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Digital Content Provision and Optimal Copyright Protection

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Advances in digital technologies have led to an increasing concern about piracy for providers of digital content (e.g., e-books, games, music, software, videos). Yet controversies exist over the influence of copyright protection on firm profitability. The objective of this paper is to provide an alternative rationale for the growing anti-protection trend and to investigate optimal copyright enforcement and quality provision in a monopoly setting. The proposed economic mechanism centers on the influence of copyright protection on consumer search when consumers can get to know the firm's actions (e.g., price, quality) only after costly search. We show that more stringent copyright protection can induce the consumers to rationally expect lower ex post surplus, thus exerting a negative strategic effect on the consumers' willingness to search. This strategic effect may outweigh the positive main effect on the relative attractiveness of the authorized versus the pirated product, which can hence explain the optimality of incomplete and even zero copyright protection policies in markets where consumer prepurchase search is important (e.g., information goods, digital products). It is also because of this strategic effect that the firm may provide lower quality as copyright enforcement increases. Interestingly, quality unobservability can moderate this strategic effect and thus lead to an increasing incentive for copyright protection.

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1. Introduction

With the digitization of information goods, massive copyright infringement has emerged as a major concern for content providers of products such as e-books, games, music, software, and video. It is becoming unprecedentedly easy to digitize, duplicate, and distribute products with virtually zero quality degradation from their initial physical, analog, or broadcast formats. The ubiquity of personal computers and the Internet has further accelerated the process of copying, sharing, and spreading pirated products among potential users. Unauthorized reproduction and use of digital products are becoming increasingly prevalent, especially for movies and music, as online peer-to-peer sharing networks (e.g., Kazaa, Napster, YouTube) gain more prosperity. Moreover, the growing popularity of location- and time-shifting digital recording devices such as TiVo has substantially reduced the labor and costs in producing unlicensed copies in the entertainment industry.

The threat of piracy has led some digital content providers, publishers, and copyright owners to take a variety of initiatives to protect their intellectual property. Firms can exert efforts in monitoring, detecting, and prosecuting copyright-violating cases (Chen and Png 2003). Many lawsuits are seen in the film and music industries to penalize users' pirating behavior (Kantor 2004). To combat piracy, firms can also resort to digital rights management (DRM) technologies (e.g., software locks) that make unauthorized use of media or devices technically formidable (Vernik et al. 2011). Other means of copyright protection that limit the usage of unlicensed products without content modification include serial numbers, keyfiles, software registrations, digital watermarks, etc. The anti-piracy steps also involve lobbying efforts for law extensions that "expand the scope of criminal sanctions and raise the penalties for copyright infringement" (Chen and Png 2003, p. 107). For example, the passage of the Digital Millennium Copyright Act (DMCA) in 1998 made it illegal to produce and disseminate technologies that allow users to circumvent copy restriction measures.

However, ample evidence suggests that the execution of these copyright protection initiatives varies considerably in practice. Despite the common belief and the empirical support that pirating is detrimental to firm profitability (e.g., Hui and Png 2003), not all digital content providers adopt a perfect copyright protection policy.[1] For example, e-book publishers choose varying levels of usage protection for their intellectual property, ranging from printing to copying to modifying (Foster 2004). In addition, recent years have seen a growing anti-protection trend in the Internet music industry, and some firms have started to suspend the stringent copyright protection strategy they adopted. Online music providers such as iTunes and Napster are switching to a DRM-free policy for their download tracks. Significant lobbying efforts are also invested to convince major record labels such as EMI to abandon strict protection and to release albums with no DRM restrictions (Bangeman 2006, Marechal 2007). Some anti-restriction advocates such as Apple have advanced to publicly express their strong position against DRM (Jobs 2007). Adding to the industry controversy, Gu and Mahajan (2005) suggest that software piracy can actually increase industry-level sales.

These disagreements raise two important research questions we address in this paper. First, would a stricter anti-piracy strategy necessarily improve firm profitability? We reexamine the conventional wisdom that unauthorized copying is always detrimental to sales. The objective is to improve our understanding about the mixed practice of copyright enforcement and about the recent anti-protection trend advocated by some Internet music providers such as iTunes and Napster. Furthermore, we investigate the optimal level of copyright protection. Given the availability of initiatives a firm can take to influence the feasibility and attractiveness of pirating, the analysis in this paper can provide insights into optimal management of copyright protection. Second, how should copyright protection influence firms' incentive for quality innovation? Should a firm provide more or less quality improvement over its base product as unlicensed copying becomes more attractive? We formally address the general belief that copyright protection would necessarily increase firms' incentive for quality provision. This investigation can shed light on how firms should coordinate their strategies on research and development and on copyright enforcement. It can also provide guidance about quality improvement as the piracy level in the market exogenously changes.

We consider a market in which a firm sells a product (e.g., information goods, digital products) that can be potentially pirated. There are two types of consumers. The first type of consumer considers only the licensed product potentially because they have sufficiently high value for the support and services that are absent in the pirated product or because their moral acceptability of copyright violation is low enough (Shy and Thisse 1999, Chen and Png 2003). They also have a higher search cost than the other type of consumers, who consider both the licensed and the pirated products as acceptable options. The firm can decide and commit to a copyright protection policy that influences the expected utility of the pirated product for the potential copiers. Prior to search, the consumers know the firm's copyright protection level and their value for the authorized product. However, only after search can they get to know the relevant firm actions (e.g., price, quality) and decide whether to make a purchase. Nevertheless, when deciding whether to search, they can rationally infer the firm's optimal behavior.[2]

In the basic model, we focus on the endogenous interaction between price setting and consumer search. As expected, a stricter copyright protection policy can increase the relative attractiveness of the licensed product and thus boost demand from the potential copiers. As a result, the main effect of restricting copyright violation is positive, and, keeping the consumers' search behavior fixed, it is beneficial to stringently protect the product's copyright. Nevertheless, stricter copyright protection can lead to a higher expected equilibrium price. This can thus yield a strategic effect whereby the consumers' incentive to search is negatively influenced. This is because the consumers' expected surplus of search is adversely affected by their expectation of the firm's price. The consumers are hence less willing to incur the search cost in order to consider whether to buy the licensed product, as copyright protection becomes stricter. In other words, all else being equal, a lenient copyright protection policy can benefit the firm through encouraging more consumer search.

We establish conditions under which the firm may optimally enforce imperfect and even zero restriction on pirating its product. We show that the firm's optimal strategy for copyright protection hinges on the relative importance of the main effect versus the strategic effect. When there are relatively more consumers with negligible search cost, the main effect is more important, and therefore it is optimal to impose a stringent policy to reduce the feasibility and attractiveness of pirating. However, as the relative size of consumers with high search cost increases, the strategic effect becomes more dominant, and the firm's incentive to induce consumer search looms larger. The firm can then benefit from choosing an incomplete copyright protection policy, or even no policy at all.

We then extend the analysis to incorporate the firm's decision on quality provision. When quality can be

[1] See Prasad and Mahajan (2003) and Haruvy et al. (2004) for more examples on intentional tolerance of piracy.

[2] See Iyer and Kuksov (2010) for a model in which consumers can rationally infer the true quality level from their perceived quality that is influenced by firms' investments on both the true quality and affect. Consumers can also draw rational inferences from other consumers' past choices in an observational-learning setting (Zhang 2010).

observed prior to consumer search, interestingly, more copyright protection can induce the firm to choose a lower level of quality innovation. This is also driven by the aforementioned strategic effect on consumer search, and it occurs when there are enough consumers with positive search cost. Nevertheless, copyright protection always results in higher quality in the alternative setup in which both price and quality are unknown to the consumers before search. This is because, as quality becomes ex ante unobservable, the strategic effect of unauthorized copying on consumer search does not directly influence the firm's incentive for quality improvement any more. In addition, we find that the unobservability of quality leads the firm to offer a lower equilibrium quality, which is analogous to the firm charging a higher equilibrium price under price unobservability. Moreover, quality unobservability can moderate the strength of the strategic effect of copyright protection on consumer search, resulting in a more compelling incentive for the firm to strictly enforce its copyright. Therefore, interestingly, the optimal level of copyright protection is higher when consumers need to search for both price and quality than when the search is just about price.

This paper is related to previous studies that identify the beneficial effects of piracy on firm profitability. A majority of the literature focuses on positive demand-side externalities.[3] In the presence of network externality, consumers' utility increases with the number of users of either the licensed or the pirated product. Thus, unauthorized copying can raise firms' profits if the network effect is sufficiently strong (Conner and Rumelt 1991, Takeyama 1994, Shy and Thisse 1999). Similarly, piracy can generate indirect demand externality (e.g., word of mouth from early adopters) and facilitate product diffusion (e.g., Givon et al. 1995, Prasad and Mahajan 2003, Haruvy et al. 2004). Other factors that may boost demand as copying becomes more viable include indirect appropriability, whereby buyers such as libraries supply copies to other users (Liebowitz 1985, Besen and Kirby 1989, Varian 2000), or value homogenization among sharing peers (Bakos et al. 1999).

Other researchers investigate supply-side benefits of piracy. For example, unlicensed copying can effectively remove low-value consumers from the market and credibly commit firms not to cut future prices. Profits can then be improved as the durable goods pricing problem is softened (Takeyama 1997). In a similar vein, pirating could drive out low-value consumers and mitigate price competition through shifting the competitive focus to high-value consumers (Gu and Mahajan 2005). Jain (2008) further demonstrates that this competition-reducing effect can induce firms to adopt weak copyright enforcement policies and invest more in quality innovation.

Vernik et al. (2011) consider the benefits of removing DRM restrictions in the digital music industry. DRM restrictions can, on the demand side, reduce user value for the legal download album; on the supply side, it can lead to insufficient downstream competition between download and traditional retailers. Therefore, DRM-free albums may, in equilibrium, result in less piracy and increase the upstream record label's profits. Our setup departs from this study in that copyright protection necessarily reduces the value of the pirated product relative to the legitimate one and that we focus on a monopoly seller without either a distribution structure or any competition.

This paper contributes to the literature by considering the endogenous influence of copyright protection on consumer search. Unlike previous studies, we focus on a monopoly firm's optimal strategies on copyright enforcement and quality provision, in the absence of any kind of demand-side externality. Moreover, our explanation for the optimality of weak and even zero copyright enforcement does not rely on (1) escalated consumer willingness to pay (e.g., through indirect appropriability), (2) softened time-inconsistency pricing problems for durable goods, or (3) reduced competition. Note that these explanations offered in the literature hinge on raising the firms' ability to charge a higher price and/or to extract more consumer surplus. In contrast, the economic mechanism in this paper lies in the role of copyright protection in influencing consumer search, through its effect on the consumers' expectation of firm actions (e.g., price, quality). As a result, this paper complements previous studies and identifies a different rationale for imperfect copyright protection. The proposed perspective can also explain why some firms with strong monopoly power (e.g., Microsoft, Apple) choose not to strictly enforce their copyright (e.g., monitoring and prosecuting efforts against illegal copying are rare) even in mature markets in which the effect of network externality or competition is weak.

That product search can be costly has been long recognized in the literature. For example, Hauser and Wernerfelt (1990) argue that consumers incur evaluation costs in considering alternative products. Mehta et al. (2003) offer empirical evidence that consumers incur significant search costs prior to price discovery. Other studies consider committable policies that can mitigate sellers' ex post opportunism in extracting consumer surplus when consumers have to incur sunk search costs before purchase, including price advertisements (Lal and Matutes 1994), product return and colocation

[3] Conner (1995) examines the rationale of enabling entry by a clone when network externality is present. Xie and Sirbu (1995) show that competitive entry by firms with a compatible product can facilitate product diffusion and thus benefit incumbent monopolies in markets characterized by strong network effects.

(Wernerfelt 1994), and limited assortments (Villas-Boas 2009, Kuksov and Villas-Boas 2010).

The rest of the paper is organized as follows. In the next section we describe the model setup. Section 3 presents the main analysis and results. The provision of quality is analyzed in §4. The final section concludes the paper.

2. The Model

Consider a monopoly firm selling a digital product (e.g., e-book, game, music, software, video) to end consumers. The development costs for the product are sunk, and the firm's fixed and marginal costs of production are normalized to 0. The product can be potentially copied, shared, and disseminated by the consumers without license. Let us denote the licensed and the pirated version of the product as L and P, respectively. The firm is aware of the potential piracy issue and makes decisions on the price of the authorized product and on the copyright protection policy that influences the utility of the unauthorized product. In §4 we extend the basic model to the case in which the firm's decisions also involve the optimal provision of quality. Both the firm and the consumers are risk neutral and maximize expected payoffs.

The mass of consumers in the market is normalized to 1. Each consumer wants to consume at most one unit of either the licensed or the pirated product. The utility of no consumption is set to 0. No consumer can make positive profits from reselling or sharing her licensed product with other consumers. There are two segments of consumers in the market, denoted as $I \in \{N, C\}$, which we refer to as the "noncopiers" and the "copiers," respectively. The relative segment size is α and $1-\alpha$ for the noncopiers and the copiers, respectively, where $\alpha \in (0, 1)$. The two consumer segments differ from each other in two aspects. First, they have different values for the unlicensed product. The noncopiers have a sufficiently low value for the pirated product and therefore consider only the licensed one. In contrast, the copiers consider both the licensed and the pirated products as acceptable options, where the substitutability, as will be elaborated below, depends on the firm's copyright protection policy. There are a variety of consumer characteristics that may contribute to the difference in the consumers' utility of the pirated product. For example, institutional buyers and professionals may place higher value on support and services that may be available only for authorized copies than individual buyers and students would. Alternatively, some consumers may have higher moral standards and/or legal costs for copyright violation than other consumers. Similar premises have been employed in previous studies (e.g., Shy and Thisse 1999, Chen and Png 2003).

Second, the consumer segments differ in their search costs, denoted as s_I. In particular, the noncopiers must incur a positive search cost $s_N = s$ to be able to make a purchase decision and to be informed of the relevant characteristics of the licensed product (e.g., stock availability, price, quality), whereas the search cost for the copiers is negligible (i.e., $s_C = 0$). We focus on the case when the noncopiers' search cost is positive but sufficiently small, i.e., $s \in (0, 1/2)$.

Note that we implicitly assume that the consumer segments' difference in the value for the pirated product is negatively correlated with their difference in the search cost. This could be because these two types of consumer differences are driven by the same underlying consumer characteristics. For instance, consumers with higher income tend to have both lower preference for piracy (because of a higher value for product support, ethical standards, and/or legal costs) and higher search cost (because of a higher marginal value of time) than consumers with lower income. Nevertheless, this negative correlation between the value of piracy and search cost is not necessary for the paper's main insights, which, as we show in the supplemental appendix (available at http://ssrn.com/abstract=2495286), continue to hold even when search is costless for some consumers who consider only the licensed product.

The utility of a consumer in segment $I \in \{N, C\}$ for the licensed product is

$$U_{IL} = v - p - s_I, \tag{1}$$

where v denotes the consumer's general consumption value and p is the price. It is assumed that the distribution of the consumers' value is uniform between 0 and 1 within each consumer segment and independent across consumer segments. The firm cannot exercise price discrimination between the noncopiers and the copiers.

The utility of the pirated product for the noncopiers and the copiers is given by, respectively,

$$U_{NP} = 0 \quad \text{and} \tag{2}$$

$$U_{CP} = (1-\gamma)\beta v, \tag{3}$$

where $\gamma \in [0, 1]$ represents the influence on the pirated product's value that can be directly controlled by the firm (i.e., copyright protection efforts), and β captures other firm-independent factors (e.g., social pressure against piracy) that reduce the pirated product's value relative to the authorized version.[4] When $\gamma \to 1$, copyright protection becomes perfect, and the pirated product is completely inaccessible or valueless; when $\gamma \to 0$, zero copyright protection is adopted, and the pirated product retains the maximum possible value βv. For

[4] To guarantee the existence of interior equilibrium, it is assumed that β is sufficiently small. If β is sufficiently close to 1, it is possible that pure-strategy equilibrium does not exist in the second stage.

simplicity, we assume that pirating is costless for the copiers. The digitization of information goods has substantially reduced the costs of copying, sharing, and disseminating unlicensed products among potential users. This assumption of cost-free copying can also represent scenarios in which the pirated product is supplied by third parties (e.g., counterfeits) and the competition among the pirating sellers drives down their equilibrium prices to marginal cost. Nevertheless, as we show in the supplemental appendix, the key result in this paper that imperfect copyright protection can be optimal is robust in an alternative setup in which pirating is costly and the influence of copyright protection is to increase the cost of pirating.

We consider a three-stage game in the basic model. The sequence of moves is shown in Figure 1 and elaborated as follows. The actions in an earlier stage become common knowledge to all parties in later stages. In Stage 1, the firm decides and commits to the copyright protection level γ. For example, the firm can exert efforts in monitoring, detecting, and prosecuting copyright violation cases (Chen and Png 2003). The firm can also resort to copy restriction measures such as DRM technologies (e.g., software locks), serial numbers, and digital watermarks.[5] Although a firm may adopt an imperfect copyright protection level because of cost considerations, we deliberately assume that the firm's cost of copyright enforcement is negligible. We intend to show that, even if it is costless to prevent piracy, the firm may prefer not to do so.

In the second stage, the firm decides on the price p for the licensed product and the consumers decide whether to search in order to make a purchase. Prior to incurring the search cost s_I, the consumers know the firm's copyright protection level γ and their value v for the licensed product, but they do not know the price p charged by the firm. After incurring the search cost s_I, the consumers are able to find out the actual price. Note that we are assuming that search is *necessary* for a consumer to be in the market and to consider purchasing the licensed product. For example, consumers may have to invest transportation costs to visit stores prior to finding out the price and making a purchase. Similarly, it can be time consuming and effort consuming for online purchasers to figure out where the licensed product is available and how much it is charged. Alternatively, consumers may need to decide whether to incur cognitive costs to evaluate a product and process price information even when the price is accessible from advertisements or the Internet.[6] This assumption on costly consumer search prior to making the purchase decision is adopted in previous research (e.g., Lal and Matutes 1994, Wernerfelt 1994, Villas-Boas 2009).

Finally, conditional on search, the consumers make their purchase decisions in Stage 3. The noncopiers decide to buy the licensed product if and only if $v - p \geq 0$. The copiers choose between buying the authorized product and resorting to the pirated version by comparing $U_{CL} = v - p$ with $U_{CP} = (1-\gamma)\beta v$. In solving the game, backward induction is used to ensure subgame perfection.

Some discussions on the model setup are warranted. Note first that the firm's copyright protection decision precedes the setting of the price. This assumption recognizes that copyright protection policies typically involve long-term strategic moves and substantial commitment, whereas pricing decisions are normally short-term tactical tools that can be implemented with frequent adjustment (e.g., promotions). For example, piracy deterrence through DRM technologies inevitably entails product configurations that are costly to modify in the short run.

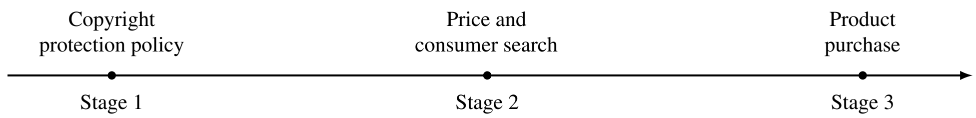
Second, the consumers' search decision is made without observing the price. Therefore, the equilibrium concept we use to solve the second-stage subgame is the Nash equilibrium whereby the consumers, when deciding whether to search, form rational expectations about the firm's optimal price. This is the natural and standard approach in similar settings with costly consumer search (e.g., Lal and Matutes 1994, Wernerfelt 1994, Villas-Boas 2009).

We also implicitly assume that prior to search consumers have more knowledge about the copyright protection policy than about the price. This again reflects the practice that firms' piracy policy is a long-term strategy that can be (at least partially) learned by consumers through previous experience, firm communication, and/or word of mouth, but pricing is a short-term tactical decision that can be readily adjusted from time to time (e.g., through secret price cuts) such that consumers may not know the actual price without visiting a store. However, this assumption is unnecessary. For the main insights to hold, we only require that (1) price be a "search" attribute that can be learned by incurring a search cost, whereas the level of copyright protection is an "experience" attribute, and hence consumers' perception about it does not change with a search; and (2) consumers' perception on copyright protection (or the expected utility of the

[5] A firm may choose not to perfectly enforce its copyright if the protection measures (e.g., DRM technologies) reduce the legitimate product's value (Vernik et al. 2011). We intentionally assume this possibility away to focus on the strategic effect of copyright protection on consumer search. This allows us to show that, even in the absence of any harmful impact on the licensed product, the firm may decide not to perfectly protect its copyright.

[6] Hong and Shum (2006) estimate median search costs for textbooks to be between \$1.31 and \$2.90. Brynjolfsson et al. (2010) find substantial online price dispersion and significant search costs on a major shopbot for books.

Figure 1 **Timing of the Basic Model**



pirated product) be not completely irresponsive to the firm's copyright enforcement decision and efforts.[7] As long as these conditions are met, the firm's copyright protection decision would necessarily take into account its influence on the consumers' expected utility for the pirated product and thus on their decision to search.

3. Analysis and Results

We start with the benchmark when the consumers know the price without search. We then analyze the basic model, as in Figure 1, when price setting and consumer search are simultaneous and influenced by each other. In §3.2 we address the endogenous interaction between pricing and consumer search. We then investigate optimal copyright protection, highlighting its influence on endogenous consumer search.

3.1. Benchmark

Consider the case when the consumers can costlessly find out the price. As a result, as shown in Figure 2, search is immaterial, and the consumers' decision involves only whether to buy the authorized product. However, to ensure comparability with the basic model, we assume that the noncopiers continue to incur a transaction cost s to purchase the licensed product (Tyagi 2004). Other assumptions in the basic model are maintained. So the only difference from the basic model is that search is costless, although the ex post consumer surplus (conditional on purchase) remains the same. Thus, comparing the basic model with the benchmark case allows us to capture the role of endogenous consumer search in determining the firm's optimal copyright protection policy.

The noncopiers choose to buy the authorized product if and only if $v \geq v_N = \min\{p+s, 1\}$, where v_N represents the noncopier who is indifferent between the authorized product and the outside option of no consumption. The demand from the segment of noncopiers is then $D_N = \alpha(1-v_N)$. Similarly, in the copier segment the marginal consumer who is indifferent between the licensed and the pirated products is represented by $v_C = \min\{p/(1-(1-\gamma)\beta), 1\}$, and the demand from this segment is $D_C = (1-\alpha)(1-v_C)$. Therefore, the firm's optimization problem is given by

$$\max_{p,\,\gamma} \Pi(p, \gamma) = p(D_N + D_C). \tag{4}$$

We can readily obtain that, conditional on γ, the equilibrium price and firm profit are $p^b = ((1-\alpha s)[1-(1-\gamma)\beta])/(2-2\alpha(1-\gamma)\beta)$ and $\Pi(p^b, \gamma) = ((1-\alpha s)^2[1-(1-\gamma)\beta])/(4-4\alpha(1-\gamma)\beta)$, respectively. It is also straightforward from (4) that $\partial\Pi/\partial\gamma > 0$. Intuitively, more stringent copyright protection leads to a lower utility of the pirated product for the copiers, thus increasing consumer demand and firm profit for the licensed product. It follows that it is optimal for the firm to completely prevent the copiers from pirating the product; i.e., the equilibrium copyright protection level is given by $\gamma^b = 1$.

3.2. Equilibrium Price Setting and Consumer Search

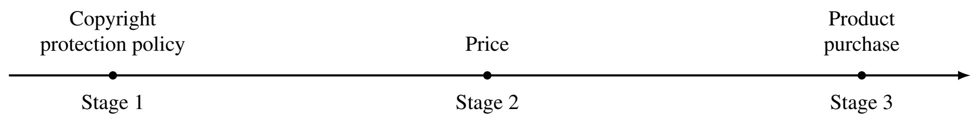
We then analyze how the firm's price setting and the consumers' optimal search behavior are interactively determined in the second-stage subgame of the basic model, conditional on the copyright protection level γ committed in the first stage. The firm sets the price to maximize its profit given the consumers' search and the subsequent purchase behavior. Conversely, the consumers can make an inference about the setting of the firm's profit-maximizing price, and their search decision takes into account the expectation on the firm's optimal price-setting behavior.

Note first that all consumers in the copier segment will choose to search since their search is costless. As a result, as in the benchmark, the copiers' purchase behavior and demand are characterized by $v_C = \min\{p/(1-(1-\gamma)\beta), 1\}$ and $D_C = (1-\alpha)(1-v_C)$, respectively. However, now the noncopiers' third-stage purchase is conditional on their second-stage search decision. A noncopier with value v decides to search if and only if the expected surplus of search, $v - \bar{p} - s$, where $\bar{p}$ is the price that is anticipated to be charged by the firm, is not less than 0. It is then obvious that a noncopier searches if and only if $v \geq \hat{v}$, where the threshold type who is indifferent between search and no search is

$$\hat{v} = \bar{p} + s. \tag{5}$$

[7] Formally, we can make the following extension to the basic model without qualitatively changing the main results. Consumer perception on copyright protection is $\gamma' = \gamma + \epsilon_\gamma$, where ϵ_γ is a random shock. The variance of ϵ_γ is nonzero but finite such that the consumers have some imperfect knowledge about the level of copyright enforcement. After incurring the search cost, the consumers can find out the actual price p but maintain their prior perception on γ' (i.e., the actual γ remains unknown). Under this modified setup, the firm's copyright protection decision (i.e., γ) can still exert influence on the consumers' (perceived) utility of the pirated product and thus on the consumers' search decision through affecting their expectation on the optimal price p.

Figure 2 **Timing of the Benchmark Model**



A noncopier who searches will subsequently buy the product after she finds out the actual price p, if and only if $v \geq v_N = \min\{\max\{\hat{v}, p\}, 1\}$. This gives rise to the demand from the noncopiers, $D_N = \alpha(1 - v_N)$, conditional on the noncopiers with $v > \hat{v}$ deciding to search. The firm's second-stage profit is then $\Pi_2(p; \hat{v}, \gamma) = p(D_N + D_C)$, conditional on $\hat{v}$ and γ. Note that in equilibrium, the expected price $\bar{p}$ must be equal to the equilibrium price p^*. It follows from (5) that in equilibrium we must have $\hat{v} > p^*$. This implies that in equilibrium, those consumers who choose to search will necessarily buy the licensed product. Therefore, the firm's profit maximization problem in the interior equilibrium when both consumer segments are served is reduced to

$$\max_p \Pi_2(p; \hat{v}, \gamma) = p\left\{\alpha(1-\hat{v}) + (1-\alpha)\left[1 - \frac{p}{1-(1-\gamma)\beta}\right]\right\}. \quad (6)$$

The firm's optimal price setting is determined by the first-order condition

$$1 - \alpha\hat{v} - \frac{2(1-\alpha)p}{1-(1-\gamma)\beta} = 0. \quad (7)$$

Note that the noncopier's optimal search behavior is characterized by $\hat{v}$ as in (5), conditional on the anticipated price (i.e., $\bar{p}$), and the firm's optimal pricing is given by (7), conditional on the noncopier's search behavior (i.e., $\hat{v}$). Therefore, we can determine the equilibrium price p^* and the threshold consumer type $\hat{v}^*$ by substituting (5) into (7) and imposing the rational expectation condition $\bar{p} = p^*$.[8]

Proposition 1. *When β is not sufficiently large, there exists a unique second-stage equilibrium:*

$$p^* = \frac{(1-\alpha s)[1-(1-\gamma)\beta]}{2-\alpha-\alpha(1-\gamma)\beta},$$

$$\hat{v}^* = \frac{1-(1-\gamma)\beta + 2(1-\alpha)s}{2-\alpha-\alpha(1-\gamma)\beta},$$

$$\Pi_2^*(p^*; \hat{v}^*, \gamma) = \frac{(1-\alpha)(1-\alpha s)^2[1-(1-\gamma)\beta]}{[2-\alpha-\alpha(1-\gamma)\beta]^2}.$$

In equilibrium the price is higher, and the demand and firm profit are lower, than in the benchmark.

[8] Note that (5) is substituted into the first-order condition (7) but not into the profit function (6) and that the first-order condition is taken over p (while taking $\hat{v}$ as given) but not over $\bar{p}$. This is because varying the price does not directly influence consumer search behavior.

Proposition 1 compares the equilibrium outcome, when consumer search is costly, with the benchmark. It shows that price unobservability and endogenous consumer search lead to excessively higher equilibrium price and lower demand and firm profits. Holding the price fixed, the demand for either consumer segment, D_N or D_C, is the same in either the basic or the benchmark model. Therefore, the driving force here for the higher equilibrium price lies in the endogeneity of consumer search. Intuitively, because the noncopiers are ex ante uninformed of the actual price, their search is irresponsive to the charged price. That is, demand is less elastic than when consumers know and can respond directly to the price. Moreover, once the search cost is incurred, it becomes sunk and will not influence purchase any more. This suggests that, conditional on search, the firm does not need to cut the price to compensate for the noncopiers' search cost in order to generate consumer demand. In other words, the firm can opportunistically extract more consumer surplus by setting a higher price when the consumers have to incur sunk search costs before purchase. As a result, the inelasticity in consumer search in response to the actual price, coupled with the ex post firm opportunism after consumer search, induces the firm to charge a higher equilibrium price.

In anticipation of this, the noncopiers are less willing to search, and the firm's equilibrium demand is lower. In making their search decision, the noncopiers know that once the search cost is incurred and becomes sunk, they are less likely to purchase the licensed product since they expect that the firm will charge a higher price. This in turn gives rise to a lower ex ante incentive for the noncopiers to search the product. Therefore, the firm's ability to ex post extract more consumer surplus can backfire and the firm actually ends up with less demand. Moreover, the excessively higher equilibrium price and the lower demand, when the price is unknown prior to search, yield a lower equilibrium profit.

Next, we conduct comparative statics analysis to examine the impacts on the equilibrium pricing and consumer search behavior.

Proposition 2. *In the interior second-stage equilibrium,*

(i) *as the size of the noncopier segment increases, the equilibrium price increases and fewer consumers search, i.e., $dp^*/d\alpha > 0$ and $d\hat{v}^*/d\alpha > 0$; and*

(ii) *as the copiers' utility for the pirated product increases, the equilibrium price decreases and more consumers search, i.e.,* $dp^*/d\beta < 0$, $dp^*/d\gamma > 0$, $d\hat{v}^*/d\beta < 0$, *and* $d\hat{v}^*/d\gamma > 0$.

Proposition 2 shows that the equilibrium price increases when the noncopier segment becomes more sizable or when pirating becomes less attractive relative to purchasing the authorized product. This is because the firm's optimal pricing behavior reflects the trade-off between two counteracting incentives. On the one hand, the firm wants to set a high price in order to extract more consumer surplus from those noncopiers who choose to search. Therefore, holding all other things constant, the firm's surplus-extracting incentive becomes more important and the firm will hence charge a higher equilibrium price as the number of the noncopiers increases.[9] On the other hand, the firm desires to cut the price to promote demand from the copiers whose search is costless. Note that these consumers can costlessly find out the price and thus can intensely respond to the price cut. As a result, when the pirated product's utility becomes higher to the copiers (i.e., β increases or γ decreases), all else being equal, the increasing substitutability between the licensed and the pirated products drives the firm to charge a lower equilibrium price.

Interestingly, as the size of the noncopiers looms larger, they are less likely to search, resulting in a lower equilibrium demand. This is driven by the positive effect of the size of the noncopier segment on the equilibrium price. When the equilibrium price is anticipated to escalate because of the firm's increasing incentive to extract consumer surplus, the noncopiers' expected surplus of search becomes lower, and they hence exhibit a higher reluctance to search. In the opposite vein, as the competition between the licensed and the pirated products becomes intensified, the equilibrium price is expected to drop, and the noncopiers thus become more willing to engage in costly search. This suggests that there exists an endogenous cross-segment demand externality: more intense competition in the copier segment increases consumer search and demand in the noncopier segment.

3.3. Optimal Copyright Protection

Next, we analyze the first stage of the game and determine the firm's optimal copyright protection policy by taking into account its influence on the subsequent consumer search. In particular, the firm decides on γ to maximize the first-stage profit function:

$$\max_{\gamma} \Pi_1(\gamma) \equiv \Pi_2^*(p^*; \hat{v}^*, \gamma). \tag{8}$$

[9] This stands in contrast to the benchmark in which a larger noncopier segment leads the firm to charge a lower equilibrium price. When the firm's incentive to ex post appropriate consumer surplus is absent, a larger noncopier segment implies an increasing need to compensate for consumers' transaction cost, i.e., a downward force for pricing.

Proposition 3. *The optimal copyright protection is given by* $\gamma^* = \max\{\min\{1 - (3\alpha - 2)/(\alpha\beta), 1\}, 0\}$.

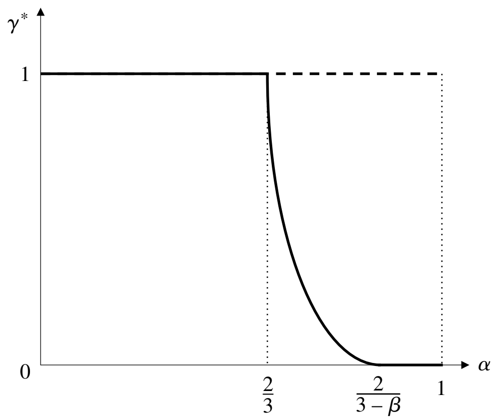
Proposition 3 establishes the central result of the paper: the firm may not exert perfect copyright protection to completely remove piracy, even when the cost of copyright protection is zero. Moreover, zero copyright protection can strictly increase profitability even for a monopoly firm and in the absence of network effect. In other words, the firm may in equilibrium exercise self-restriction in anti-piracy efforts. This is opposite to the benchmark in which perfect copyright enforcement is the dominant firm strategy (i.e., $\gamma^b = 1$). To understand this, we use the envelope theorem to investigate the total effect of γ on the second-stage equilibrium profit $\Pi_2^*(p^*; \hat{v}^*, \gamma)$:

$$\frac{d\Pi_2^*}{d\gamma} = \frac{\partial \Pi_2^*}{\partial \gamma} + \frac{\partial \Pi_2^*}{\partial \hat{v}} \frac{d\hat{v}^*}{d\gamma}. \tag{9}$$

The total effect of copyright protection can be decomposed into two parts. The first part represents the main effect of copyright protection on the firm's profit through influencing the copiers' purchase behavior. This main effect is positive since a lower utility for the pirated product enhances the copiers' demand for the authorized product; i.e., $\partial\Pi_2^*/\partial\gamma > 0$. In other words, keeping consumer search fixed, it is beneficial to strictly protect the product's copyright. This is the driving force in the benchmark when the role of consumer search is immaterial. Furthermore, copyright protection can exert a strategic effect on the firm's profit through its influence on the noncopiers' search behavior, which is captured by the second part in (9). As shown in Proposition 2, this strategic effect is negative; i.e., $d\hat{v}^*/d\gamma > 0$. That is, holding the copiers' demand constant, the firm can benefit from adopting a less stringent copyright protection policy. This is because the consumers can rationally infer that a lenient copyright protection policy would lead to a lower equilibrium price. This in turn induces more noncopiers to search the product and hence generates more demand.

The equilibrium relationship between the optimal level of copyright protection and the relative size of the noncopier segment is displayed in Figure 3. The optimal protection policy is perfect when the size of the noncopier segment is sufficiently small (i.e., $\alpha < 2/3$), and it can decrease to zero when there are enough noncopiers in the market (i.e., $\alpha > 2/(3 - \beta)$). This negative relationship arises because the change in the relative segment size influences the relative importance of the main versus the strategic effect of copyright protection on firm profits. When α is sufficiently small, the main effect is more important and the firm cares more about its demand from the copiers, and as a result, it is optimal to impose a stringent policy to protect the product from being pirated. However, as

Figure 3 **Optimal Copyright Protection Level**



the relative size of the noncopier segment increases, the strategic effect becomes more important and the firm's incentive to induce search from the noncopiers looms larger. The firm can then benefit from choosing an imperfect, and even zero, copyright protection policy.

Note that optimal copyright protection, γ^*, is independent of the noncopiers' search cost s. As a result, as long as consumers are not perfectly informed of price prior to search and consumer search is not completely costless, as in most markets, the strategic effect we highlight in this paper will obtain and can become dominant whereby the firm can benefit from adopting an anti-protection policy in order to encourage consumer search.

4. Quality Improvement

We now extend the basic model to incorporate the firm's decision on quality improvement. To this end, we modify the consumers' utility for the authorized product:

$$U_{IL} = v + q - p - s_I, \tag{10}$$

where $q \geq 0$ represents the level of quality (or quality improvement) offered by the firm over the general value v. For example, firms can provide additional functions, innovations, or upgrades to a base product. The firm incurs a fixed cost of $kq^2/2$ to develop a product with quality q, where $k > 0$ is assumed to be not too small to ensure interior solution. Furthermore, whereas the noncopiers' utility for the pirated product remains $U_{NP} = 0$, the copiers' becomes

$$U_{CP} = (1-\gamma)\beta(v+q). \tag{11}$$

We will analyze two alternative setups regarding the consumers' information about quality when they decide whether to search. First, we study the case when quality is known prior to consumer search. We then address the case when the consumers have to search to be informed of the quality.

4.1. Observable Quality

Consider the following extended model when quality improvement is ex ante observable to the consumers and hence precedes both price setting and consumer search, as shown in Figure 4. In the first stage, the firm decides and commits to the copyright protection policy γ and the level of quality improvement q. The other two stages are the same as in the basic model. Therefore, prior to search, the consumers know the level of copyright protection, the quality, and their general value, but not the price. They make rational inference about the firm's optimal price. The actual price can be found out only after search. This setup could represent scenarios in which the firm's quality decision involves long-term strategic considerations and can be credibly committed.

The solution approach to the second-stage subgame is similar to the basic model. A noncopier decides to search if and only if $v \geq \hat{v}$, where

$$\hat{v} = \bar{p} + s - q. \tag{12}$$

Moreover, the firm selects the optimal p by maximizing the interior profit function:

$$\begin{aligned}\max_p \Pi_2(p; \hat{v}, q, \gamma) &= p\left\{\alpha(1-\hat{v}) + (1-\alpha)\left[1 + q - \frac{p}{1-(1-\gamma)\beta}\right]\right\} \\ &\quad - kq^2/2.\end{aligned} \tag{13}$$

The first-order condition with respect to p is

$$1 - \alpha\hat{v} + (1-\alpha)q - \frac{2(1-\alpha)p}{1-(1-\gamma)\beta} = 0. \tag{14}$$

The equilibrium price $p^{\#1}$ and the marginal consumer $\hat{v}^{\#1}$ are obtained by jointly solving (12) and (14) and noting that $\bar{p} = p^{\#1}$. It can be readily verified that the results are qualitatively similar to the basic model regarding the equilibrium price setting and consumer search behavior.

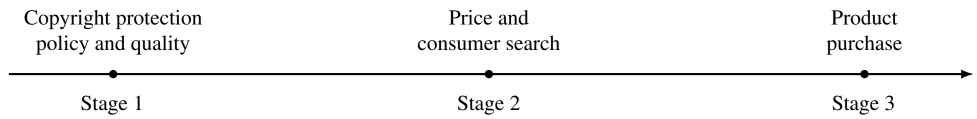
Next, the firm decides on the optimal copyright protection and the quality by choosing γ and q to maximize the first-stage profit function $\Pi_1(q, \gamma)$:

$$\max_{q,\gamma} \Pi_1(q, \gamma) \equiv \Pi_2^{\#1}(p^{\#1}; \hat{v}^{\#1}, q, \gamma). \tag{15}$$

Maximizing first over q yields the optimal quality, $q^{\#1} = (2(1-\alpha)(1-\alpha s)[1-(1-\gamma)\beta])/(k[2-\alpha-\alpha(1-\gamma)\beta]^2 - 2(1-\alpha)[1-(1-\gamma)\beta])$, conditional on γ. It can be readily obtained that this optimal quality is lower than that in the alternative setup in which the price is known to the consumers prior to search (i.e., akin to the benchmark in §3.1). Intuitively, price unobservability leads to less consumer search, which in turn suppresses the firm's incentive to invest on quality improvement.

Moreover, we can investigate the firm's incentive to improve quality.

Figure 4 **Timing of the Extended Model with Observable Quality**



Proposition 4. *In the extended model when quality is ex ante observable, the optimal quality decreases with the copiers' utility for the pirated product (i.e., $dq^{\#1}/d\beta < 0$ and $dq^{\#1}/d\gamma > 0$) if the size of the noncopier segment is sufficiently small (i.e., $\alpha < 2/(3-(1-\gamma)\beta)$). The optimal quality increases with the copiers' utility for the pirated product (i.e., $dq^{\#1}/d\beta > 0$ and $dq^{\#1}/d\gamma < 0$) if the size of the noncopier segment is sufficiently large (i.e., $\alpha > 2/(3-(1-\gamma)\beta)$).*

Proposition 4 suggests that the firm's incentive to improve quality may not monotonically change with the copiers' utility for the pirated product. Interestingly, the firm may want to invest more on quality when there is less copyright protection on the licensed product. This counterintuitive result arises if and only if there are sufficient noncopiers in the market. This contrasts sharply with the result that the optimal quality strictly increases with copyright protection, which obtains in the alternative setup in which the price is ex ante known to the consumers (i.e., akin to the benchmark in §3.1). The mechanism underlying this nonmonotonic relationship is also the firm's desire to balance between the two effects of copyright protection on firm profits that are identified in the basic model. Recall that when the noncopier segment is sufficiently small, the main effect of copyright protection is dominant and the firm can thus benefit from higher copyright protection. This tends to increase the return on the firm's investment on quality innovation. Conversely, the strategic effect of copyright protection in discouraging consumer search becomes more dominant when there are enough noncopiers in the market. The firm may then have a higher incentive for quality improvement only if there are sufficient noncopiers who are induced to search by a lenient copyright protection policy.

We continue to investigate the firm's decision on the optimal level $\gamma^{\#1}$ of copyright protection. From the above discussion we can expect that the driving forces in the basic model are still influential in this extended model with endogenous and observable quality. In effect, the optimal level of copyright protection in this extended model remains the same as in the basic model; i.e., $\gamma^{\#1} = \gamma^* = \max\{\min\{1-(3\alpha-2)/(\alpha\beta), 1\}, 0\}$.

4.2. Unobservable Quality

Consider then the following alternative model in which the firm's decisions on both pricing and quality improvement are unobservable to the consumers prior to search. As shown in Figure 5, this setup departs from the basic model in that the firm makes the quality decision in the second stage of the game along with price setting and consumer search while keeping the other two stages intact. As a result, before search the consumers know the level of copyright protection γ and their general value v, but they do not know either the charged price p or the quality q. Nevertheless, they form rational expectations, $\bar{p}$ and $\bar{q}$, on the firm's optimal behavior on both pricing and quality. It is only after search that the consumers can figure out the actual price and the quality chosen by the firm. This alternative setup could represent scenarios in which the evaluation of quality is costly to the consumers or the provision of quality cannot be credibly committed by the firm.

Similarly, the marginal consumer in the noncopier segment who is indifferent between search and no search is given by

$$\hat{v} = \bar{p} + s - \bar{q}. \tag{16}$$

The firm decides on both p and q to maximize the following second-stage interior profit function:

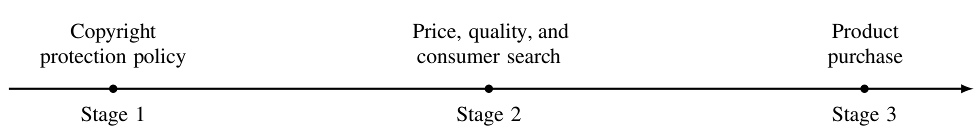
$$\max_{p,q} \Pi_2(p, q; \hat{v}, \gamma) = p\left\{\alpha(1-\hat{v}) + (1-\alpha)\left[1 + q - \frac{p}{1-(1-\gamma)\beta}\right]\right\} - kq^2/2. \tag{17}$$

The first-order conditions with respect to p and q are given by (14) and the following equation:

$$(1-\alpha)p - kq = 0. \tag{18}$$

The trinity decisions in the second-stage equilibrium, $(p^{\#2}, q^{\#2}, \hat{v}^{\#2})$, can then be determined by simultaneously solving (14), (16), and (18) and noting that $\bar{p} = p^{\#2}$ and $\bar{q} = q^{\#2}$.

Figure 5 **Timing of the Extended Model with Unobservable Quality**



Proposition 5. *In the extended model when quality is ex ante unobservable,*

(i) *the equilibrium quality is lower than when quality is ex ante observable, i.e.,* $q^{\#2} < q^{\#1}$; *and*

(ii) *the equilibrium quality decreases with the copiers' utility for the pirated product, i.e.,* $dq^{\#2}/d\beta < 0$ *and* $dq^{\#2}/d\gamma > 0$.

This result demonstrates that quality unobservability prior to search leads the firm to offer a lower equilibrium level of quality. This is analogous to the firm charging a higher equilibrium price in the basic model, as shown in Proposition 1, where the price becomes known only after costly search. In either case, the noncopiers' search behavior does not respond directly to unobservable firm behavior. Nevertheless, after search, the search cost is sunk and immaterial for the purchase decision. The firm thus has an incentive to ex post extract more consumer surplus through charging a higher price or offering a lower quality. As a result, one may expect that the noncopiers are less willing to search and the firm's profits are lower when quality is ex ante unobservable than when it is ex ante observable. Again, this is the flip side of the same coin as in the case of price unobservability—the firm's opportunism in ex post surplus extraction can be ex ante harmful.

The endogeneity of consumer search can also explain why the equilibrium quality monotonically increases with copyright protection when quality is ex ante unobservable (i.e., part (ii) of Proposition 5) but may decrease when the quality is ex ante observable (i.e., Proposition 4). When the quality is unobservable before consumer search, as shown in (18), the marginal benefit of quality provision is determined by the equilibrium profit margin for the copier segment, which in turn increases with copyright protection. However, when quality is observable prior to consumer search, the copyright protection level γ can, through its strategic impact on the noncopiers' search decision, exert a negative influence on the firm's incentive for quality provision.

Finally, the firm decides on the optimal copyright protection by choosing γ to maximize the first-stage profit function:

$$\max_{\gamma} \Pi_1(\gamma) \equiv \Pi_2^{\#2}(p^{\#2}, q^{\#2}; \hat{v}^{\#2}, \gamma). \tag{19}$$

This yields the optimal copyright protection policy

$$\gamma^{\#2} = \max\left\{\min\left\{1 - \frac{k(3\alpha-2)+(1-\alpha)(1-2\alpha)}{[\alpha k+(1-\alpha)(1-2\alpha)]\beta}, 1\right\}, 0\right\}.$$

It is evident that, similar to the case when quality is ex ante observable, the firm may not pursue perfect copyright protection to its product, and an imperfect and even zero protection policy can be optimal. Moreover, the optimal level of protection is negatively influenced by the size α of the noncopier segment. Again, this counterintuitive result is driven by the interplay of the two effects exerted by copyright protection: the main effect whereby the copiers are less likely to choose the pirated product and the strategic effect whereby the noncopiers are more reluctant to search as the expected surplus of search decreases with more stringent copyright protection.

Proposition 6. *The optimal copyright protection level when quality is ex ante unobservable is higher than when quality is ex ante observable; i.e.,* $\gamma^{\#2} \geq \gamma^{\#1}$.

Interestingly, in comparison to the case with observable quality, the optimal copyright protection policy is more stringent when quality is ex ante unobservable. This is because quality unobservability can moderate the strength of the strategic effect of copyright protection on consumer search. Recall that in either the basic model or the extended model with observable quality, as in (5) or (12), copyright protection affects the noncopiers' incentive to search only through the impact on the expected price $\bar{p}$. Nevertheless, when quality is ex ante unobservable, as in (16), the noncopiers' search behavior is influenced not only by the expected price $\bar{p}$ but also by the expected quality $\bar{q}$. Recall from part (ii) of Proposition 5 that the expected quality is positively related to copyright protection; i.e., $dq^{\#2}/d\gamma > 0$. That is, all else being equal, a more stringent copyright protection policy can lead the firm to offer a higher equilibrium quality and thus can induce a higher willingness to search from the noncopiers. As a result, it is better off for the firm to adjust upward the optimal level of copying restriction when quality is ex ante unobservable than when it is not. Therefore, counterintuitively, although it is the ex ante uncertainty about firm decisions, which underlies consumer search, that drives the firm to choose imperfect copyright protection, it does not necessarily follow that the firm should enforce less protection as the consumers become uncertain not only about price but also about quality.

5. Conclusion

This study is motivated by the recent controversies about copyright protection. The central issue we address is the influence of copyright enforcement on firm profitability and quality provision. The threat of piracy has long led many copyright holders to pursue an array of strategies, ranging from legislation and prosecution efforts to technological controls, to protect their intellectual property. It is generally believed that unlicensed copying is detrimental to demand and that efforts to reduce violation of copyright can increase firm profitability and incentive for quality improvement. However, this wisdom has received increasing objections in recent years, especially in the entertainment industry. Anecdotal evidence suggests that many digital content providers are switching to a restriction-free policy for pirating their products. To improve our understanding about this growing anti-protection trend, in this paper we develop a parsimonious model to reexamine the intuition that unauthorized copying is always harmful for sales. We establish conditions under which it is optimal to enforce only imperfect or even zero restriction on unauthorized copying. We also investigate the influence of copyright protection on quality improvement and find that increasing protection may lead to the provision of products with lower quality.

Our explanation differs from previous studies and hinges on the influence of copyright protection on consumer search. We show that a more stringent copyright protection policy can induce the consumers to rationally expect that the firm would extract more consumer surplus, thus exerting a negative strategic effect on the consumers' willingness to search. This strategic effect on consumer search may outweigh the positive main effect on the relative attractiveness of the authorized versus the pirated product, constituting a force toward imposing an incomplete and even zero copyright protection policy. It is also this strategic effect that, counterintuitively, may drive firms to provide products with lower quality as copyright protection increases. Furthermore, we show that quality unobservability can moderate this strategic effect and thus lead to an increasing incentive for copyright protection.

The main insights in the current paper do not require that search be costly for all consumers or that the search cost be substantial. For example, as Proposition 3 demonstrates, the results hold as long as search is not completely free for all consumers. It would be implausible, even with the prevalence of the Internet and search engines, to expect that search is perfectly free for all digital products. In fact, there exist many digital goods for which search for purchase-relevant information (e.g., price, quality, service) is not perfectly costless, especially for consumers who have a high value of time. Consumer search prior to purchase is particularly relevant in these markets that are characterized by information overload and product proliferation.

The economic mechanism we present here does not rely on either demand- or supply-side externality that unauthorized copying may exert to enhance a firm's ability to charge a higher price and/or to extract more consumer surplus (e.g., network effect, indirect appropriability, softened competition), which are the mechanisms proposed in previous research. Rather, in this paper unauthorized copying can be beneficial because it increases the firm's commitment to charge lower prices (or offer better quality) and appropriate less consumer surplus. In this regard, this paper provides an additional perspective on the benefits of piracy, particularly in many mature markets in which the impact of network effect or competition is weak. Nevertheless, it is an empirical issue for future research to compare the relative strength, across industries, firms, and/or time, of the alternative explanations presented in the literature and in this paper. To empirically identify the effect of copyright protection on consumer search, we need to collect data not only on revenue but also on price (or on quality improvement), since it is the mediating role of the latter information that differentiates the current mechanism from those in previous studies.

There are several directions to extend the current research. First, one can consider a multiple-period setup and investigate consumers' optimal timing for search. Second, future research can study alternative devices for copyright enforcement, i.e., fine, tax, or subsidy (Chen and Png 2003). Third, it would be interesting to investigate the role of channel decentralization in copyright enforcement, especially when consumers' surplus of purchase can be differentially influenced by different channel members. For example, the utility of an Internet music album can be affected not only by the quality of the record label but also by the online store's price and services. Moreover, the channel members may have different incentives for copyright enforcement.

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Appendix

Proof of Proposition 1. Jointly solving (5) and (7), we can readily obtain that

$$p^* = \frac{(1-\alpha s)[1-(1-\gamma)\beta]}{2-\alpha-\alpha(1-\gamma)\beta}$$

and

$$\hat{v}^* = \frac{1-(1-\gamma)\beta+2(1-\alpha)s}{2-\alpha-\alpha(1-\gamma)\beta}.$$

Substituting p^* and $\hat{v}^*$ into (6) leads to the equilibrium subgame profit

$$\Pi_2^*(p^*;\hat{v}^*,\gamma) = \frac{(1-\alpha)(1-\alpha s)^2[1-(1-\gamma)\beta]}{[2-\alpha-\alpha(1-\gamma)\beta]^2}.$$

It is straightforward that $p^* < \hat{v}^*$ and that $\hat{v}^* < 1$ given $s < 1/2$. Moreover, $\hat{v}^* < 1-(1-\gamma)\beta$ when $(1-\gamma)\beta$ is sufficiently small (i.e., $\beta < ((1-\sqrt{1-4\alpha(1-\alpha)(1-2s)})/(2\alpha))(1-\gamma)$). Therefore, if the firm deviates and charges a price $p \in [\hat{v}^*, 1-(1-\gamma)\beta]$, its profit function becomes

$$\Pi_2(p;\gamma) = p\left\{\alpha(1-p)+(1-\alpha)\left[1-\frac{p}{1-(1-\gamma)\beta}\right]\right\}.$$

The first-order derivative with respect to p is

$$1-\frac{[2-2\alpha(1-\gamma)\beta]p}{1-(1-\gamma)\beta},$$

which is negative when p goes to either $\hat{v}^*$ or $1-(1-\gamma)\beta$. Moreover, if the firm charges a price $p > 1-(1-\gamma)\beta$, the deviating profit function is $\Pi_2(p;\gamma) = \alpha p(1-p)$. The first-order derivative with respect to p, $\alpha(1-2p)$, is again negative. Given the continuity of the profit function, we can then obtain that these deviations do not lead to higher profits.

To prove the uniqueness of the interior equilibrium, note first that there does not exist an equilibrium in which $p \geq \hat{v}$. This is because only those noncopiers with $v \geq p+s$ will choose to search, which in turn leads to the contradiction that $\hat{v} = p+s > \hat{v}$. Moreover, there does not exist an equilibrium in which $p > 1-(1-\gamma)\beta$ either. This is because the demand from the copiers is then zero, and the firm will thus optimally set a price $p = \max\{\hat{v}, 1/2\}$, which is again a contradiction.

Next, we derive the equilibrium outcome for the benchmark model, conditional on γ. When both consumer segments are served, the profit function is

$$\Pi(p,\gamma) = p\left\{\alpha(1-s-p) + (1-\alpha)\left[1-\frac{p}{1-(1-\gamma)\beta}\right]\right\}.$$

Solving the first-order condition with respect to p yields the equilibrium price $p^b = ((1-\alpha s)[1-(1-\gamma)\beta])/(2-2\alpha(1-\gamma)\beta)$ and the equilibrium profit $\Pi(p^b,\gamma) = (1-\alpha s)^2[1-(1-\gamma)\beta]/(4-4\alpha(1-\gamma)\beta)$. We need to verify that this is indeed an equilibrium by checking possible deviations. If the firm deviates and charges a price $p \in [1-s, 1-(1-\gamma)\beta]$, its profit function would be $\Pi(p,\gamma) = (1-\alpha)p[1-p/(1-(1-\gamma)\beta)]$. The first-order derivative with respect to p, when evaluated at $1-s$, is negative. Similarly, we can readily obtain that deviating to $p > 1-(1-\gamma)\beta$ does not result in a higher profit either.

It follows that the equilibrium price in the basic model, $p^* = (1-\alpha s)[1-(1-\gamma)\beta]/(2-\alpha-\alpha(1-\gamma)\beta)$, is clearly higher than in the benchmark, $p^b = (1-\alpha s)[1-(1-\gamma)\beta]/(2-2\alpha(1-\gamma)\beta)$. Moreover, note that holding the price fixed, the demand function for either consumer segment, D_N or D_C, is the same in both cases. Therefore, the equilibrium consumer demand is lower in the basic model. Finally, it can be readily verified that $\Pi_2^*(p^*;\hat{v}^*,\gamma) = (1-\alpha)(1-\alpha s)^2[1-(1-\gamma)\beta]/[2-\alpha-\alpha(1-\gamma)\beta]^2 < \Pi(p^b,\gamma) = (1-\alpha s)^2[1-(1-\gamma)\beta]/(4-4\alpha(1-\gamma)\beta)$.

Proof of Proposition 4. Jointly solving (12) and (14) leads to $p^{\#1} = (1-\alpha s+q)[1-(1-\gamma)\beta]/(2-\alpha-\alpha(1-\gamma)\beta)$ and $\hat{v}^{\#1} = (1-(1-\gamma)\beta+2(1-\alpha)s-(1-\alpha)[1+(1-\gamma)\beta]q)/(2-\alpha-\alpha(1-\gamma)\beta)$. Substituting $p^{\#1}$ and $\hat{v}^{\#1}$ into (13), we can derive $\Pi_2^{\#1}(p^{\#1};\hat{v}^{\#1},q,\gamma)$. Maximizing then over q yields the optimal quality level, $q^{\#1} = 2(1-\alpha)(1-\alpha s)[1-(1-\gamma)\beta]/(k[2-\alpha-\alpha(1-\gamma)\beta]^2 - 2(1-\alpha)[1-(1-\gamma)\beta])$. Taking the first-order derivative of $q^{\#1}$ with respect to β, we obtain that the sign of $dq^{\#1}/d\beta$ is the same as that of $-2+3\alpha-\alpha(1-\gamma)\beta$. Conversely, the sign of the first-order derivative of $q^{\#1}$ with respect to γ, $dq^{\#1}/d\gamma$, is the same as that of $2-3\alpha+\alpha(1-\gamma)\beta$. The proposition follows immediately.

Next, we analyze another benchmark model in which both price and quality are known prior to consumer search. When both consumer segments are served, the profit function is

$$\Pi(p,q,\gamma) = p\left\{\alpha(1+q-s-p) + (1-\alpha)\left[1+q-\frac{p}{1-(1-\gamma)\beta}\right]\right\} - \frac{kq^2}{2}.$$

Solving the first-order conditions with respect to p and q yields the equilibrium price $p^o = k(1-\alpha s)[1-(1-\gamma)\beta]/(2k[1-\alpha(1-\gamma)\beta]-1+(1-\gamma)\beta)$, the equilibrium quality $q^o = (1-\alpha s)[1-(1-\gamma)\beta]/(2k[1-\alpha(1-\gamma)\beta]-1+(1-\gamma)\beta)$, and the equilibrium profit $\Pi^o = k(1-\alpha s)^2[1-(1-\gamma)\beta]/(4k[1-\alpha(1-\gamma)\beta]-2+2(1-\gamma)\beta)$, conditional on γ. It follows that $dq^o/d\beta < 0$, $dq^o/d\gamma > 0$, $d\Pi^o/d\beta < 0$, $d\Pi^o/d\gamma > 0$, and $q^{\#1} < q^o$.

Proof of Proposition 5. Jointly solving (14), (16), and (18) yields

$$p^{\#2} = \frac{k(1-\alpha s)[1-(1-\gamma)\beta]}{k[2-\alpha-\alpha(1-\gamma)\beta]-(1-\alpha)[1-(1-\gamma)\beta]},$$

$$q^{\#2} = \frac{(1-\alpha)(1-\alpha s)[1-(1-\gamma)\beta]}{k[2-\alpha-\alpha(1-\gamma)\beta]-(1-\alpha)[1-(1-\gamma)\beta]},$$

and

$$\hat{v}^{\#2} = \frac{k[1-(1-\gamma)\beta+2(1-\alpha)s]-(1-\alpha)[1+(1-\alpha)s][1-(1-\gamma)\beta]}{k[2-\alpha-\alpha(1-\gamma)\beta]-(1-\alpha)[1-(1-\gamma)\beta]}.$$

It is straightforward that $q^{\#2} < q^{\#1}$ when k is sufficiently large. Moreover, it can be easily verified that $dp^{\#2}/d\beta < 0$, $dp^{\#2}/d\gamma > 0$, $dq^{\#2}/d\beta < 0$, and $dq^{\#2}/d\gamma > 0$, and that $d\hat{v}^{\#2}/d\beta < 0$ and $d\hat{v}^{\#2}/d\gamma > 0$, when k is sufficiently large.

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