from mimicking the action played by an incumbent of type a_t, such that $p_t^I(r) = \widetilde{p}^I(a_t)$, since $\delta > \overline{\delta}$, $T > T(\delta)$, and $\alpha_H \leq \alpha_H(\delta, T(\delta))$. Therefore, from Claim 3 and 4, given the conditions stated in Theorem 1, we can show that the equilibrium outcome is unique. ■

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