Bundling New Products with Old to Signal Quality, with Application to the Sequencing of New Products

by

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Abstract

This paper provides a new rationale for bundling based on *informational leverage*. Bundling a product of established quality to one of unknown quality can mitigate the problem of asymmetric information encountered in the latter market. Leveraging reputation in one market into another has implications for the timing of new product introductions. Bundling motivated by informational leverage enhances efficiency by increasing consumer's access to costly information. When the possibility of endogenous timing of product introduction is considered, however, the welfare consequences of bundling are ambiguous. The positive effect of *market creation* must be weighed against the negative effect of *market delay*.

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1. Introduction

This paper provides a theory of *informational leverage* and its implications for the endogenous timing of product introductions. A firm is said to have informational leverage when it is able to use the leverage provided by its reputation in one market to overcome informational asymmetry in a second market. Most importantly, the possibility of leveraging information across markets will be shown to have profound implications for the timing of new product introductions.

I introduce the theory of informational leverage as a reason for bundling. Consider an "experience" good market in which the quality of the good is initially unknown to consumers and can be ascertained only after the good is bought and consumed by them. In this type of market, it is well known that the incentive to provide a high quality product relies on the repeat purchase mechanism [Nelson (1974), Kihlstrom and Riordan (1984), Klein and Leffler (1981), Milgrom and Roberts (1986), and Schmalensee (1978)]. I consider a case where producers of the high quality products need to engage in introductory pricing to separate themselves from low quality producers.

Now suppose that a new experience good (called B) with uncertain quality is introduced by a multi-product monopolist, who has also been selling a good (called A) whose quality is already known to consumers. Further assume that the firm sells product A with a positive profit. In such a setting, I show that *irrevocable* bundling of the experience good (B) with the product of known quality (A) can be used as a credible signal of quality of good B. The reason is that with bundling the multi-product firm is required to sell product B in order to appropriate the surplus associated with product A. This implies that bundling can be considered as a commitment mechanism for the firm to continue to produce B in the future even if B is revealed to be of low quality and is not a profitable product in isolation. In other words, the surplus from product A serves as an exit cost for product B, which makes the "fly-by-night" strategy less attractive. As a result, bundling is more costly for the low quality producer. The asymmetry in the cost of bundling suggests that bundling can serve as a signaling device about uncertain quality of one of the products when the quality of the other product in the bundle is already known. This paper thus provides a new rationale for bundling based on informational leverage.[1]

The approach in the paper is related to a new development in the theory of bundling in that it focuses on the precommitment aspects of bundling in the ensuing stages. Whinston (1990) and Choi (1996), for instance, examine whether bundling can be used as a leverage device to extend monopoly power in one market to another otherwise competitive market. Even though this paper is also interested in the interaction of two product markets through bundling, the purpose of bundling in the present paper is not the leverage of market power in an attempt to monopolize a competitive market; the model in the present paper is devoid of strategic interaction in the product market. Rather, bundling is based purely on efficiency considerations. By tying the experience good to a good of known quality, it reduces the cost of information.

The possibility of informational leverage also has important implications for the

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[1] In my model, the introductory prices are below the full information price but always nonnegative. Bundling in the presence of uncertainty may also allow negative introductory prices. If one product were introduced with a negative price without bundling, buyers would swarm to it and bankrupt the company unless quantity were restricted. Bundling means that a certain segment of consumers get negative prices for the new good –but not for the bundle – and they have no incentive to buy too great a quantity, either. See Farrell and Gallini (1988) for a model where negative introductory prices may be necessary.

timing of product introductions. In particular, the multi-product firm may deliberately *asynchronize* the timing of product introductions when the qualities of both products are unknown to consumers; by sequencing the introduction of products, the multi-product firm can take advantage of informational leverage of the lead product in the introduction of the subsequent product. This paper, therefore, can be considered a first step towards a theory of *endogenous* timing of product introductions, on which the literature is virtually nonexistent.[2] Most surprisingly, I show that the sequential introduction of two products with bundling may create markets that would not be viable as separate entities due to asymmetric information.

Furthermore, when the possibility of endogenous timing of product introductions is considered, the welfare consequences of bundling are not always benign. The positive effect of *market creation* should be weighed against the negative effect of *market delay*. Bundling is unambiguously beneficial to the extent that it mitigates informational asymmetry and creates new markets that would have failed without it. However, when it is used despite both markets being viable on their own, bundling with sequential timing of product introductions only delays the availability of the product that is introduced later.

The remainder of the paper is organized in the following way. Section 2 sets up the basic two-period model. Section 3 demonstrates that bundling is irrelevant in the sense that it is never profitable if consumers are uninformed about the quality of both products. Section 4 modifies the basic model and considers a situation in which the quality of one product is

[2]Moorthy and Png (1992) is a notable exception. They address the issue of the timing of product introductions in a framework of durable goods markets with two types of consumers. The reason for sequential introduction of products in their paper is to avoid cannibalization of demand between two related products. They do not address the issue of informational asymmetry and, thus, the focus of their paper is rather different from mine.

known while the quality of the other is unknown. In this case, it is shown that bundling can be an effective way of signaling the quality of the product whose quality is unknown. In Section 5, I demonstrate that the possibility of informational leverage through bundling has important implications for the timing of product introductions. Section 6 concludes.

2. The Basic Model

In this section, I set up the basic model of bundling that will be used to develop a theory of informational leverage in later sections. Let me consider two *independent* products A and B that can be consumed separately. The quality for each product can be either high or low: $q^i \in \{H, L\}$, where i = A, B. There is a multi-product firm which is the sole producer of products A and B. The firm knows the actual qualities of the products, but the potential consumers, whose size is normalized to 1, do not know before purchase. In other words, the products have the characteristics of an "experience good" (Nelson, 1974). The *a priori* probability that the producer is endowed with the ability to produce the high quality product is denoted by ρ^i, where i = A, B. The quality realization for each product is assumed to be uncorrelated across products. The high quality producer has a choice of producing either a high quality product or a low quality product.

There are two periods. As in Kihlstrom and Riordan (1984), I assume that quality is unalterable in the second period once it is chosen in the first period. This assumption can be justified if production requires investments in quality-specific assets that, once committed, have a low opportunity cost. This assumption is made to eliminate the analytical complications induced by the possibility that a firm initially produces high quality and then, having established a reputation, switches to low quality. The producer endowed with the ability to produce only low quality products has no choice but to produce a low quality product. Each consumer demands at most one unit of each product in each period and has an identical reservation value of θ^i for high quality product, where i = A, B. If a good is of low quality, the gross surplus from the good is 0 for both products. Let c^i_H and c^i_L be the cost of product i for the high quality and low quality producer, respectively, where i=A, B. I assume that $\theta^i > c^i_H > c^i_L$ to reflect the fact that high quality goods are more costly to produce.

Before analyzing the bundling decision of a multi-product firm, I first consider a signaling model of introductory pricing in an isolated market, say product A, as a benchmark. Since a single market is analyzed, I omit the superscript denoting the identity of the market analyzed. The game is played in the following sequence. In the first period, the monopolist chooses a price. Consumers observe the price (P), form beliefs as to the probability that the product quality is high ($\hat{\rho}$), and make purchase decisions. The demand function in the first period depends on the price and consumers' beliefs and is given by:

$$D(P, \hat{\rho}) = 1, \text{ if } P \leq \hat{\rho}\theta$$
$$0, \text{ otherwise}$$

In the second period, consumers have complete information about the quality of the product. The high quality producer is able to charge its complete information monopoly price θ and gets the profit of $(\theta - c_H)$ whereas the low quality producer is unable to sell at any positive price and gets the profit of zero.

Let $\pi(P, q, \hat{\rho})$ be the profit function of the firm of true quality q (q = H or L) that sets a price P in the first period when consumers believe that the firm's quality is high with probability $\hat{\rho}$:

$$\pi(P, H, \hat{\rho}) = (P - c_H)\, D(P, \hat{\rho}) + \delta(\theta - c_H),$$

$$\pi(P, L, \hat{\rho}) = (P - c_L)\, D(P, \hat{\rho}) + \delta\, 0, \text{ where } \delta \text{ is the discount factor.}$$

Now let $\hat{P}(H)$ and $\hat{P}(L)$ be the prices charged by the high and low quality producers, respectively, and let $\hat{\rho}(P)$ be the consumers' posterior beliefs as to the probability that the product quality is high after observing price P in the first period. Then, the triplet $\{\hat{P}(H), \hat{P}(L), \hat{\rho}(P)\}$ forms a Perfect Bayesian Equilibrium (PBE) if and only if it satisfies the following sequential rationality (**P**) and Bayesian consistency in beliefs (**B**).

(**P**) $\hat{P}(H) \in \arg\max_P \pi(P, H, \hat{\rho}(P)) = \arg\max_P (P - c_H)\, D(P, \hat{\rho}(P)) + \delta(\theta - c_H),$

$\hat{P}(L) \in \arg\max_P \pi(P, L, \hat{\rho}(P)) = \arg\max_P (P - c_L)\, D(P, \hat{\rho}(P))$

(**B**) If $\hat{P}(H) = \hat{P}(L) = P$, then $\hat{\rho}(P) = \rho$

If $\hat{P}(H) \neq \hat{P}(L)$, then $\hat{\rho}(\hat{P}(H)) = 1$ and $\hat{\rho}(\hat{P}(L)) = 0$

Potentially, there are two types of equilibrium. In a separating equilibrium, the consumers identify high and low quality firms since they charge different prices. In a pooling equilibrium, consumers cannot update their beliefs just by observing the price since they charge the same price. In this paper, I shall assume that $\rho\theta < c_L$. This assumption eliminates pooling equilibrium since the highest price that can be charged in the first period in such equilibrium is $\rho\theta$. Thus, the low quality producer will not produce.

I now focus on separating equilibria where the identity of the producer is revealed through pricing.

Lemma 1. There is no separating equilibrium in which the high quality firm charges a price in the set (c_L, ∞).

Proof. For separation of types to occur, the high quality firm cannot charge a price in the set (c_L, ∞). Otherwise, the low quality firm will have an incentive to mimic the price and have a positive profit.

Lemma 1 implies that the high quality firm cannot charge its complete information monopoly price and needs to distort its price downward in a separating equilibrium. Given $\hat{P}(H) \notin (c_L, \infty)$, the best action for the low quality producer is to charge any price in $[c_L, \infty)$.

As usual, due to the freedom in specifying off-the-equilibrium beliefs, there is a plethora of equilibria. Most of these equilibria, however, are based on arguably implausible consumer beliefs. To pare down such unreasonable equilibria, we shall focus on the PBE that remain equilibria even after dominated strategies are removed sequentially from the game as in Milgrom and Roberts (1986).[3] This criterion imposes the condition that dominated strategies are never played and the "off-the-equilibrium path" beliefs assign zero probability to such strategies whenever possible. In the context of our signaling model, this implies that the low quality firm never sets a price lower than c_L in the first period, regardless of how such an action would be interpreted. This implies that if such a price is observed, consumers believe that the product is high quality, that is, $\hat{\rho}(P) = 1$ at a separating equilibrium for $P \notin [c_L, \infty)$.

Lemma 2. There is no separating equilibrium that survives the elimination of dominated strategies in which the high quality firm charges a price lower than c_L.

[3]For the justification of this refinement, see Milgrom and Roberts (1986) who apply this refinement to eliminate separating equilibria that entail excessive, inefficient amounts of signaling.

Proof. If the low quality firm charges c_L, the high quality producer needs to charge a price lower than c_L. Then, there is no solution to the high quality firm's maximization problem since the firm wants to set is price as close to c_L as possible without equaling it. Thus, there is no separating equilibrium in which the high quality firm charges a price lower than c_L.

Lemma 2 implies that the high quality firm does not need to charge under c_L to signal high quality since the low quality producer would never charge below c_L. Lemmas 1 and 2, taken together, lead me to conclude that the high quality firm chooses $\hat{P}(H) = c_L$ in any separating equilibrium whereas the low quality firm chooses a price $\hat{P}(L) \in (c_L, \infty)$ and makes no sales. The posterior beliefs sustaining this equilibrium strategy profile can be given as $\hat{\rho}(P) = 1$ if $P \leq c_L$ and $\hat{\rho}(L) = 0$, if $P > c_L$.[4]

Proposition 1. If $\rho\theta < c_L$, there is no pooling equilibrium. There is a continuum of separating equilibria which is given by $\hat{P}(H) = c_L$, $\hat{P}(L) \in (c_L, \infty)$. Despite the multiplicity of equilibria due to the leeway in specifying the low quality producer's strategy, we have a unique outcome in terms of profits. The high quality firm earns the profits of max $\{(c_L - c_H) + \delta(\theta^A - c_H^A), 0\}$ since it has an option of not selling the product. The low quality firm earns zero since it is not able to sell any.

3. (Dis)incentives of Bundling if Neither Product's Quality is Known to Consumers

In this section, I return to the analysis of multi-product firm and consider its incentives to bundle. In the beginning of the first period, the firm makes a decision on bundling. This decision is assumed to be *irreversible*. As in Whinston (1990) and Carbajo et al. (1990), this precommitment can be made possible through costly investments in product design and the production process.[5] The irreversibility of bundling decision implies that once two products are bundled, it is costly to de-couple and withdraw one of the two products later. As a result, bundling of a high quality product with a low quality one can be a risky proposition. There are many channels through which the inclusion of a low quality product in a bundle can have negative consequences. For instance, the bundling firm may suffer from the additional production cost of a low quality item for which consumers refuse to pay in the future when the quality is revealed.[6]

Even in the absence of significant variable production cost, tying with a low quality product can be harmful. It can lower the surplus from the high quality product in the bundle if irreversible tie-ins with a low quality product can degrade the performance of the high

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[4] Alternatively, if there is a very small entry cost of ε, the low quality producer will not enter the market.

[5] In the software industry, a recent case involving Microsoft's bundling practice provides an example. When Microsoft upgraded Internet Explorer to version 3.0, it placed some of the program's improved code into files that also contained instructions for operating system functions. The sharing of these files, called dynamic linked libraries, in the design of software makes these two programs difficult to separate without jeopardizing the stability of each program. In the Microsoft case, however, more relevant is the strategic theory of bundling in which bundling is used as a mechanism to foreclose rival firms from the market. See Whinston (1990), Choi (1996), Aron and Wildman (1999), Carlton and Waldman (1998), and Nalebuff (1999). In this paper, I consider a monopolistic supplier and there is no strategic interaction between firms.

[6] In this paper, I only consider *pure* bundling. In my model, mixed bundling in which the firm offers the products on a stand-alone basis as well as in a bundle is equivalent to no bundling. Thus, a firm's unwillingness to offer stand-alone prices in addition to bundled prices *per se* is not a sign of anticompetitive intent. If there is some variation in demand with some consumers valuing only one product, say A, there might be an incentive to offer the goods separately as well as bundled as a price discrimination device.

quality product when consumed together. As long as the separation of the two products is costly for consumers and as a result induces consumers to pay less for the high quality component, there may be a degrading cost associated with bundling.[7] This type of cost is especially relevant for software products where the "weakest link" principle tends to apply and variable production cost is negligible once development costs are sunk.[8] Merrill Lynch's experience with its Cash Management Account provides an example that illustrates the cost of bundling. The Cash Management Account was basically bundling of financial services that permits card and check withdrawals from an investment account. Merrill Lynch, however, had encountered significant operational problems with its account because of the time-consuming customer inquiries directed to its brokers. The company eventually had to hire several hundred clerks for the program (Yoffie, 1990, p. 374).

As discussed above, the costs associated with the inclusion of a low quality product in a bundle can take many forms that depend on the specifics of the case. They could be the additional production cost of the low quality item (c^i_L) for which consumers refuse to pay in the future when the quality is revealed and/or the cost of degrading as in the Merrill Lynch example. Without being specific about the sources of these costs, let me denote them as χ.

I first demonstrate that bundling is never a profitable strategy if consumers know the quality of both products or neither of them. To see this, suppose that the two products are

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[7] For example, the Windows 95 operating system was alleged to disable a key piece of competing on-line access software and made it too difficult for users to reinstall, forcing users to adopt Microsoft's on-line system (the Microsoft Network, MSN), which was bundled with the operating system (Gleick, 1995).

[8] The weakest link principle says that the performance of a system comprising of many components depends on the lowest quality component.

not bundled. Then, each market can be analyzed separately as in the previous section. I assume that $\rho^i\theta^i < c_L^i$, where i = A, B, to eliminate the pooling equilibrium. To signal the quality, the high quality producer charges the production cost of the low quality producer in the first period (c_L^i). Profit from the product A for the high quality producer is

$$\pi^A = \max\ \{(c_L^A - c_H^A) + \delta(\theta^A - c_H^A), 0\}.$$

Similarly, the profit for the high quality producer of product B is given by

$$\pi^B = \max\ \{(c_L^B - c_H^B) + \delta(\theta^B - c_H^B), 0\}.$$

In a separating equilibrium, the low quality producer is unable to sell and makes zero profit. The market for the high-quality product i exists if $(c_L^i - c_H^i) + \delta(\theta^i - c_H^i) > 0$, i.e., the second period profit from the repeat purchase outweighs the first period loss from introductory pricing. In this case, I will say that market i is *viable*. Otherwise, there is a complete market failure in that the existence of a low quality producer drives the high quality producer out of the market.

Let $\Pi(q^A,q^B)$ denote the profit for the multi-product monopolist when the qualities of products A and B are given by $q^A$and q^B, respectively, where $q^A, q^B \in \{H, L\}$. Then, we have

$$\Pi(H, H) = \pi^A + \pi^B$$

$$= \max\ \{(c_L^A - c_H^A) + \delta(\theta^A - c_H^A), 0\} + \max\ \{(c_L^B - c_H^B) + \delta(\theta^B - c_H^B), 0\}$$

$$\Pi(H, L) = \pi^A = \max\ \{(c_L^A - c_H^A) + \delta(\theta^A - c_H^A), 0\}$$

$$\Pi(L, H) = \pi^B = \max\ \{(c_L^B - c_H^B) + \delta(\theta^B - c_H^B), 0\}$$

$$\Pi(L, L) = 0 \qquad (1)$$

Now suppose that the two products are bundled. Applying the same logic we used for the single market case, the condition for the price of the bundled product to signal quality is given by $P \leq c_L^A + c_L^B$. Let $\tilde{\Pi}(q^A, q^B)$ denote the corresponding profit for the multi-product monopolist when the qualities of products A and B are given by $q^A$and q^B and they are sold as a bundle.[9]

$$\tilde{\Pi}(H, H) = \max\{(c_L^A + c_L^B - c_H^A - c_H^B) + \delta(\theta^A + \theta^B - c_H^A - c_H^B), 0\}$$

$$\tilde{\Pi}(H, L) = \max\{(c_L^A + c_L^B - c_H^A - c_L^B) + \delta(\theta^A - c_H^A - \chi), 0\}$$

$$\tilde{\Pi}(L, H) = \max\{(c_L^A + c_L^B - c_L^A - c_H^B) + \delta(\theta^B - c_H^B - \chi), 0\}$$

$$\tilde{\Pi}(L, L) = 0 \qquad (2)$$

It can be easily verified that $\tilde{\Pi}(q^A, q^B) \leq \Pi(q^A, q^B)$, for all $(q^A, q^B) \in \{H, L\} x \{H, L\}$.

The discussion above leads us to conclude the following.

Proposition 2. When the qualities of both products are unknown to consumers in the first period, bundling cannot be used to signal quality and thus, is not a more profitable strategy than unbundling.

It is instructive to identify the types of the multi-product monopolist who would be strictly worse off with bundling. For simplicity, consider the case where a separating equilibrium exists in both markets if the goods are sold separately, i.e., $\delta(\theta^i - c_H^i) > (c_H^i - c_L^i)$, where i = A, B. Then, it is immediate that

$$\Pi(H, H) = (c_L^A - c_H^A) + \delta(\theta^A - c_H^A) + (c_L^B - c_H^B) + \delta(\theta^B - c_H^B) = \tilde{\Pi}(H, H)$$

$$\Pi(H, L) = (c_L^A - c_H^A) + \delta(\theta^A - c_H^A) > \max\{(c_L^A - c_H^A) + \delta(\theta^A - c_H^A - \chi), 0\} = \tilde{\Pi}(H, L)$$

$$\Pi(L, H) = (c_L^B - c_H^B) + \delta(\theta^B - c_H^B) > \max\{(c_L^B - c_H^B) + \delta(\theta^B - c_H^B - \chi), 0\} = \tilde{\Pi}(L, H)$$

[9]Throughout the paper, profits associated with bundling will be denoted with tilde.

That is, the multi-product monopolist of high quality in both products is indifferent to the bundling decision whereas the firms of high quality in only one product are strictly worse-off with bundling.

There are two cases to consider for the monopolist of latter type, say (H, L), that bundles. If it continues to produce in the second period, bundling induces an extra cost of χ in that period. The reason is that this type of monopolist suffers from the additional production cost of a low quality item and/or the cost of degrading when the quality is revealed. If it stops producing the bundled products in the second period, it bears a loss of $(\theta^A - c_H^A)$, which makes the "fly-by-night" strategy less attractive. Hence, bundling creates an extra cost of $\xi = \Pi(H, L) - \widetilde{\Pi}(H, L) = \min\{\chi, \theta^A - c_H^A\}$ for the (H, L) type firm. This asymmetry in the incentive to bundle suggests that the bundling decision may be used as a signal of quality. This possibility is explored in the next section by modifying the informational structure of the basic model.

4. Bundling when One Product is Known to be of High Quality

In the previous section, I established the fact that when the two products have the same informational status, bundling cannot be used as an information revelation device. Now I modify the basic model by introducing asymmetry across markets in the informational structure. More specifically, I assume that the quality of one product, say A, is already established to be of high quality whereas product B is just developed and the quality of it is unknown to potential consumers.[10] Once again, the multi-product monopolist makes an

[10]Alternatively, product A is an "inspection good" whose quality can be ascertained before purchase whereas product B is an experience good (Nelson, 1974).

irrevocable decision about bundling at the beginning of the first period.

To economize on space, let me assume that the monopolist's potential surplus in market A, which is given by $\theta^A - c_H^A$, is sufficiently large that the following condition holds:

$$\theta^A - c_H^A > \chi$$

This condition ensures that the multi-product monopolist whose quality for product B is low, will still sell the bundled product even after its identity is revealed. Thus, the cost of bundling for the low quality producer of B is given by $\xi = \min\{\chi, \theta^A - c_H^A\} = \chi$. I consider two cases.

Proposition 3. If $\theta^B < c_L^B + \delta\chi$, bundling alone signals that product B is of high quality. There is no need for introductory pricing.

Proof. The equilibrium concept I use in this signaling game is once again the Perfect Bayesian Equilibrium that is immune to sequential elimination of dominated strategies. With this refinement requirement imposed, it suffices to show that bundling is a dominated strategy for the low quality producer of B. The maximum profit under bundling for the low quality producer of B is given by $(\theta^A + \theta^B - c_H^A - c_L^B) + \delta(\theta^A - c_H^A - \chi)$. Under the maintained assumption $\theta^B < c_L^B + \delta\chi$, it is straightforward to verify that the profit from bundling is smaller than the alternative profit of selling only in market A, which is given by $(1+\delta)(\theta^A - c_H^A)$. For the high quality producer of B, in contrast, bundling is costless and allows the firm to sell at the perfect information price. Thus, the consumers' posterior beliefs should be 1 if there is bundling in this case. Q.E.D.

Now suppose that $\theta^B > c_L^B + \delta\chi$. Then, bundling alone is not sufficient to signal the quality of product B since it is not a dominated strategy for the low quality firm. It will, however, be shown that bundling can still minimize the losses during the introductory phase. Moreover, physical tie-in with the established product may make it possible for product B to be marketed profitably as a part of a bundled product. This is so even when asymmetric information makes it impossible for the high quality producer of B to sell with nonnegative profit and, therefore, the stand-alone market for B does not exist. In this case, bundling can create an otherwise nonviable market.

To compare the relative merits of bundling vis-à-vis independent marketing, I need to consider two cases depending on whether or not product B is viable on its own. Product B is defined to be viable if it can be marketed independently with nonnegative profit, i.e., $\delta(\theta^B - c_H^B) > c_H^B - c_L^B$. Tirole (1988) interprets this condition in the following way. The left hand side (LHS) of the inequality is the *Nelson effect* (1974) reflecting the fact that a high quality producer generates repeat purchases. The right hand side (RHS), a cost differential in favor of the low-quality producer, is called the *Schmalensee effect* (1978) and represents the low quality producer's incentive to masquerade as a high quality producer. Then, a separating equilibrium exists if the Nelson effect dominates the Schmalensee effect.

<u>Case I</u>. Tied product (B) is viable ($\delta[\theta^B - c_H^B] > c_H^B - c_L^B$).

In this case, market B is viable on its own and the profit from market B without bundling is given by $\pi^B = (c_L^B - c_H^B) + \delta(\theta^B - c_H^B) > 0$. Therefore, it is always better to introduce product B to the market and the total profit for the firm without bundling can be written as:

$$\Pi = (1+\delta)(\theta^A - c_H^A) + [(c_L^B - c_H^B) + \delta(\theta^B - c_H^B)] \quad (3)$$

Now suppose that the multi-product firm with two high quality products decides to bundle the two products. To distinguish itself from the low quality producer of B, the price for the bundled product P should satisfy the following incentive compatibility constraint:

$$(P - c_H^A - c_L^B) + \delta(\theta^A - c_H^A - \chi) \le (1+\delta)(\theta^A - c_H^A), \tag{4}$$

i.e.,

$$P \le \theta^A + c_L^B + \delta\chi \tag{5}$$

That is, the low quality producer's profit from bundling is less than his profit from merely selling product A, which ensures that the low quality producer have no incentive to mimic the high quality producer's strategy. Since P cannot be higher than its reservation value $\theta^A + \theta^B$, $P = \min[\theta^A + c_L^B + \delta\chi, \theta^A + \theta^B]$. With the maintained assumption of $\theta^B > c_L^B + \delta\chi$, $P = \theta^A + c_L^B + \delta\chi$.

Therefore, I can write the profit from the bundling as:

$$\widetilde{\Pi} = (\theta^A + c_L^B + \delta\chi - c_H^A - c_H^B) + \delta(\theta^A + \theta^B - c_H^A - c_H^B) \tag{6}$$

Comparison of the profit levels from bundling (Eq. (6)) and independent marketing (Eq. (3)) shows that bundling generates unambiguously higher profits.

$$\widetilde{\Pi} - \Pi = \delta\chi > 0 \tag{7}$$

The intuition for this result is the following. For the high quality producer of B, bundling becomes irrelevant in terms of future profit when the quality of B is revealed. However, for the low quality producer, bundling is a less attractive option once information is revealed. The reason is that consumers are not willing to pay for the low quality product B, while the producer has to continue to incur the production cost of B due to irrevocable physical tie-ins with product A. Alternatively, there may be negligible variable cost involved with the continued production of B as in the software case. However, the inclusion of the low quality product B may degrade A's performance, and thus reduce consumers' willingness to pay for product A to the extent that the separation of the two products is costly for consumers. As a result, bundling can be a commitment that is costly for the low quality producer. This asymmetry in the commitment cost of bundling (0 vs. $\delta\chi$) allows the high quality producer to signal its quality by bundling. Interpreted this way, it is not surprising that the profit gain from bundling is given by $\delta\chi$, which I call the *costly commitment effect* facing the low quality producer.

Case II. Tied product (B) is not viable ($\delta[\theta^B - c_H^B] < c_H^B - c_L^B$).

In this case, market B is not viable on its own and the profit from market B without bundling is zero. Therefore, the total profit for the firm without bundling can be written as:

$$\Pi = (1+\delta)(\theta^A - c_H^A). \tag{8}$$

Now suppose that the multi-product firm with two high quality products decides to bundle the two products. To distinguish itself from the low quality producer of B, the price for the bundled product should satisfy the same incentive compatibility constraint (4) and the profit is the same as before. The difference between the profit from bundling and the profit from independent marketing is:

$$\tilde{\Pi} - \Pi = \delta\chi - [(c_H^B - c_L^B) - \delta(\theta^B - c_H^B)]. \tag{9}$$

Expression (9) can be interpreted in the following way. Once again, bundling enables the monopolist to charge a higher price for the product B ($c_L^B + \delta\chi$ vs. c_L^B). The first term on the RHS ($\delta\chi$) represents the beneficial effect of bundling due to the costly commitment effect. When product B is not viable on its own, however, bundling also absorbs the cost of satisfying the viability constraint for product B. The expression in square bracket represents this loss. Bundling will be practiced only when the benefit outweighs the cost. Proposition 4 summarizes the bundling decision for the case where $\theta^B > c_L^B + \delta\chi$.

Proposition 4. Suppose that $\theta^B > c_L^B + \delta\chi$. Then, when product B is introduced, it is always sold as a part of a bundled product *with* introductory pricing. More specifically:

(a) If product B is viable on its own, bundling is always beneficial.

(b) Even if product B is not viable on its own, it can be introduced with A as a part of a bundled package if $\delta\chi - [(c_H^B - c_L^B) - \delta(\theta^B - c_H^B)] > 0$, i.e., the costly commitment effect cum Nelson effect dominates the Schmalensee effect. Otherwise, product B is not introduced in the market.

Figure 1 summarizes Propositions 3 and 4 and depicts the region of cost parameters in which bundling is beneficial.

[Insert Figure 1 about Here]

Three remarks are in order. First, an explanation is needed for why bundling is beneficial when the quality of one product is already established whereas bundling has no bite when the qualities of both products are unknown. The reason has something to do with the cost of posting a bond for the high quality producer whose quality is already known. When the qualities of both products are unknown, the presence of (L, L) producers prohibits the price of the bundled product from being above $(c_L^A + c_L^B)$ in a separating equilibrium; an (L, L) producer has nothing to lose in the future by mimicking the (H, H) producer with bundling. However, when the monopolist is already known to produce A with high quality, mimicking by the (L,L) type is irrelevant. In this case, bundling can effectively post a bond because bundling with low quality B necessarily impels the firm to incur an unnecessary cost of $\delta\chi$ in the future in order to get the surplus from product A. Therefore, the multi-product monopolist can use bundling to signal the quality of B. It can be said that the product of known quality provides *informational leverage* which can be used in the market where quality information is imperfect.

Second, in the case where the quality of only one of two products is known, there is an efficiency reason for bundling. When product B is viable on its own, bundling is inconsequential from the social planner's perspective because with identical consumers with unit demand, the price change has only distributional consequences. In the case where product B is not viable on its own, however, bundling can also have a beneficial welfare effect because it can create a new market; without bundling the market for B will be nonexistent and the potential surplus will not be realized due to asymmetric information.[11]

Third, in the model presented above, the costly commitment effect is coming from additional production costs and/or degrading costs facing the low quality producer of B. The model, however, can be interpreted more broadly. Because it is precisely the bonding mechanism upon which bundling depends to signal quality, the results should be understood as more generally applicable. For instance, if there is uncertainty in regard to the attributes of products that are important to consumers, bundling may be considered as a commitment to support and ensure the quality of a tied product. In this case, bundling is a signal to guarantee the *future* quality rather than the existing one. If the new product is independently introduced, the seller might just pull the product out of the market if it turns out that the new

[11]With independent marketing, the condition for a market to exist is that the Nelson effect dominate the Schmalensee effect. With bundling, this condition is relaxed because the new condition is that the Nelson effect *cum* the costly commitment effect dominate the Schmalensee effect.

product receives a low level of consumer acceptance and if upgrading is too costly. However, with bundling, the firm might have no choice but to support the tied product in order to avoid negative externalities on the tying product. This type of commitment is especially important for the products that involve a significant adoption cost such as computer software to induce consumers to make a purchase [Farrell and Gallini (1987) and Shepard (1987)].

Moreover, the possibility of informational leverage is not restricted to physical tying. As the discussion above indicates, informational leverage can be generated through a variety of marketing arrangements employed by a multi-product firm. The extent of these arrangements will depend on how much a low quality product can adversely affect the profits in the high quality product market. To make this point, I consider brand extension as an example elsewhere in Choi (1998). For brand extension, no physical tie-ins are involved between products. Rather, a multi-product firm uses its *reputation* as a bond for quality by using a brand name for an established product when it introduces a new experience good. Therefore, the theory of informational leverage can be applied to a wider variety of circumstances than bundling.

5. Endogenous Timing of Product Introductions

Section 4 demonstrates that bundling may be used to signal the quality of an experience good when the quality of one of the bundled product is already established whereas bundling is not useful when both products are of unknown quality. This result has implications for the timing of product introductions. To address the endogenous timing of product introductions, a three-period extension of the basic model is used to allow for the asynchronization of product introductions. More specifically, I explore whether it is useful to introduce products sequentially in order to establish the quality of one product first and then use this information as leverage in a second market.

The endogenous timing of product introductions is analyzed in a three period model in which the multi-product monopolist has a choice between simultaneous and sequential product introductions. The monopolist has two products, and both qualities are initially unknown to consumers. In the first period, the monopolist decides to introduce both of them or only one of them. In the case of simultaneous introduction, I assume that they are independently marketed since from section 3, we know that unbundling weakly dominates bundling when both qualities are unknown to consumers. If only one product is introduced in the first period, the monopolist can introduce the remaining product in the second period. At this time, the monopolist makes an irreversible decision regarding whether to introduce the second product as a bundled product with the one introduced earlier. To simplify the analysis, discounting is ignored in this section ($\delta = 1$). I consider three cases depending on the viability of products when they are marketed independently.

5.1. Only one product is viable.

Without loss of generality, let me call the viable product A. Then, the conditions under which only one product is viable are:

$$\pi^A = (c_L^A - c_H^A) + 2(\theta^A - c_H^A) > 0, \ \pi^B = (c_L^B - c_H^B) + 2(\theta^B - c_H^B) < 0$$

In this case, introducing two products simultaneously in the first period is dominated by introducing only A. The question is whether the monopolist has incentive to introduce product B in the second period as part of a bundled product.

The decision problem in the second period is the same one analyzed in the previous section. I can conclude that product B will be introduced later as a bundled product if either $\theta^B < c_L^B + \chi$ or $\theta^B > 2c_H^B - c_L^B - \chi$ (see section 4).[12] In the former case, product B is introduced without introductory pricing whereas in the latter case it is introduced with introductory pricing. Therefore, informational leverage provided by product A through bundling allows product B to be introduced later profitably even in the case that B is not viable on its own. In this case, bundling also enhances welfare because the alternative is the complete failure of market B and non-realization of surplus in that market due to asymmetric information.

5.2. Both products are viable on their own.

For both products to be independently viable, the following conditions must hold for *i* = A, B:

$$\pi^i = (c_L^i - c_H^i) + 2(\theta^i - c_H^i) > 0 \qquad (10)$$

The first term in condition (10) represents first-period profit from the price of c_L^i and the cost of c_H^i and the second term represents two periods of sales at the high quality reservation price. In this case, both products can be profitably marketed independently. I examine whether sequential product introduction can be useful even in this case. First, note that if products are independently marketed, it is never optimal to introduce the products sequentially because the firm foregoes one period of profit with no corresponding benefit. When both products are viable, the profit from simultaneous introduction will be the same whether the goods are bundled or not as in the two period model. The profit from

[12] Note that I ignore the discount factor in this section, i.e., set δ=1.

simultaneous introduction is given by:

$$\Pi = \pi^A + \pi^B = [(c_L^A - c_H^A) + (c_L^B - c_H^B)] + 2[(\theta^A - c_H^A) + (\theta^B - c_H^B)] \qquad (11)$$

Now consider an alternative strategy of introducing one product first and a second product later, bundled with the first product. Suppose that product A is introduced and its quality is revealed in the first period. Once again, for ease of presentation, let me assume that $\theta^A - c_H^A > \chi$ holds. I consider two subcases.

Case I. $\theta^B < c_L^B + \chi$

In this case, bundling in the second period is a dominated strategy for the multi-product firm who already established the quality of product A and has a low quality product B.

$$(\theta^A + \theta^B - c_H^A - c_L^B) + (\theta^A - c_H^A - \chi) < 2(\theta^A - c_H^A) \qquad (12)$$

The LHS of inequality (12) is the maximum possible profit from bundling while the RHS represents the profit from product market A from the second period onwards. Therefore, bundling alone is sufficient to signal the quality of product B and the monopolist can charge the full information price $\theta^A + \theta^B$.

$$\tilde{\Pi} = (c_L^A - c_H^A) + 2(\theta^A + \theta^B - c_H^A - c_H^B) \qquad (13)$$

In this case, $\tilde{\Pi} - \Pi = c_H^B - c_L^B$; sequential introduction with bundling is a strictly better strategy for the multi-product firm even though both of them can be introduced in the first period with positive profit. The increase in profit due to sequential introduction with bundling, $c_H^B - c_L^B$, represents the loss from introductory pricing for product B with independent marketing. The reason is that by delaying the introduction of product B until the second period and using the leverage provided by the quality of product A, the multi-product firm can charge the full information price from the time of product introduction. This allows the multi-product firm to avoid the loss in the introductory phase associated with independent marketing.

Case II. $\theta^B > c_L^B + \chi$

In this case, bundling alone is no longer sufficient to signal quality. For the separation of types, introductory pricing is required. The price of the bundled product in the second period should satisfy the same type of incentive compatibility constraint as (4). Ignoring the discount factor (i.e., set $\delta=1$), the incentive compatible price is given by $P = \theta^A + c_L^B + \chi$. The profit from sequential introduction cum bundling is:

$$\tilde{\Pi} = (c_L^A - c_H^A) + [\theta^A + c_L^B + \chi - c_H^A - c_H^B) + (\theta^A + \theta^B - c_H^A - c_H^B)] \quad (14)$$

Comparison of (11) and (14) yields:

$$\tilde{\Pi} - \Pi = \chi - (\theta^B - c_H^B)$$

The tradeoff is the following. Sequential introduction allows the multi-product firm higher introductory pricing due to informational leverage provided by the product introduced earlier. This beneficial effect is χ. The firm, however, foregoes one period of profit, $\theta^B - c_H^B$, by delaying introduction one period. Figure 2 depicts the region in which sequential product introduction can be profitable assuming that product A is viable on its own and introduced in the first period.

[Insert Figure 2 about Here]

Note that with sequential introduction, social welfare is strictly reduced in this case due to the delay of product introduction even though it is profitable for the multi-product firm. This welfare result, however, should be interpreted with two important caveats. First, our model assumes that the firm develops A and B simultaneously. If the company could choose when to spend the innovation cost, it would spend on A immediately but delay spending on B. Thus, not only the social benefit, but also the social cost of B is delayed. Second, the model takes it as exogenous that the seller has the option of high and low quality, as opposed to only being able to produce low quality. However, it may be possible that a seller can produce a high quality at some cost by spending on R&D or capital capable of producing high quality. In such a case, the sequential introduction provides more return on the investment.

5.3. Neither product is viable on its own.

For neither product to be viable on its own, the following condition need be satisfied:

$$\pi^i = (c_L^i - c_H^i) + 2(\theta^i - c_H^i) < 0. \tag{15}$$

This is the most interesting case. It can be demonstrated that even though both products are not viable, it is possible to avoid market failure by introducing these two products sequentially. To demonstrate this possibility, suppose that

$$\theta^A - c_H^A > \chi \text{ and } \theta^B > c_L^B + \chi \tag{16}$$

Consider a strategy of introducing products sequentially with A as the lead product. Then, the total profit summed over the three periods can be written as Eq. (14). Therefore, the condition for sequential product introduction to be profitable is:

$$\tilde{\Pi} = (c_L^A - c_H^A) + [\theta^A + c_L^B + \chi - c_H^A - c_H^B) + (\theta^A + \theta^B - c_H^A - c_H^B) > 0 \tag{17}$$

It is easy to verify that the set of parameters that satisfy conditions (15), (16), and (17) is not empty as shown in the following numerical example.

Example. Let $\theta^A = 10$, $c_L^A = 7-\varepsilon$, $c_H^A = 9$; $\theta^B = 2$, $c_L^B = 1-\varepsilon$, $c_H^B = 1\frac{2}{3}$, where ε is a small positive number. Then,

$$\pi^A = (c_L^A - c_H^A) + 2(\theta^A - c_H^A) = -\varepsilon, \pi^B = (c_L^B - c_H^B) + 2(\theta^B - c_H^B) = -\varepsilon.$$

Therefore, both products are not profitable with independent marketing. With sequential marketing with bundling, however, the profit is

$$\tilde{\Pi} = (c_L^A - c_H^A) + [\theta^A + c_L^B + \chi - c_H^A - c_H^B) + (\theta^A + \theta^B - c_H^A - c_H^B) = \chi - \frac{1}{3} - 2\varepsilon.$$

Therefore, as long as $\chi > \frac{1}{3} - 2\varepsilon$, the profit is positive with sequential marketing.[13]

Even though each product is not viable on its own, once the quality of one product is established, the other product can be introduced profitably by leveraging off the quality of the known product. If this profit from the second product outweighs the loss from the first period product, both products can be marketed by sequencing the introduction of the products judicially.[14] The welfare implications of bundling in this case is unambiguously beneficial because without it the market outcome is outright market failure.

The endogenous sequencing of product introductions in my model also provides an alternative theory of the diversification process of a multi-product firm over time. One common explanation revolves around financial market imperfections. For example, if financial markets are imperfect, a gradual expansion in the array of product offerings by a

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[13] To satisfy condition (15), it is also required that $\chi < 1$.

[14] This is in sharp contrast to the leverage theory for R&D competition in which bundling can be profitable *only if* there is a slack in the (preemptive) constraint in one market (Choi, 1996). Here the market viability constraint is binding in both markets in that neither market can survive independently. However, it is possible that markets for both products can be created profitably with the help of informational leverage.

firm may be driven by the liquidity constraint facing the firm in introducing the whole spectrum of products at the same time. In this case, the resources necessary to expand the firm's product offering may have to be raised by retained earnings, which explains a gradual expansion process in product offerings. However, according to my model, sequencing in the introduction of products may be used to leverage off the reputation of the already known product even though it had enough financial resources for simultaneous introduction in order to use informational leverage provided by sequential introduction.

6. Conclusion

This paper provides a theory of *informational leverage* in which a firm leverages off a good's reputation in one market to alleviate the problem of informational asymmetry encountered in a second market. Its implications for the endogenous timing of product introductions are also explored.

The theory is introduced in the context of bundling. As with umbrella branding analyzed by Wernerfelt (1988), bundling a product of unknown quality with an already proven high quality one serves as a mechanism to post a bond; it is a costly commitment for a low quality producer because he has to continue incurring the production cost of the low quality item for which consumers refuse to pay once its quality is revealed. This possibility of informational leverage has important implications for the endogenous sequencing of product introductions. The most surprising result is that the sequential introduction of new products allows the use of informational leverage, and thus makes it possible that both products be introduced even when neither of them is viable on its own.

The welfare implications of bundling are also discussed. Many special features of the model enable me to draw a clear cut conclusion on the welfare implications of bundling.

When at least one of the products is not viable on its own, bundling is efficiency enhancing because it creates an otherwise nonexistent market. However, when both products are viable on their own, sequencing impairs welfare. The reason for welfare reduction is different from the usual leverage theory where bundling is used to extend monopoly power in one market to the other. Rather in this paper, it rather comes from a delay in product availability.

Even though I couch the basic theory in the context of bundling, the logic of the theory indicates that any marketing arrangement that purposely associates one product with another may serve the same purpose as bundling, if the association of a high quality product with a low quality product can adversely affect the profits in the high quality product market. Therefore, any such arrangement may be considered a form of informational leverage. This point is further explored in Choi (1998) where the theory of informational leverage is applied to brand extension. In the case of brand extension, no physical tie-ins between the two products are involved. Instead, a multi-product firm stakes its *reputation* as a bond for quality.[15]

There are many extensions worth pursuing to test the robustness of the model. In this paper, I use a model in which a low introductory price signals a high quality. I expect the basic results to hold also for models in which high quality is signaled through high prices [See, for instance, Milgrom and Roberts (1986) and Bagwell and Riordan (1991)]. Suppose that bundling forces a low quality product to be produced in higher quantity when it is bundled with a high quality product. This raises the costs from current period imitation by

[15] See also Chu and Chu (1994), Biglaiser (1993), and Biglaiser and Friedman (1994) for related ideas. In these papers, shared retailers or shared middlemen are used as guarantors of quality. Other examples of creating a signal include advertising and warranties. We expect bundling to be a useful signaling device if the two products bundled tend to be used together.

inducing less efficient production in the future. In a model in which initial period signaling is through high prices, this effect would allow a reduction in prices (i.e., less distortion from the full information monopoly price) when bundling is allowed. I can also extend the model to allow for heterogeneous reservation values of consumers. Another dimension of heterogeneity to be examined is consumers' information regarding the quality of products. For instance, there could be two types of consumers, the informed and the uninformed. Even though I am optimistic about the robustness of the basic insight of this paper, a detailed study awaits further research.

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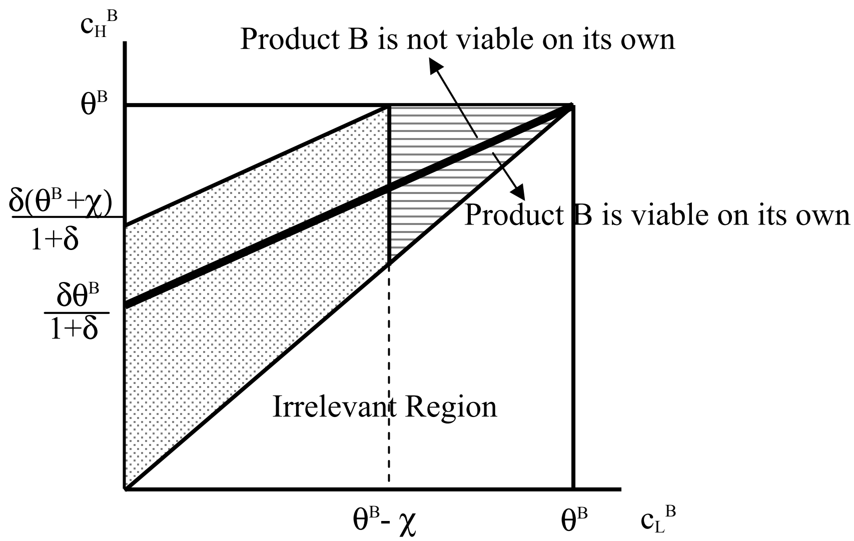

Figure 1. Bundling as a Signal of Quality: The horizontally-shaded area represents the parameter space where bundling alone is sufficient to signal high quality. In the dotted area, signaling of quality requires bundling cum introductory pricing. Moreover, the horizontally shaded and dotted areas above the thick line are the parameter space where bundling enables the introduction of B and improves welfare.

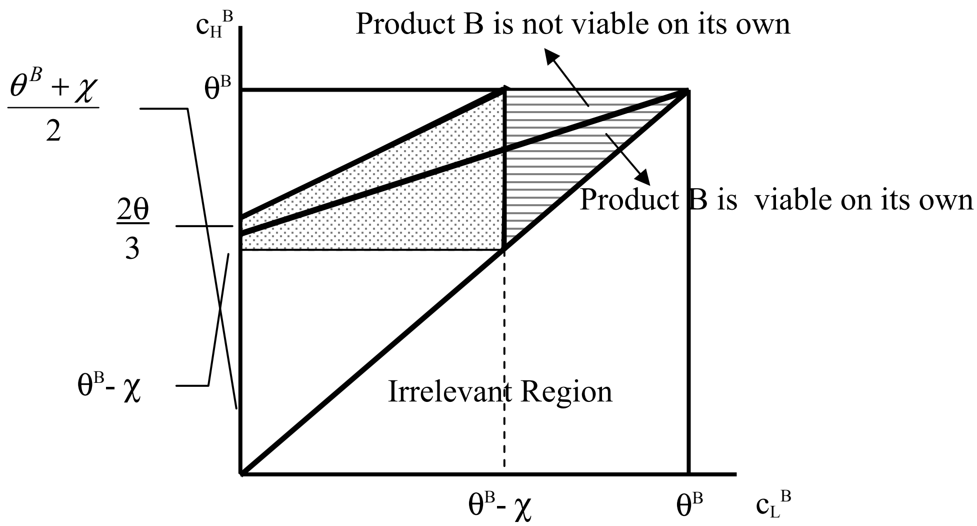

Figure 2. Simultaneous versus Sequential Product Introduction: The horizontally-shaded and dotted areas represent the region where sequential introduction with bundling is more profitable. In the horizontally-shaded area, bundling alone is sufficient to signal quality and no introductory pricing is needed. In the dotted area, introductory pricing is needed.