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MARKET SEGMENTATION, CANNIBALIZATION, AND THE TIMING OF PRODUCT INTRODUCTIONS*

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Consider a seller who faces two customer segments with differing valuations of quality of a durable product. Demand is stationary and known, the technology exists to release two products simultaneously, and the seller can commit in advance to subsequent prices and qualities. Should he introduce two differentiated products at once or one at a time? Under the simultaneous strategy, the lower quality would cannibalize demand for the higher quality. To reduce cannibalization, the seller could lower the quality of the low-end model and reduce the price of the high-end. Alternatively, he could increase the quality of the low-end model, but delay its release. Sequential introduction, however, would mean that the profits from the low-end model arrive later. We show that sequential introduction is better than simultaneous introduction when cannibalization is a problem and customers are relatively more impatient than the seller. However, when the seller cannot pre-commit, sequential selling is much less attractive because then he cannot use his product designs to alleviate cannibalization.
(MARKETING—NEW PRODUCT SEGMENTATION)

1. Introduction

On 26 June 1990, IBM released its PS/1 home computer, several years after its PS/2 business-oriented microcomputer. Minolta Corporation of the United States launched its intermediate 5000i model of auto-focus single-lens reflex cameras more than a year after launching the higher-end 7000i and the lower-end 3000i in July 1988. Publishers routinely introduce books first in hard covers, and then paperback versions about a year later (McDowell 1989). Volvo of North America released its 6-cylinder 760 model in October 1983 and the 4-cylinder 740 model 17 months later in March 1985 even though both cars shared the same chassis and the 4-cylinder engine was available earlier.

Why do leading manufacturers of books, cameras, computers, and cars systematically introduce their high-end products before the low-end models? *The Economist's* report on IBM's PS/1 provides a clue:

> The company has to offer a home computer sufficiently appealing to unsophisticated users . . . Yet these cheaper home machines cannot be so good that they cut deeply into the market for IBM's much more profitable business-oriented PS/2 range.[1]

If the PS/1 had been released simultaneously with the PS/2, then the PS/1 could have cannibalized demand for the PS/2 even more than it does now. IBM would have had to take still more care to avoid offering too many features on the PS/1 that would draw potential PS/2 buyers. Sequential product introduction alleviates cannibalization by forcing consumers of the low-end model to wait before they can buy the product. It allows the seller to charge more for the high-end product, and at the same time not reduce the features of the inferior model too much.

The sequential strategy, however, has a down side. The seller will have to wait for his

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[1] "IBM Tries Again," *The Economist* (June 30, 1990), 65–66.

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profits from the low-end product. Accordingly, in choosing between simultaneous and sequential introduction, the seller must balance the benefits of reducing cannibalization against the postponement of profits. We analyze this trade-off in a specific context in this paper. A seller faces two customer segments with differing valuations of product quality.[2] Customer demand is stationary and known, the technology is available to introduce two products simultaneously, and the seller can commit in the first period to subsequent prices and qualities.

We show that sequential introduction is better than simultaneous introduction when cannibalization is a problem and customers are relatively more impatient than the seller. However, sequential selling becomes much less attractive when the seller cannot commit in advance to his subsequent prices and product designs. This is because the inability to commit precludes the possibility of mitigating cannibalization through product choices. Indeed, the seller is forced to offer both segments their respective efficient products,[3] and, as a result, must reduce the price of the high-end product. By contrast, if commitment were possible, the seller would commit to introducing first a high-end product that is efficient for customers who value quality relatively more, and then subsequently, a low-end model that is *less* than efficient for the remaining customers.[4] Put differently, when he cannot commit, the seller must rely solely on the unavailability of the lower-quality product in the first period to reduce cannibalization. When commitment is possible, both the unavailability of the lower-quality product in the first period *and* its design can be used to reduce cannibalization.

There are several other important factors governing the timing of product introductions which we ignore in this paper. First, technology may drive sequential introduction. For instance, IBM introduced the 8088-based PC and XT first, then the 80286-based AT, and, recently, the 80386-based PS/2 in step with Intel's development of the respective computer chips. Norton and Bass (1987) and Levinthal and Purohit (1989) consider sequential introductions dictated by exogenous technological improvements. Second, the choice between sequential and simultaneous product introductions may depend upon the development of consumer demand for the product category. Narasimhan (1989) analyzes the effect of diffusion of information about a durable product's value on its pricing, while Wilson and Norton (1989) study how diffusion affects the timing of durable-goods line extensions. Finally, sequential introductions may not be optimal if competitors can preempt the market for the later-introduced products.

2. Model

Consider a durable product that may be differentiated on some dimension on which consumers agree in their preference ordering, *ceteris paribus*, for example, engine power or gas-mileage in the case of cars, range of focal lengths in the case of cameras, etc. For brevity, we call this dimension "quality." Suppose there are two segments, h and l, n_h and n_l in size, which differ in their intensity of preference for the quality of the product. Each customer in segment h values a unit of the product with quality q at $v_h q$, while each customer in segment l values the same unit at $v_l q$. Let $v_h > v_l > 0$, so that customers in segment h value quality more highly; we will call h the high segment and l the low

[2] We assume that the seller is a monopolist for ease of analysis. But, as discussed in §5, our results extend easily to the case of a seller facing nonstrategic competitors.

[3] By "efficient" product, we mean the quality that maximizes the difference between the segment's willingness to pay and the seller's marginal cost of quality.

[4] In previous research by Stokey (1979), Bulow (1982), Landsberger and Meilijson (1985), Moorthy (1988), Narasimhan (1989), and Besanko and Winston (1990) on the pricing of a *given* durable good, the advantage of commitment was that the seller could commit not to cut price and sell to new customers in later periods. Here, because product qualities can also be chosen by the seller, the power to commit allows him, *in addition*, to commit not to introduce a relatively attractive product later in time. See also Kumar (1990).

segment. Denote v_h/v_l by v_l^h, n_h/n_l by n_l^h, and $n_l^h(v_l^h - 1)$ by R. (R is a measure of potential cannibalization as we will soon see.) Finally, we assume that once any customer has bought a unit of the product—regardless of quality—she will leave the market forever.[5]

On the supply side, there is a single seller, for whom the marginal cost of supplying the product increases with its quality. For simplicity, we assume that the marginal cost of supplying one unit with quality q is cq^2, where $c > 0$. There are constant returns to scale in producing multiple units of one quality, and no economies or diseconomies of scope in producing more than one quality of the product.[6] We further assume that any fixed costs of product introductions are small enough that they do not constrain the seller if he wishes to introduce two products. This simply keeps the focus on demand considerations as the driving factor in determining how many products to introduce.[7]

Figure 1 shows the nature of customer preferences and seller costs in our model. Also shown are the *efficient* qualities of the two segments. The efficient quality for a segment is the quality that maximizes the difference between a customer's valuation and the firm's marginal cost of quality. So, for instance, the efficient quality for the low segment maximizes $v_l q - cq^2$, and is

$$q_l^* = \frac{v_l}{2c}. \tag{1}$$

Similarly, the efficient quality for the high segment is

$$q_h^* = \frac{v_h}{2c}. \tag{2}$$

Given our model, the seller must decide *if*, *how* and *in what order* to serve the two segments. He can serve only one segment, both segments simultaneously, or one segment before the other. Given that there are only two segments, there can only be one or two products and at most two product introduction dates. We assume that product introduction dates are fixed exogenously in the industry. That is, if the seller chooses to introduce products sequentially, then the time between successive introductions is fixed exogenously. The reason for this assumption is that we don't want to focus on the precise timing of any second product introduction, only on whether the second product is introduced simultaneously or sequentially with respect to the first product.

3. Commitment Possible

In this section we assume that the seller commits in advance to his subsequent product and pricing strategy. This means that before any sales take place, the seller decides, and commits, to the qualities, prices, and the order in which the products will be introduced, and moreover, that customers believe these commitments and act accordingly. The seller thus solves the two-period maximization problem only once—at the start of the first period.[8]

Whether a seller can or cannot commit credibly depends on a number of things, including his reputation, industry practice, whether the seller is willing to make it costly for himself to break the commitment, etc. In the case of book publishers, industry practice

[5] Sequential product introduction can attenuate cannibalization only in categories where customers who buy early do not re-enter the market when the next product is introduced; cf. Moorthy (1988).

[6] So, for instance, if the seller supplies three units of quality q_1 and four of quality q_2, then the marginal cost of the seven units will be simply $c(3q_1^2 + 4q_2^2)$.

[7] Dobson and Kalish (1988) consider both demand and fixed cost factors in the problem of simultaneous introduction of a product line.

[8] In general, he could commit to the second period quality and price as *functions* of sales in the first period, i.e., adopt a closed-loop solution. But in our model customer demand is deterministic. Hence there is no distinction between closed and open-loop solutions.

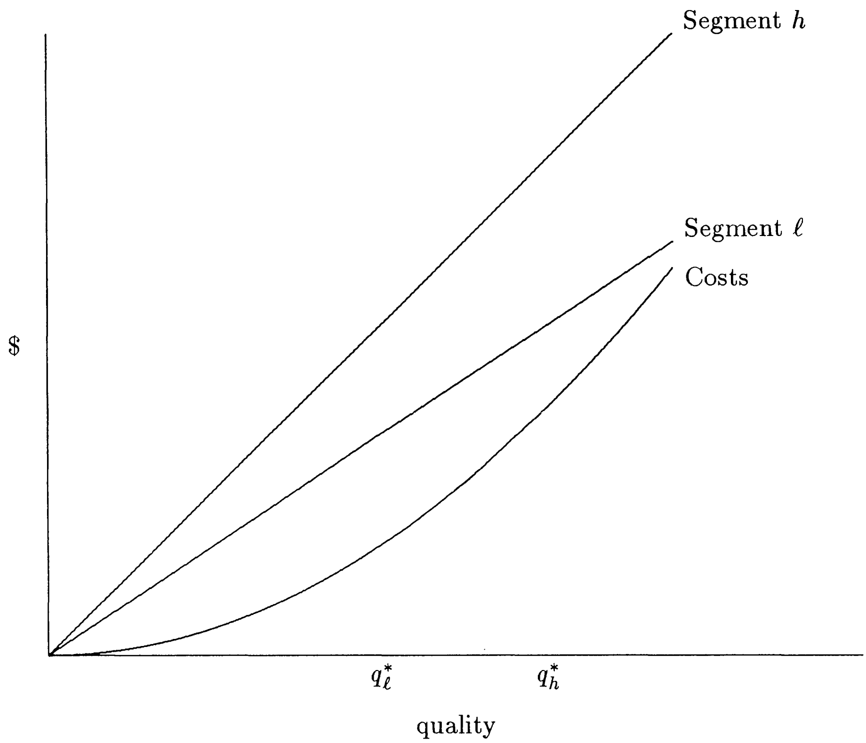

FIGURE 1. Customer Reservation Values and Marginal Costs in Our Model.

dictates at least a year's gap between the hardcover edition and the softcover, and this serves as an implicit commitment.[9] Appliance and furniture retailers achieve commitment on price by promising to reimburse current customers if they reduce their price soon.

3.1. *One-Period Introductions*

The seller's first option is to introduce products in one period only. That is, if he introduces two products, then both products are introduced in the same period. If only one product is introduced, then the seller commits not to introduce any other product. Now, one-period introductions can be first-period introductions or second-period introductions, but since the seller discounts second-period profits, he will consider only first-period introductions.

Let the seller target a product of quality q_l at price p_l to the low segment, and one of quality q_h at price p_h to the high segment. Then the seller's problem is

$$\max_{q_h, q_l, p_h, p_l} \; n_l(p_l - cq_l^2) + n_h(p_h - cq_h^2) \tag{3}$$

subject to:

$$v_l q_l - p_l \geq v_l q_h - p_h, \tag{4}$$

$$v_h q_h - p_h \geq v_h q_l - p_l, \tag{5}$$

$$v_l q_l \geq p_l, \tag{6}$$

$$v_h q_h \geq p_h. \tag{7}$$

[9] Viking's repeated denials about publishing a softcover version of Salman Rushdie's *The Satanic Verses* illustrates the extent to which a publisher has to go to break the implicit commitment; cf. *The New York Times*, (May 10, 1989).

The constraints (4) and (5) are the "self-selection" constraints for the two segments: since the seller cannot identify the customer's type, he must design the product line so that each segment *voluntarily* chooses the product-price combination meant for it; cf. Mussa and Rosen (1978), Moorthy (1984). The other two constraints are the *participation* constraints that ensure that each segment will buy the product directed to them rather than not buy anything at all.

□ Suppose the seller offers two qualities. If the seller tries to extract all the high segment's consumer surplus by setting $p_h = v_h q_h$, then these customers will switch to the lower quality: they will get a positive surplus by doing so because, by (6), $p_l \leq v_l q_l$ (see Figure 1). Nothing, however, prevents the seller from extracting the lower segment's entire customer surplus. Hence, he should set p_l so that (6) binds,

$$p_l = v_l q_l. \tag{8}$$

The self-selection constraints (4) and (5) may be written as $v_l(q_h - q_l) \leq p_h - p_l$ and $v_h(q_h - q_l) \geq p_h - p_l$, respectively. Since $v_h > v_l$, both constraints cannot bind. Which constraint should bind? The high-segment customers are more willing to pay for additional quality, so the seller should direct the higher quality product to them, i.e., $q_h > q_l$, and set price p_h so that they will be exactly indifferent between the two products, i.e., (5) binds. Then

$$p_h = p_l + v_h(q_h - q_l) = v_l q_l + v_h(q_h - q_l) = v_h q_h - (v_h - v_l) q_l. \tag{9}$$

Substituting these prices into the seller's profit function, and maximizing with respect to q_l and q_h, we obtain

$$q_l = \frac{v_l}{2c}(1 - R), \tag{10}$$

$$q_h = \frac{v_h}{2c}. \tag{11}$$

The seller's profits are $(n_h v_h^2/4c) + (n_l v_l^2/4c)(1 - R)^2$. This solution is feasible if and only if $q_l > 0$, i.e., $R < 1$.

What if $R \geq 1$? Then an optimal two-product solution doesn't exist. Given *any* two products of positive quality serving the two segments, the seller can always improve profits by reducing the lower quality. To see this, suppose $0 < q_l < q_h$ is some two-product solution which satisfies the self-selection and participation constraints. The optimal prices are still given by (8) and (9), so the seller's profit function is $n_h[v_l q_l + v_h(q_h - q_l) - cq_h^2] + n_l(v_l q_l - cq_l^2)$. Differentiating this with respect to q_l we see that the derivative is $n_l v_l[(1 - R) - (2cq_l/v_l)]$, which is negative when $R \geq 1$. So profits increase as we reduce q_l. What is the upper bound on these profits? In any two-product solution it is optimal to supply segment h its efficient quality, $v_h/2c$, and price it at $v_l q_l + v_h[(v_h/2c) - q_l]$. And we just noted that profits increase as q_l goes down. So no two-product solution can have profits greater than

$$\lim_{q_l \downarrow 0} \left[n_h\left(v_l q_l + v_h\left(\frac{v_h}{2c} - q_l\right) - \frac{v_h^2}{4c}\right) + n_l(v_l q_l - cq_l^2) \right] = \left(\frac{n_h v_h^2}{4c}\right).$$

To sum up, when $R < 1$, the optimal two-product solution is to offer the products (10) and (11) and price them at (8) and (9), respectively. When $R \geq 1$, no optimal two-product solution exists, but we can always find two products and price them according to (8) and (9) and achieve profits arbitrarily close to, but not exceeding, $(n_h v_h^2/4c)$. Thus, the profits with two distinct products are[10]

[10] We adopt the convention of using Π to denote profits, superscripts to distinguish between one-period and two-period and commitment and no-commitment solutions, and subscripts to specify the number of distinct qualities offered. Also, $\lesssim$ stands for "less than but arbitrarily close to."

$$\Pi_2^{1c} \begin{cases} = \dfrac{n_h v_h^2}{4c} + \dfrac{n_l v_l^2}{4c}(1-R)^2 & \text{if} \quad R < 1, \\ \le \dfrac{n_h v_h^2}{4c} & \text{if} \quad R \ge 1. \end{cases} \tag{12}$$

□ Now suppose the seller offers only one quality, q, at price, p. There are essentially only two possibilities here: (i) serve both segments, (ii) serve only the h segment. Serving *only* the l segment is impossible because whenever l buys—whenever $p \le v_l q$—so does h; see Figure 1.

Consider the first possibility. Then the maximum the seller can charge for the product is $p = v_l q$, otherwise the l segment won't buy. The seller's profits will be $(n_l + n_h)(v_l - cq)q$. Maximizing this with respect to q we see that the maximum profits obtainable by selling one product to both segments is $(n_h + n_l)(v_l^2/4c)$. Comparing this with the profits in the two-product solution, (12), we see that the latter is greater. Thus, it is never optimal to serve both segments with a single product.

Now consider serving only the h segment. Clearly, the optimal price now is $v_h q$ and the optimal quality is the efficient quality for segment h, $v_h/2c$. The optimal profits are

$$\Pi_1^{1c} = \frac{n_h v_h^2}{4c}.$$

Comparing this with the two-product solution, we see that serving only the h segment beats the two-product solution when $R \ge 1$ and is beaten by the two-product solution when $R < 1$. We summarize these results in Proposition 1.

PROPOSITION 1. *If the seller chooses to introduce products in one period only, then he will do so in the first period, and offer two qualities if $R < 1$; if $R \ge 1$, then he will offer only one quality and commit not to introduce any more products.*

The low-quality product cannibalizes the demand for the high quality. That is why the seller chooses the low quality to be less than efficient for the low segment. The more the number of high-segment customers relative to the low segment (the larger is n_l^h), and the more the high segment's valuation of quality exceeds the low segment's (the higher the differential valuation, v_l^h), the more serious the cannibalization problem. Accordingly, $R = n_l^h(v_l^h - 1)$ measures the degree of potential cannibalization. When $R \ge 1$, the cannibalization is so bad that the seller simply sells to the high segment and ignores the low segment.

3.2. *Sequential Product Introductions*

If the seller introduces products sequentially, each customer must decide *which* product to buy and *when*. A customer who purchases in the second period must wait to enjoy the product. Since most individuals prefer to consume earlier rather than later, we assume that each customer equates one unit of consumer surplus in the second period to $\delta_c \in (0, 1)$ unit in the first period. So the *discount factor*, δ_c, will be close to 1 if customers are very patient, while δ_c will be close to 0 if they are very impatient. Similarly, let $\delta_s \in (0, 1)$ be the seller's discount factor on second-period profits. Denote δ_c/δ_s by δ_s^c.

Should the seller introduce the low-end model before or after the high-end? Introducing the low-end model first would aggravate cannibalization: the lower quality product is even more attractive to segment h when it is available earlier. Moreover, the profits from the higher-quality will arrive later. So introducing the lower-quality product before the higher-quality product is worse than introducing both products in the first period.[11]

[11] More formally, for any feasible solution (q_l, q_h, p_l, p_h) with q_l introduced before q_h, the self-selection constraint for segment h is $\delta_c(v_h q_h - p_h) \ge v_h q_l - p_l$. This implies $p_h \le v_h q_h - (v_h q_l - p_l)/\delta_c$. By introducing the same two products in the first period, the seller can raise p_h to $v_h q_h - (v_h q_l - p_l)$. Clearly, profits will increase.

Accordingly, we focus on sequential strategies under which the seller introduces the superior product first. Let the seller choose quality q_h at price p_h for release in period 1, and q_l at price p_l for release in period 2, to solve

$$\max_{q_h, q_l, p_h, p_l} \; n_h(p_h - cq_h^2) + \delta_s n_l(p_l - cq_l^2) \tag{13}$$

subject to:

$$\delta_c(v_l q_l - p_l) \geq (v_l q_h - p_h), \tag{14}$$

$$(v_h q_h - p_h) \geq \delta_c(v_h q_l - p_l), \tag{15}$$

$$v_l q_l \geq p_l, \tag{16}$$

$$v_h q_h \geq p_h. \tag{17}$$

This problem differs from that of one-period introduction in two important ways. First, the seller discounts the profits from the low segment as he receives these only in the second period. Second, when deciding between the low and high-quality products, each customer must also discount any surplus from the low-end product because of its later availability.

As in the problem of introducing two distinct qualities in the first period, the seller will choose qualities and prices so that the self-selection constraint for the high segment, (15), and the low-segment participation constraint, (16), bind. Hence, prices will be

$$p_l = v_l q_l, \tag{18}$$

$$p_h = v_h q_h - \delta_c(v_h - v_l) q_l. \tag{19}$$

Compared to the one-period setting, the optimal price for the high-end product is higher now because the later appearance of the lower-end product mitigates cannibalization (compare (9) and (19)).

Substituting these prices into the seller's profit function, and maximizing with respect to q_l and q_h, we obtain

$$q_l = \frac{v_l}{2c}(1 - \delta_s^c R), \tag{20}$$

$$q_h = \frac{v_h}{2c}. \tag{21}$$

In terms of discounted present value, the seller's profits are $(n_h v_h^2/4c) + (\delta_s n_l v_l^2/4c)(1 - \delta_s^c R)^2$. This solution is feasible if and only if $q_l > 0$, i.e., $\delta_s^c R < 1$. When $\delta_s^c R \geq 1$, as in the one-period solution when $R \geq 1$, the seller's profits in any two-product solution are bounded above by $n_h v_h^2/4c$, but he can approach it arbitrarily closely. Thus, the "maximum" profits while selling two products sequentially are

$$\Pi_2^{2c} \begin{cases} = \dfrac{n_h v_h^2}{4c} + \dfrac{\delta_s n_l v_l^2}{4c}(1 - \delta_s^c R)^2 & \text{if} \quad \delta_s^c R < 1, \\ \leq \dfrac{n_h v_h^2}{4c} & \text{if} \quad \delta_s^c R \geq 1. \end{cases} \tag{22}$$

3.3. *When to Introduce Products Sequentially*

□ *Case* 1: $R \geq \max\{1, \delta_s/\delta_c\}$. In this case, $R \geq 1$ and $\delta_s^c R \geq 1$. By Proposition 1, the optimal one-period strategy is to introduce only a high-quality product, $v_h/2c$, and commit not to sell any other product. The profits will be $n_h v_h^2/4c$. By (22), any two-product sequential strategy yields profits less than $n_h v_h^2/4c$ when $\delta_s^c R \geq 1$. So, in this situation, the optimal strategy is to introduce only one product and commit not to introduce anymore.

□ *Case* 2: $1 \leq R < \delta_s/\delta_c$. Same one-period strategy as above, but since $\delta_s^c R < 1$, an optimal solution with two products exists with sequential introduction. The profits in this solution are greater than $n_h v_h^2/4c$ by (22), so sequential introduction is better.

□ *Case* 3: $\delta_s/\delta_c \leq R < 1$. The one-period solution with two distinct products yields profits of Π_2^{1c} which are greater than the profits from the one-product solution (Proposition 1) and also greater than the profits from any sequential solution with two products (22).

□ *Case* 4: $R < \min\{1, \delta_s/\delta_c\}$. Two products are optimal in both the one-period and two-period solutions. Comparing Π_2^{2c} and Π_2^{1c} we see that $\Pi_2^{2c} > \Pi_2^{1c}$ if and only if

$$R < 1 \quad \text{and} \quad \delta_c < \frac{\delta_s - (1-R)\sqrt{\delta_s}}{R} \quad \text{or} \quad R \geq 1 \quad \text{and} \quad \delta_c \leq \frac{\delta_s}{R}. \tag{23}$$

We summarize these observations in the following proposition and illustrate them in Figure 2 (for $\delta_s = 0.5$).[12]

PROPOSITION 2. *When the seller commits in advance to his subsequent product and pricing strategy, then he will*

(a) *sell two qualities simultaneously in the first period if*

$$R < 1 \quad \textit{and} \quad \delta_c \geq \frac{\delta_s - (1-R)\sqrt{\delta_s}}{R}; \tag{24}$$

(b) *sell a high quality in the first period and a lower quality in the second if*

$$R < 1 \quad \textit{and} \quad \delta_c < \frac{\delta_s - (1-R)\sqrt{\delta_s}}{R} \quad \textit{or} \quad R \geq 1 \quad \textit{and} \quad \delta_c \leq \frac{\delta_s}{R}; \quad \textit{and} \tag{25}$$

(c) *sell a high quality in the first period and nothing in the second if*

$$R \geq 1 \quad \textit{and} \quad \delta_c \geq \frac{\delta_s}{R}. \tag{26}$$

Proposition 2 shows that sequential introduction with commitment "works" in one of two ways. First, when the best one-period strategy involves selling two qualities of the product (Case 4 above)—the efficient quality to the high segment, a less than efficient quality to the low segment—the sequential strategy lets the seller charge more for the high-end product, and at the same time increase the quality of the low-end product. The seller can *compress* his product line on quality because sequential introduction enables him to use time as another differentiating attribute. Second, in cases where the cannibalization problem with simultaneous introduction is so severe that the seller must offer only one quality targeted at the high segment (Case 2 above), sequential introduction lets the seller serve the low segment as well with a lower-quality product. Here, the opportunity to differentiate products by the additional dimension of time allows the seller to expand the variety of products.

The above advantages of a sequential strategy must be weighed against the disadvantage of postponing profits from one of the products. This tradeoff depends on two things: the seriousness of the cannibalization problem (measured by R) and the relative patience of the seller vis-a-vis the customers (δ_s/δ_c). As R increases toward 1, the cannibalization problem increases in severity. The best one-period strategy is to sell two products, but its profitability is decreasing. Correspondingly, the sequential strategy becomes more attractive: even values of δ_c close to δ_s keep the sequential strategy optimal when R

[12] We are indebted to a referee for suggesting this figure.

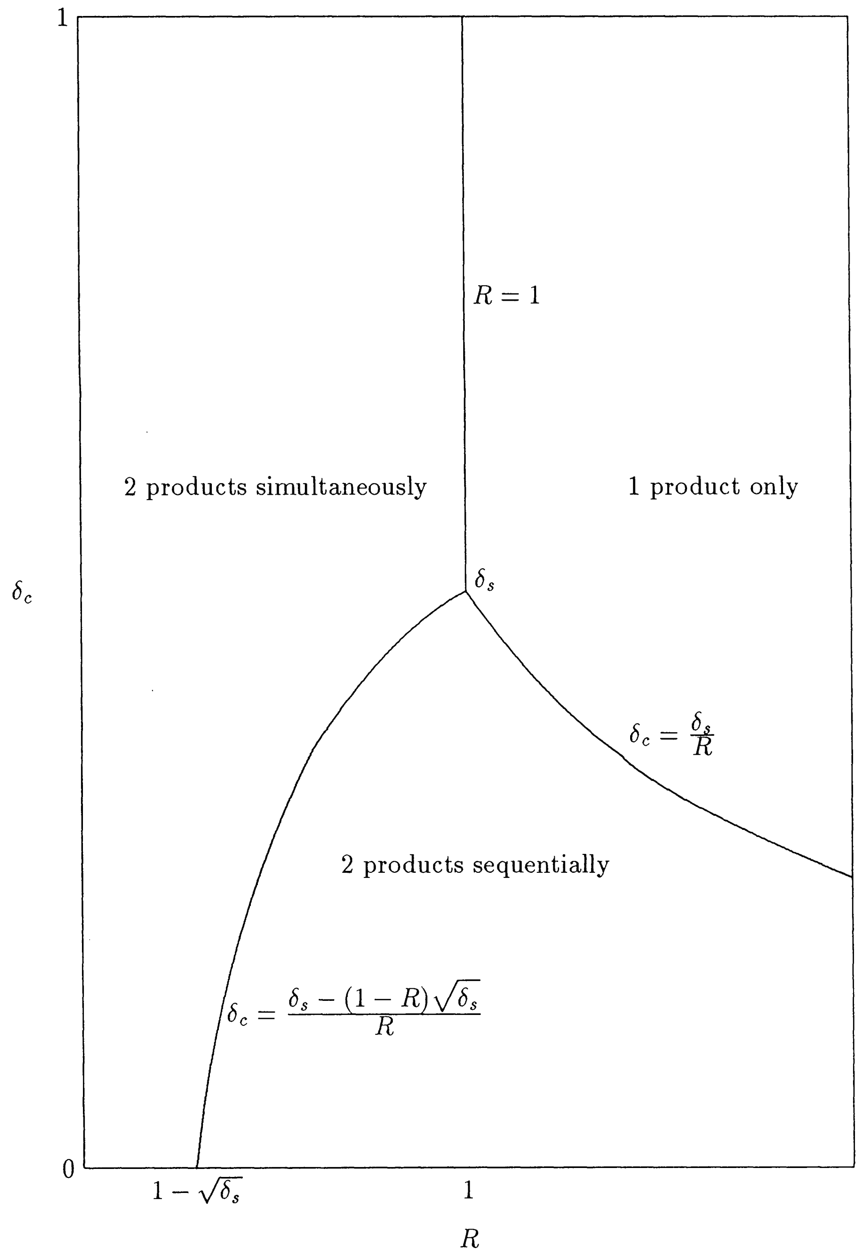

FIGURE 2. The Optimal Product Introduction Strategy with Commitment.

approaches 1 (Figure 2). But as R increases beyond 1, it becomes progressively harder to justify a sequential strategy. The best one-period strategy now is to offer only one high-quality product, and increases in R do not affect its profitability. The sequential strategy, however, is adversely affected. The growing pressure of cannibalization forces the seller to push the lower quality further and further down. Ultimately, the cannibalization problem becomes so bad that, unless the customers are *really* impatient, the seller would rather offer just one quality in the first period and nothing afterward.

Two extreme situations are worth noting. When R is so small that $R \leq 1 - \sqrt{\delta_s}$, cannibalization ceases to be a problem. Then, no matter how impatient the customers are, the seller wouldn't choose a sequential strategy (see Figure 2). Similarly, if the seller is more impatient than the customers ($\delta_s < \delta_c$), then, no matter how serious the cannibalization problem, sequential selling is never optimal.

PROPOSITION 3. *Sequential introduction of two qualities cannot be better for the seller than one-period introduction if customers are more patient than the seller* ($\delta_c > \delta_s$) *and cannibalization is not a problem* ($R < 1 - \sqrt{\delta_s}$).

4. Seller Incapable of Commitment

So far in this paper we have assumed that the seller can commit to his future product and pricing strategy. But many sellers, for instance, recent entrants into the marketplace who don't have an established trademark or corporate identity, or sellers in industries characterized by large production uncertainties, may not be able to credibly commit in advance to a product and pricing strategy. They can only position and price their products one period at a time, as and when they are physically offered. For example, given the repeated inability of software manufacturers to meet their new-product launch forecasts (most recently, Lotus with Versions 2.2 and 3 of 1-2-3), commitment is almost impossible in this industry.

When the seller cannot commit, potential customers will rationally look ahead to what the seller might do in the second period before deciding when to buy. The seller, in turn, must take this customer behavior into account when choosing his strategy. In this section we analyze the seller's problem when he cannot precommit and compare it with the commitment case.

□ Suppose the seller aims to serve only the low segment in the first period. Then, in the second period, there will be only segment h customers. He will then price the second-period product to extract these customers' entire surplus. Segment h customers will expect this, however, and find the first-period product q_l priced at $p_l \leq v_l q_l < v_h q_l$ relatively more attractive. Thus the seller will not be able to sell only to the low segment in the first period.

□ Suppose the seller chooses to serve only the high segment in the second period.[13] By the arguments of §3.1, in this case he will offer quality $q_h = v_h/2c$ at price $p_h = v_h q_h$. Hence, from the standpoint of the first period, his profits will be

$$\Pi_1^{2nc} = \frac{\delta_s n_h v_h^2}{4c}. \tag{27}$$

When the seller can commit, he would never choose such a strategy, because he could raise profits by offering the same product in the first period. In the present setting, the seller cannot commit, hence the only way to credibly serve only one segment is to do so in the final period.

□ Now suppose the seller serves both segments in the first period.[14] In this situation there is no difference between the commitment and no-commitment cases because there is nothing to commit to once everyone has been served in the first period. So we simply recall our results from §3.1. The seller should offer $v_h/2c$ and a lower quality product at prices (9) and (8), respectively. The profits will be

$$\Pi_2^{1nc} = \Pi_2^{1c} \begin{cases} = \dfrac{n_h v_h^2}{4c} + \dfrac{n_l v_l^2}{4c}(1 - R)^2 & \text{if} \quad R < 1, \\[2ex] \leq \dfrac{n_h v_h^2}{4c} & \text{if} \quad R \geq 1. \end{cases} \tag{28}$$

[13] Serving only the high segment in the first period is impossible because, once this segment has been served, the seller will want to extract the low segment's consumer surplus. See below.

[14] Selling to both segments in the first period obviously beats selling to both segments in the second period.

These profits are greater than $n_h v_h^2/4c$ (when $R < 1$) or arbitrarily close to $n_h v_h^2/4c$ (when $R \geq 1$). In contrast, because $\delta_s < 1$, the profits in the one-product solution just considered are less than $n_h v_h^2/4c$. Hence selling only to the high segment in the second period can never be optimal.

□ Finally, suppose the seller serves the high segment in the first period and the low segment in the second. Clearly, in the second period, the seller will extract all of the low segment's consumer surplus by pricing at

$$p_l = v_l q_l. \tag{29}$$

Hence, profits in the second period are $\pi_2 = n_l(v_l - cq_l)q_l$, and these are maximized at $n_l v_l^2/4c$ when

$$q_l = \frac{v_l}{2c}. \tag{30}$$

In the first period, the seller will choose (q_h, p_h), to maximize discounted profit from that point onward,

$$\pi_1 = n_h(p_h - cq_h^2) + \delta_s \pi_2, \tag{31}$$

subject to the constraints,

$$\delta_c(v_l q_l - p_l) \geq v_l q_h - p_h, \tag{32}$$

$$v_h q_h - p_h \geq \delta_c(v_h q_l - p_l), \tag{33}$$

$$v_h q_h \geq p_h, \tag{34}$$

and taking into account the product and price he will offer later. Once again, the self-selection constraint for the high segment will be binding, so

$$p_h = v_h q_h - \delta_c(v_h q_l - p_l) = v_h q_h - \delta_c(v_h - v_l)\frac{v_l}{2c}, \tag{35}$$

by (29). Substituting in (31), and maximizing with respect to q_h, we obtain

$$q_h = \frac{v_h}{2c}. \tag{36}$$

It is easy to check that (32) is satisfied, so we have an optimal solution. By (31), profits from the first period onward are

$$\Pi_2^{2nc} = \frac{n_h v_h^2}{4c} + \delta_s \frac{n_l v_l^2}{4c}(1 - 2\delta_s^c R). \tag{37}$$

These profits are always positive.

4.1. *When to Introduce Products Sequentially*

Let us compare Π_2^{2nc} and Π_2^{1nc}. When $R < 1$, $\Pi_2^{1nc} = (n_h v_h^2/4c) + (n_l v_l^2/4c)(1 - R)^2$. Comparing this with (37), we get $\Pi_2^{2nc} > \Pi_2^{1nc}$ if and only if $\delta_c < [\delta_s - (1 - R)^2]/2R$. When $R \geq 1$, $\Pi_2^{1nc} \leq (n_h v_h^2/4c)$. So $\Pi_2^{2nc} > \Pi_2^{1nc}$ if $1 \geq 2\delta_s^c R$, i.e., $\delta_c \leq \delta_s/2R$. If $\delta_c > \delta_s/2R$, then $\Pi_2^{1nc} > \Pi_2^{2nc}$. Note that Π_2^{1nc} is never equal to Π_2^{2nc} when $R \geq 1$. This is because introducing only the high quality product in the first period (and nothing in the second period) is not feasible when the seller cannot commit.

Proposition 4 summarizes these results and Figure 3 illustrates them.

PROPOSITION 4. *When the seller cannot commit in advance to his subsequent product strategy, then he will*

(a) *sell two qualities simultaneously in the first period if*

$$R < 1 \quad and \quad \delta_c \geq \frac{\delta_s - (1-R)^2}{2R} \quad or \quad R \geq 1 \quad and \quad \delta_c > \frac{\delta_s}{2R}; \tag{38}$$

(b) *sell a high quality in the first period and a lower quality in the second if*

$$R < 1 \quad and \quad \delta_c < \frac{\delta_s - (1-R)^2}{2R} \quad or \quad R \geq 1 \quad and \quad \delta_c \leq \frac{\delta_s}{2R}. \tag{39}$$

Figure 3 shows that sequential introduction is likely to be more attractive than simultaneous introduction for moderate values of R and small values of δ_c relative to δ_s.

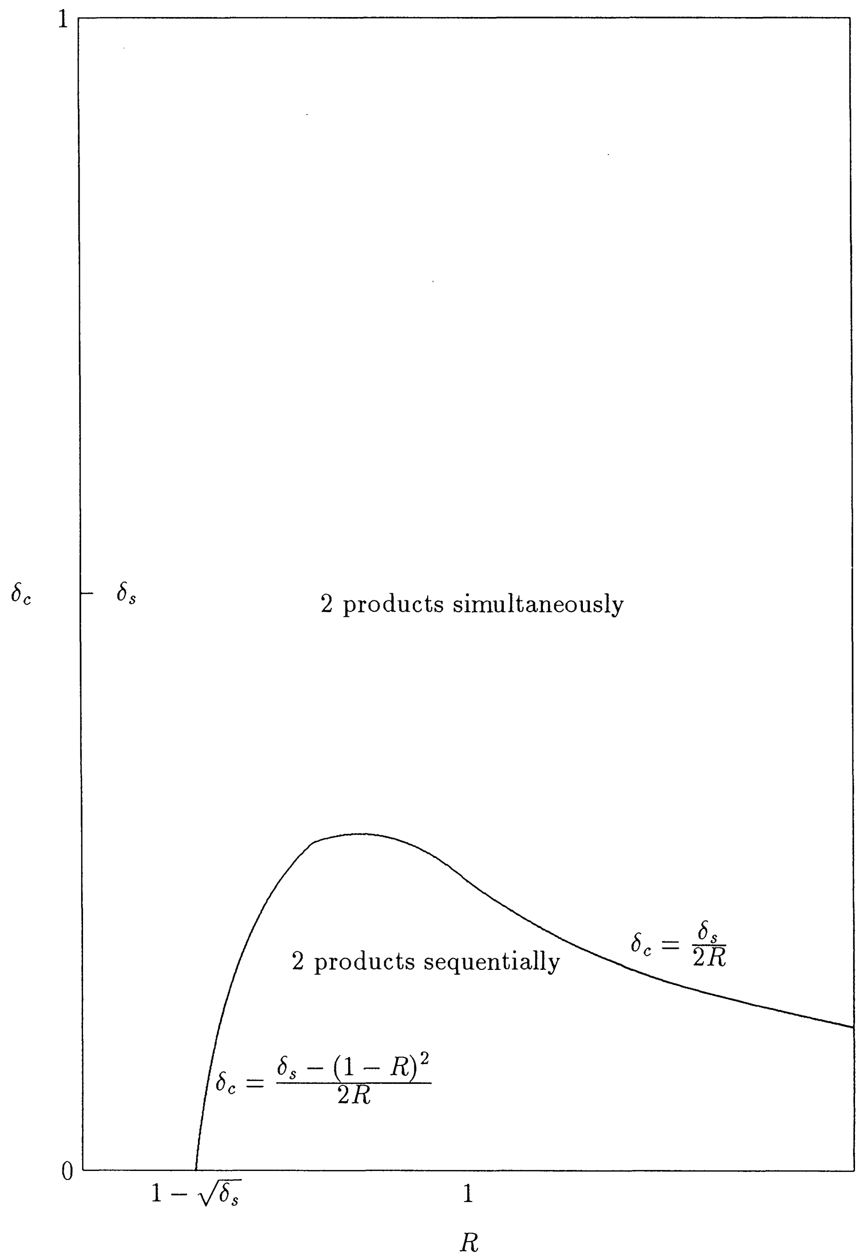

FIGURE 3. The Optimal Product Introduction Strategy without Commitment.

(As δ_s increases, the entire curve moves up and left, including the "hump" in the curve.) For small values of R, the cannibalization problem is not serious enough to warrant postponing the introduction of the lower quality product. For large values of R, the cannibalization problem is so serious that the seller would like to push the lower quality as far away from the high quality as possible. With simultaneous introduction, he can do that, with sequential introduction he cannot; compare (10) and (11) with (30) and (36). As for the δ's, the smaller δ_c is relative to δ_s, the more impatient are customers relative to the seller. So the seller can make a big dent on the cannibalization problem by postponing the lower quality while not suffering too much from the delay in lower-quality profits.

This much is similar to the commitment case. But there are some key differences between the commitment and no-commitment cases. First, as we noted earlier, the inability to commit makes it impossible for the seller to serve only the high segment in the first period and none in the second. Rational customers anticipate the seller's interest in serving the low segment once the high segment has been served, so the seller is forced to follow a high quality product with a lower quality. The only way to serve only the high segment is to offer nothing in the first period, but that is not as attractive as selling to both segments in the first period. In contrast, when commitment is possible, the seller does find it attractive some times to commit to introducing only a high quality product in the first period; cf. Proposition 1.

Second, comparing (20) and (21) with (30) and (36), we see that in sequential introduction without commitment, the seller offers *both* products at their efficient quality whereas, with commitment, the lower quality is less than efficient for segment l. The reason is, in the no-commitment case, when it comes time to choose the low-quality product, the seller perceives his first-period price and quality to be "history," and thus ignores the externality imposed by the second-period quality on the demand for the first-period quality. His inability to commit prevents him from fully internalizing the cannibalization problem. By contrast, when the seller commits, he decides on both first- and second-period products in the first period. Then he recognizes the externality, and picks a lower quality further away from the high quality. This explains why sequential introduction is more likely with commitment than without commitment. Formally, if the parameters R, δ_c and δ_s are such that the seller will introduce sequentially when he cannot commit, then he will also introduce sequentially when he can commit (compare (25) and (39)). Graphically, the area where sequential introduction is optimal in Figure 2 contains the corresponding area in Figure 3.[15]

The superiority of commitment over no-commitment may seem paradoxical at first. Doesn't commitment imply a reduction in flexibility and isn't that bad for the decision-maker? Our analysis shows that commitment can increase the flexibility of a seller dealing with rational customers. Every option open to the seller who cannot commit is open to the seller who can commit. Moreover, certain strategies which are ruled out when the seller cannot commit—such as selling only a high quality product in the first period—are feasible when he can commit. Here is another example, then, of strategic interaction between two decision-makers overturning conclusions derived from single-person decision theory.

5. Concluding Remarks

We have shown that a seller of durable goods can use time to reinforce the product differentiation built into his product line by introducing products sequentially instead

[15] In traditional homogeneous-goods models of temporal price discrimination—e.g., Stokey (1979) and Bulow (1982)—commitment is better because it assures high-end customers that the seller won't reduce his price too much in the future. In our model, commitment is better because it assures high-end customers that the seller won't reduce his price *and* offer an attractive quality in the future.

of simultaneously. In our model, the need for a differentiated product line arises from the heterogeneous preferences of customers for a "quality-like" attribute. If the seller were to introduce the entire product line simultaneously, then the lower-quality product would cannibalize the sales of the higher-quality product. Sequential introduction, beginning with the higher quality, alleviates this problem by making the cannibalized product unavailable at the same time as the cannibalizing product.

Sequential introduction is not always better, however. Depending on the seriousness of the cannibalization problem, and how impatient the seller is vis-a-vis the customers, the reduction in profits due to the postponement of sales of the lower-quality product may be too high a price to pay. Sequential introduction cannot be better than simultaneous introduction if the seller is more impatient than the customers. Also, much of the effectiveness of a sequential strategy comes from the seller's ability to commit to his future product and pricing strategy. If the seller is unable to commit, then he is unable to fully internalize the cannibalization problem, and ends up choosing an overly narrow range of qualities. The product line, instead of alleviating cannibalization, exacerbates it. So, given the possibility of committing, the seller should commit.

How sensitive are our results to our assumptions? We assumed that the seller faced just two segments and could sell over two periods. If the number of periods falls short of the number of segments, then the seller will have to offer several distinct products in each period even under a sequential strategy. If there are more time periods than segments, as for instance when time is continuous but segments discrete, then the seller must also decide how long to delay introducing a lower-quality product. Our results suggest that under certain conditions a finite delay will be optimal. We also conjecture that the delay will be shorter when the seller cannot commit to the date of future products.

We assumed that customers' utility functions are linear in quality and the seller's marginal costs are quadratic in quality. The essential content of these assumptions is that there exist finite efficient qualities for each segment and there is a positive correlation between marginal and total utility. If efficient qualities didn't exist, then the seller could keep increasing his quality. Obviously, that is unrealistic. The positive correlation between marginal and total utility makes the low segment the cannibalizing segment and the high segment the cannibalized segment. As we showed, the seller's optimal response is to *decrease* the quality aimed at the low segment, moving it away from the high segment's efficient quality. Srinagesh and Bradburd (1989) consider the negative correlation case and show that the cannibalizing segment may be the segment with the higher efficient quality. Then the seller's optimal response would be to *enhance* the quality aimed at that segment in order to pull it away from the cannibalized segment's efficient quality. In terms of our story, this means that the seller may choose to introduce the low quality before the high. Finally, Lutz and Png (1990) show that, in the case of negative correlation, it is possible that there is no cannibalization even if each segment's efficient product is introduced simultaneously.[16]

Our results depend on the ratio n_h/n_l, not n_h and n_l per se, hence they do not change if demand is uncertain only in terms of the absolute sizes of the segments. But if the seller is also uncertain about the relative sizes of the two segments or the two segments' valuation of quality, then the seller's strategy isn't clear. On the one hand, he may introduce several products simultaneously to gather information about the market's preferences, but this may mean selling products at prices that prove to be suboptimal in light of subsequent information. Also, commitment is harder to achieve with uncertainty. The optimal strategy with commitment would be a function of the demand revealed, but this kind of commitment may be difficult to convey to customers.

With regard to potential or actual competition, our essential assumption is that com-

[16] This may have been the justification for Minolta's simultaneous introduction of the 7000i and the 3000i.

petitors do not act strategically. Sequential introduction is less likely when competitors are strategic: if one seller delays serving some segment, his competitors will preempt that segment in the current period, which may be worse than the cannibalization associated with simultaneous introduction.[17]

We have focussed on only one of several important factors that influence the timing of product introductions. At the beginning of this paper, we outlined work on two other factors, availability of technology, and the speed of diffusion of information among potential customers. There are other considerations as well. First, a firm will only introduce products for which it knows there is demand, and it may learn about demand by observing the success of competing products. For example, several additions to Apple's Macintosh line of microcomputers may be viewed as the result of Apple's gradual recognition of the demand for IBM-compatibility, power, and speed. Second, a sequential introduction strategy may be dictated by the need to introduce a low-priced entry-level version of the product first to reduce the risk of product trial, followed by higher-end models as customers become more sophisticated.[18]

[17] We are grateful to Patrick DeGraba for pointing this out to us. The sequential-introduction examples mentioned in the Introduction are likely to be cases where, given the considerable monopoly power of the protagonists, the cannibalization problem is more of a threat than the prospect of being preempted by competitors.

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