December 2000

# Versioning Information Goods with Network Externalities

Bing Jing
*University of Rochester*

# VERSIONING INFORMATION GOODS WITH NETWORK EXTERNALITIES

**Bing Jing**
William E. Simon School of Business Administration
University of Rochester
U.S.A.

## Abstract

*Positive externalities characterize the consumption of a majority class of information goods and services such as software, e-mail, and online content and services including virtual communities. We show that network externality is critical for the market segmentation and product line decisions of an information goods seller. With externality, a monopoly of multiple existing products offers exactly two distinct qualities. When development costs are taken into account, the low quality is developed only if the gain in revenue due to an enlarged network exceeds the extra development costs. In particular, if developed, the low quality should be offered for free under very general conditions. Network externality itself thus can explain the market provision of free information goods by proprietary sellers from a product line design perspective.*

**Keywords:** Information goods, network externality, product line design.

## 1. INTRODUCTION

Information has been part of human civilization, even though the term information goods only gained popularity recently. TV programs, books, digital images, software, and online trading services are all examples of information goods. A defining property of information goods is that the first copy is costly to make but the costs of reproducing the subsequent copies are negligible (Shapiro and Varian 1999). By this criterion, information goods may be more prevalent than we think: the product designs built into the numerous physical goods such as cars and aircraft are also information goods. The prominence of information goods has been promoted by waves of new technologies. The bloom of personal computers made packaged software a standard commodity in the 1980s. In the past decade, the proliferation of the Internet has brought about even more varieties of information goods and closely tied them to our everyday lives. Interestingly, a vast amount of information goods on the Internet are freely available, which has reciprocated the rapid adoption of these new technologies.

Many information goods such as software and online content including online communities demonstrate salient consumption externalities: the larger the user base, the greater the user perceived value. The network externality in software is due to the scale economies in usage, such as exchange of data and learning tips. Members in a virtual community contribute and share a significant portion of the content (Hagel and Armstrong 1997). In this paper, we focus on the role of externality in the market segmentation of such information goods and provide a new theoretical underpinning for free information goods from the perspective of product line selection.

The current paper draws upon three lines of existing research: network externalities, vertical product differentiation, and information goods. Economists first realized that consumers of many products benefit from the products' installed base as well as their intrinsic utilities. The telecommunications industry is a classic example (Rohlfs 1974; Oren and Smith 1981). Such markets with network externalities (or "network markets") have properties not demonstrated in conventional markets: both market history and consumer expectations about the ultimate network size are crucial to network formation. Due to these idiosyncrasies of network markets, an inferior product may beat a superior one (Arthur 1989; Farrell and Saloner 1986).

These unique features complicate the competing strategies of firms operating in a network environment, such as product compatibility, technology sponsorship, penetration pricing, and product pre-announcements (Farrell and Saloner 1986; Katz and

Shapiro 1985,1986). Among these strategies, penetration pricing is of particular relevance to us. A clear reason for offering low prices (even below marginal costs) is to obtain an installed base advantage at the expense of short-run profit sacrifice. In the case of information goods with negligible marginal costs, this involves giving away products for free (Bessen and Farrell 1994; Shapiro and Varian 1999). In the context of systems competition (such as Acrobat Reader and Distiller), the vendor of the system may lower the price of one product (even to zero) to gain better control over the market of the complementary product (Katz and Shapiro 1994; Parker and van Alstyne 1999). In contrast to the predatory pricing and cross-subsidization explanations for the market provision of free information goods, our research draws upon the theory of product line pricing to show that a monopoly may also offer a free low quality product to expand the network for its high quality product.

Following the lead of Hotelling (1929), later economists introduce models of vertical differentiation in which all consumers prefer the highest available quality but differ in their *marginal* willingness to pay (Gabszewicz and Thisse 1979; Mussa and Rosen 1978). Mussa and Rosen establish the optimality of inducing consumer self-selection via price discrimination. In a simple and elegant model, Shaked and Sutton (1982) show that firms can reduce price competition by differentiating their products. A universal assumption in this literature is that each consumer has a constant marginal willingness to pay for quality (Moorthy 1988; Salant 1989; Tirole 1988), which will be inherited in this paper.

To our best knowledge, there are three studies examining the network externality aspect of software, but none of them addresses the issue of market segmentation. Conner and Rumelt (1991) show that no protection can be the best policy against piracy in certain circumstances. Two more recent studies (Brynjolfsson and Kemerer 1996; Gallaugher and Wang 1999) empirically investigate the impact of network effects on software prices, with the latter stressing the role of free goods. By reducing the costs for distributing information, the Internet has spotlighted the importance of information goods and inspired pronounced research interests in their economic issues. Bundling unrelated information goods is shown to be much more profitable than selling them separately and larger bundles can better compete against smaller ones (Bakos and Brynjofsson 1999, 2000). Dewan et al. (2000) study how a proprietary content provider can best organize his distribution channels in the Internet setting.

Extending of Moorthy's model, Jones and Mendelson (1998) and Bhargava and Choudhary (1999) examine the product and price competition for generic information goods without network externalities. Assuming a quadratic cost of product development, Jones and Mendelson compute the optimal product positioning and pricing under alternative market structures (welfare maximization, monopoly, duopoly, and oligopoly). One startling result they obtain is that a multi-product monopoly will not segment his market by selling only the highest quality.[1] Realizing that many important information goods do demonstrate salient externalities, we incorporate network externality and tightly focus on its significant impact on the market segmentation for such information goods. We show that, with externality, the seller is inclined to expand the length of his product line to harvest the maximum network benefits. Our finding can better explain the popular practices of offering quality-differentiated products and giving away the low-end product for free among near-monopoly vendors such as proprietary content providers (e.g., WSJ Interactive, AOL, etc.)

Our major contribution is two-fold. First, the critical role of externality in the market segmentation for information goods is clearly shown in a monopoly setting. With externality, a monopoly of multiple existing products will adopt limited segmentation by providing no more than two products. Market segmentation with existing products has significant bearings for determining the product line structure of information goods when development costs are taken into account. Second, we prove that when the low quality is developed, it should be offered for free under very general conditions. The free low-quality product is essential for expanding market coverage and enhancing consumer valuation of the high quality.

The rest of the paper is organized as follows. A model is presented in section 2. Section 3 establishes the limited segmentation result with a general distribution of consumer preferences. A monopoly's optimal product line design and pricing are analyzed in section 4. Section 5 discusses our limitations and potential extensions. The Appendix contains a notation table and the proofs omitted in the body of the paper.

## 2. MODEL

Our basic framework is similar to that of Katz and Shapiro (1985) and the way we incorporate network externality is due to Conner (1995), who examines the optimal cloning strategy of an innovator.

---

[1]Ignoring externality and adopting a rare assumption that each consumer has a *decreasing* marginal willingness to pay for quality, Varian (1997) shows that quality differentiation can be optimal. However, please note that Varian's basic assumption deviates from that of the broad literature of vertical differentiation. See section 6 for an expanded discussion.

### 2.1 Consumer Preference

Each consumer has a demand for at most one unit of the information good. The cumulative distribution function $F$ of consumers' willingness to pay is defined on $[-A, 1]$, where $A$ is a finite positive number.[2] Absent externality, a consumer may perceive a disutility if the cost of adopting the information good exceeds its intrinsic value for him. This is reflected by the negative segment in consumer distribution. A consumer of type $\theta$ values quality $s$ at $\theta s$. Here $\theta$ is the consumer's constant *marginal* willingness-to-pay or taste.

Suppose $F$ has a continuous probability density function $f$. Two specific assumptions are made to obtain a tractable analysis.

***Assumption 1.*** *The probability density function f is log-concave.*

***Assumption 2.*** $2f(\theta) + \theta f'(\theta) > 0$.

The roles of these assumptions will be explicitly addressed in the ensuing analysis.

In our one-period model, rational consumers form identical expectations about the ultimate network size and make corresponding choices. The equilibrium concept we deploy is the so-called fulfilled expectations equilibrium, i.e., the *ex post* equilibrium network size is exactly as expected by consumers prior to their purchases (cf. Katz and Shapiro 1985). A firm follows a Stackleberg strategy vis-à-vis consumers and firms in a duopoly follow Nash price-setting strategies vis-à-vis each other.

### 2.2 The Network Benefits

Network externality increases each consumer's taste by $\gamma Q$, where $Q$ is the *installed base* or *network size* of the information good and $\gamma$ is the *externality intensity*, which reflects the increase in willingness to pay when an additional consumer joins the network. Externality intensity is a conceptual metric for the interdependence among consumers, and different information goods may have different magnitudes of externality intensity. For example, online communities and productivity software typically demonstrate stronger externality intensities than regular online contents and most computer games, respectively.

When purchasing product $s$ in a network of size $Q$ at price $p$, consumer $\theta$ obtains net utility $(\theta + \gamma Q)s - p$. In the jargon of Farrell and Saloner (1986), $\theta \cdot s$ is the product's "*network-independent*" or standalone value, which depends on both consumer taste and product quality. The "*network-generated*" value is $\gamma Qs$ and exhibits complementarity between network size and quality. Therefore, in the same network, a high quality has both higher standalone and network values than a lower quality (see Figure 1). To be realistic, we impose a lower bound $s^*$ on quality for a product to create network benefits, i.e., the feasible region for product quality is $[s^*, \infty)$. In Katz and Shapiro (1985) and most other research on network externality, products are homogeneous and consumers differ in their *total* willingness to pay;[3] the network-generated benefit only depends on the network size.

### 2.3 High-to-Low Versioning

In selecting its product line, the firm develops the high-end version first and then degrades to obtain lower quality versions. Information good vendors usually adopt such a high-to-low or "value-subtraction" versioning strategy to exploit the cost savings in content, design, and code reuse (Deneckere and McAfee 1996; Shapiro and Varian 1999). As our emphasis is on the *structure* of the product line, not the exact positioning of the high quality, we do not specify a cost function for developing the high quality. We only modestly assume that the cost for developing the low quality $s_l$ after the high quality is built, $g(s_l)$, is non-decreasing. Information goods have zero marginal costs throughout this study.

---

[2] Both Katz and Shapiro (1985) and Conner (1995) assume $A$ to be infinite to focus on the market-not-covered case. Our assumption for $A$ to be finite is more realistic and does not cause technical difficulties, as we shall see later.

[3] An exception is Farrell and Saloner (1986), who consider heterogeneous technologies but assume consumers are homogeneous.

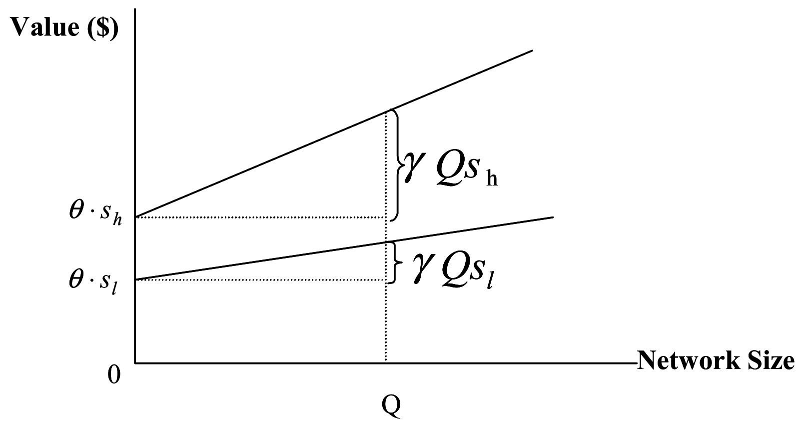


**Figure 1. The Standalone and Network-Generated Values of Products $s_h$ and $s_l$ ($s_h > s_l$) for Consumer θ**

## 3. LIMITED MARKET SEGMENTATION: TWO VERSIONS ARE ENOUGH

To determine a monopoly's optimal product line structure, we first have to identify his market segmentation policy with a set of existing compatible products.[4] Therefore, product development cost is not considered until section 4.

Consider a monopoly offering a low quality product $s_l$ at price $p_l$ and a high quality product $s_h$ at price $p_h$ ($s_l < s_h$). To avoid triviality, assume $s^* < s_l$. Denote $\theta_l$ to be the consumer indifferent between purchasing $s_l$ and doing nothing and $\theta_h$ the consumer indifferent between purchasing $s_l$ and $s_h$. We thus have

$$(\theta_l + \gamma Q)s_l - p_l = 0 \tag{1}$$

and

$$(\theta_h + \gamma Q)s_h - p_h = (\theta_h + \gamma Q)s_l - p_l = 0, \tag{2}$$

where $Q$ is the total expected (and also realized) sales of the two products. It is easy to verify that $(\theta + \gamma Q)s_h - p_h > (\theta + \gamma Q)s_l - p_l \ \forall\ \theta_h < \theta \leq 1$ and that $(\theta + \gamma Q)s_l - p_l > (\theta + \gamma Q)s_h - p_h \ \forall\ \theta_l \leq \theta \leq \theta_h$. Therefore, consumers in $[\theta_l, \theta_h)$ will purchase $s_l$ and consumers in $[\theta_h, 1]$ will purchase $s_h$, as shown in Figure 2 below.

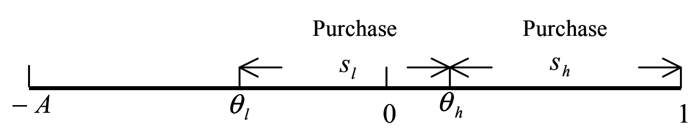


**Figure 2. Market Segmentation of a Two-Product Monopoly**

[4]Obviously, a monopoly will make compatible products to take full advantage of the network effect.

We then have $\theta_l = p_l / s_l - \gamma Q$ and $\theta_h = (p_h - p_l)/(s_h - s_l) - \gamma Q$, where $Q$ is the total sales determined by

$$Q = 1 - F(\theta_l) = 1 - F\left(\frac{p_l}{s_l} - \gamma Q\right). \tag{3}$$

The monopoly chooses prices $p_l$ and $p_h$ to maximize his profits:

$$\underset{p_l, p_h}{Max} \; p_l\left( F\left(\frac{p_h - p_l}{s_h - s_l} - \gamma Q\right) - F\left(\frac{p_l}{s_l} - \gamma Q\right)\right) + p_h\left(1 - F\left(\frac{p_h - p_l}{s_h - s_l} - \gamma Q\right)\right) \tag{4}$$

subject to (3).

The formulation in (4) is not tractable because equation (3) prohibits an explicit expression of total sales. To convert the monopoly's problem into an equivalent but tractable form, we utilize the fact that the two products' respective lower market boundaries, $\theta_l$ and $\theta_h$, can be viewed as the monopoly's choice variables. The total sales are simply $Q = 1 - F(\theta_l)$. As the monopoly extracts the full surplus from the marginal consumer $\theta_l$, the prices of $s_l$ and $s_h$ become dependent variables: $p_l = (\theta_l + \gamma Q)s_l$ and $p_h = (\theta_l + \gamma Q)s_l + (\theta_h + \gamma Q)(s_h - s_l)$. Plugging these substitutions into (4) and collecting terms, we obtain its equivalent form:

$$\underset{\theta_l, \theta_h}{Max} \; [\theta_l + \gamma(1 - F(\theta_l))]s_l(1 - F(\theta_l)) + [\theta_h + \gamma(1 - F(\theta_1))](s_h - s_l)(1 - F(\theta_h)). \tag{5}$$

Theorems 1 is then derived by solving (5).

*Theorem 1. (Market Segmentation) With positive network externality, the two-product monopoly will provide both products and benefit from versioning.*

**Proof:** The first order conditions of the monopoly's problem are

$$\frac{\partial \pi}{\partial \theta_h} = 0 \Rightarrow 1 - F(\theta_h) - f(\theta_h)[\theta_h + \gamma(1 - F(\theta_l))] = 0 \tag{6}$$

and

$$\frac{\partial \pi}{\partial \theta_l} = 0 \Rightarrow (1 - \gamma f(\theta_l))s_l(1 - F(\theta_l)) - [\theta_l + \gamma(1 - F(\theta_l))]s_l f(\theta_l) - \gamma f(\theta_l)(s_h - s_l)(1 - F(\theta_h)) = 0 \tag{7}$$

Equation (6) can be transformed to

$$\theta_h = \frac{1 - F(\theta_h)}{f(\theta_h)} - \gamma(1 - F(\theta_l)) = \frac{1 - F(\theta_h)}{f(\theta_h)} - \gamma Q \tag{8}$$

and (7) can be restated as

$$\theta_l = \frac{1 - F(\theta_l)}{f(\theta_l)}(1 - \gamma f(\theta_l)) - \gamma(1 - F(\theta_l)) - \gamma\frac{s_h - s_l}{s_l}(1 - F(\theta_h)), \tag{9}$$

from which we obtain

$$\theta_l < \frac{1 - F(\theta_l)}{f(\theta_l)} - \gamma(1 - F(\theta_l)) = \frac{1 - F(\theta_l)}{f(\theta_l)} - \gamma Q. \tag{10}$$

Under Assumption 1, (8) has a unique solution for $\theta_h$ since the RHS is non-increasing and the LHS is the 45-degree line passing through the origin. Note that $\theta_l$ and $\theta_h$ can take negative values. Inspecting (8) and (10), we must have $\theta_l < \theta_h$. The second-order condition is satisfied because the Hessian of (5) is negative semi-definite under Assumption 2. *Q.E.D.*

*Corollary 1. Without network externality ($\gamma = 0$), a multi-product monopoly will only provide the highest quality product.*

**Proof:** When $\gamma = 0$, (8) and (9) become $\theta_h = [1 - F(\theta_h)]/f(\theta_h)$ and $\theta_l = [1 - F(\theta_l)]/f(\theta_l)$ respectively. Because $\theta = [1 - F(\theta)]/f(\theta)$ has a unique solution, we must have $\theta_h = \theta_l$. *Q.E.D.*

Corollary 1 thus confirms the one-product and no-segmentation conclusion of Jones and Mendelson (1998) and Bhargava and Choudhary (1999). We first examine the rationale behind this no-segmentation result without externality. Unlike industrial goods (see Moorthy 1988), a high quality information good does not have a marginal cost disadvantage compared with a low quality information good, but generates strictly higher value for consumers, allowing the monopoly to charge a higher price. If the monopoly enforces segmentation by adding a low quality product at a lower price, total sales may increase, but some original buyers of the high quality product will switch to the low quality product and pay the lower price. The market presence of the low quality product also limits the price of the high quality product. *Without network externality, the cannibalization between the two information goods is so severe that the monopoly chooses to produce the high quality product only.*

With externality, adding the low-end product expands total sales, which in turn drives up the perceived value of the high quality product. Similarly, the demand of the high quality product also improves consumers' valuation for the low quality product. However, the incremental valuation for the high quality product is higher than that for the low quality product. This is because we assume network externality enhances consumers' *marginal* willingness to pay and the *absolute* valuation is proportional to product quality. *Existence of network externality creates an asymmetric complementary effect between the two products, which dominates the cannibalization effect.*

Will the monopoly benefit from further segmenting his market? It turns out that a monopoly of information goods will provide only two versions of different qualities.

***Theorem 2. (Two Versions are Enough)*** *With positive network externality, a multi-product monopoly will not provide a third, intermediate product $s_m$ ($s_l < s_m < s_h$).*

The proof is delegated to the Appendix. Proposition 2 shows that a multi-product monopoly adopts *limited* market segmentation. This is because inserting an intermediate quality $s_m$ has mixed effects. First, it increases the monopoly's total sales. Second, a larger network also drives up consumers' willingness to pay. Finally, adding the middle quality also phases in more cannibalization among these products. It seems that the resulting higher sales and network benefits do not justify the exacerbated cannibalization. Two products can achieve the best balance between fully exploiting the network effect and minimizing cannibalization.

## 4. PRODUCT LINE DESIGN AND PRICING

We next show how a monopoly vendor of information goods should position and price his product line in a market environment with externality. To ease exposition, from here on we assume consumers are uniformly distributed on $[-A,1]$ with density 1. The equilibrium total sales of a two-product monopoly satisfy $Q = 1 + \gamma Q - p_l / s_l$, or $Q = (s_l - p_l)/[(1 - \gamma)s_l]$. Here we assume $\gamma < \dfrac{A}{A+1}$ to focus on the market-not-covered case even when the low quality is free ($p_l = 0$). The monopoly chooses prices to maximize his profits:

$$\max_{p_l, p_h} \; p_h\left(1 + \frac{\gamma(s_l - p_l)}{(1-\gamma)s_l} - \frac{p_h - p_l}{s_h - s_l}\right) + p_l\left(\frac{p_h - p_l}{s_h - s_l} - \frac{p_l}{s_l}\right). \tag{11}$$

$$s.t. \quad p_l \geq 0.$$

The other constraint $p_k > p_l$ is guaranteed whenever $s_h > s_l$[5] and thus not explicitly included. An observant reader might have noticed that the network effect only directly expands the demand for the high quality. This is due to our assumption that the network-generated value of a product is proportional to its quality.[6] We have the following Lemma regarding the price of the low quality.

*Lemma 1. When* $s_l > \frac{\gamma s_h}{2-\gamma}$, $p_l = \frac{s_l[(2-\gamma)s_l - \gamma s_h]}{(2-\gamma)^2 s_l - \gamma^2 s_h} > 0$. *When* $s_l \le \frac{\gamma s_h}{2-\gamma}$, $p_l = 0$.

**Proof:** Denote λto be the Lagrangian multiplier for the constraint. The Kuhn-Tucker analysis gives the optimal solution:

$$p_h^* = \frac{(1-\gamma)s_l[\lambda^*(2-\gamma)s_l + (2-\gamma\lambda^*)s_h]}{(2-\gamma)^2 s_l - \gamma^2 s_h} \tag{12}$$

$$p_h^* = \frac{s_l[-\gamma s_h + s_l(2-\gamma+2(1-\gamma)^2\lambda^*)]}{(2-\gamma)^2 s_l - \gamma^2 s_h} \tag{13}$$

and

$$\lambda^* p_l^* = 0. \tag{14}$$

Lemma 1 then follows from (13) and (14). *Q.E.D.*

Clearly, the monopoly's optimal solution depends upon the relative qualities of the two products.

**Case 1:** When $s_l \ge \frac{\gamma s_h}{2-\gamma}$.

From Lemma 1, the monopoly's optimal prices are $p_h = \frac{2(1-\gamma)s_h s_l}{(2-\gamma)^2 s_l - \gamma^2 s_h}$ and $p_l = \frac{s_l[(2-\gamma)s_l - \gamma s_h]}{(2-\gamma)^2 s_l - \gamma^2 s_h}$.

The two-product monopoly's revenue is $w = \frac{s_h s_l}{(2-\gamma)^2 s_l - \gamma^2 s_h}$.

The sales of $s_h$ and $s_l$ are

$$Q_h = \frac{(2-\gamma)s_l}{(2-\gamma)^2 s_l - \gamma^2 s_h} \tag{15}$$

and

$$Q_l = \frac{\gamma s_h}{(2-\gamma)^2 s_l - \gamma^2 s_h}, \tag{16}$$

respectively.

[5]See (12) nd (13) below.

[6]In a market of vertically differentiated goods, our current assumption is more appropriate than the alternative assumption that the network-generated value only depends on the network size but not on quality. We can verify that, under this alternative assumption, the network effect directly expands the demand for the low quality but has no direct impact on the demand for the high quality.

**Case 2:** When $s_l < \frac{\gamma s_h}{2-\gamma}$.

In this case, the optimal prices are $p_h = \frac{s_h - s_l}{2(1-\gamma)}$ and $p_l = 0$. The sales of $s_h$ and $s_l$ are

$$Q_h = Q_l = \frac{1}{2(1-\gamma)}. \tag{17}$$

The monopoly's revenue is

$$w = \frac{s_h - s_l}{4(1-\gamma)^2}. \tag{18}$$

When $s_l \geq \frac{\gamma s_h}{2-\gamma}$, from (15) and (16) we can find the monopoly's total sales and the market shares of $s_h$ and $s_l$ Taking the derivatives of prices, sales, and market shares with respect to $\gamma$, we obtain the following result.

*Theorem 3. When* $s_l \geq \frac{\gamma s_h}{2-\gamma}$, *stronger externality intensity induces higher price for the high quality product* $s_h$, *lower price for the low quality product* $s_l$, *larger sales for both products, but a smaller market share for the high quality product.*

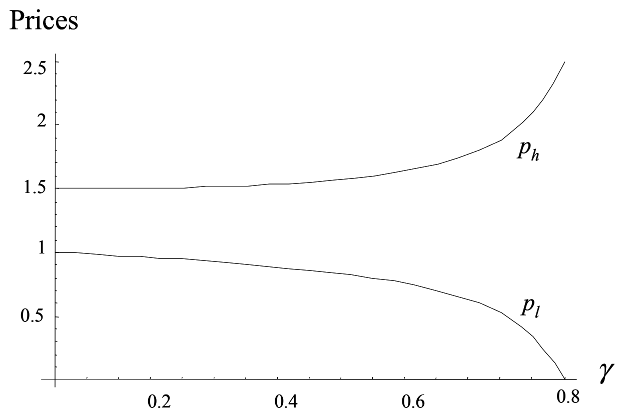


**Figure 3. Monopoly Price Adjustment to Stronger Externality Intensity**
Parameter Values: $s_l = 2$; $s_h = 3$; $\gamma \in [0,0.8]$

Surprisingly, when externality intensity increases, the monopoly adjusts the prices of the two products in opposite directions (see Figure 3). Facing stronger externality intensity, the monopoly has a greater incentive to enlarge his network, which necessitates a lower price for the low quality (see (11)). An expanded network implies higher consumer willingness to pay. The monopoly then raises the price for the high quality, making higher profits. Intuitively, the two products serve distinct purposes: *the low quality helps inflate the network and the high quality extracts the network benefits and is the primary source of revenue.*

We have shown that a monopoly of multiple *existing* products only actively sells two of them. We next determine the optimal positioning of the low-end product if its development costs justify the increase in revenue due to an expanded network.

We can easily verify the following: when $s_l > \frac{\gamma s_h}{2-\gamma}$, $\frac{\partial \pi}{\partial s_i} = -\frac{\gamma^2 s_h^2}{((2-\gamma)^2 s_l - \gamma^2 s_h)^2} < 0$, and when $s_l < \frac{\gamma s_h}{2-\gamma}$, $\frac{\partial \pi}{\partial s_l} = -\frac{1}{4(1-\gamma)^2} < 0$. For any given high quality $s_h$, monopoly revenue is decreasing in the low quality $s_l$ (see Figure 4). However, the cost of developing $s_l$, $g(s_l)$ is non-decreasing by assumption. Together with Lemma 1, this leads to Theorem 4.

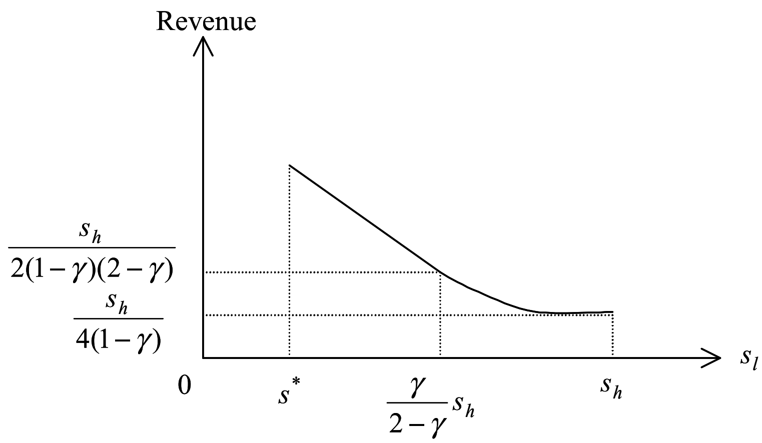


**Figure 4. Monopoly Revenue as a Function of Low Quality** $s_l$ ($s^* < s_l \le s_h$)

*Theorem 4. When* $s^* \ge \frac{\gamma s_h}{2-\gamma}$, *the monopoly develops a low quality of* $s_l \cdot s^*$ *if* $g(s^*) \le \frac{s_h s^*}{(2-\gamma)^2 s^* - \gamma^2 s_h} - \frac{s_h}{4(1-\gamma)}$; *when* $s^* < \frac{\gamma s_h}{2-\gamma}$, *the monopoly develops a low quality of* $s_l \cdot s^*$ *if* $g(s^*) \le \frac{\gamma s_h - s^*}{4(1-\gamma)^2}$. *In particular, the optimal price for the low quality is* $p_l = 0$ *when* $s^* \le \frac{\gamma s_h}{2-\gamma}$.

When developing both products, the monopoly always sets the low quality at the threshold feasible quality and may offer the low-end product for free if it is below a certain fraction of the high quality. Offering the low-end product for free is an extreme version of using the low quality to expand network coverage and using the high quality to extract consumer surplus, as pointed out earlier. Built upon the theory of product line pricing, Proposition 4 sheds light on the provision of free information goods by monopoly vendors.

When taking development costs into account, the monopoly provides at most two distinct quality levels. Rooted in a stylized, abstract modeling setup, such a prediction can find its support in numerous real-world observations. Online periodicals often offer some basic articles for free browsing but require subscription or a fee for accessing the full-featured articles. Similarly, it is not atypical for online brokers (such as E*Trade) to offer one set of free services and one set of premium services to their account holders. Game players can download free, unregistered versions of computer games with limited playable levels, but have to pay to obtain the full version (www.Cnet.com).

We also observe that many vendors of productivity software, such as office suites and enterprise resources planning (ERP) systems, do not simultaneously carry multiple versions with distinct qualities. This is because, for this kind of software, carving a coherent low-quality version out of a high-quality one takes tremendous effort. In the mean time, their compartmentalized product structure ideally suits them for another popular differentiation knack—bundling (cf. Bakos and Brynjofsson 1999). Shapiro and Varian (1999) propose the so-called "goldilocks pricing" of offering three distinct products when the classification of heterogeneous consumers is not directly addressable. Our limited segmentation result does not conflict with goldilocks pricing, because the latter relies on a consumer psychology hypothesis of "extremeness aversion" rather than the consumer rationality assumption used in the current paper.

## 5. CONCLUDING REMARKS

Information goods are becoming an increasingly important part of our social and economic activities, but research on the various economic aspects of information goods is just emerging. Many important information goods such as software and online services including digital communities demonstrate prominent consumption externalities. This paper focuses on the role of externality in segmenting the market for information goods and draws insights on several strategic issues facing an information good provider such as the number of quality levels offered and product line selection and pricing. Our results indicate that sellers of information goods should take into consideration their products' externality effect when designing and pricing a product line.

Without externality, a monopoly of multiple existing products only offers the highest-quality product. With externality, the monopoly will offer exactly two products. Such a limited segmentation result is an outcome of the interplay between two opposing forces. The zero marginal cost of information goods leads to excessive cannibalization in a product line. On the other hand, network externality also creates a complementary effect between products of different qualities; it is their joint demand that determines the increment in consumer valuation of each quality. This limited segmentation result can better explain why many vendors of proprietary information goods provide quality-differentiated goods and adopt a price discrimination strategy.

When designing a product line, the low quality product is developed only if the added revenue benefit from an expanded network exceeds the extra development costs. We further show that if developed, the low quality should be offered for free in very general circumstances. Besides competitive factors, externality itself thus may justify the optimality of providing freebies.

Several important extensions can be made to our current work. First, we can use the same model to examine the versioning decisions of an information good vendor in a competitive rather than monopoly setting. Second, buyer surplus and social welfare are not considered. It may be interesting to study the social welfare under alternative market structures and evaluate the desirability of certain regulatory policies for information goods with network externality (such as the software industry). Finally, our static analysis based on a one-period model does not capture inter-temporal product improvement and network evolution. Studying the potential impacts of market segmentation on network formation might reveal different insights.

## References


Arthur, B. "Competing Technologies, Increasing Returns, and Lock-in by Historical Events," *The Economic Journal* (99), March 1989.

Bakos, Y., and Brynjofsson, E. "Bundling Information Goods: Pricing, Profits, and Efficiency," *Management Science* (45:12), December 1999.

Bakos, Y., and Brynjofsson, E. "Bundling and Competition on the Internet," *Marketing Science* (19:1), Winter 2000.

Bhargava, H., and Choudhary, V. "Price Discrimination and Product Differentiation for Information Goods," paper presented at the Eleventh Workshop on Information Systems Economics (WISE), Charlotte, NC, 1999.

Bessen, S., and Farrell, J. "Choosing How to Compete: Strategies and Tactics in Standardization," *Journal of Economic Perspectives* (8:2), Spring 1994.

Brynjofsson, E., and Kemerer, C. "Network Externalities in Microcomputer Software: An Econometric Analysis of the Spreadsheet Market." *Management Science* (42:12),December 1996.

Conner, K. "Obtaining Strategic Advantage from Being Imitated: When Can Encouraging 'Clones' Pay?" *Management Science* (42:2), February 1995.

Conner, K., and Rumelt, R. "Software Piracy: An Analysis of Protection Strategies," *Management Science* (37:2), February 1991.

Deneckere, R., and McAfee, R. P. "Damaged Goods," *Journal of Economics and Management Strategy* (5:2), 1996.

Dewan, R., Freimer, M., and Seidmann, A. "Organizing Distribution Channels for Information Goods on the Internet," *Management Science* (46:4), April 2000.

Farrell, J., and Saloner, G. "Installed Base and Compatibility: Innovation, Product Preannouncements, and Predation," *American Economic Review* (76:5), December 1986.

Gabszewicz, J., and Thisse, J. F. "Price Competition, Quality and Income Disparities," *Journal of Economic Theory* (20), 1979.

Gallaugher, J., and Wang, Y. "Network Effects and the Impact of Free Goods: An Analysis of the Web Server Market," *International Journal of Electronic Commerce* (3:4), Summer 1999.

Hagel, J., and Armstrong, *A. Net Gain: Expanding Markets Through Virtual Communities*, Boston: Harvard Business School Press, 1997.

Horn, R. A., and Johnson, C. R. Matrix Analysis,. Cambridge, UK: Cambridge University Press, 1985.

Hotelling, H. "Stability in Competition," *The Economic Journal* (39), 1929.

Jones, R., and Mendelson, H. "Product and Price Competition for Information Goods," Working Paper, Graduate School of Business, Stanford University, Stanford, CA, 1998.
Katz, M., and Shapiro, C. "Network Externalities, Competition and Compatibility," *American Economic Review* (75:3), June 1985.
Katz, M., and Shapiro, C. "Technology Adoption in the Presence of Network Externalities," *Journal of Political Economy* (94:4), August 1986.
Katz, M., and Shapiro, C. "Systems Competition and Network Effects," *Journal of Economic Perspectives* (8:2), Spring 1994.
Levinthal, D., and Purohit, D. "Durable Goods and Product Obsolescence," *Marketing Science* (8:1) Winter 1989.
Moorthy, K. S. "Product and Price Competition in a Duopoly," *Marketing Science* (7:2), Spring 1988.
Mussa, M., and Rosen, S. "Monopoly and Product Quality," *Journal of Economic Theory* (18), 1978.
Oren, S., and Smith, S. "Critical Mass and Tariff Structure in Electronic Communications Markets," *Bell Journal of Economics* (12), 1981.
Parker, G., and van Alstyne, M. W. "Information Complements, Substitutes, and Strategic Product Design," paper presented at the Eleventh Workshop on Information Systems Economics (WISE), Charlotte, NC, 1999.
Reiganum, J. "Dynamic Games of Innovation," *Journal of Economic Theory* (25:1), 1981.
Rohlfs, J. "A Theory of Interdependent Demand for a Communications Service," *Bell Journal of Economics and Management Science* (5), 1974.
Salant, S. "When is Inducing Self-Selection Suboptimal for a Monopolist?" *The Quarterly Journal of Economics* (104:2), May 1989.
Shaked, A, and Sutton, J. "Relaxing Price Competition through Product Differentiation," *Review of Economic Studies* (49), 1982.
Shapiro, C., and Varian, H. *Information Rules*, Boston: Harvard Business School Press, 1999.
Simonson, I., and Tversky, A. "Choice in Context: Tradeoff Contrast and Extremeness Aversion," *Journal of Marketing Research* (29), 1992.
Tirole, J. *The Theory of Industrial Organization*, Cambridge, MA: The MIT Press, 1988.
Varian, H. "Versioning Information Goods," Working Paper, University of California, Berkeley, CA, 1997.

# Appendix

### Table 1. Summary of Notations

| | |
|---|---|
| $f(\cdot)$ | The probability density function of consumer preference. |
| $F(\cdot)$ | The cumulative distribution function of consumer preference. |
| $g(\cdot)$ | Cost of developing a lower quality product after a higher quality is in place. |
| $p$ | Price. |
| $p_h$ ($p_l$) | Price of the high (low) quality product. |
| $Q$ | Network size or total sales of a product or compatible products. |
| $Q_h$ ($Q_l$) | Sales of the high (low) quality product. |
| $s$ | Product quality. |
| $s_h$ ($s_l$) | Quality of the high- (low-) end product. |
| $s^*$ | The minimum quality level for the information good to generate network benefits. A constant. |
| $w$ | Seller revenue. |
| $\theta$ | Consumer type or marginal willingness to pay for quality. |
| $\theta_h$ | The consumer indifferent between purchasing the high- and low-quality products. |
| $\theta_l$ | The consumer indifferent between purchasing the low-quality product and not purchasing. |
| $\gamma$ | Externality intensity, or the degree of consumer interdependence. |
| $\pi$ | Seller profit. |

*Proof of Theorem 2*: Suppose the monopoly now adds an intermediate quality product $s_m$ ($s_l < s_m < s_h$) into his product line. Applying similar techniques as in the two-product case, we can formulate the monopoly's problem as follows:

$$\underset{\theta_l,\theta_m,\theta_h}{Max} \quad [\theta_l + \gamma(1 - F(\theta_l))]s_l(1 - F(\theta_l)) + [\theta_m + \gamma(1 - F(\theta_l))](s_m - s_l))(1 - F(\theta_m)) + [\theta_h + \gamma(1 - F(\theta_l))](s_h - s_m)(1 - F(\theta_h)) \tag{A1}$$

The first-order conditions of (A1) are

$$\frac{\partial\pi}{\partial\theta_h} = 0 \Rightarrow 1 - F(\theta_h) - f(\theta_h)[\theta_h + \gamma(1 - F(\theta_l)] = 0, \tag{A2}$$

$$\frac{\partial\pi}{\partial\theta_m} = 0 \Rightarrow 1 - F(\theta_m) - f(\theta_m)[\theta_m + \gamma(1 - F(\theta_l)] = 0, \tag{A3}$$

and

$$\frac{\partial\pi}{\partial\theta_l} = 0 \Rightarrow (1 - \gamma f(\theta_l))s_l(1 - F(\theta_l)) - [\theta_l + \gamma(1 - F(\theta_l))]s_l f(\theta_l) - \gamma f(\theta_l)(s_m - s_l)(1 - F(\theta_m)) - \gamma f(\theta_l)(s_h - s_m)(1 - F(\theta_h)) = 0 \tag{A4}$$

Equations (A2) through (A4) can be stated equivalently as (A5) through (A7):

$$\theta_h = \frac{1 - F(\theta_h)}{f(\theta_h)} - \gamma(1 - F(\theta_l)) = \frac{1 - F(\theta_h)}{f(\theta_h)} - \gamma Q, \tag{A5}$$

$$\theta_m = \frac{1 - F(\theta_m)}{f(\theta_m)} - \gamma(1 - F(\theta_l)) = \frac{1 - F(\theta_m)}{f(\theta_m)} - \gamma Q, \tag{A6}$$

and

$$\theta_l = \frac{1 - F(\theta_l)}{f(\theta_l)}(1 - \gamma f(\theta_l)) - \gamma(1 - F(\theta_l)) - \gamma\frac{s_m - s_l}{s_l}(1 - F(\theta_m)) - \gamma\frac{s_h - s_m}{s_l}(1 - F(\theta_h)). \tag{A7}$$

Here (A7) implies

$$\theta_l < \frac{1 - F(\theta_l)}{f(\theta_l)} - \gamma Q. \tag{A8}$$

Inspecting (A5), (A6), and (A8), we must have $\theta_l < \theta_m = \theta_h$ due to the assumption of a non-decreasing hazard rate. Therefore the multi-product monopoly will provide exactly two products. *Q.E.D.*