Experience Information Goods: "Version-to-Upgrade"

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Abstract

In contrast to "search goods" whose true quality can be determined before inspection, we examine information goods that are "experience goods" - goods whose true quality can only be determined through use. We analyze a "version-to-upgrade" strategy where a monopolist generates vertically differentiated versions as bridges that lead consumers to experience the goods so that they can assess their true quality, and then provide upgrades to consumers that initially purchase lower quality versions. Adopting a two-stage model, we find that if consumers have homogeneous expectations about quality before experience, then the version-to-upgrade strategy involves upgrading all the consumers that in the first stage purchased the low quality version. In this way, consumers that upgrade effectively pay a tax for learning. When consumers have heterogeneous expectations about quality before experience, if consumers are pessimistic, then the version-to-upgrade strategy still drives all consumers to upgrade. However, if consumers are optimistic, then, the version-to-upgrade strategy may induce only some of the consumers that initially purchased the low quality version to upgrade. As profits from upgrades increase, the monopolist sets the quality of the low quality version to the lowest quality that can feasibly reveal the true quality, justifying the use of trial or demonstration versions.

Keywords: Information Goods, Experience Goods, Versioning Strategies, Pricing Strategies.

1. Introduction

Development of information technology has made information goods popular. Characterized by large sunk costs of development, and negligible costs of reproduction and distribution, information goods are distinct from traditional physical goods [13]. Products such as computer software, online content and digitalized music, movies and books are typical examples of information goods [7].

Shapiro and Varian [13] suggest almost all information goods can be considered experience goods because consumers have to experience them to reveal their true quality. Different from

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search goods whose quality can be determined simply by inspection before purchase, the quality of experience goods are realized only after use [10, 19]. For example, it is difficult for a software vendor to credibly describe all the features of its software in sufficient detail to communicate its true quality before use. Indeed, the more a consumer actually uses or experiences the software, the better they know its true value.

The concept of experience goods is originally due to Nelson [10], who contrasts an experience good with a search good. When a new product or service is introduced, potential users typically have imperfect information about the product's features, even though these features may be important to them. A critical source of information about the good comes with actual experience - hence the term "experience good" [10, 19, 12]. Shapiro [12] examines pricing of experience goods with repeat purchases when consumers are optimistic and when they are pessimistic. With a multi-period model, he finds that when consumers are optimistic - that is, when consumers' expected quality is higher than the true quality, the monopolist takes advantage of consumers' optimism via a declining price path followed by a jump to a terminal price. But when consumers are pessimistic, the monopolist encourages more consumers to experience the good by using a low introductory price followed by a higher regular price. Similarly, Kim [8] uses a two-stage model to investigate monopoly pricing strategies for experience goods based on the credibility of price precommitment. His model shows that if the monopolist can credibly precommit prices, then it is optimal to set a high price in the first stage and a low price for the second stage. If the price precommitment is not credible, then the results reverse. Other research about experience goods includes Riordan [11] who investigates product variety and equilibrium quality of experience goods, Liebeskind and Rumelt [9] who analyze market for goods with uncertain product quality, and Villas-Boas [17] who models dynamic competition with experience goods.

Previous research mostly focuses on non-durable experience goods with repeat purchases. However, information goods are reusable durable goods and consumers typically purchase at most one unit of the good. To contrast our work with previous research, with durable goods consumers may choose to replace the old product with a new improved version where "version-to-upgrade" can be a strategic option, whereas with repeat purchases there is no need for upgrades.

In order to communicate the true quality of their information goods, some producers distribute demonstration versions, and others even send out trial versions. Recently, Microsoft has adopted a versioning and upgrading strategy for the delivery of Windows Vista and Windows 7. Windows Vista has four versions, and in increasing order of capability/quality they are: Home Basic, Home Premium, Business and Ultimate. Windows Vista anytime upgrade (http://www.microsoft.com) allows consumers to upgrade from a lower quality version to any of the higher quality versions anytime by purchasing the corresponding upgrade license.

Without upgrades, providing four versions of Windows Vista is normally referred to as "versioning".[2] Versioning is second-degree price discrimination: "offer a product line and let users choose the version of the product most appropriate for them" [13]. To implement versioning, the monopolist usually produces a flagship version and disables some functionality to generate lower quality versions. Individual versions are delivered to separate targeted market segments.

Versioning of information goods has been studied in various contexts such as network externalities [6], competition [7, 18] and anti-piracy [20]. In a setting of vertical product differentiation of information goods, they all reach the conclusion that versioning is not optimal without certain constraints, consistent with Bhargava and Choudhary [1]. Combining experience and information goods together, Chellappa and Shivendu [2] model pricing and sampling strategies for digital ex-

[2]The demonstration and trial versions mentioned above can also be treated as a lower quality versions of the final product. In that sense, providing demonstration and trial versions is versioning as well.

perience goods in vertically segmented markets to manage piracy. They find that piracy losses are more severe for products that do not live up to their hype rather than for those that have been undervalued in the market, thus requiring a greater deterrence investment for the former. Dogan et al [4] propose a software versioning model when a monopolist offers a lower quality product in the first period with an upgrade in the second period. They find that the optimal software design in each period depends on demand variability and endogeneity. In their model, an upgrade is offered only after the initial version is provided. In contrast, our model explores the situation when a lower version, a higher version, and an upgrade option are provided simultaneously in the first period, letting the consumers decide whether to upgrade in the second period.

Allowing an upgrade makes versioning more complicated. Naming the strategy "version-to-upgrade", we examine how a monopolist prices different versions and the upgrade, and how the version-to-upgrade strategy impacts consumers' choices. Using a two-stage model where consumers purchase a version in the first stage and those that chose a lower quality version can upgrade in the second stage, we show that version-to-upgrade whereby at least two versions are offered can be an optimal strategy. We find that if consumers have homogeneous expectations about quality before experience, then the result of the version-to-upgrade strategy is to drive all consumers that chose the low quality version in the first stage to upgrade to the high quality version in the second stage. In this way, consumers that upgrade effectively pay a tax for learning. When consumers have heterogeneous expectations about quality before experience, the results depend on whether consumers are pessimistic or optimistic. If consumers are pessimistic, then the version-to-upgrade strategy still drives all consumers that chose the low quality version in the first stage to upgrade. However, if consumers are optimistic, then under certain conditions, the version-to-upgrade strategy results in only some of the consumers that purchased the low quality version in the first stage upgrading in the second stage. This is our first contribution.

We also find that in choosing qualities, the optimal quality of the high quality version depends on the tradeoff between increased profits from consumers purchasing the high quality version and from the upgrade as a result of an increase in quality, and the costs of developing a higher quality good. The optimal quality of the low quality version depends on the tradeoff between consumers that switch from the high to low quality version in the first stage and an increase in the overall number of consumers that purchase with an increase in the quality of the low quality version. In some cases this results in demonstration or trial versions that are of sufficient quality as to reveal the true quality of the higher quality versions. This is our second contribution.

The rest of the paper is organized as follows. We set up our modeling structure as well as notation and assumptions in Section 2. We propose the version-to-upgrade strategy in Section 3. In Section 4 we present a two-stage, two-version model of experience information goods with homogeneous consumer expectations of quality. We extend the model to the situation when consumers have heterogeneous expectations in Section 5. In Section 6 we endogenize the monopolist's quality choices. Discussion and future research are included in Section 7.

2. Modeling Structure

Our structure is a two-stage model that involves a monopoly producer of information goods and consumers with heterogeneous tastes for quality. The information good we consider is an experience good so that before purchase, consumers only know the expected quality of the good. The true quality of the good is known to consumers only after actual purchase and use. We assume a consumer that only purchases a lower quality version of the good is able to appreciate the true quality of the higher quality version. This is reasonable because features embedded in the lower quality version usually help consumers appreciate the value of possible features included in the higher quality version. The typical example is Adobe Reader – only after we are familiar with

Adobe Reader can we fully appreciate the editing features included in the Adobe Professional.

We further assume each consumer purchases at most one unit of the good per period. In the first stage the monopolist offers its highest quality version and a degraded lower quality version. In the second stage, consumers that purchased the low quality version in the first stage can upgrade to the high quality version.

Consumers are heterogeneous in their individual taste of quality denoted as θ which is normalized to be in the interval [0,1]. We assume that θ has probability density and cumulative density functions $f(\theta)$ and $F(\theta)$ to set the population to unity. The density is strictly positive over its support and continuously differentiable. Following Bhargava and Choudhary [1], Jing [6] and Sundararajan [15], we make the following assumption about the distribution of consumer tastes:

Assumption 1. *The reciprocal of the hazard function,* $\frac{1-F(\theta)}{f(\theta)}$*, is non-increasing in* θ*.*[3]

We denote the true quality of the good as $q \in [\underline{q}, \overline{q}]$, where $\overline{q}$ is the highest possible quality under a general technology constraint and $\underline{q}$ is the lowest quality that reasonably can be used so that consumers can update their information about the quality of the good from experience. After the high quality version q_h is developed, it can be degraded to generate a lower quality version q_l. Before experiencing the good, the expected quality of the information good by a consumer with individual taste θ is denoted by $R(\theta, q)$. After experiencing the good, the consumer knows the true quality q. We take the expected quality of the good before experience to be non-decreasing in the true quality so that $\partial R(\theta, q)/\partial q \geq 0$. Such would be the case for rational consumers that have partial knowledge of the good.

[3]As discussed in Bhargava and Choudhary [1], this assumption is satisfied by common distributions such as the uniform, normal, logistic, chi-squared, exponential, and Laplace distributions, and any distribution with increasing density.

We also presume that before use, a higher taste consumer has at least as good judgment about the expected quality as a lower taste consumer. It means that the deviation between expected quality and true quality does not increase with consumer taste. This is reasonable because a higher taste consumer is normally associated with a consumer that has more familiarity and expertise with the class of information good, can better understand the features an information good provides and is less biased by advertisement or word-of-mouth, and therefore is more accurate in judging the expected quality. For example, even before use, we expect a professional user to have the same or better judgment about the quality of different versions of Windows 7 than a home user. Thus, we have the following assumption:

Assumption 2. *The gap between the expected and the true quality is non-increasing in consumer taste:* $\forall \theta_i < \theta_j,\ |R(\theta_i, q) - q| \geq |R(\theta_j, q) - q|$.

In Assumption 2 we use the absolute value as it allows consumers to be optimistic or pessimistic. We define optimistic and pessimistic consumers as follows:

Definition 1. *Optimistic consumers are those whose expected quality is higher than the true quality,* $R(\theta, q) > q$. *Pessimistic consumers are those whose expected quality is lower than the true quality,* $R(\theta, q) < q$.

Using Definition 1, Assumption 2 implies that higher taste consumers have no worse judgment, and that is judgment is independent of whether consumers are optimistic or pessimistic. For optimistic consumers where the expected quality before experience is greater than the true quality, higher taste consumers have lower expectations, $\partial R(\theta, q)/\partial \theta \leq 0$, and for pessimistic consumers where the expected quality before experience is lower than the true quality, higher taste consumers have higher expectations, $\partial R(\theta, q)/\partial \theta \geq 0$.

Accordingly, higher taste consumers are normally more sensitive or at least at sensitive as lower taste consumers about the quality difference between the high and low quality versions before purchasing. For example, an artist can better evaluate the quality difference of the same photo with different resolutions and a software expert can better determine the quality difference between various versions of software. Consequently, we assume that the gap in the expected quality between the two versions q_h and q_l is non-decreasing with consumer taste.

Assumption 3. *The difference between the expected qualities of the high and low quality versions is non-decreasing in consumer taste:* $\forall \theta_i < \theta_j, R(\theta_i, q_h) - R(\theta_i, q_l) \leq R(\theta_j, q_h) - R(\theta_j, q_l)$.

An equivalent form of Assumption 3 can also be written as the cross-partial derivative $\partial^2 R(\theta, q)/\partial\theta\partial q \geq 0$.

As a standard and commonly adopted assumption in previous research, we take a consumer's utility to be multiplicatively separable in taste and quality in the whole product life cycle. In that sense, after experience from use, a given consumer has constant marginal value for quality. Before experience, consumer taste also affects the expected quality. Because information goods are durable goods, we assume the time it takes for a consumer to learn from experience is sufficiently short compared to the whole product life cycle so that the utility a consumer gets after experience is still based on the whole product life cycle value.

Assumption 4. *A consumer's utility is multiplicative in taste and expected quality, which is* $U(\theta, q) = \theta R(\theta, q)$ *before experience and* $U(\theta, q) = \theta q$ *after.*

We denote the price of good i as p_i. Consumers maximize their surplus, $U(\theta, q_i) - p_i$, by choice of which version to purchase if any. If they purchased the low quality version in the first stage, then they can choose whether to upgrade in the second stage. From the first stage consumers know

the prices of both versions and the price of the upgrade. Table 1 provides a summary of notation used throughout the paper.

Table 1. Summary of Key Notation

Notation	Description
θ	consumer taste for quality
$F(\theta)$	cumulative distribution function of consumer taste
$f(\theta)$	probability density function of consumer taste
p	price of the information good
q	quality of the information good
δ	discount factor
$R(\theta, q)$	expected quality before experience
$C(q)$	cost of developing information good with quality q
$U(q, \theta)$	utility that consumer θ gets from information good with quality q
$\Pi(\cdot)$	profit function of the firm

3. The Version-to-Upgrade Strategy

We assume a monopolist has developed a high quality version (often called a flagship version), which can be degraded to generate multiple vertically differentiated versions. For simplicity, we study a monopolist that provides only two versions – a high quality version and a low quality version, with accordant quality levels $q_h > q_l$. Prices for these two versions are denoted by p_h and p_l, respectively. Both versions are available to the consumers simultaneously with an option for consumers that purchased the low quality version in the first stage to later upgrade to the high quality version in the second stage. The price for upgrade is denoted as p_u. The detailed version-to-upgrade strategy is demonstrated in Diagram 1.

In the first stage, the monopolist offers the high quality version with price-quality pair (p_h, q_h) and the low quality version with price-quality pair (p_l, q_l), together with an option to upgrade from the low quality to the high quality version at price p_u. Consumers decide which version to purchase or whether to purchase based on their expected quality. In the second stage, consumers

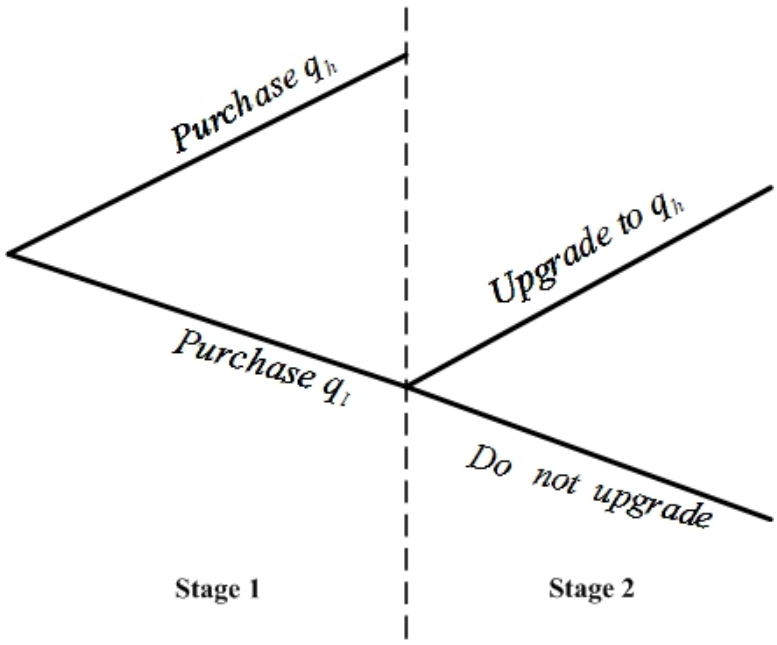

Diagram 1: The Version-to-Upgrade Strategy

that purchased either version update their expectations of quality for both versions, and some (or all) of those that purchased the low quality version in the first stage may upgrade to the high quality version at price p_u. We assume the duration of Stage 1 is sufficiently short compared to Stage 2, thus when consumers decide whether to upgrade or not, the utility they expect from the information goods after experience is still based on the whole product life cycle value.

With the version-to-upgrade strategy, consumers are divided into four segments: those that do not purchase, those that purchase the low quality version in the first stage and do not upgrade, those that purchase the low quality version in the first stage and upgrade to the high quality version in the second stage, and those that purchase the high quality version in the first stage. For the first stage, consumers separate into three groups. We denote θ_l as the consumer that is indifferent between purchasing q_l and not purchasing, and θ_h as the consumer that is indifferent between purchasing q_h and q_l. In the second stage, for the range of consumers that purchase the low quality version in the first stage, we denote θ_u as the consumer that is indifferent between upgrading and not. The segmentation of consumers is shown in Diagram 2.

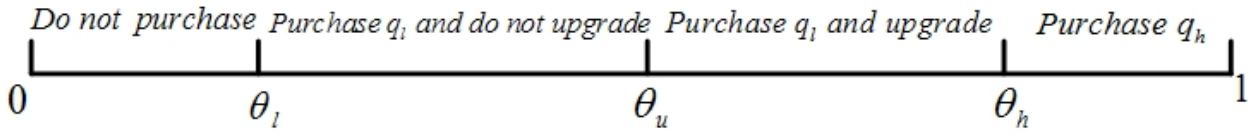

Diagram 2: Market Segmentation of Information Goods

Price Determination. Using the revelation theorem, profit maximizing monopoly prices are determined such that they follow individual rationality (IR) and incentive compatibility (IC) constraints.

The price of the low quality version, p_l, is determined by the IR constraint such that those consumers with taste $\theta < \theta_l$ do not purchase and those with taste $\theta > \theta_l$ purchase the low quality version. Thus, finding the indifferent consumer between purchasing the low quality version and not we have

$$p_l = U(\theta_l, q_l). \qquad \text{[IR]} \tag{1}$$

The price of the high quality version, p_h, is determined by the IC constraint such that consumers select the version that provides them with the greatest value. Consumers with taste $\theta > \theta_h$ purchase the high quality version and those with taste $\theta_l < \theta < \theta_h$ purchase the low quality version. The consumer that is indifferent between purchasing the high and low quality versions is defined by

$$p_h = p_l + U(\theta_h, q_h) - U(\theta_h, q_l). \qquad \text{[IC]} \tag{2}$$

After purchasing and experiencing the good, at the beginning of Stage 2, consumers update their expectations of the quality of the version they purchased to match their experience. Consumers that purchased the low quality version in the first stage are offered an option to upgrade to the high quality version. From the IC constraint, if the price of upgrade is lower than utility difference from the two versions, then consumers that purchased the low quality version upgrade. Because

consumers with $\theta_u \leq \theta < \theta_h$ choose to upgrade, we have

$$p_u = [U(\theta_u, q_h) - U(\theta_u, q_l)]. \tag{3}$$

To make the version-to-upgrade strategy feasible, the price of the high quality version must be less than the sum of the price of the low quality version plus the price of the upgrade. Otherwise consumers would be better off by acquiring the high quality version through purchasing the low quality version and then upgrading. We refer to this constraint as C1:

$$p_h < p_l + p_u. \qquad \text{[C1]} \tag{4}$$

Profit Maximization. In the first stage, the demand for the high quality version q_h is $1 - F(\theta_h)$ and the demand for the low quality version q_l is $F(\theta_h) - F(\theta_l)$. In the second stage, the demand for upgrade is $F(\theta_h) - F(\theta_u)$. The monopolist sets prices p_h, p_l and p_u to maximize overall profits from both stages. We denote the discount factor for profits in the second stage (as compared to the first stage) as $\delta \in (0, 1]$. δ depends on the time gap between the two stages and the interest rate. The discount factor can also be written as $\delta = e^{-r\,t}$, where r is the interest rate and t is the time between stages. We express the monopolist's profit maximization problem as[4]

$$\begin{aligned} \max_{\theta_h, \theta_l, \theta_u} \Pi \;\; &= \;\; [1 - F(\theta_h)]\;\, p_h \;\, + [F(\theta_h) - F(\theta_l)]\;\, p_l + \;\, \delta \;\, [F(\theta_h) - F(\theta_u)]\;\, p_u \\ &\ni \;\; 0 \;\leq \theta_l \;\leq\; \theta_u \leq \;\theta_h \leq \;1, \text{ IR, IC, C1.} \end{aligned} \tag{5}$$

4. Consumers with Homogeneous Expectations

In this section, we follow Shapiro [12] in assuming that although consumers are heterogeneous in individual taste, they have homogeneous expectations about quality before experience. It means

[4]Because it is an one to one mapping between prices and indifferent consumer types, it is equivalent that the monopolist chooses optimal θ_h, θ_l and θ_u instead of p_h, p_l and p_u.

that the expected quality for either version does not depend on consumer taste, which in our notation simplifies the expected quality to only depend on the announced quality and not on consumer taste: $R(\theta, q) = R(q)$. This simplification applies to information goods where the expected quality can be uniformly agreed upon between consumers with different tastes, such as digital music and video, online content and computer software with limited functions. For example, this is true for voice recognition software where quality is mainly determined by capacities of vocabulary and for online dictionaries where quality is mostly determined by the number of entries.

When consumers have homogeneous expectations, for version-to-upgrade to be a feasible strategy for the monopolist requires the following condition that we express as a lemma:

Lemma 1. *For version-to-upgrade to be a feasible strategy, it is necessary that* $R(q_h) - R(q_l) < q_h - q_l$.

Proof. For version-to-upgrade to be a feasible strategy, there must be a positive number of customers that would upgrade from the low quality version to the high quality version. In terms of our consumer segments this means that $\theta_u < \theta_h$. From (3) we have $\theta_u = \frac{p_u}{q_h - q_l}$, and from (2) we have $\theta_h = \frac{p_h - p_l}{R(q_h) - R(q_l)}$. For $\theta_u < \theta_h$ implies that $\frac{p_u}{q_h - q_l} < \frac{p_h - p_l}{R(q_h) - R(q_l)}$. From C1, we know that $p_u > p_h - p_l$, and therefore we have the relation $1 < \frac{p_u}{p_h - p_l} < \frac{q_h - q_l}{R(q_h) - R(q_l)}$. Consequently, $R(q_h) - R(q_l) < q_h - q_l$. Q.E.D.

Lemma 1 shows that in order for version-to-upgrade to be a feasible strategy, the difference between the true quality of the two versions, learnt after experience, must be greater than the difference that was expected before experience.

Substituting the pricing relationships in (1), (2) and (3) into the profit function in (5), we transform the monopolist's profit maximization problem so that it can be written in terms of

indifferent consumers and qualities of the two versions:

$$\begin{aligned}\max_{\theta_h,\theta_l,\theta_u} \Pi \;\; = \;\; & [1-F(\theta_h)]\;[\theta_l\; R(q_l) + [R(q_h)-R(q_l)]\;\theta_h] + [F(\theta_h)-F(\theta_l)]\;\theta_l\; R(q_l) \\ & + \delta\;[F(\theta_h)-F(\theta_u)]\;[q_h-q_l]\;\theta_u \\ & \ni \;\; 0 \;\leq \theta_l \;\leq\; \theta_u \leq\; \theta_h \leq\; 1,\; \text{IR},\; \text{IC}, \end{aligned} \tag{6}$$

where the inequality in the constraint $\theta_u \;\leq\; \theta_h$ is inferred from C1. We write the Lagrangian for this problem as $\mathcal{L} = \Pi + \lambda(\theta_u - \theta_l)$. Because θ_h, θ_u and θ_l are positive, the first-order (Kuhn-Tucker) conditions are

$$\mathcal{L}_{\theta_h} = [1-F(\theta_h)]\;[R(q_h)-R(q_l)] - f(\theta_h)\;[R(q_h)-R(q_l)]\;\theta_h + \delta\; f(\theta_h)\;[q_h-q_l]\;\theta_u = 0, \tag{7}$$

$$\mathcal{L}_{\theta_u} = \delta\,[q_h-q_l]\;[F(\theta_h)-F(\theta_u)-f(\theta_u)\;\theta_u] + \lambda = 0, \tag{8}$$

$$\mathcal{L}_{\theta_l} = [1-F(\theta_l)]\;R(q_l) - f(\theta_l)\;\theta_l\;R(q_l) - \lambda = 0, \quad \text{and} \tag{9}$$

$$\mathcal{L}_{\lambda} = \theta_u - \theta_l \geq 0, \;\; \text{if} >,\; \lambda = 0. \tag{10}$$

For (10), we first assume that the constraint is not binding, which implies $\theta_u > \theta_l$ and $\lambda = 0$ and means that some of the consumers that purchased the low quality version in the first stage do not upgrade in the second stage. Substituting back into (8) and (9), we have $\theta_u = \frac{F(\theta_h)-F(\theta_l)}{f(\theta_u)}$ and $\theta_l = \frac{1-F(\theta_l)}{f(\theta_l)}$. From Assumption 1 where we specify that the inverse hazard function is non-increasing, and from the upper limit $\theta_h \leq 1$, we find that $\theta_u < \theta_l$, which violates our constraint in (10).

Therefore, we must conclude that the constraint is binding, which means $\theta_u = \theta_l$ and $\lambda > 0$, and consequently all the consumers that purchase the low quality version in the first stage upgrade to the high quality version in the second stage. Substituting this equality back into (7), (8) and (9), we can derive the specification of the two indifferent consumers,

$$\theta_h - \delta \frac{q_h - q_l}{R(q_h)-R(q_l)}\;\theta_u = \frac{1-F(\theta_h)}{f(\theta_h)} \tag{11}$$

and

$$\theta_u = \theta_l = \frac{R(q_l)}{R(q_l) + \delta\left[q_h - q_l\right]} \frac{1 - F(\theta_l)}{f(\theta_l)} + \frac{\delta\left[q_h - q_l\right]}{R(q_l) + \delta\left[q_h - q_l\right]} \frac{F(\theta_h) - F(\theta_l)}{f(\theta_l)}. \tag{12}$$

We can compare our version-to-upgrade solution to the case when an upgrade is not offered by the monopolist. In the case of no upgrade, the monopolist's profit function is

$$\max_{\theta_h, \theta_l} \Pi = \left[1 - F(\theta_h)\right]\left[\theta_l R(q_l) + \left[R(q_h) - R(q_l)\right]\theta_h\right] + \left[F(\theta_h) - F(\theta_l)\right]\theta_l R(q_l).$$

The first-order conditions with respect to θ_h and θ_l generate

$$\theta_h = \frac{1 - F(\theta_h)}{f(\theta_h)} \text{ and } \theta_l = \frac{1 - F(\theta_l)}{f(\theta_l)}.$$

The non-increasing inverse hazard function (Assumption 1) means that there is unique solution for $\theta = [1 - F(\theta)]/f(\theta)$, which we denote as θ^*. Thus, we have $\theta_h = \theta_l = \theta^*$. This is consistent with literature in versioning [1, 6, 7] where in this basic setup and the in absence of upgrades, it is not profit maximizing for the monopolist to version its information good.

Now let us return to the solutions when the monopolist uses a version-to-upgrade strategy. From (11) we know $\theta_h - \delta\theta_u\left[q_h - q_l\right] / \left[R(q_h) - R(q_l)\right] < \theta_h$, and thus (11) generates the solution $\theta_h > \theta^*$. This means the monopolist's high quality version using a version-to-upgrade strategy is higher quality than its single version without upgrades. From (12) we know

$$\frac{R(q_l)}{R(q_l) + \delta\left[q_h - q_l\right]} \frac{1 - F(\theta_l)}{f(\theta_l)} + \frac{\delta\left[q_h - q_l\right]}{R(q_l) + \delta\left[q_h - q_l\right]} \frac{F(\theta_h) - F(\theta_l)}{f(\theta_l)} < \frac{1 - F(\theta_l)}{f(\theta_l)},$$

thus we have $\theta_l < \theta^*$. The result is that $\theta_l < \theta^* < \theta_h$, meaning that the monopolist's low quality version using a version-to-upgrade strategy is of lower quality than its single version without upgrades. More critically, it confirms that for experience information goods, with a version-to-upgrade strategy the monopolist offers multiple versions to maximize profits.

However, the fact that all consumers that purchase the low quality version in the first stage upgrade to the high quality version in the second stage indicates that the low quality version serves

as a bridge for consumers that purchase the low quality version to learn the true quality of the information good. Thus, consumers that purchase the low quality good in the first stage effectively pay a tax $p_l + p_u - p_h$ for learning through experience. To summarize, we have the following proposition.

Proposition 1. *If consumers have homogeneous expectations, then the monopolist's optimal version-to-upgrade strategy involves versioning; all consumers that purchase the low quality version in the first stage upgrade to the high quality version in the second stage.*

We observe that when consumer expectations are homogeneous, demand for the high and low quality versions, and the upgrade, do not depend on whether consumers are optimistic ($R(q_h) > q_h$ and $R(q_l) > q_l$) or pessimistic ($R(q_h) < q_h$ and $R(q_l) < q_l$). However, the optimal prices for the high and low quality versions, p_h and p_l, are directly related to the expectations of quality before experience, $R(q_h)$ and $R(q_l)$. The more optimistic are the expectations of quality, the higher are the prices for both versions, and consequently profits are higher. Hence, positive promotion, advertising for example, that raises consumer expectations of quality can effectively increase profits from experience goods.

5. Consumers with Heterogeneous Expectations

In this section we relax the restriction that the expectations of quality held by consumers are homogeneous by allowing the expected quality of the goods before experience to depend on consumer taste, θ. This situation applies to most of the complicated software and other information goods whose quality cannot be uniformly agreed upon by different consumers. This relaxation also generalizes our model so that it applies to a wider variety of circumstances. From our Assumption 2 we can see that how expected quality before experience depends on consumer taste in turn

depends on whether consumers are optimistic or pessimistic. We return to the full notation for expected quality, $R(\theta, q)$. As we described in our implications of Assumption 2 whereby higher taste consumers have better judgment, for optimistic consumers expected quality decreases with consumer taste, $\partial R(\theta, q)/\partial\theta \leq 0$, and for pessimistic consumers expected quality increases with consumer taste $\partial R(\theta, q)/\partial\theta \geq 0$.

Substituting the same price relationships (1), (2) and (3) into the monopolist's profit maximization problem in (5), we can write the profit maximization as

$$\begin{aligned}\max_{\theta_h,\theta_l,\theta_u} \Pi \;=\; & [1-F(\theta_h)]\;[\theta_l\; R(\theta_l, q_l) + [R(\theta_h, q_h) - R(\theta_h, q_l)]\;\theta_h] + [F(\theta_h) - F(\theta_l)]\;\theta_l\; R(\theta_l, q_l) \\ & + \delta\;[F(\theta_h) - F(\theta_u)]\;[q_h - q_l]\;\theta_u \\ & \ni\;\; 0 \leq \theta_l \;\leq\; \theta_u \leq\; \theta_h \leq\; 1,\ \text{IR},\ \text{IC},\ \text{C1}. \end{aligned} \tag{13}$$

The Lagrangian for this problem is $\mathcal{L} = \Pi + \lambda\,[\theta_u - \theta_l]$. Because θ_h, θ_u and θ_l are positive, the first-order (Kuhn-Tucker) conditions are

$$\begin{aligned}\mathcal{L}_{\theta_h} = & -f(\theta_h)\,[R(\theta_h, q_h) - R(\theta_h, q_l)]\,\theta_h + [1-F(\theta_h)]\,[R(\theta_h, q_h) - R(\theta_h, q_l)] \\ & + [1-F(\theta_h)]\,[\Delta(\theta_h)]\,\theta_h + \delta f(\theta_h)\,[q_h - q_l]\,\theta_u = 0, \end{aligned} \tag{14}$$

$$\mathcal{L}_{\theta_u} = \delta\,[q_h - q_l]\;\,[F(\theta_h) - F(\theta_u) - f(\theta_u)\theta_u] + \lambda = 0, \tag{15}$$

$$\mathcal{L}_{\theta_l} = [1-F(\theta_l)]\left[R(\theta_l, q_l) + \theta_l \frac{\partial R(\theta_l, q_l)}{\partial \theta_l}\right] - f(\theta_l)\theta_l R(\theta_l, q_l) - \lambda = 0, \quad \text{and} \tag{16}$$

$$\mathcal{L}_{\lambda} = \theta_u - \theta_l \geq 0,\;\; \text{if} >,\; \lambda = 0, \tag{17}$$

where to simplify the expression

$$\Delta(\theta_h) = \frac{\partial R(\theta_h, q_h)}{\partial \theta_h} - \frac{\partial R(\theta_h, q_l)}{\partial \theta_h}.$$

From (14) we find

$$\theta_h = \frac{1-F(\theta_h)}{f(\theta_h)}\left[1 + \theta_h \frac{\Delta(\theta_h)}{R(\theta_h, q_h) - R(\theta_h, q_l)}\right] + \delta\theta_u \frac{q_h - q_l}{R(\theta_h, q_h) - R(\theta_h, q_l)} > \frac{1-F(\theta_h)}{f(\theta_h)}.$$

Thus, we have $\theta_h > \theta^*$, which means the market for the high quality version shrinks with a version-to-upgrade strategy at the first stage (experience stage). From (17), we first assume that the constraint is not binding, which implies that $\theta_u > \theta_l$ and $\lambda = 0$, and as before means that some of the consumers that purchased the low quality version in the first stage do not upgrade in the second stage. Substituting back into (15) and (16), we have

$$\theta_u = \frac{F(\theta_h) - F(\theta_u)}{f(\theta_u)} < \frac{1 - F(\theta_u)}{f(\theta_u)}. \tag{18}$$

From (18) we know that $\theta_u < \theta^*$, which means including consumers who upgrade to the high quality version after experience, the total market for the high quality good is larger than when only one version is offered. This immediately implies that the version-to-upgrade strategy induces more consumers to purchase the high quality version than a monopolist with a single version, which results in improvement in social welfare. From (15) and (16) we can also determine the consumer that is indifferent between purchasing the low quality version and not purchasing:

$$\theta_l = \frac{1 - F(\theta_l)}{f(\theta_l)} \left[1 + \frac{\partial R(\theta_l, q_l)/\partial \theta_l}{R(\theta_l, q_l)} \theta_l \right]. \tag{19}$$

To compare the taste of the consumer that is indifferent between purchasing the low quality version and not purchasing, θ_l, relative to the indifferent consumer for a monopolist with a single version, θ^*, we have to consider two situations: when consumers are pessimistic and when consumers are optimistic.

When Consumers are Pessimistic. When consumers are pessimistic it means that $R(\theta, q_l) < q_l$ and $R(\theta, q_h) < q_h$. From Assumption 2, $\partial R(\theta, q_l)/\partial \theta > 0$, which means that the consumer that is indifferent between the low quality version and not purchasing is $\theta_l > \frac{1-F(\theta_l)}{f(\theta_l)}$, where θ_l is defined in (19). As a consequence this implies that $\theta_l > \theta^* > \theta_u$. This violates our Lagrangian constraint (17). Therefore, the constraint must be binding, which means $\theta_l = \theta_u$, and indicates that all consumers

that purchased the low quality version in the first stage upgrade to the high quality version. This result is the same as the result when consumers have homogeneous expectations. Thus, we have the following proposition.

Proposition 2. *If consumers have heterogeneous expectations of quality before experience and are pessimistic, then all consumers that purchased the low quality version in the first stage upgrade to the high quality version in the second stage.*

When Consumers are Optimistic. When consumers are optimistic it means that $R(\theta, q_l) > q_l$ and $R(\theta, q_h) > q_h$. From Assumption 2, optimistic consumers with higher taste have better judgment and have lower expectations of quality before experience, $\partial R(\theta, q)/\partial\theta < 0$, the reverse of when consumers are pessimistic. Using (19),

$$\theta_l = \frac{1 - F(\theta_l)}{f(\theta_l)} \left[1 + \frac{\partial R(\theta, q_l)/\partial\theta}{R(\theta_l, q_l)}\theta_l\right] < \frac{1 - F(\theta_l)}{f(\theta_l)}.$$

Consequently we find $\theta_l < \theta^*$, that is, with a version-to-upgrade strategy the consumer that is indifferent between the low quality version and not purchasing is a lower taste consumer than indifferent consumer for a monopolist with a single version. Because from (18) we know that the consumer indifferent between upgrading in the second stage and not, θ_u, is also less than θ^*, we require an additional condition to determine the relationship between θ_l and θ_u. We derive this condition in the following proposition.

Proposition 3. *If consumers have heterogeneous expectations of quality before experience and are optimistic, then a sufficient condition for a proper subset of consumers that purchased the low quality version in the first stage to upgrade is that* $\forall\theta, \left|\frac{\partial R(\theta,q_l)/\partial\theta}{R(\theta,q_l)}\theta\right| > 1$.

Proof. Because $\theta_h > \theta^*$ and $\theta_l, \theta_u < \theta^*$, it is straightforward that $\theta_l, \theta_u < \theta_h$. For a proper subset of consumers that purchased the low quality version in the first stage to upgrade requires $\theta_l < \theta_u$,

which is equivalent to

$$\frac{1-F(\theta)}{f(\theta)}\left[1+\frac{\partial R(\theta,q_l)/\partial\theta}{R(\theta,q_l)}\theta\right]<\frac{F(\theta_h)-F(\theta)}{f(\theta)}.$$

Simplifying,

$$-\frac{\partial R(\theta,q_l)/\partial\theta}{R(\theta,q_l)}\theta>\frac{1-F(\theta_h)}{1-F(\theta)}.$$

For $\theta<\theta_h$, we have $\frac{1-F(\theta_h)}{1-F(\theta)}<1$. Because $\partial R(\theta,q_l)/\partial\theta<0$, we have $-\frac{\partial R(\theta,q_l)/\partial\theta}{R(\theta,q_l)}\theta>1$. Thus, $-\frac{\partial R(\theta,q_l)/\partial\theta}{R(\theta,q_l)}\theta>\frac{1-F(\theta_h)}{1-F(\theta)}$, which implies $\theta_l<\theta_u$. □

The sufficient condition in Proposition 3 shows the responsiveness of the expected quality before experience to a change in consumer taste. Mathematically defined as an elasticity, we can term it as an expected quality elasticity of consumer taste. Proposition 3 indicates that when the expectations of quality before experience are more responsive to a change in consumer taste from higher taste consumers, then the version-to-upgrade strategy causes only a portion of consumers that purchased the low quality version to upgrade to the high quality version. Consequently, other consumers that purchased the low quality version in the first stage choose not to upgrade and continue to use the low quality version.

6. Endogenized Qualities

So far in our model, we have treated the qualities of the high and low quality versions as exogenous variables. Here we discuss the optimal quality levels a monopolist chooses when the qualities of the information good are endogenized. We denote the development cost function as $C(q)$ which is non-decreasing in quality, $C'(q)\geq 0$ for $q\in[\underline{q},\overline{q}]$. In addition to development costs, after the flagship version q_h has been developed, for information goods the cost to degrade the flagship version to generate a lower quality version is usually fixed. Here we normalize this fixed versioning cost to zero.

When qualities of the two versions are endogenized, we can set up the monopoly profit maximization using the reduced form profit function in (5), which after defining prices with respect to indifferent consumers results in (6) and (13). Recognizing that when the qualities of the high and low quality versions are endogenous, then the three indifferent consumers in (6) and (13) are optimal value functions that depend on those qualities: $\theta_h^*(q_h, q_l)$, $\theta_l^*(q_h, q_l)$ and $\theta_u^*(q_h, q_l)$. Consequently we can write the profit maximization by choice of qualities as

$$\max_{q_h, q_l} N(q_h, q_l) = \max_{q_h, q_l} \{\Pi(\theta_h^*(q_h, q_l), \theta_l^*(q_h, q_l), \theta_u^*(q_h, q_l), q_h, q_l) - C(q_h)\}.$$

Dropping the arguments (q_h, q_l) from the profit function without development costs, Π, and the optimal value functions θ^* for convenience, the first-order condition with respect to the high quality version, q_h, generates

$$\frac{\partial \Pi}{\partial \theta_h^*}\frac{\theta_h^*}{q_h} + \frac{\partial \Pi}{\partial \theta_l^*}\frac{\theta_l^*}{q_h} + \frac{\partial \Pi}{\partial \theta_u^*}\frac{\theta_u^*}{q_h} + \frac{\partial \Pi}{\partial q_h} - C'(q_h) = 0. \tag{20}$$

In (20) there is a direct effect of q_h on profit and indirect effects through the indifferent consumers. Due to the envelop theorem, the indirect effects through indifferent consumers are zero, $\partial \Pi / \partial \theta_h^* = 0$, $\partial \Pi / \partial \theta_l^* = 0$ and $\partial \Pi / \partial \theta_u^* = 0$. This applies even in the case of homogeneous or pessimistic consumers where one of the Lagrangian constraints is binding because the binding constraint is $\theta_l^* = \theta_u^*$ and the actual solutions θ^* are based on first-order conditions. For both homogeneous and heterogeneous consumer expectations, and using the full notation for expected quality before experience, (20) reduces to

$$[1 - F(\theta_h^*)]\theta_h^* \frac{\partial R(\theta_h^*, q_h)}{\partial q_h} + \delta[F(\theta_h^*) - F(\theta_u^*)]\theta_u^* = C'(q_h).$$

The first term on the left hand side is the increase in profit from the high quality version and second is the increase in profit from the upgrade, and both are weakly positive. Consequently, the optimal quality of the high quality version is determined by balancing the marginal increases profit

through the high quality version and upgrade from an increase in the quality of the high quality version with the marginal cost of development.

The first-order condition with respect to the low quality version, q_l, generates

$$\frac{\partial N(q_h, q_l)}{\partial q_l} = \frac{\partial \Pi}{\partial \theta_h^*}\frac{\theta_h^*}{q_l} + \frac{\partial \Pi}{\partial \theta_l^*}\frac{\theta_l^*}{q_l} + \frac{\partial \Pi}{\partial \theta_u^*}\frac{\theta_u^*}{q_l} + \frac{\partial \Pi}{\partial q_l} = \frac{\partial \Pi}{\partial q_l} = 0,$$

where again there are direct and indirect effects. For both homogeneous and heterogeneous consumer expectations, again using the full notation for expected quality before experience and dropping terms based on the envelope theorem, the first-order condition reduces to

$$[1-F(\theta_h^*)][\theta_l^*\frac{\partial R(\theta_l^*, q_l)}{\partial q_l} - \theta_h^*\frac{\partial R(\theta_h^*, q_l)}{\partial q_l}] + [F(\theta_h^*) - F(\theta_l^*)]\theta_l^*\frac{\partial R(\theta_l^*, q_l)}{\partial q_l} - \delta[F(\theta_h^*) - F(\theta_u^*)]\theta_u^* = 0. \quad (21)$$

As the quality of the low quality version increases, from Assumption 3 the first term on the left hand side is negative reflecting those consumers that choose the low quality version rather than the high quality version, and the third term is also negative as fewer consumers upgrade. The second term is positive from the increased number of consumers that purchase the low quality version.

From this analysis it is clear that the quality of the high quality version depends on the convexity of development costs. In contrast, the quality of the low quality version depends on tradeoffs between more consumers purchasing either version versus the additional profit the monopolist can get from upgrades in the version-to-upgrade strategy. In this latter case if the negative terms related to upgrades in (21) outweigh the effect from greater number of consumers purchasing, then it means the lower the quality of the low quality version, the higher the profits. Consequently, the optimal quality of the low version should be reduced to the lowest quality $\underline{q}$ that reasonably can be used to reveal the true quality of the high quality version. Hence, with a version-to-upgrade strategy, a feasible solution for the monopolist is to minimize the quality of the low quality version so that it contains just sufficient information to reveal the true quality of the information good.

This could well explain why a monopolist may offer trial or demonstration versions as suggested by Cheng and Tang [3].

7. Conclusions

In this research we examine experience information goods and construct models to investigate a version-to-upgrade strategy to determine if by using this strategy a monopolist implements versioning. Adopting a two-stage model, we find that if all consumers have homogeneous expectations about the information goods' quality before experience, then using a version-to-upgrade strategy a monopolist offers at least two distinct versions, and the monopolist's optimal pricing strategy involves upgrading all consumers that purchased the low quality version in the first stage to the high quality version in the second stage. In this way, consumers that upgrade effectively pay a tax for learning. When consumers have heterogeneous expectations, we find that if consumers are pessimistic, then the version-to-upgrade strategy continues to yield two distinct versions, and the optimal pricing still causes all consumers that purchased the low quality version in the first stage to upgrade later. However, if consumers are optimistic, then under a specific and easily-interpretable condition, the version-to-upgrade strategy induces only some of the consumers that purchased the low quality version in the first stage to upgrade. When qualities of the two versions are endogenous, the version-to-upgrade strategy can cause the monopolist to minimize the quality of the low quality version to the lowest quality that can feasibly be used to reveal the true quality of the high quality version. As such, the monopolist may use demonstration or trial versions.

A limitation of our work here is that we only model a monopoly producer. Whether the version-to-upgrade strategy can be applied in a competitive setting is not clear. In previous research we found that versioning strategies can be implemented by an incumbent firm to deter entry [18], but this result may not hold when we treat information goods as experience goods and use a version-

to-upgrade strategy. This is because potential entry may come from the high quality-end of the market, making versioning not optimal. Another limitation is that in our models we assume that the only way to learn the true quality of the goods is through use after purchase, and that this learning is both quick and perfect. In fact, there are many other channels such as "word of mouth", social networks, that are used to assess – albeit imperfectly – the true quality of information goods. Moreover, purchasing and using a low quality version may not be sufficient for consumers to learn the true quality of the higher quality versions.

A third and important limitation of our model is that we do not incorporate intertemporal process discrimination, that is, different prices across the two periods. Indeed, our model timeline has the prices of both versions and the upgrade as announced in the first stage and unchanging, and is thus, precommitted. However, consumers do not consider the upgrade price in their first stage decision of which version to purchase, and for consumers that purchased the low quality version in the first stage, only the upgrade price matters in the second stage. Consequently, allowing a change of prices at the second stage will not impact the versioning decision of the monopolist. We do not model the case of consumers that are myopic regarding price, substantial discount factors between stages, later-stage increases market size, or network externalities – all of which might otherwise be dimensions on which price discrimination between stages could be based.

Following this, one possible extension to our work with experience information goods is to include network effects in our models. Many information goods such as operation systems and Database management systems display strong positive network effects where the consumers' willingness to pay increases with the total size of the users [3, 5, 14], and these value of network effects can be separate from word-of-mouth used to assess quality mentioned above. Network effects may provide the monopolist even greater incentive to version information goods as a mechanism to

expand its user base.

8. Acknowledgements

We thank Albert Dexter, Vidyanand Choudhary, Rahul Telang, two anonymous reviewers and participants of INFORMS CIST 2007 for helpful comments. We thank Christian Weiss for his contribution to the preliminary version. We thank the Natural Science and Engineering Research Council of Canada, the Social Science and Humanities Research Council of Canada, the David B. Robson Endowment, the iRC at the Haskayne School of Business at the University of Calgary, and the National Natural Science Foundation of China (Project No. 70972047), Shanghai Pujiang Program and the E-Commerce Research Center at the School of Management at Fudan University for support.

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