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Managing Piracy: Pricing and Sampling Strategies for Digital Experience Goods in Vertically Segmented Markets

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Digital goods lend themselves to versioning but also suffer from piracy losses. This paper develops a pricing model for digital experience goods in a segmented market and explores the optimality of sampling as a piracy-mitigating strategy. Consumers are aware of the true fit of an experience good to their tastes only after consumption, and as piracy offers an additional (albeit illegal) consumption opportunity, traditional segmentation findings from economics and sampling recommendations from marketing, need to be revisited. We develop a two-stage model of piracy for a market where consumers are heterogeneous in their marginal valuation for quality and their moral costs. In our model, some consumers pirate the product in the first stage allowing them to update their fit-perception that may result in re-evaluation of their buying/pirating decision in the second stage. We recommend distinct pricing and sampling strategies for underestimated and overestimated products and suggest that any potential benefits of piracy can be internalized through product sampling. Two counterintuitive results stand out. First, 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, and second, unlike physical goods where sampling is always beneficial for underestimated products, sampling for digital goods is optimal only under narrowly defined circumstances due to the price boundaries created by both piracy and segmentation.

Key words: digital products; experience goods; vertical segmentation; pricing; piracy; sampling
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1. Introduction

Publishing, software, music, movie, and videogame vendors are transforming their business models due to ongoing technological changes. Three common themes bind these product categories. First, they are moving from physical to largely digital forms. Second, they belong to a class of economic goods known as experience goods. Third, they are subjected to a particularly disturbing trend of piracy due to increasing ease of duplication and availability of illegal copies. Even as these *digital experience goods* industries are struggling with online strategies and pricing issues, trade associations (global industry revenues are in parentheses) such as the Business/Entertainment Software Alliance (BSA/ESA—\$60 B), the Recording Industry Association of America (RIAA—\$9 B), and the Motion Picture Association of America (MPAA—\$14 B) have also been reporting piracy losses to the tune of \$22 billion in non-U.S. markets alone.

Industry specific responses to piracy have been varied; while software and games businesses are experimenting with vertical segmentation or even sampling, those that belong to the RIAA and the MPAA have been fighting piracy largely through legal actions against pirates and peer-to-peer (p2p) services such as Morpheus and Kazaa (Goldstein 2002) and through technological tools such as "decoy" strategies, watermarking, and tagging (see whitepaper at http://www.baytsp.com). Technological deterrence efforts are often limited in their efficacy (Berst 2002) as they are only as good as the first successful hacker, while legal deterrence relies on enforcement and consumers' awareness of the law. The existence of legitimate demand for digital experience goods, albeit with variable price boundaries, piracy deterrents, and quality/feature preferences has largely been ignored. While the industry has been engaged in piracy proofing, academic literature has largely focused on pricing issues without adequately addressing the experience goods character of these digital products. The impending arrival of digital television combined with digital recorder technologies such as TiVo and ReplayTV is only likely to exacerbate piracy losses (Mount and Caulfield 2002), and hence it is imperative to re-evaluate the overall implication of pricing, segmenting, sampling, and deterrence strategies.

Our research is primarily based on analytical models of vertical segmentation (Mussa and Rosen 1978), experience goods (Nelson 1970), product sampling (Ailloni-Charas 1984), and empirical research on piracy (Gopal and Sanders 1998). While recent research (Sundararajan 2004) has studied price discrimination under piracy albeit through a quantity-price schedule, we adopt a classical vertical-segmentation approach and model a quality-price schedule (contract) along the lines of Chellappa and Shivendu (2003a). It is known that pricing of physical experience goods whose valued attributes cannot be fully ascertained before consumption needs to take into account the *initial* information or knowledge that consumers may have about them (Liebeskind and Rumelt 1989), and that differential pricing strategies are needed when a market overestimates versus underestimates the valued attribute (Shapiro 1983). A distinguishing characteristic of *digitized* experience goods, in contrast to their physical counterparts, is that vendors cannot let consumers experience their products without fear of it being pirated. Further, simple price-based explanations offered by early analytical models (Conner and Rumelt 1991) need to be pooled with nonprice, piracy-related aspects such as consumers' expectation of deterrence, prevalent ethical indices (Solomon and O'Brien 1991), and consumers' ethical propensity to pirate (Gopal and Sanders 1997), as well as institutional and cultural aspects of the market (Ginarte and Park 1997, Marron and Steel 2000).

Recent analytical work (Chellappa and Shivendu 2003a) has abstracted the above nonprice deterrence factors through consumers' *moral cost* of pirating and expected punitive costs. We extend this model to include a recent empirical observation that the second most important reason why consumers pirate is their need to "try out" (Cheng et al. 1997), suggesting that some piracy could have been prevented if some other legitimate means of "trying out" was provided. As the concept of "return" is ill-defined for digital products, even the applicability of optimal return policies is somewhat limited (Che 1996). Generally, this legitimate consumer need has largely been ignored in academic research with the exception of recent empirical work that examines the role of consumer search (Gopal et al. 2002, Hui and Png 2001). While for most physical goods one-time consumption without lifetime ownership can be easily provided through samples, expiration of samples or other forms of limited ownership have to be explicitly built into the product.

In this paper, we examine pricing and sampling strategies through a two-stage consumer piracy-behavior model and by abstracting consumers' perception of a digital product's fit to their tastes based on their *indirect* and *direct* experiences. Specifically we examine segmentation and sampling under piracy when products may be *underestimated* or *overestimated* by the market. Our research recommends a part-product sampling approach where the optimal sample size not only depends on the prevalent deterrence costs but also on the relative division of this cost across the two stages. This paper is organized as follows: In §2, we develop our two-stage piracy model and analyze vendor's pricing strategies in a vertically segmented market. In §3, we investigate the efficacy of sampling and deterrence requirements to mitigate piracy. Section 4 concludes with a discussion of theoretical and managerial implications while noting the limitations. The proofs of the lemmas and propositions are given in the appendix.

2. Model

Transactions involving digital products may be modeled as principal-agent contracts in that there is an agreement (to not use a pirated copy), a potential for breach (by pirating), some enforcement possibilities (through deterrence mechanisms), and some information that is private to the agent (their valuation for quality and propensity to pirate). Our model consists of a principal (digital product vendor) and two types of agents (consumers), each of whom have either a high $\bar{\theta}$ or a low $\underline{\theta}$ ($\underline{\theta} < \bar{\theta}$) marginal willingness to pay for quality (x). The market is divided in proportion v and $1 - v$ in these consumer types and the vendor knows only the point distribution that is common knowledge, while consumers know their own types. This is posed as a contract-theoretic framework along the lines of Laffont and Martimort (2002), who observe that such discrete setups turn out to be "sufficient to highlight the main phenomena arising around adverse selection without having to deal with the technicalities of continuum of types" (p. 31).

In our model, the vendor can offer two qualities of a digital product—a high ($\bar{x}$) and a low quality ($\underline{x}$). Note that as in most economic literature, we use the term quality to refer to any valued attribute of a product (Liebeskind and Rumelt 1989, Nelson 1970, Shapiro 1983). Information goods readily lend themselves to versioning or quality segmentation (Varian 1997), and one can indeed observe different forms of versioning and segmentation strategies today (see Table 1). Let the vendor's cost of offering a quality x be $a + c(x)$, where a is some fixed cost and $c(x)$ is the cost of producing quality x, where $c' > 0$, $c'' > 0$. This cost function merely states that the cost of producing a higher quality (or feature) becomes increasingly expensive, e.g., improving upon a base 2D videogame to create a 3D multiplayer interactive game becomes increasingly costly as each new feature is added. As with other digital products, the *marginal* cost of serving an additional customer is assumed to be zero. Note that the quality/features of the digital good (x) represents the *nonexperience* part of the good (known to consumers before consumption), and specifying a fixed/constant marginal cost of serving additional consumers does not affect the qualitative arguments presented below.

2.1. Consumers' Perception of a Digital Product's Fit to Their Tastes

Our digital goods have a lifetime utility, i.e., consumers need to own a copy of the full product by purchasing or pirating, be it software, music, movies, or games. While the *quality* of the good is known, consumers only have beliefs about the good's *fit* (*experience part*) to their preferences or tastes, known as the private information contained within an experience good (Nelson 1970, Shapiro 1983). In the case of software, the experience part becomes apparent only after installing it in one's own work environment and using it for specific tasks; for entertainment products the hedonic aspects represent the experience part. The initial perception of a digital good's fit to the consumers' preferences and needs is known to be shaped by *indirect experiences* created by advertisements (McGuinness et al. 1992), word-of-mouth communication, and signals such as warranties. However, as Shapiro (1983, p. 498) points out, these sources of nonconsumption information have limitations, e.g., "advertising is subject to credibility problems…, warranties are limited by adverse selection or moral hazard problems." Thus, the true value to a consumer of an experience good is known only after consumption.

Table 1 Common Segmentation Strategies for Digital Goods

Software	Music	Movies	Video games
Small versus large number of features/components included Network versus nonnetwork versions Automatic versus manual future updates Availability of online technical support, manuals, etc. e.g., Microsoft Office standard versus premium	Lossy versus lossless compression (influencing the ability to be played in HiFi audio systems) Burning and multiformat conversion enabled versus single-format, single-machine requirement Inclusion of live versions versus studio recordings e.g., AAC (Apple) versus MP3	Wide screen versus regular format Seamless branching of movie versus ability to handle multiple story lines Menus, interactive features, and other extra content versus plain vanilla options Broadband versus narrowband for online delivery Hi-definition versus regular format e.g., Spiderman double disc release	Multiplayer versus single player versions Multilevel versus low-level games Virtual collaborative team play versus independent play e.g., Many RealArcade games have two versions

In our model, we denote the consumers' perception of how a product fits their tastes or preferences by $k \in (0, 1)$, and as fit perceptions have no natural scale, we effectively choose a scale by setting the maximal k at 1 (when a product fully fits the consumers' tastes). We represent the initial perception (common to all consumers) by $k = k_0$, where k_0 maybe lesser than or greater than the true fit of the product. We classify our digital experience goods to be one of two types such that *after* consumption, we have $k = 1$, suggesting that the good fully matched the consumers' tastes and was initially underestimated, or $k = 0$, implying that the good's fit was overestimated initially. A more general form of this abstraction is to assume that the initial perception of fit k_0 has a distribution $F(\cdot)$ and the true fit, which is realized only after consumption, is given by a distribution $G(\cdot)$. An overestimated product will imply that $F(\cdot)$ *first-order stochastically dominates* $G(\cdot)$, while an underestimated product will imply the converse. In this paper for the sake of simplicity, we assume that $F(\cdot)$ and $G(\cdot)$ are point functions as discrete models are often sufficient to highlight the qualitative results.

2.2. Consumers' Utility from Purchasing or Pirating a Digital Product—The Two-Stage Model

Consumers in our model have a linear utility function $(k_0\theta x - p)$ with zero reservation value, i.e., they will buy at price p if their utility is nonnegative. An important difference between physical experience goods (as modeled by research in economics) and digital experience goods (as modeled in this paper) is that the latter offers two possible consumption channels to the consumers to update their belief on the experience part of the good: buying *and* piracy. When pirating, consumers do not incur a monetary cost but depending upon individual specific factors (age, gender, and other ethical indices), they are known to suffer an internal cost of committing an illegal activity (Solomon and O'Brien 1991) captured by a construct called the *moral cost of pirating* (Chellappa and Shivendu 2003a). This is given by a parameter $\beta \sim U(0, \bar{\beta})$, where consumers closer to $\bar{\beta}$ suffer a high moral cost representing the most moral individuals with the least ethical propensity to pirate (Gopal and Sanders 1997).

A parameter E captures nonindividual specific piracy costs due to both technological and legal factors and is a measure of the prevailing difficulty of pirating that can be influenced by vendors. While country-specific copyright laws and track record of enforcement contribute to the consumers' expectation of getting caught and the resultant fine (Ginarte and Park 1997, Globerman 1988), vendors can also make investments in technological and legal deterrence to increase E, e.g., through digital rights management (DRM) tools and law suits (Borland 2002, Gentile 2003). Because the vendor is creating two versions of the same product, we assume that consumers suffer the same cost of pirating for either version. This is consistent with the intuition that once a vendor has a certain DRM, he is unlikely to dumb it down for a lower quality of the same product, just as a consumer is unlikely to feel a greater moral cost in pirating a high-fidelity version of a song as compared to its compressed, low-quality counterpart. Therefore, for any quality, the consumers' combined cost of piracy is given by $(\beta + E) \sim U(E, \bar{\beta} + E)$. Note that in this model, we assume that the pirated copy suffers no deterioration in quality.

Piracy literature has largely modeled the consumers' choice between buying and pirating as a *single-stage decision*, where the pirated goods act as a competing seller's product line (although illegal) and consumers compare prices with piracy costs (see Chellappa and Shivendu 2003b for a discussion). Such models have not considered an important aspect of the consumers' piracy behavior that some consumers pirate products such as software to ascertain their usefulness (Cheng et al. 1997). Thus, the consumers' decision to pirate may not always be final. It may be an intermediate step of experiencing where if the pirated good is not found useful it will be discarded. If the pirated good is found useful, consumers may possibly keep the pirated copy or perhaps be incentivized to buy a legitimate copy. This piracy behavior may be potentially beneficial to vendors in that pirates are informed of a product's usefulness, and some research has explored this potentially beneficial aspect of piracy in the context of positive externalities (Takeyama 1994), diffusion of legitimate software demand (Givon et al. 1995), and increased revenues (Gopal et al. 2002, Hui and Png 2001). Note that prior literature assumes that piracy benefits will somehow propagate through the market to increase aggregate demand to benefit the vendor. However, no light is shed on how vendors may operationally be able to appropriate or extract piracy benefits. By modeling individual consumer behavior, rather than assuming a demand function, we are able to pinpoint the impact of piracy on an individual's buying decision so as to develop operationalizable vendor strategies.

If consumers may keep or perhaps even discard a product after experiencing it, any costs of pirating need to be split between the stage when they first pirate and the step where they finally decide to keep or discard the pirated product. An important point to note here is that whether or not pirates keep or discard the pirated good, their knowledge of the product's fit to their taste has been updated due to direct consumption. This creates an interesting situation where some pirates who did not consider purchasing based on their initial perception may now, based on their updated perception, decide to discard the pirated version and buy a legitimate copy.

Therefore, we develop a *two-stage model* of piracybehavior. In the first stage, consumers decide between buying, pirating, or not participating in the market. While the buying and not participating actions are final, pirating is transient because in the second stage some pirates may choose to discard the copy while some may buy a legitimate one. To capture the fact that consumers will incur the full cost of committing an illegal activity only if they continue to own the pirated copy, we introduce a transient cost parameter $\delta \in (0, 1)$, such that the pirating cost in the first stage is given as $\delta(\beta+E)$. The first or the transient stage can be interpreted as the stage where the pirates may not feel the full moral obligation toward copyright or fully suffer from the fear of getting caught until they have decided to keep the pirated copy in the second stage. If consumers decide to buy the product in Stage 2, then they do not carry over their cost of pirating (as they had only temporarily held the illegitimate copy) because they have now paid the full price for the legitimate product (Figure 1). Thus, while all pirates suffer the transient cost in the first stage, those who buy a legitimate copy in the final stage do not keep this cost.

When consumers move from Stage 1 to Stage 2, their perception of the product's fit now changes due

Figure 1 To Pirate or Not: The Consumers' Two-Stage Decision Tree

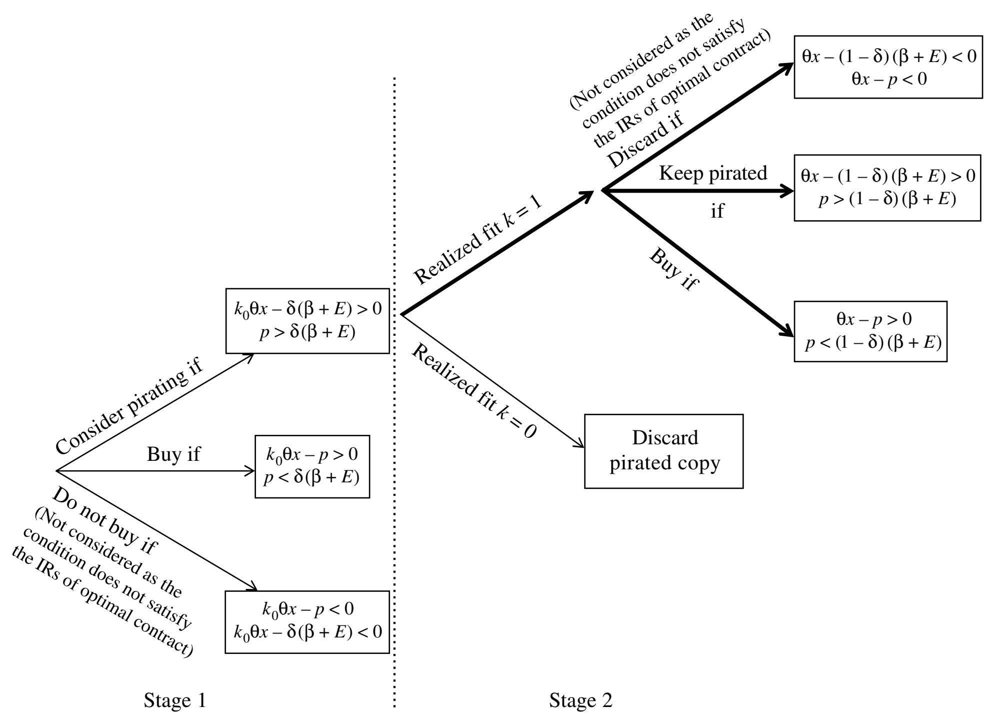

Table 2 Notation

Description	Notation	Description	Notation
Marginal willingness to pay for quality of consumers (*heterogeneous, two types*)	$\bar{\theta}$ (high type) (proportion v) $\underline{\theta}$ (low type) (proportion $1-v$)	Digital good quality (*any valued attribute and known to consumers*)	$\bar{x}$ (high quality) $\underline{x}$ (low quality)
Moral cost (*heterogeneous, distributed*) Deterrence cost Transient cost	$\beta \sim U(0, \bar{\beta})$ E δ	Cost of production *variable* (*in product quality and zero marginal cost of serving additional consumers*)	$c(\bar{x})$ (high quality) $c(\underline{x})$ (low quality)
Initial perception of a digital good's fit to tastes (*known to consumers before consumption and based on advertising/hype-related perceptions*)	k_0 (all products)	Optimal prices in the absence of piracy	$\bar{p}^*$ (high quality) $\underline{p}^*$ (low quality)
Realized fit of the digital experience good (*known to consumers only after consumption, legally or otherwise, of the full product*)	$k=1$ (underestimated product) $k=0$ (overestimated product)	Optimal prices in the presence of piracy	$\bar{p}_p^*$ (high quality) $\underline{p}_p^*$ (low quality)
Perception of the digital experience good's fit after consumption of sample of size $s \in (0,1)$	$\bar{k}_s = k_0 + (1-k_0)s$ (underestimated product) $\underline{k}_s = k_0(1-s)$ (overestimated product)	Optimal prices in the presence of piracy and when sampling is employed	$\bar{p}_s^*$ (high quality) $\underline{p}_s^*$ (low quality)

to directly experiencing the good, and the direction in which it has changed depends upon whether the good was initially under or overestimated as shown in Figure 1. Thus, $k = k_0$ is now updated to $k = 1$ for the underestimated product, while it becomes $k = 0$ (or some negligible value) for the overestimated product. In the latter case, the utility from the product becomes near zero, and hence consumers will neither buy nor keep the pirated copy. Note that it is the piracy cost that is split across two stages and if the consumer (based on his updated fit) buys a legitimate copy after having pirated in the first stage, then he does not carry over the interim piracy costs incurred in the first stage. Further, consumers will only pirate the high-quality product even if they may have been potential purchasers of the low-quality product. The simple intuition is that the low-type consumer's utility from pirating the high-quality product is greater than pirating the low-quality product at the first stage because the cost to a consumer in either situation is the same ($\delta(\beta+E)$), while the value to the consumer from the high-quality product is higher ($\underline{\theta}\bar{x} > \underline{\theta}\,\underline{x}$). Therefore, in the second stage the $\underline{\theta}$ types will trade off cross-segment pirating with own-segment buying, i.e., $\underline{\theta}\bar{x} - (1-\delta)(\beta+E)$ versus $\underline{\theta}\,\underline{x} - \underline{p}$. Now we consider the vendor's profit-maximizing behavior. We first consider the case where piracy is absent and subsequently incorporate consumers' two-stage piracy behavior in the vendor's pricing decision. (Table 2 provides a summary of notation used throughout the text and the appendix.)

2.3. Vendor's Problem

In the *absence* of piracy, the vendor's pricing decisions that maximize his profit depend only on the production cost of creating two qualities and the proportion that will buy each quality, given by

$$\max_{\{\bar{p},\underline{p}\}} [v\bar{p} - c(\bar{x}) + (1-v)\underline{p} - c(\underline{x}) - a]. \tag{1}$$

Along the lines of well-known vertical-segmentation strategies under incomplete information (Liebeskind and Rumelt 1989), the vendor would take into account the consumers' individual rationality (IR) and incentive compatibility (IC) constraints to determine prices for the two qualities. If the vendor finds it optimal to maintain two segments (see §2.4 for cases when segmentation is suboptimal), he will set prices for the high- and low-quality products to be $\bar{p}^* = k_0(\bar{\theta}\bar{x} - \Delta\theta\underline{x})$ and $\underline{p}^* = k_0\underline{\theta}\,\underline{x}$, respectively (see the appendix for details). In models with asymmetric information (the vendor does not know the consumers' types), vendors have to pay an *information rent* so as to prevent the high-type consumer from being tempted to buy the low-type product (given by $k_0\Delta\theta\underline{x}$ in our model). Note that as k_0 increases, the information rent to be paid increases and the overall revenue $k_0[v(\bar{\theta}\bar{x} - \Delta\theta\underline{x}) + (1-v)\underline{\theta}\,\underline{x}]$ also increases. Hence, in terms of actionable strategies in the absence of piracy, the vendor can perhaps focus on raising k_0 so that consumers believe that the product is highly likely to fit their tastes. Indeed, when we observe the advertising strategies of many firms and in different product categories, the focus of television, print, or Web messages is often to make the product appear closer to the consumers' preferences.

The strategy of product "hyping" perhaps needs to be revisited for digital experience goods. If a vendor has over-hyped a physical experience good to make it attractive to consumers and because consumers will not be able ascertain the full experience aspect until they have purchased and consumed it, the vendor may be able to extract a higher price and can in some sense "get away with it!" On the other hand, for digital experience goods, the option of piracy provides an indirect opportunity for some consumers to experience the product without purchasing it, thus potentially limiting the value of "hyping" to the vendor. Piracy can also potentially affect the segmentation strategy of the vendor. Note that a common strategy to mitigate piracy losses is to lower prices (Chellappa and Shivendu 2003a); however, the strategy of lowering or changing prices is itself constrained by price boundaries that are needed to maintain segmentation. Hence, before we develop any price-related strategies, we first need to identify the portions of consumers who will change their piracy/buying behavior due to the updating of their fit in the second stage.

Lemma 1a. *The proportion of high-type* ($\bar{\theta}$) *consumers that will buy a high-quality good during the first stage is*

$$\bar{r}_e = \frac{1}{\bar{\beta}}\left(\bar{\beta} - \frac{\bar{p}_p}{\delta} + E\right),$$

and the proportion of low-type ($\underline{\theta}$) *consumers that will buy a low-quality good at this stage is*

$$\underline{r}_e = \frac{1}{\bar{\beta}}\left(\bar{\beta} - \frac{k_0\underline{\theta}\bar{x}}{\delta} + E\right).$$

The consumers will pirate in Stage 1 only if their transient cost of pirating $(\delta(\beta + E))$ is less than the corresponding prices $(\bar{p}_p, \underline{p}_p)$ charged for the high- and low-quality products. From our earlier discussions, we can see that while the high-type consumer compares the price and costs of pirating the high-quality product, the low-type consumer will compare his utility from pirating a high-type product $(k_0\underline{\theta}\bar{x} - \delta(\beta + E))$ with the utility from purchasing the low-quality product $(k_0\underline{\theta}\,\underline{x} - \underline{p}_p)$. In other words, what was hitherto unavailable to the low-type consumer due to prices is now available due to piracy. In this paper, we are mostly interested in the general case when both the high- and low-quality product markets encounter a mix of pirates and legitimate buyers. This will be true in Stage 1 only if $\delta E < \bar{p}_p < \delta(\bar{\beta} + E)$ for the high-type and $\delta E < k_0\underline{\theta}\,\underline{x} < \delta(\bar{\beta} + E)$ for the low-type, and because $\bar{p}_p > k_0\underline{\theta}\,\underline{x}$, we can safely say that there will always be a mix of pirates and buyers whenever $\bar{p}_p < \delta(\bar{\beta} + E)$ and $\delta E < k_0\underline{\theta}\,\underline{x}$. If these two conditions are not satisfied, then either all consumers pirate (a trivial problem) or no consumers pirate (the solutions for which have been derived earlier). Thus, the boundaries on the legal/technological deterrence (E) and the highest combined piracy costs in the market $(\bar{\beta} + E)$ are not a restrictive assumption; rather they depict a general case where some piracy does occur in both segments. Note that these boundaries also ensure that the proportions of buying or pirating segments discussed in Lemmas 1a and 1b are bounded between $(0, 1)$. Because the decision of those who buy in the first stage is final, for the second stage we only need to analyze the behavior of first-stage pirates. Because experiencing the digital good now fully informs the pirates of the true fit of the good to their preferences, depending upon whether a product was overestimated or underestimated the realized perception of fit k is now either zero or one. It is also easy to see that if the product was overestimated (realized $k = 0$), independent of their marginal willingness to pay for quality, consumers will discard the pirated product in the second stage. Hence, we are interested in the proportion of consumers who will engage in the further and final action (buying, keeping the pirated copy, or discarding it) only for underestimated goods.

Lemma 1b. *For an underestimated product in the second stage, the proportion of high-type* ($\bar{\theta}$) *pirates* (*consumers who had pirated in the first stage*) *that will buy a high-quality product is given by*

$$\bar{r}_f = \frac{1}{\bar{\beta}}\left(\bar{\beta} + E - \frac{\bar{p}_p}{1-\delta}\right),$$

and the proportion of low-type ($\underline{\theta}$) *pirates who will buy the low-quality product is*

$$\underline{r}_f = \frac{1}{\bar{\beta}}\left(\bar{\beta} + E - \frac{\underline{\theta}\bar{x}}{1-\delta}\right).$$

Shapiro (1983) points out that experience good vendors should pursue two very different pricing approaches based on whether they expect their consumers to be pessimistic or optimistic (in estimating a valued attribute) and there cannot be an optimal generalized approach. This observation is significant to our piracy context as well, as in the second stage, an overestimated digital product will neither be bought by the pirates nor will they keep the pirated product. Thus, we need to consider separate objective functions for the two product types. The combined proportions of the high- and low-type consumers buying the products meant for their respective segments can be written as

$$\begin{aligned}\Pr(\bar{\theta} \xrightarrow{\text{buy}} \bar{x}) &= \bar{r}_e + (\bar{r}_f - \bar{r}_e\bar{r}_f),\\ \Pr(\underline{\theta} \xrightarrow{\text{buy}} \underline{x}) &= \underline{r}_e + (\underline{r}_f - \underline{r}_e\underline{r}_f).\end{aligned} \tag{2}$$

Thus, we write the profit-maximization problem for an underestimated product as

$$\begin{aligned}\pi_p = \max_{\{\bar{p}_p;\,\underline{p}_p\}} \big[&\upsilon\bar{p}_p(\bar{r}_e + (1-\bar{r}_e)\bar{r}_f) - c(\bar{x})\\ &+ (1-\upsilon)\underline{p}_p(\underline{r}_e + (1-\underline{r}_e)\underline{r}_f) - c(\underline{x}) - a\big],\end{aligned} \tag{3}$$

and for the overestimated product $\bar{r}_f, \underline{r}_f = 0$, the profit function is written as

$$\pi_p = \max_{\{\bar{p}_p;\,\underline{p}_p\}} \big[\upsilon\bar{p}_p\bar{r}_e - c(\bar{x}) + (1-\upsilon)\underline{p}_p\underline{r}_e - c(\underline{x}) - a\big]. \tag{4}$$

First, because both consumer types only pirate the high-quality product, there is nothing to be gained by changing the prices of the low-quality ($\underline{x}$) digital good, and therefore the vendor will charge the same prices as in the absence of piracy ($\underline{p}_p^* = \underline{p}^* = k_0\underline{\theta}\,\underline{x}$) for the low-quality product. However, he may need to lower the price of the high-quality product to incentivize some would-be pirates to buy. Note that while prices under piracy are a function of the deterrence and transient costs, the price the vendor can charge for the high-quality product is still constrained by segmentation price boundaries. The vendor cannot price above $\bar{p}^*$ as it will incentivize the high-type consumers to buy the low-quality product, and similarly he will not price below $k_0\underline{\theta}\bar{x}$ because at such low prices the vendor might as well not maintain segmentation. The difference in price ($\bar{p}^* - \bar{p}_p^*$) has been referred to as the *moral rent* in single-stage piracy models and is paid to the high-type consumers as an incentive not to pirate (Laffont and Martimort 2002).

Proposition 1. *The optimal price for an underestimated digital product is*

$$\bar{p}_p^* = \begin{cases}\bar{p}_p & \text{if } k_0\underline{\theta}\bar{x} < \bar{p}_p < \bar{p}^*,\\ \bar{p}^* & \text{if } \bar{p}_p \ge \bar{p}^*,\end{cases}$$

$$\text{where } \bar{p}_p = \frac{E + \sqrt{E^2 - 3\delta(1-\delta)(E^2 - \bar{\beta}^2)}}{3}.$$

The optimal price for an overestimated digital product is $\bar{p}_p^* = (\bar{\beta} + E)\delta/2$.

Proposition 1 provides some important insights about the vendor's pricing strategies under piracy when he finds segmentation to be optimal. A first insight is that while the price of the low-quality product is independent of the transient cost and the initial estimation of the product's fit, the price of the high-quality product is critically dependent on both. A second insight is that for an overestimated product, the moral rent paid is decreasing in the transient cost parameter, which implies that for an overestimated product, the vendor is better off when consumers find pirating even at the first stage for experiencing the good to be highly immoral and illegal. On the other hand, the transient cost has an ambiguous effect on the moral rent to be paid if the product is underestimated. For underestimated products, the moral rent is the highest when the cost of pirating is evenly spread across the two stages ($\delta = 1/2$). Hence, for underestimated products, the vendor is better off under two extreme situations: (1) when consumers consider pirating to experience the product to be acceptable ($\delta \to 0$) but keeping the pirated copy to be highly immoral, and (2) when they consider pirating to experience the good itself to be highly immoral ($\delta \to 1$). Hence, in these extreme situations, the vendor might as well price the underestimated good based on the realized fit after pirating, i.e., pricing with respect to θx, that is, $k_0\theta x$. The higher price point suggests that piracy after all may be good in some consumer segments in that it could generate externality-type benefits. This is consistent with recent research (Heiman et al. 2001) that observes that some engage in piracy to sample digital products and that reducing the piracy costs may be beneficial to vendors (Ailloni-Charas 1984). However, a significant claim of our research is that simply relying on piracy alone to generate these benefits is perhaps detrimental as the vendor is now solely dependent on the deterrence abilities to prevent the consumer from keeping the pirated copy in the second stage. Such investment in piracy-proof deterrence (even if only for the second stage) may perhaps not be optimal and is discussed in §3.2.

2.4. Piracy and Viability of Segmentation Strategies

While we have predominantly discussed pricing under segmentation, even in the absence of piracy, it is not *always* optimal for the vendor to create two product qualities. These extreme conditions are commonly referred to as the "shutdown conditions" in economics literature on vertical segmentation (McGuinness et al. 1992).

Proposition 2. *Under some extreme market conditions (that differ based on the presence or absence of piracy), the vendor may consider doing away with segmentation. However, whether a high- or low-quality good is offered and whether only the high-type consumer (only low-type being served is never an option) or the entire market is served is determined by the relative valuations and proportions of the two consumer segments.*

Whether a vendor will persist with segmentation is a decision that is closely related to the variable cost of quality, the relative marginal value for quality, and the proportion of consumers in each segment. Consider one example of an extreme market, where the marginal valuation of the low-type is significantly low ($\underline{\theta} < \bar{\theta}v$). In such a situation and for certain cost functions (given in the appendix), the vendor will consider offering only the high-quality product and will set prices such that he serves only the high-type ($k_0\bar{\theta}\bar{x}$) rather than the entire market ($k_0\underline{\theta}\bar{x}$). The decision to adopt segmentation will further depend on the cost of offering the low-quality product, where if $c(\underline{x}) > k_0((1-v)\underline{\theta}\,\underline{x} - v\Delta\theta\bar{x})$, he will offer only the high-quality product. Similarly, one can derive conditions for other extreme cases; however, throughout this paper we consider the more general case where offering both qualities is optimal to the vendor.

It is salient to note here that the vendor may engage in such an evaluation (segmentation or not) even in the presence of piracy and may consider shutting down the production of one quality type, albeit for additional reasons. During vertical segmentation with information asymmetry, the quality offered to the low-type consumers is lower (just as the price charged to the high-type consumers is lowered) than when the vendor knows the consumer types ($\bar{\theta}/\underline{\theta} > \bar{x}/\underline{x}$). Thus, if the price derived in Proposition 1 is low (as combined piracy costs are low) such that $\bar{p}_p \le k_0\underline{\theta}\bar{x}$, the vendor will only offer one quality, namely the high quality. The intuition behind this observation is that if the piracy costs are so low such that the derived price is lower than the utility for the low-type from consuming the high-quality product, the low-type consumers will begin to buy the high-quality product at that price. Hence, it does not make sense for the vendor to offer the low-quality product as well. Again, whether he will serve only the high-type ($k_0\bar{\theta}\bar{x}$) or all of the market ($k_0\underline{\theta}\bar{x}$) will further depend on the relative valuations and consumer proportions, just as whether he will consider offering the low-quality product rather than the high-quality product will additionally depend on the production costs. In addition to the conditions described in the absence of piracy, the piracy costs to the consumers pose stricter bounds on when it is viable to maintain segmentation. In §3, we evaluate the efficacy of legitimate sampling strategies (rather than depending upon the consumers to pirate and learn about the product) and optimal investments in deterrence abilities.

3. Sampling and Investments in Deterrence Mechanisms to Mitigate Piracy

A main theme of our digital product sampling strategy is that it is feasible to convert some of the consumers who pirated in the transient stage into buyers by providing a sample. We can indeed observe various dimensions along which such product samples

Table 3 Common Dimensions of Sampling for Digital Goods

Software	Music	Movies	Video games
Expires after a certain time Has only a portion of features Cannot handle full data sets (restricted based on the number of columns or file size) Is unable to save copies a certain number of uses Trialware by Adobe, Macromedia, etc.	Has only a portion of songs or albums Limited number of plays Retailers like Amazon and CDNow and online stores such as Rhapsody offer samples in both Windows and Real formats for downloads	Online clips and trailers DVDs, online clips with a montage of clips Studios such as Paramount and Disney commonly provide these samples directly from their after websites	Very similar to the software industry and employed by most game publishers Many RealArcade games have two versions

are being tested for different digital experience goods (Table 3) even if their efficacy and strategic benefits have not been studied in academic research. From a practical perspective, a sample is a "part" of the full product. Such product samples may refer to a full product that expires after a certain time, or it could be a subset of the value providing features of the product. Our conceptualization is one of lifetime utility where the consumer must *own* (through purchasing or keeping the pirated copy) the full product.

Sampling has been used to good effect by physical experience goods vendors, and research in marketing sheds light on the usefulness of sampling in increasing goodwill in the long term and propensity to buy in the short term (Heiman et al. 2001). It is a way of allowing consumers to experience products with little risk or obligation by giving a "trial size" portion of products (see Ailloni-Charas 1984 for a complete discussion on sampling). Because samples serve as a *direct* source of information to consumers, it is indeed superior to influencing them to buy than advertising, which only offers indirect experiences (Liebeskind and Rumelt 1989). Conveniently for physical products, the consumers' needs cannot be fully met as samples are not a replenishable source, and if consumers like the product they have to eventually purchase it when they run out of samples.

However, note that it is not always clear that sampling is a suitable marketing strategy for experience goods that can be pirated. Intuitively, we can see that sampling may reduce the segment of buyers (or the price they are willing to pay) if the product fit has initially been overestimated and hence is not a suitable strategy, but even for underestimated products where sampling increases the fit perception, sampling may not be optimal. For example, a sample not only provides the potential buyers with a greater incentive to purchase, but it also provides the potential pirates with a greater incentive to pirate. It is also not clear if sampling will have the same impact on both the high- and low-type consumers given that the low-type consumers are tempted to pirate only the high-quality product. Taking these factors into account, it is also not obvious as to what "portion" of the product should be provided as a sample. To address these issues, we introduce an abstraction of consumer learning from sampling similar to that of Heiman et al. (2001). Let the free sample size of the digital product be given by $s \in (0, 1)$, where $s = 1$ refers to the digital product in its entirety. Upon experiencing the sample, a product's initial fit perception k_0 is updated to k_s. This post-sampling perception of a digital product's fit may be higher ($\bar{k}_s > k_0$) or lower ($\underline{k}_s < k_0$) depending upon whether the good was initially underestimated or overestimated. For analytical tractability, we assume that learning from directly experiencing the sample is linear where the realized fit is given by $\bar{k}_s = k_0 + (1 - k_0)s$ for underestimated product and $\underline{k}_s = k_0(1 - s)$ for the overestimated case. Because sampling is costless to consumers in our model, all consumers experience the sample prior to making the buy/pirate decision and update their perception of fit from k_0 to $\bar{k}_s(\underline{k}_s)$ for underestimated (overestimated) products.

If the new price contracts are $\bar{p}_s$ for quality $\bar{x}$ and $\underline{p}_s$ for quality $\underline{x}$ when a sample of size s is provided, the proportions derived in Lemmas 1a and 1b can be rewritten as in Lemma 2.

Lemma 2. *For underestimated products, the proportion of low-type* ($\underline{\theta}$) *consumers who will buy a low-quality good at Stage* 1 *itself is*

$$\underline{r}_{es} = \frac{1}{\bar{\beta}}\left(\bar{\beta} - \frac{k_s \underline{\theta} \bar{x}}{\delta} + E\right),$$

and in Stage 2 a proportion of pirates from this segment given by

$$\underline{r}_{fs} = \frac{1}{\bar{\beta}}\left(\bar{\beta} - \frac{\underline{\theta}\bar{x}}{1-\delta} + E\right)$$

will buy the low-quality good. The corresponding proportions for the high-type consumers ($\bar{\theta}$) are given by

$$\bar{r}_{es} = \frac{1}{\bar{\beta}}\left(\bar{\beta} - \frac{\bar{p}_s}{\delta} + E\right) \quad \textit{and}$$

$$\bar{r}_{fs} = \frac{1}{\bar{\beta}}\left(\bar{\beta} + E - \frac{\bar{p}_s}{1-\delta}\right),$$

respectively.

Before we consider the case where a product is underestimated, we first analyze the simpler case of overestimation. The vendor has to reduce prices for buyers in the low-type ($\underline{\theta}$) segment, and those who pirate will neither keep the copy nor buy as their realized fit after experiencing the product is zero. However, the high-type consumers ($\bar{\theta}$) may pursue one of three options: (1) buy the high-quality product if the sample offered is

$$s \le \frac{1}{1-k_0}\left(k_0 - \frac{\bar{p}_p - \underline{p}}{\bar{\theta}(\bar{x}-\underline{x})}\right),$$

(2) buy the low-quality product (when the sample size is greater than in (1)), or (3) pirate the high-quality product (in which case they will not keep the pirated product after fully realizing the fit). The sample given in option (1) is the maximum sample size that the vendor can provide that will keep the high-type consumer from buying the low-quality product taking into account the information and moral rents. Even if the consumers may buy under options (1) or (2), the profits are decreasing as compared to not offering a sample at all, and hence the vendor should never provide samples for overestimated goods irrespective of other consumer parameters. The reasoning behind offering samples for underestimated products is clouded by both the cross-segment piracy behavior of the low-type consumers and the potential overall increase in the pirating population, and hence requires a careful analysis.

Proposition 3. *For underestimated digital products, sampling directly affects the proportion of low-type consumers who buy and it will indirectly affect the revenue from the proportion of high-type buyers by affecting the amount of surplus that can be extracted.*

Counterintuitively, even for underestimated digital goods, sampling is not an unambiguously superior strategy as piracy by the low-type ($\underline{\theta}$) consumers go up. The reason behind this occurrence is that while the benefit from consuming the high-quality good (through pirating) has increased from $k_0\underline{\theta}\bar{x}$ to $k_s\underline{\theta}\bar{x}$, the cost of pirating has remained the same. In pricing the low-quality product the vendor will attempt to extract full surplus, i.e., $\underline{p}_s = k_s\underline{\theta}\,\underline{x}$, and hence at Stage 1, piracy becomes an attractive option for more low-type consumers. Note that the price that the vendor can charge for the low-type product has increased by $\underline{\theta}\,\underline{x}(k_s - k_0)$, but the proportion of pirates has also increased by $(\underline{\theta}\bar{x}/\bar{\beta}\delta)(k_s - k_0)$. For the high-type ($\bar{\theta}$) consumers, sampling increases the value from $k_0\bar{\theta}\bar{x}$ to $k_s\bar{\theta}\bar{x}$, while the cost of pirating remains unchanged. The optimal price of the high-quality product will again only depend upon the deterrence level and transient cost parameter as in Proposition 1; however, both the lower and upper bounds for this price now increase so as to maintain vertical segmentation. The lower and upper bounds of the optimal price ($\bar{p}_s^*$) of the high-quality product will now be $k_s\underline{\theta}\bar{x}$ and $(k_s/k_0)\bar{p}^*$, respectively, while the vendor will set the price ($\bar{p}_p$) given in Proposition 1 if $k_s\underline{\theta}\bar{x} < \bar{p}_p < (k_s/k_0)\bar{p}^*$.

Interestingly, the effect of sampling on prices and profits in the high-valuation segment depends on whether or not $\bar{p}_p^*$ assumes boundary values as given in Proposition 1. Counterintuitively, even when products are likely to be underestimated, there may be situations where sampling can lead to a decrease in profits, e.g., when $\bar{p}_p^*$ is set at the lower bound. This is because the lower bound is chosen only when price reduction for piracy begins to affect the segmentation strategy, i.e., the vendor cannot reduce prices below the lower bound as high-type consumers will then be incentivized to buy the low-quality product. Hence, increase in fit from k_0 to k_s due to sampling moves the price of the high-quality product further away from the profit-maximizing price. However, if the upper bound was chosen as $\bar{p}_p^*$, then offering samples will lead to an increase in both prices and profits as prices move closer to the profit-maximizing price. If $\bar{p}_p$ was chosen as the $\bar{p}_p^*$, then sampling does not change the prices or profits in the high-type segment as this price is independent of change in fit and only depends upon deterrence and the transient parameter.

While the prices for both the high- and low-quality products are decreasing with sampling for the overestimated goods, for the underestimated goods, the price of low quality is strictly increasing and that of high quality is weakly increasing with sampling. Note that while the information rent that is paid is strictly higher with sampling, the moral rent to be paid remains unchanged when the prices are set at the upper bound and is higher otherwise. Hence, the effectiveness of sampling as a strategy and the optimal sample size will depend upon the relative values of the willingness to pay of the two segments, the deterrence level, and the transient cost parameter.

3.1. The Optimal Sample Size

The effectiveness of sampling depends upon the trade-off between the marginal increase in revenue from increased surplus extraction and the marginal loss in revenue from increased piracy. As both the surplus and piracy loss are dependent upon the sample size offered, we seek to find the optimal level.

Proposition 4. *If the transient cost parameter $\delta > 1 - \underline{\theta}\bar{x}/E$, then sampling is an optimal strategy and the optimal sample size is given by*

$$s^* = \frac{1}{1-k_0}\left[\delta\frac{(1-\delta)(\bar{\beta}^2 - E^2) + E\underline{\theta}\bar{x}}{2\underline{\theta}\bar{x}(\underline{\theta}\bar{x} - (1-\delta)E)} - k_0\right].$$

Sampling is not a good strategy for underestimated digital products if the transient cost is sufficiently small ($\delta < 1 - \underline{\theta}\bar{x}/E$), and even if sampling is appropriate, there is an optimal size of the sample implying that under threats of piracy, the vendor cannot simply offer the entire product as a sample. In the case of physical experience goods that are not under threats of piracy as discussed in Shapiro (1983), Kim (2002), Besen and Raskind (1991), and others, providing direct experience through sampling or other means is *always* good for the vendor when the products are underestimated.

From a managerial perspective this raises some important issues, i.e., when should a vendor invest in advertising, hype, and other indirect experiences (thus increasing the initial perception of the fit), and when should he provide direct experiences to the consumer? The constraint on the transient parameter provides us with some intuition; when the consumers suffer a sufficiently high transient cost of piracy in Stage 1, then sampling may be an optimal strategy as piracy does not provide the purported externality benefits for underestimated products. Investments in indirect experiences (e.g., advertisements and other product hypes) are useful only if accompanied by investments in deterrence mechanisms as well. However, there appears to be no ideal exogenously given level of deterrence other than to suggest that it should be so high that no consumer (irrespective of their moral costs) pirates. The piracy-proof level may be economically detrimental or even infeasible, and hence we need to explore a vendor's optimal investments in technological and legal deterrence mechanisms.

3.2. Investments in Deterrence Mechanisms

"I wonder what type of copy protection will come next. Maybe they will ban markers!"[1]

There are two primary forms of deterrence—technological and legal. Technological protection solutions are often both expensive and short lived; sometimes breaking these technical barriers may be far simpler than expected. For example, Sony and Universal Studios have adopted a very aggressive anti-piracy stance and recently began offering "copy-proof" CDs to prevent consumers from illegally distributing songs. However, it has recently come to light that this proprietary protection mechanism is easily overcome by simply blackening out the edges of the shiny side of a CD using a felt-tip marker, leading to the comment at the beginning of this subsection (Berst 2002). Similarly, even as entertainment firms are pursuing individual pirates to make them an example of successful legal efforts, they are increasingly facing legal challenges due to the complex nature of online information sharing. For example, in tracking and proving that an end-user was responsible for pirating, the RIAA has run into the territory of privacy and an individual's legal rights as evident from a recent court case involving Verizon Communications Corp and RIAA (Conner and Rumelt 1991). Further, the global nature of piracy coupled with differences in laws and legal enforcements in different countries (see

[1] A music fan's posting on alt.music.prince after it was discovered that Sony's "copy-proof" CDs could be copied by blackening out the edges on the shiny side of a CD using a permanent marker (Reuters 2002).

Conner and Rumelt 1991 and Takeyama 1994 for a full discussion on the legal aspects of copyright enforcement) have led some to observe that, "The battle over music piracy is like the war on drugs: You can't win it, but you can fight it forever, and spend millions on the battle" (Berst 2002). Our research does not suggest an end to deterrence investments; rather we examine if there are other economically sound alternatives to piracy-proof objectives.

Prior research on piracy (Chellappa and Shivendu 2003a) finds that profits and prices may increase in protection technologies. However, in a vertically segmented market, there may not be proportional surplus extraction as price caps are also dependent upon the information asymmetry. Because creating deterrence is costly, it becomes imperative to the vendor to consider the price deterrence interplay in determining its level in different situations. For example, while a piracy-proof approach requires a level of deterrence given by $E = \bar{p}^*/\delta$, to pursue the same pricing strategies as in the absence of piracy, the vendor only needs to set the level of deterrence to be

$$E_u = \frac{\bar{p}^* - \sqrt{\bar{p}^{*2} - \delta(1-\delta)(\bar{p}^{*2} - \bar{\beta}^2)}}{\delta(1-\delta)}$$

for the underestimated digital product, or $E_o = (2\bar{p}^*/\delta) - \bar{\beta}$ for the overestimated product (from Proposition 1). This tells us that pursuing a piracy-proof approach will imply very high investments in deterrence if the transient parameter is very small. Further, in attempting to thwart piracy completely (as some industries appear to be intent upon), the vendor does not make use of the fact that some consumers suffer moral costs at the individual level.

Note that in our analysis, we had not considered any explicit cost function for deterrence (E). Let this cost be given by a convex cost function $g(E)$, i.e., high levels of deterrence become increasingly costly. This cost can potentially be purely a sunk cost or can have a marginal component as well. To determine the optimal investment, we simply need to incorporate this cost in the profit function and set the derivative $\partial\pi/\partial E = 0$ and simultaneously solve for prices and optimal deterrence. Intuitively, we can see that if this is a purely sunk cost, then the optimal E will be applied to all product versions as a higher E is always beneficial if there are no costs to applying it. However, if this parameter has a marginal application cost (either to each product version or each legitimate buyer), then there may be conditions where differential deterrence may be adopted for the two consumer/product segments. These conditions may be a function of the size of the high- and low-type segments and whether the product was overestimated or underestimated by the consumers. For example, if there are marginal costs to deterrence (such as due to licensing or cost of law suits), then a differential deterrence can be adopted for underestimated and overestimated products where the optimal deterrence will be bounded by E_u and E_o, respectively, at the upper limit.

Proposition 5. *For underestimated digital goods, where consumers do not consider pirating to experience in Stage* 1 *to be an issue* ($\delta \to 0$), *it may be optimal for the vendor to simply ignore piracy and price the digital product assuming that* $k = 1$. *Losses from piracy are lower for underestimated digital goods than for their overestimated counterparts, requiring higher deterrence for the latter goods.*

Proposition 5 discusses approaches required under certain specific instances of consumers' piracy behavior, e.g., when they have negligible cost of pirating (due to negligible δ) at Stage 1. These may realistically represent many instances where consumers do not necessarily intend to commit an illegal activity such as pirating but merely intend to "check out" the product's fit. In such situations, the intended benefit from sampling can be extracted through piracy itself and the vendor's efforts are better spent on managing piracy in the Stage 2. Otherwise, if the vendor attempts to price his product so as to incentivize some consumers to buy in the first stage, then he may end up greatly underpricing the digital good. At the second stage, pirates are fully aware of the product's fit, and hence their point of value assessment will be θx and not $k_0\theta x$ or $k_s\theta x$, allowing higher prices to be set. However, note that for this to be a viable price, the vendor is heavily dependent upon the deterrence abilities at the second stage. When prior research on piracy alludes to the externality "benefits" of piracy, it is this particular ability of the vendor to raise prices (or capture a greater market segment when valuations are distributed) that is being referred to (Shapiro

1983). Our results point out that the so-called externality benefits of piracy can indeed exist, however, only under very narrowly defined circumstances.

Intuitively, one might suggest that vendors should invest more in deterring piracy for those products that are highly valued by the consumers; however, the two-stage piracy model reveals that it is more important to prevent consumers from experiencing those products that may be hyped so that consumers are in favor of purchasing at Stage 1. Note that there are two ways in which the vendor can potentially incentivize the consumer to buy at the first stage: (1) by lowering prices, and (2) by increasing the cost of pirating through investments in deterrence. In a vertically segmented market, while the vendor can consider lowering prices of the high-quality product, he cannot reduce prices of the low-quality product as it will create cross-segment buying by the high-type consumer, and hence his options are limited to investments in deterrence.

A critical issue with deterrence is that the return on investments (ROI) is not always guaranteed as it may take just one hacker to effectively reduce the returns to zero. Our analysis points out that going after a piracy-free world may not perhaps be the best strategy for digital experience good industries; rather they should consider a combination of product and consumer characteristics in determining the deterrence level. Further, if vendors have invested heavily in increasing the initial expectations of the consumer through advertisements, then the vendor should also simultaneously invest in a higher deterrence level. On the other hand, products that are underestimated may require lesser deterrence as some amount of piracy-related externality benefits can be internalized by the vendor.

4. Discussion and Conclusions

We develop a two-stage piracy regime for a vertically segmented market where consumers are heterogeneous in their willingness to pay for quality and piracy costs, and where pirates from the first stage decide between buying and keeping the pirated copy in the second stage after having updated their perception of fit. We then derive optimal prices for underestimated and overestimated digital goods in the presence and absence of piracy, and study the efficacy of sampling strategies by deriving an optimal sample size and conditions under which it is beneficial to the vendor. Subsequently, we analyze deterrence levels coupled with pricing as an alternative to piracy proofing.

4.1. Implications to Theory and Practice

From a theoretical perspective, we integrate research from literature in economics on pricing, information systems research on piracy, and marketing literature on sampling. We add to the research in experience goods pricing by separating the consumers' perception of a good's valued attribute from *indirect experiences* and *direct experiences*, and analyzing the impact of piracy in pricing these goods. Our research also extends the single-stage piracy model for vertically segmented markets to incorporate a critical empirical observation that some piracy occurs because consumers want to experience a good first hand, legally or otherwise. In developing the two-stage piracy model, we add to the emerging literature on product piracy and digital experience goods pricing.

From the perspective of a manager, digital experience goods exhibit two characteristics: (1) the digital part implies that these goods have negligible marginal cost of production, are easily amenable to vertical segmentation, but are susceptible to piracy, and (2) the experience aspect implies that some product information is bundled with the product itself and is revealed only upon consumption. Together, these two characteristics create unique challenges for digital product vendors. Digital experience goods vendors primarily face two investment choices: (1) invest in product advertisement to increase hype, and (2) invest in technological and legal deterrence for copyright protection. Examining these choices together with the viability of partial product sampling, we draw some important managerial insights for vertically segmented markets.

If the vendor invests in raising the initial perception of fit for an underestimated product, then it positively influences the vendor's return in two different ways: (1) it can influence the low-type consumers to purchase rather than pirate, and (2) it can allow a greater surplus to be extracted from the high-type consumers. However if this initial perception is a hype, even then vendors can extract higher surplus but this ability is critically dependent on preventing piracy. Hence, an important rule of thumb is that a vendor should not hype a product that he cannot protect. Piracy itself is useful to the vendor in limited cases, such as when consumers find pirating as acceptable but have issues with keeping the pirated copy, as this allows the vendor to extract greater surplus from the market. However relying on piracy to generate this surplus implies that the vendor assumes that piracy costs are tilted toward the second stage.

Instead, our results suggest that the vendor can adopt a proactive sampling strategy to internalize these externality benefits. However, as sampling may inform both the potential buyers as well as pirates, it is critical that the vendor understands when sampling is optimal and how much of the product is to be offered as a sample. When the vendor engages in hype advertising early on to raise consumer expectations, it is obvious that he should not engage in sampling. Even if informing the consumers of the value is beneficial, however, sampling increases the benefit of pirating the high-quality good for the low-type consumers, hence making piracy more attractive for them. Sampling does allow the vendor to extract a greater surplus from the high-type consumers but the amount by which he can raise his prices is constrained by the limits of vertical segmentation, i.e., if prices become too high for the high-quality product, the high-type consumers may be incentivized to buy the low-quality product. Thus, an important managerial conclusion is that unlike physical products, digital product sampling is beneficial to the vendor only in narrowly defined cases when the prices for the high-quality product are constrained by segmentation requirements and not by deterrence levels. While the sample size is a function of consumer and deterrence parameters, in determining the form of the sample, the digital product industry can learn from the software industry that has a long history of providing trial versions of software that expire and lite versions that provide a reduced set of features.

Finally, our analysis suggests that piracy proofing may never be a feasible solution as investments in deterrence mechanisms are costly. The vendor should determine the optimal deterrence level based on his pricing, advertising, and sampling strategies and the consumers' piracy costs. Piracy threatens hyped-up products more than products that are truly valued by the market, and if consumers suffer little or no piracy costs in "checking out" a product, it may be optimal for the vendor to price products assuming that all consumers are aware of the true value, ignoring piracy to a certain degree. In this case, a vendor should ideally invest in legal and watermarking technologies more than copy-protection technologies as legal ramifications can play an important role in dissuading consumers from keeping pirated copies, while copy-protection technologies primarily focus on creating or obtaining pirated copies.

4.2. Limitations and Future Research

As with all analytical models, our model of piracy also has assumptions built in, mostly for reasons of analytical tractability. We do not endogenize quality by assuming a functional form for the cost function, and while this does not detract from our analysis of pricing and sampling, allowing quality itself to be endogenously determined is known to be a valuable subproblem. Our model also assumes that pirating either version provides an accurate assessment of the fit because while technical quality may differ across versions, the content (governing the fit) is the same in both versions. Some experience goods such as movies also have a unique feature where the first consumption experience is more valuable than subsequent ones. While intuitively we can see that for such goods, piracy can be more detrimental, and that even goods that have been underestimated are likely to fall in valuation after the first consumption experience; the impact of sampling is somewhat unclear and can make for interesting future research. Empirical research on the price points of vertically segmented digital goods would prove to be invaluable, specifically in computing optimal deterrence investments to be made. It may also be interesting to explore contracts between copyright owners and distributors and the nature of royalty negotiation when piracy is involved.

Appendix. Proofs of Lemmas and Propositions (Notation Given in Table 2)

The profit function in the absence of piracy is $\max_{\{\bar{p},\, \underline{p}\}}[\upsilon\bar{p} - c(\bar{x}) + (1-\upsilon)\underline{p} - c(\underline{x}) - a]$. The vendor's problem is subject to individual rationality (IR) constraints ($k_0\bar{\theta}\bar{x} - \bar{p} \geq 0$ ($\overline{\text{IR}}$)

& $k_0\underline{\theta}\,\underline{x} - \underline{p} \geq 0$ ($\underline{\text{IR}}$)) and incentive compatibility (IC) constraints ($k_0\bar{\theta}\bar{x} - \bar{p} \geq k_0\bar{\theta}\underline{x} - \underline{p}$ ($\overline{\text{IC}}$) & $k_0\underline{\theta}\,\underline{x} - \underline{p} \geq k_0\underline{\theta}\bar{x} - \bar{p}$ ($\underline{\text{IC}}$)). Adding $\overline{\text{IC}}$ & $\underline{\text{IC}}$, we get $\bar{x}(\bar{\theta} - \underline{\theta}) \geq \underline{x}(\bar{\theta} - \underline{\theta})$. Because $(\bar{\theta} - \underline{\theta}) > 0$, $\bar{x} \geq \underline{x}$. $\underline{\text{IR}}$ & $\overline{\text{IC}}$ immediately imply $\overline{\text{IR}}$, therefore we ignore $\overline{\text{IR}}$, and $\underline{\text{IR}}$ is binding. Similarly, $\overline{\text{IC}}$ is binding. Therefore, both $\underline{\text{IR}}$ and $\overline{\text{IC}}$ must be binding at the optimum. Hence, in the absence of piracy, the vendor will offer two price contracts given by $\bar{p}^* = k_0(\bar{\theta}\bar{x} - \Delta\theta\underline{x})$ and $\underline{p}^* = k_0\underline{\theta}\,\underline{x}$.

Proof of Lemma 1a. We have $\beta \sim U(0, \bar{\beta}) \Rightarrow \Pr(x < \beta) = (1/\bar{\beta})(\bar{\beta} - x)\ \forall x \in [0, 1]$. The probability that the high-valuation type will buy at the first stage is

$$\Pr(\bar{p}_p \leq \delta(\beta + E)) = \Pr\left(\frac{\bar{p}_p}{\delta} - E \leq \beta\right) \Rightarrow \frac{1}{\bar{\beta}}\left(\bar{\beta} - \frac{\bar{p}_p}{\delta} + E\right).$$

In the lower-valuation segment, if $\underline{\theta}$ pirates the high-quality type, she gets a utility $k_0\underline{\theta}\bar{x}$, and hence she will pirate if $k_0\underline{\theta}\bar{x} \leq \delta(\beta + E)$. Therefore, the probability that the low-valuation type will buy at the first stage is

$$\Pr(k_0\underline{\theta}\bar{x} \leq \delta(\beta + E)) = \Pr\left(\frac{k_0\underline{\theta}\bar{x}}{\delta} - E \leq \beta\right) \Rightarrow \frac{1}{\bar{\beta}}\left(\bar{\beta} - \frac{k_0\underline{\theta}\bar{x}}{\delta} + E\right).$$

Proof of Lemma 1b. If a digital product is underestimated, then the arms of the decision tree in the final stage will be symmetrical to those in Stage 1. We can now substitute the new costs, i.e., $\delta(\beta + E)$ by $(1 - \delta)(\beta + E)$, and the new fit realized from pirating, i.e., k_0 by 1. The total probability of the high and low types buying can be given as

$$\Pr(\bar{\theta} \xrightarrow{\text{buy}} \bar{x}) = \bar{r}_e + (\bar{r}_f - \bar{r}_e\bar{r}_f) \quad \text{and}$$

$$\Pr(\underline{\theta} \xrightarrow{\text{buy}} \underline{x}) = \underline{r}_e + (\underline{r}_f - \underline{r}_e\underline{r}_f), \quad \text{where}$$

$$\bar{r}_f = \frac{1}{\bar{\beta}}\left(\bar{\beta} - \frac{\bar{p}_p}{1 - \delta} + E\right) \quad \text{and} \quad \underline{r}_f = \frac{1}{\bar{\beta}}\left(\bar{\beta} + E - \frac{\underline{\theta}\bar{x}}{1 - \delta}\right).$$

Proof of Proposition 1. The profit-maximization problem for underestimated products is

$$\pi_u = \max_{\{\bar{p}_p;\, \underline{p}_p\}} \big[v\bar{p}_p(\bar{r}_e + (1 - \bar{r}_e)\bar{r}_f) - c(\bar{x}) + (1 - v)\underline{p}_p(\underline{r}_e + (1 - \underline{r}_e)\underline{r}_f) - c(\underline{x}) - a\big].$$

Differentiating with respect to $\bar{p}_p$, setting the first-order condition to zero, and noting that all the probabilities of the lower types are independent of $\bar{p}_p$, we can solve π_u to get the roots as

$$\bar{p}_p^* = \frac{E \pm \sqrt{E^2 - 3\delta(1 - \delta)(E^2 - \bar{\beta}^2)}}{3}.$$

The term under the root is always positive because $\delta \in (0, 1)$ and the second-order condition is negative for the positive root. The lowest price for the high quality is determined by the utility that the low-type consumer gets by consuming the high-quality product. Because $\underline{\text{IR}}$ is also binding, the lower bound is given by $k_0\underline{\theta}\bar{x}$. Because $\overline{\text{IC}}$ is binding, the vendor cannot fix a price higher than $\bar{p}^*$. For the low-type consumers, $\underline{\text{IR}}$ is binding and they pirate only the high-quality product so the vendor will not change the price of the low-quality product. For an overestimated product, anyone who pirates will not purchase, and hence the profit function is given by

$$\pi_o = \max_{\{\bar{p}_p;\, \underline{p}_p\}} \big[v\bar{p}_p\bar{r}_e - c(\bar{x}) + (1 - v)\underline{p}_p\underline{r}_e - c(\underline{x}) - a\big].$$

Because all the probabilities of the lower types are independent of $\bar{p}_p$, solving for π_o, we get $\bar{p}_p^* = \delta(\bar{\beta} + E)/2$.

Proof of Proposition 2. In the absence of piracy, substituting for the prices, the optimal profit under segmentation can be written as $\pi_{\underline{x},\bar{x}} = k_0\underline{\theta}(\underline{x} + v(\bar{x} - \underline{x})) - (c(\bar{x}) + c(\underline{x}) + a)$. Depending upon whether the marginal value for quality of the low type is rather low ($\underline{\theta} < v\bar{\theta}$) or not, the vendor will set prices such that only the high types buy or all consumers buy. In the former case, when the high (low)-quality product is produced, the price will be $k_0\bar{\theta}\bar{x}$ ($k_0\bar{\theta}\underline{x}$), and in the latter, the price will be $k_0\underline{\theta}\bar{x}$ ($k_0\underline{\theta}\,\underline{x}$). Consider the first case when only the high quality is offered (implies $c'(0) < k_0v\bar{\theta}$), resulting in a profit given by $\pi_{\bar{x}} = vk_0\underline{\theta}\bar{x} - (c(\bar{x}) + a)$; comparing this with the segmented profit, we get the condition that segmentation is not optimal when $c(\underline{x}) > k_0((1 - v)\underline{\theta}\,\underline{x} - v\Delta\theta\bar{x})$. Similarly, shutdown under other extreme conditions can be derived (the proof is available upon request from the authors). Note that if the consumer type is known, then $\underline{x} = \underline{\theta}$; $\bar{x} = \bar{\theta}$, and the quality offered to the low-type consumers under asymmetry will be lowered when the consumer type is not known, i.e., $\underline{x} < \underline{\theta}$, and hence $\bar{\theta}/\underline{\theta} > \bar{x}/\underline{x}$. While in the body of this paper we show when only a high-quality product will be offered during piracy, we can also see that if the enforcement is so poor that the combined piracy cost is lower than $k_0\underline{\theta}\bar{x}$ such that $\bar{p}_p \leq k_0\underline{\theta}\,\underline{x}$ (the price charged for the low-quality product), then the vendor will offer only the low-quality product at price $\bar{p}_p$.

Proof of Lemma 2 and Proposition 3. Similar to the proofs of Lemmas 1a and 1b by replacing k_0 by k_s, and given that $k_s > k_0$, the probability of buying for the low-type consumers is lower with sampling. Similarly, the upper and lower bounds of $\bar{p}_s^*$ will be weakly higher than $\bar{p}_p^*$, implying potential for greater extraction for surplus. Propositions 3 and 4 follow from Lemma 2.

Proof of Proposition 4. To find the optimal sample size for underestimated products, we need to solve

$$\pi_s = \max_{\{\bar{p}_s,\, \underline{p}_s,\, s\}} v\bar{p}_s(\bar{r}_e + (1 - \bar{r}_e)\bar{r}_f) - c(\bar{x}) + (1 - v)\underline{p}_s(\underline{r}_{es} + (1 - \underline{r}_{es})\underline{r}_f) - c(\underline{x}) - a.$$

The probabilities of the high-type consumers are independent of $\underline{p}_s$, and we can substitute $k_s\underline{\theta}\,\underline{x}$ for $\underline{p}_s$. As s and k_s are linearly related, we differentiate with respect to k_s, and setting the first-order condition to zero, we get

$$\frac{\partial \pi_s}{\partial k_s} = \frac{\partial}{\partial k_s} k_s\underline{\theta}\,\underline{x}(\underline{r}_{es} + (1 - \underline{r}_{es})\underline{r}_f) = 0.$$

By simplifying, we have

$$k_s^* = \delta \frac{(1-\delta)(\bar{\beta}^2 - E^2) + E\underline{\theta}\bar{x}}{2(\bar{x}^2\underline{\theta}^2 - (1-\delta)E\underline{\theta}\bar{x})}.$$

From the equation $k_s = k_0 + (1-k_0)s$, we get

$$s^* = \frac{\delta \frac{(1-\delta)(\bar{\beta}^2 - E^2) + E\underline{\theta}\bar{x}}{2(\bar{x}^2\underline{\theta}^2 - (1-\delta)E\underline{\theta}\bar{x})} - k_0}{1-k_0}.$$

The second-order condition is

$$\frac{\partial^2 \pi_s}{\partial k_s^2} = -\left[\frac{2\underline{x}\bar{x}\underline{\theta}^2(\bar{x}\underline{\theta} - E(1-\delta))}{\beta^2\delta(1-\delta)}\right].$$

For optimal k_s, the second-order condition is negative, implying $\underline{\theta} > E(1-\delta)/\bar{x}$, and because $s^* = (k_s^* - k_0)/(1-k_0)$ and $k_s \in [k_0, 1]$, we have $s^* \in [0, 1]$. Further, $\partial\pi/\partial k_s > 0$, $\partial^2\pi/\partial k_s^2 < 0$ if $k_s < k_s^*$, $\partial\pi/\partial k_s < 0$, $\partial^2\pi/\partial k_s^2 < 0$ if $k_s > k_s^*$, and $\partial\pi/\partial k_s = 0$ if $k_s = k_s^*$.

Proof of Proposition 5. When $\delta \to 0$, the vendor can assume that all consumers pirate at the first stage. For an underestimated product, the vendor can charge prices for the high-quality product given by $\bar{\theta}\bar{x} - \Delta\theta\underline{x}$ if $\bar{\theta}\bar{x} - \Delta\theta\underline{x} \le E$ and $(\bar{\beta}+E)/2$ if $E < \bar{\theta}\bar{x} - \Delta\theta\underline{x} < \bar{\beta}+E$. We can also see that that the terms $\bar{r}_f$ and $\underline{r}_f$ are absent when a product is overestimated as there is no buying in the second stage. So, all profits have to be realized in the first stage, where the piracy threshold is only $\delta(\bar{\beta}+E)$. Formally, we need to prove that the loss from piracy when the product is overestimated as opposed to when it is underestimated is weakly higher for all relevant values of the deterrence level E, i.e., to show $\pi^* - \pi_o^*(E) \ge \pi^* - \pi_u^*(E)\ \forall E \in (0, E^*)$, where $\pi^* = \pi_u^*(E = E^*) = \pi_o^*(E = E^*)$ is the profit when there is no piracy (where E^* is the piracy-proof deterrence level). At zero enforcement, we need to show that $\pi_u^*(E=0) - \pi_o^*(E=0) \ge 0$. We can expand this expression in terms of prices and probabilities as $(1-v)\underline{p}_{pu}(1-\underline{r}_{eu})\underline{r}_{fu} + v(\bar{p}_{pu}\bar{r}_{eu} - \bar{p}_{po}\bar{r}_{eo} + \bar{p}_{pu}(1-\bar{r}_{eu})\bar{r}_{fu}) \ge 0$. Given that all probabilities and parameters are nonnegative, it will suffice to show that $\bar{p}_{pu}\bar{r}_{eu} - \bar{p}_{po}\bar{r}_{eo} + \bar{p}_{pu}(1-\bar{r}_{eu})\bar{r}_{fu} \ge 0$, which is always true as it compares the underestimated revenue with the overestimated revenue. The worst that the vendor can do is to set the prices at the overestimated level where he has to extract all revenue at Stage 1 itself. He will raise or lower $\bar{p}_{pu}$ as compared to $\bar{p}_{po}$ only if he believes that doing so will yield some revenue from consumers who buy at Stage 2 such that the total revenue will be maximized. Thus, $\bar{p}_{pu}\bar{r}_{eu} + \bar{p}_{pu}(1-\bar{r}_{eu})\bar{r}_{fu} \ge \bar{p}_{po}\bar{r}_{eo}$. Now, if we can show that $\partial\pi_u^*/\partial E$ and $\partial\pi_o^*/\partial E$ are monotonically increasing, then we have shown that $\pi_u^*(E) \ge \pi_o^*(E)\ \forall E \in (0, E^*)$. Substituting the optimal prices in π_u and π_o and differentiating with respect to E, we have

$$\begin{aligned}\frac{\partial\pi_u^*}{\partial E} = \frac{1}{9\bar{\beta}^2\delta(1-\delta)}\big[&v(2-\delta(1-\delta))E^2 + 2\big(v\sqrt{A}(1-3\delta(1-\delta)) \\ &- 9\delta(1-\delta)(1-v)k_0\underline{q}\underline{\theta}\big)E \\ &+ 9k_0\bar{x}\underline{x}\,\underline{\theta}^2(1-v) + 3v\bar{\beta}^2\delta(1-\delta)\big],\end{aligned}$$

where

$$A = E^2 - 3\delta(1-\delta)(E^2 - \bar{\beta}^2) \quad \text{and}$$

$$\frac{\partial\pi_o^*}{\partial E} = \frac{1}{2\bar{\beta}}\big[\delta v E + 2k_0\underline{q}\underline{\theta}(1-v) + \delta v\bar{\beta}\big].$$

We can see that both $\partial\pi_u^*/\partial E$ and $\partial\pi_o^*/\partial E$ are positive and monotonic.

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