

**Preliminary**

**Piracy, Asymmetric Information,  
and Product Quality Revelation**

by

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## **Piracy, Asymmetric Information, and Product Quality Revelation**

### **Abstract**

**This paper considers the possibility that consumption of copies of intellectual property (e.g., pirated software) can reveal the product quality of originals when they are experience goods. Imperfect substitutability between copies and originals allows for the possibility of subsequent sales of originals to informed copiers. Consequently, the presence of copying can induce a Pareto improvement in social welfare, as it has the potential to solve the adverse selection problem as well as preempt the production of socially undesirable low quality which might otherwise be produced in the absence of copying. Furthermore, the paper also demonstrates that not enforcing (or temporarily suspending) the copyright can in and of itself be a signal of high quality. Finally, any measure of the relative “harm” from copying must appropriately account for variations in product quality that might exist between the copying and no-copying regimes as well as any costs of signaling high quality that must be employed in the regime without copying.**

## 1. Introduction

This paper considers the potential benefits of unauthorized reproduction of intellectual property when the quality of the product is a priori unknown by consumers. In particular, this paper explicitly considers the possibility that consumption of copies of intellectual property (e.g., pirated software) can reveal the product quality of originals when they are experience goods. If copies convey information about the quality of originals, but copies are themselves imperfect substitutes in use for originals, once a consumer has obtained full information by consuming a copy, the consumer may subsequently decide to purchase an original whenever the net surplus from doing so exceeds the value of a copy. Starting from this premise, the paper then explores how the informational value of copies may impact standard issues of asymmetric information such as adverse selection and product quality signaling.

Surprisingly, most previous studies of unauthorized copying (e.g., Novos and Waldman [1984], Liebowitz [1985], Besen and Kirby [1989], Conner and Rumelt [1991], and Takeyama [1994, 1997]) have examined the welfare implications of copying without considering the information value of reproductions. While Takeyama [1999] does consider the possibility that copies convey information, the information imperfection is symmetric across both sides of the market. Thus, issues of adverse selection and product quality signaling do not arise. In the present paper, these issues are of primary interest.

In this paper, the potential advertising value of piracy is modeled in the context of a two-period, durable goods monopoly with asymmetric information about product quality. A priori, all consumers are uncertain about the quality of the firm's product. However, consumers who pirate the good in period one become fully informed by the start of period two. These individuals may then have an increased willingness to pay for an original, conditional upon the degree of substitutability of copies for originals and the quality of the good. Consequently, copiers play a critical role: effectively, they become potential

“repeat purchasers” in a durable goods monopoly framework that does not, in general, readily lend itself to repeat purchases.

The paper offers three main conclusions. First, owing to its information value, the presence of copying may not only benefit the firm, it can also produce a Pareto improvement in social welfare. In particular, the presence of copying has the potential to solve the adverse selection problem. That is, there exist conditions under which, without copying, a high quality firm is unable to earn positive profits because of uncertainty and the presence of low quality, but with copying, earns positive profits in either a pooling or separating equilibrium. The intuition is that, because copying generates “repeat purchases” only when quality is high, any first–period losses from sales to uninformed consumers may be more than offset by the subsequent second–period profits from sales to the informed copiers.

Secondly, the paper demonstrates that because subsequent purchases of high quality originals by informed copiers is qualitatively similar to the notion of repeat purchases in a non–durable goods framework, the presence of copying can be sufficient in and of itself to induce revelation of product quality a priori. In particular, the paper considers the existence of separating equilibria for which wasteful expenditures (e.g., advertising) and strategic introductory pricing are not required to support (see for example, Milgrom and Roberts [1986] and Kihlstrom and Riordan [1984]).<sup>1</sup> In these equilibria, the presence of copying effectively “weeds out” low quality. Low quality firms are unable to earn positive profits with copying at any feasible price, making unnecessary wasteful expenditures or other costly signals of high quality. Consequently, copying can enable non–signaling high quality firms to produce and sell at full information prices, when without copying, the firm might not otherwise produce. At the same time, copying can preempt the introduction of low quality goods for which production is socially undesirable.

Thirdly, the paper also considers endogenous copyright enforcement and demonstrates that non-enforcement of the copyright in and of itself can be a signal of high product quality. That is, there exist separating equilibria in which high quality firms choose not to enforce the copyright (or to suspend the copyright temporarily) while low quality firms choose to enforce the copyright fully. Additional product quality signaling via price and/or wasteful expenditures need not be employed to achieve such equilibria.

Empirically, the results of the paper are consistent with the observation that many firms do actively promote consumer reproduction of their intellectual property. For example, many software publishers distribute free “giveaways” of scaled-down (“light”) versions of their programs on the Internet. Indeed, by facilitating the ability of consumers to obtain cheap copies (at zero marginal cost to the firm), the growth and expansion of the Internet itself may also expand the possibilities for the provision of high quality intellectual property.

Perhaps more importantly, the paper suggests that standard measures of “harm” from unauthorized reproduction of intellectual property may be largely overstated, as such measures do not account for the informational value of copies. Without copying, high quality may be absent entirely from the market, or low quality may be produced when it is socially undesirable. Still, even if without copying the high quality firm *is* able successfully to signal or guarantee its product quality, any measure of the relative harm from copying should also appropriately net out the additional costs that must be spent in the absence of copying to signal or guarantee product quality. Specifically, the true opportunity cost of reproductions made by consumers may very well be zero.<sup>2</sup>

## 2. The Basic Model with No Copying

In this section, I develop a basic two–period model for the case in which the intellectual property is prohibitively costly for consumers to reproduce. Let  $q^i$ ,  $i = H, L$ , represent the quality of the product, where high quality is given by  $q^H > 0$  and low quality is given by  $q^L = 0$ .<sup>3</sup> The product is produced by a monopolist who has an initial exogenous endowment of capacity for producing quality, such that the firm is either a “high quality” type or a “low quality” type. High quality firms must spend an amount  $f^H$  to develop intellectual property with quality  $q^H$  and low quality firms must spend an amount  $f^L$  to develop intellectual property with quality  $q^L$ . Quality is exogenous in the sense that low quality firms do not have the capacity to produce high quality and high quality firms do not produce low quality products.<sup>4</sup> Only the firm knows the true quality of its product (i.e., consumers do not). Furthermore, a firm producing a good with quality  $q^i$  has a constant marginal production cost,  $c^i$ , where no restrictions will be imposed on the relative sizes of  $c^H$  and  $c^L$  or  $f^H$  and  $f^L$ .<sup>5</sup>

Consumers live for two periods and arrive at the beginning of the first period only. Consumers are homogeneous in that each consumer's per–period valuation of the durable good with quality  $q^i$  is given by  $Vq^i = V^i$ ,  $V^H > c^H$ .<sup>6</sup> While consumers do not know prior to consumption the quality of the good, they hold a common a priori probability,  $p$ , that the good is of high quality. Since consumers are risk neutral, the most they are willing to pay in the first period to consume the good over the two periods is  $pV^H + \beta pV^H$ , where  $\beta$  is the discount factor, common to consumers and the firm.

Although the model is cast in a two period framework, the homogeneity of consumers and the absence of repeat purchases implies that the model in this case is essentially static. That is, the firm maximizes profits by making all of its sales in the first period.<sup>7</sup> Regardless of whether the firm produces low or high quality, the maximal price that can be charged is  $pV^H + \beta pV^H$ , with corresponding profits of :

$$\Pi_{nc}^H = pV^H + \beta pV^H - c^H - F^H \quad (1)$$

if quality is high, while if quality is low, the firm receives profits of

$$\Pi_{nc}^L = pV^H + \beta pV^H - c^L - F^L,$$

where the size of the market has been normalized to one and  $F^i$  represents the fixed cost appropriately adjusted for the normalization. (2)

Notice that  $\Pi_{nc}^H < 0$  describes the classic adverse selection problem. That is, the high quality firm will not find it profitable to produce because of uncertainty and the presence of low quality. Since the focus of this paper is on copying and its impact upon the adverse selection problem, the assumption that  $\Pi_{nc}^H < 0$  will be retained for all but the last section of this paper.

### 3. The Basic Model with Copying

I now extend the model of Section 2 by allowing the monopolist's product to be easily reproducible by consumers. Specifically, I assume that consumers are able to reproduce one unit of the firm's product at a common copying cost of  $P_c$ . Copies are supplied competitively, and therefore,  $P_c$  represents the marginal reproduction cost, assumed to be constant. Furthermore, I allow for the possibility that copies are imperfect substitutes for originals. Such imperfect substitutability may result from actual tangible differences (e.g., unauthorized copies of software do not come with user manuals or technical support), consumers' disutility of being dishonest, or it may result from expected consequences of being caught violating the copyright. While consumers have homogenous valuations of originals, they have heterogeneous valuations of reproductions.<sup>8</sup> Let  $V_c^k q^i$  represent a type  $k$  consumer's per-period valuation of a copy from an original with quality  $q^i$ ,  $k = \text{I, II}$ ,  $0 \leq V_c^{\text{I}} < V_c^{\text{II}} \leq V$ . Let  $D^{k,i} = (V - V_c^k)q^i$ , or a type  $k$  consumer's one-period surplus of originals over copies when the product's quality is  $q^i$ . The expected single-period differential valuation of originals over copies for a consumer of type  $k$  is therefore given by  $pD^{k,H}$ .

I now make the assumption that some fraction  $\gamma$  of all consumers have  $k = I$  and that  $P_c > (1 + \beta)V_c^I q^H$ , or that the marginal reproduction cost exceeds the type I consumer's discounted two-period valuation of consuming a copy known to be of high quality. This implies that the fraction  $\gamma$  of all consumers would not make copies regardless of the price of originals and known high quality.<sup>9</sup> The remaining fraction,  $1 - \gamma$ , of consumers ( $k = II$  types) have  $P_c < (1 + \beta)pV_c^{II} q^H$ . These consumers will thus be called “copiers”, as they will choose to copy rather than purchase an original in period one whenever  $P_1 > (1 + \beta)pD^H + P_c$  (i.e., copiers receive more expected surplus from copying than purchasing).<sup>10</sup> Importantly, if a copier does choose to copy rather than purchase in period one, by the start of the second period, the copier knows whether the good is of high or low quality, since the copier has had the opportunity to consume the quality revealing copy in the first period. A copier may then wish to purchase an original in the second period, provided the good is of high quality and  $V^H - P_2 \geq V_c^{II} q^H$ , or  $P_2 \leq D^{II,H}$ .

Next, consider the pricing decision of the firm. Suppose that the firm sells only to the non-copier types (type I consumers) in period one, while type II consumers consume copies in the first period. In period two, the high quality firm will make sales to the informed copiers by charging them their one-period differential valuation of originals over copies, or  $P_2 = D^{II,H}$ . In equilibrium, the low quality firm makes no period two sales; however, in the second period, the firm continues to rationally maximize profits in any deviation from the equilibrium path. This implies that should a type I consumer ever defer their purchase from period one, the low quality firm must mimic the pricing of the high quality firm or else be revealed as low quality. Therefore, in considering whether or not to defer purchasing until period two, a type I consumer will rationally assume the second-period price will be  $D^{II,H}$ , regardless of whether the firm produces the low or high quality good. This implies that whenever  $D^{II,H} < pV^H$ , the rationally forecasted second-period price is less than the consumer's one-period expected valuation of an



original, and therefore, the intertemporal self selection constraint preventing type I consumers from deferring their purchases until period two is binding. Consequently, to induce type I consumers to purchase in period one and not defer their purchase until period two, the firm can charge a maximal first–period price of  $pV^H + \beta \min[D^{II,H}, pV^H]$ .<sup>11</sup>

It can easily be shown that, given a first–period price of  $pV^H + \beta \min[D^{II,H}, pV^H]$ , a sufficient condition for type II consumers to copy in period one rather than a) purchase in period one or b) do nothing in period one (i.e., neither purchase nor copy) together with purchasing in period two at a price of  $D^{II,H}$  is  $D^{II,H} > pV^H$ .<sup>12</sup> In other words, the type II consumer's differential surplus of originals over copies when quality is high must exceed the expected utility of originals when quality is unknown. As will be seen shortly, this condition is also a necessary condition for the existence of a pooling equilibrium when  $\Pi_{nc}^H < 0$ . Therefore, I now make the assumption that  $D^{II,H} > pV^H$ , which implies that the maximal first–period price is given by  $pV^H + \beta pV^H$ . The discounted two–period profits for the high and low quality firms are then respectively given by:

$$\Pi_c^H = (pV^H + \beta pV^H - c^H)\gamma + \beta(D^{II,H} - c^H)(1 - \gamma) - F^H \quad (5)$$

$$\Pi_c^L = (pV^H + \beta pV^H - c^L)\gamma - F^L \quad (6)$$

Finally, in support of the pooling equilibrium, I simply assume that upon the observance of any other first period price, consumers' posterior beliefs after such observation are that the good is low quality with certainty. Provided  $\Pi_c^H$  and  $\Pi_c^L$  both exceed zero, neither firm then has any incentive to deviate from the equilibrium path.

Recall that I am assuming that  $\Pi_{nc}^H < 0$ , or when there is no copying, the market is characterized by adverse selection. Notice, however, that  $\Pi_c^H$  may in fact be strictly positive even though  $\Pi_{nc}^H < 0$ . Although first period profits (net of the fixed cost) in  $\Pi_c^H$  are unambiguously negative (the first period price is equal to the price in  $\Pi_{nc}^H$ ), if the proportion of copiers  $(1 - \gamma)$  and their differential valuation of high quality originals over

copies ( $D^{II,H}$ ) are both sufficiently large,  $\Pi_c^H$  can exceed zero. It is also easily seen that, as mentioned previously, a necessary condition for the existence of a pooling equilibrium when  $\Pi_{nc}^H < 0$  is that  $D^{II,H} > pV^H$ .<sup>13</sup> If  $D^{II,H} \leq pV^H$ , second period profits (and therefore overall two-period profits) for the high quality firm are necessarily nonpositive.<sup>14</sup> Clearly,  $\Pi_{c_2}^L$  will also exceed zero, provided  $c^L$  and  $F^L$  are sufficiently small.

I conclude therefore, that if  $\Pi_{nc}^H < 0$ , but  $\Pi_c^H > 0$  and  $\Pi_c^L > 0$ , the presence of copying solves the adverse selection problem. Consequently, standard measures of “harm” from unauthorized reproduction of intellectual property may be largely overstated, as such measures do not account for the informational value of copies. Without copying, high quality may be absent entirely from the market. If  $\Pi_{nc}^H < 0$ , but the high quality firm is in fact able without copying to successfully signal or guarantee its product quality, then any measure of the relative harm from copying should also appropriately net out the additional firm costs associated with such signals or guarantees of product quality.<sup>15</sup>

#### 4. Piracy and Product Quality Revelation

In Section 3, copying enabled high quality to be produced despite the fact that product quality remained uncertain until after consumption. In this section, I consider the possibility that the presence of copying can be sufficient in and of itself for the revelation of product quality prior to consumption by consumers. In particular, I consider the possibility that copying in and of itself “weeds out” low quality such that high quality firms are enabled to produce and sell at full information prices, while low quality producers do not produce. In other words, I consider the possibility that the presence of copying can induce a revealing equilibrium without the need for wasteful expenditures, or strategic (quality revealing) pricing by the high quality firm.<sup>16</sup>

If the presence of copying is to induce a separating equilibrium, the maximal price the high quality firm can charge former copiers in the second period remains as in the previous section,  $D^{II,H}$ , while the maximal price in the first period is now given by  $V^H + \beta D^{II,H}$ . At this point, one additional assumption is required: given these prices together with known high quality, potential copiers must receive positive single-period net surplus from consuming a copy, or  $V^{II}q^H - P_c \geq 0$ . If this inequality does not hold, potential copiers will not copy given the above prices and perceived high quality – they receive greater surplus from either purchasing in period one or doing nothing in period one together with buying in period two.

Given the first and second period prices stated above, together with the additional assumption that  $V^{II}q^H - P_c \geq 0$ , profits to the high quality firm in the separating equilibrium will be given by:

$$\Pi_s^H = (V^H + \beta D^{II,H} - c^H)\gamma + \beta(D^{II,H} - c^H)(1 - \gamma) - F^H. \quad (7)$$

If the low quality firm mimics the high quality firm, profits to the low quality firm would be given by:

$$\Pi_m^L = (V^H + \beta D^{II,H} - c^L)\gamma - F^L \quad (8)$$

If the low quality firm is perceived correctly as low quality, the firm does not produce. Importantly, if the high quality firm is also perceived as low quality, the high quality firm also does not produce. Not only will type I consumers not purchase, but type II consumers will not copy, as they receive negative net surplus from consuming copies of originals perceived to be low quality. The firm thus receives zero revenue in both periods. Since any firm perceived as low quality will not produce, the necessary and sufficient conditions for a separating equilibrium to exist is  $\Pi_s^H \geq 0$  and  $\Pi_m^L \leq 0$ , where the inequalities imply that neither the high quality nor low quality firm, respectively, is willing to mimic the other.

If  $\Pi_s^H \geq 0$  and  $\Pi_m^L < 0$ , the high quality firm's quality is immediately revealed a priori – the employment of wasteful expenditures or other costly signaling strategies are

not required.<sup>17</sup> In this case, the presence of copying alone “weeds out” low quality, since only high quality firms are able to earn positive profits with copying. Intuitively, consider what happens as  $\gamma$ , the proportion of non-copiers, becomes smaller. While both types of firms receive lower profits in the first period, only the high quality firm realizes the increase in second period profits from the subsequent and correspondingly larger proportion of purchases made by copiers. As a result, under the conditions stated above, copying makes irrational positive production by low quality firms. I conclude therefore that, when without copying, and as a result of adverse selection, neither firm produces, copying can enable high quality firms to produce and sell at full information prices without the need to employ costly signaling devices. In this case, copying clearly produces a Pareto Improvement in social welfare.

Note also that the above conditions and the conditions for both firms to earn positive profits without copying (i.e.,  $\Pi_{nc}^i \geq 0$ ,  $i = H, L$ ) may be satisfied simultaneously. In other words, the possibility exists that low quality may be produced when there is no copying, while with copying, low quality is absent from the market. The presence of copying thus has the potential to produce yet another efficiency: it can preempt the introduction of low quality goods for which production is socially undesirable.

## **5. Non-Enforcement of the Copyright as a Signal of Product Quality**

While under certain conditions the presence of copying is sufficient for revelation of product quality and therefore eliminates the need for product quality signaling entirely, in this section I endogenize copyright enforcement and show that the high quality firm may be able to signal the quality of its product simply by not enforcing, or perhaps more realistically, temporarily suspending, the copyright. Wasteful expenditures and/or strategic price signals are not necessary to achieve the revealing outcome. To

demonstrate this, I now make the assumption that with perfect information and no copying, the low quality firm is able to earn positive profits, i.e.  $q^H > q^L > 0$  such that

$$\Pi_s^L = V^L + \beta V^L - c^L - F^L > 0. \quad (9)$$

Without this assumption, the low quality firm will always wish to mimic the high quality firm whenever  $(V^H + \beta D^{II,H} - c^L)\gamma - F^L > 0$  unless additional signaling via price and/or wasteful expenditures is employed by the high quality firm.<sup>18</sup> Suppose further that the differential valuation of low quality originals over copies for type II consumers is positive, i.e.,  $D^{II,L} > 0$ , and that  $P_c > (1 + \beta)V_c^{II}q^L$ , so that copying provides type II consumers with positive surplus, regardless of the quality of the original. Finally, for similar reasons given in the previous section for the assumption that  $V^{II}q^H - P_c \geq 0$ , the assumption that  $V^{II}q^L - P_c \geq 0$  will now be maintained.

If non-enforcement of the copyright by the high quality firm is to induce a separating equilibrium, profits to the high quality firm will be given by  $\Pi_s^H$  as given in (7), while the low quality firm enforces the copyright fully and earns  $\Pi_s^L$  as given in (9).<sup>19</sup> Next, consider the incentives for each firm to mimic the other. First, suppose the low quality firm mimics the high quality firm by choosing not to enforce the copyright while charging the same first-period price as the high quality firm. This will allow the low quality firm to attain the same first-period revenue as in  $\Pi_s^H$ . However, in the second period, the maximal price the low quality firm can charge is  $D^{II,L}$ , as the firm's low quality will have been revealed to copiers. Two-period profits to the low quality firm will then be given by:

$$\Pi_{m_2}^L = (V^H + \beta D^{II,H} - c^L)\gamma + \beta(D^{II,L} - c^L)(1 - \gamma) - F^L. \quad (10)$$

Alternatively, if the high quality firm chooses to mimic the low quality firm, it will enforce the copyright and charge the maximal low quality price of  $V^L + \beta V^L$ . Since there is no copying, all sales take place in the first period. Profits to the high quality firm will then be given by:

$$\Pi_{m_2}^H = V^L + \beta V^L - c^H - F^H. \quad (11)$$

Therefore, the necessary and sufficient conditions for a separating equilibrium are:

$\Pi_s^H \geq \Pi_{m_2}^H$  and  $\Pi_s^L \geq \Pi_{m_2}^L$ , which can be characterized by the following inequalities:

$$\begin{aligned}
(V^H + \beta D^{II,H} - c^H)\gamma + \beta(D^{II,H} - c^H)(1 - \gamma) + c^H &\geq \\
V^L + \beta V^L &\geq (V^H + \beta D^{II,H} - c^L)\gamma + \beta(D^{II,L} - c^L)(1 - \gamma) + c^L. \\
\Rightarrow \\
\beta D^{II,H}(1 - \gamma) + c^H(1 - \gamma)(1 - \beta) &\geq \\
V^L + \beta V^L - (V^H + \beta D^{II,H})\gamma &\geq \beta D^{II,L}(1 - \gamma) + c^L(1 - \gamma)(1 - \beta). \tag{12}
\end{aligned}$$

Notice that the low quality firm's incentive to mimic the high quality firm arises from the first period only, when the firm can sell low quality units to non-copiers at the high quality price. In the second period, since copiers know quality is low, the maximal price that the firm can charge is  $D^{II,L} \leq V^L$ . The low quality firm's incentive to mimic the high quality firm will therefore be lower, the lower is the proportion of non-copiers,  $\gamma$ .

For example, suppose that  $\gamma$  is zero.<sup>20</sup> The inequalities in (12) then become:

$$\beta D^{II,H} + c^H(1 - \beta) \geq V^L + \beta V^L \geq \beta D^{II,L} + c^L(1 - \beta) \tag{13}$$

It is straightforward to show that the last inequality is satisfied whenever  $V^L + \beta V^L - c^L > 0$ , or the low quality firm receives positive profits when it is perceived to be low quality and there is no copying. That is, the entire incentive for the low quality firm to mimic the high quality firm is eliminated. Clearly, the first inequality will also be satisfied given a sufficiently large differential valuation of high quality originals over copies.

When the inequalities in (12) are satisfied, therefore, the high quality firm is able to employ non-enforcement of the copyright to signal the quality of its product.

Importantly, wasteful expenditures and/or low introductory prices are not required to induce the separating equilibrium.

## 6. Conclusions

This paper has demonstrated that the informational value of copying can improve social welfare over that without copying when there is asymmetric information about product quality. In some cases, the presence of copying can induce a Pareto improvement in social welfare, as it has the potential to solve the adverse selection problem. Specifically, the presence of copying can generate equilibria in which both high and low quality are produced, when without copying the market may be missing entirely. Additionally, the presence of copying can also generate equilibria in which only high quality is produced. In these equilibria, high quality firms are enabled to produce and sell at full information prices and, in particular, without the need to employ costly signaling mechanisms. The presence of copying therefore, has the potential to “weed out” low quality which, without copying, may be produced even though it is socially undesirable. Furthermore, it was also demonstrated that non-copyright enforcement (or a temporary suspension of) in and of itself can be a signal of high quality.

The results of the paper suggest that strict and absolute enforcement of copyrights can lead to missing markets and a consequent reduction in social welfare. The paper does not intend to suggest, however, that copyrights should never be enforced. Rather, the paper suggests an emphasis on the ex post remedial rather than the ex ante preventive role for copyright enforcement; that is, in its role to encourage copiers to subsequently purchase rather than to prevent them from copying at all. Indeed, consistent with this notion is the observation that several software developers do freely distribute unabridged, fully functioning versions of their programs with an explicit suspension of the copyright for a limited period of time.

The paper's main implication, however, is in regards to the appropriate measure of harm from copying. The first and more obvious point is that standard measures of harm from copying may be largely overstated, since they do not account for the possibility that copiers subsequently purchase. Less obvious, however, is the notion that such measures

should also take into consideration possible variations in the number of existing products as well as the quality of those products between the copying and no-copying regimes. An extreme example would be one in which the measured harm for a firm from lost sales to copiers is positive, but without copying, the firm does not produce. Furthermore, the paper has also demonstrated that copying has the potential to preempt the production of socially undesirable low quality which may be produced in the absence of copying. Finally, even if no such variations in product quality exist between the regimes, any measured harm from copying should also account for the possibility that without copying firms must incur additional expenses to signal their product's quality, including possibly, the costly distribution of copies produced and distributed by the firm itself.



1. See also Bagwell and Riordan [1991], as well as earlier work by Nelson [1974], Schmalensee [1978], and Spence's [1973] seminal article on quality signaling in the context of labor markets.
2. For example, the absence of copying does not preclude firms from distributing their own “copies” (e.g., abridged versions of their intellectual property). However, distribution of firm-produced “copies” is costly for the firm. The firm must incur a positive marginal cost for each copy sold (or given away) as well as any fixed cost required to differentiate the product, either one of which can limit the feasibility of such distribution. Importantly, given such distribution *is* feasible for and employed by the firm, the true opportunity cost of consumer copying should then be measured relative to that regime in which copies are distributed (perhaps given away) by the firm itself.
3. The restriction that  $q^L = 0$  (which will imply that any firm perceived as low quality is unable to earn positive profits) will be relaxed in Section 4.
4. The assumption that quality is exogenously determined implies that the model does not consider the additional moral hazard problem that arises with endogenous quality in the presence of consumer uncertainty about product quality, although similar application of the ideas here can readily be performed in that case as well.
5. However, since the good considered in this paper is intellectual property, much of the cost differential between high and low quality would be expected to be reflected primarily in the development cost, so that it is not unreasonable to suppose that  $f^L < f^H$  and  $c^H = c^L$ , although in the case of software, it can additionally be argued that  $c^H > c^L$  due to a greater use and quality of technical support for high quality programs.

6. The assumption of consumer homogeneity is made for simplicity at the expense of some loss of generality. In the next section when copying is introduced, consumer heterogeneity will be introduced via differential valuations of copies. Allowing heterogeneity in both valuations of originals as well as copies would introduce considerable complexity into the analysis and would not add to the basic points that can be made in the present framework.

7. Note that I am implicitly assuming that there is no word of mouth advertising, so that in the second period, quality remains unknown by any and all individuals who did not consume in period one.

8. As is typical in models of unauthorized copying, the differential net return from copying across consumer types is modelled either via heterogeneous valuations of copies or heterogeneous copying costs. Such heterogeneity is required in order that equilibria exist in which some consumers copy the good while others purchase.

9. The assumption that the constraint preventing type I consumers from copying is non-binding is made for simplicity and does not alter the basic conclusions of the paper. Some consumers must choose to purchase originals in equilibrium, however, as they are assumed to be suppliers of copies.

10. Purchasing in period one provides all consumers types with net expected surplus of  $(1 + \beta)pV^H - P_1$ , while copying provides type II consumers with net expected surplus of  $(1 + \beta)pV_c^H q^H - P_c > 0$ . Therefore, when  $P_1 > (1 + \beta)(pV^H - pV_c^H q^H) + P_c = (1 + \beta)pD^{H,H} + P_c$ , type II consumers receive greater expected net surplus from copying than from purchasing. For simplicity, I assume that when the surpluses are equal, type II consumers purchase.

11. To induce a type I consumer to purchase in period one and not defer their purchase until period two, the firm faces the following constraint:

$(1 + \beta)pV^H - P_1 \geq \beta(pV^H - D^{II,H})$ , where  $D^{II,H}$  is the rationally forecasted second-period price. Additionally, consumers must receive positive expected surplus from purchasing, or  $(1 + \beta)pV^H - P_1 \geq 0$ .

12. The expected two-period surplus for a type II consumer from copying is given by  $(1 + \beta)pV_c^{II}q^H - P_c > 0$ . The expected two-period surplus for a type II consumer from doing nothing in period one (i.e., neither copying nor purchasing) together with buying in period two at the rationally forecasted price of  $D^{II,H}$  is  $\beta(pV^H - D^{II,H})$ . Therefore, when  $pV^H < D^{II,H}$ , type II consumers will opt to copy or purchase in period one. However, when  $pV^H < D^{II,H}$ , the maximal first-period price the firm can charge is  $pV^H + \beta pV^H$ . Since this price leaves type II (and type I) consumers with zero expected surplus from purchasing in period one, but type II consumers receive strictly positive surplus from copying, type II consumers will opt to copy in period one rather than purchase.

13. The model could be extended to include upgrades, in which case the value of  $D^{II,H}$  could be made larger by the firm via increasing the quality of originals and by possibly also making partially obsolete previously sold originals.

14. Notice that, given  $\Pi_{nc}^H < 0$ , there is no pooling equilibrium when both  $c^L \geq c^H$  and  $F^L \geq F^H$ , since these conditions imply  $\Pi_c^L < 0$ . However, as mentioned previously, since intellectual property markets can typically be expected to have  $c^L = c^H$  and  $F^L < F^H$ , the possibility that both  $\Pi_c^H > 0$  and  $\Pi_c^L > 0$  when  $\Pi_{nc}^H < 0$  is not ruled out in these markets.

15. As noted earlier, without copying, the firm could itself produce a “copy” (e.g., an abridged version of its intellectual property) and sell it (or give it away) to all (or some) consumers in period one. As with copying, in period two, the firm receives positive profits from sales of “originals” (e.g., full–fledged versions) to informed consumers who previously consumed abridged versions. Given consumer uncertainty regarding product quality, the firm can charge at most for each copy the consumer's two–period expected valuation of a copy (which, given imperfect substitutability, is less than the consumer's two–period expected valuation of an original). If, for example, the maximal feasible price of a copy is below the firm's marginal cost, second period profits from sales to informed consumers may not be sufficient to outweigh these additional first–period losses. Alternatively, if without copying firms do find it feasible to distribute firm–produced copies, standard measures of harm from copying that include lost “sales” to copiers can still be overstated, since the true opportunity cost of *consumer*–produced copies should be measured relative to the regime in which the firm itself distributes (or gives away) its own copies. Furthermore, such measures of harm are similarly overstated to the extent that they do not account for the possibility that copiers subsequently purchase.

16. See for example, Milgrom and Roberts [1986] and Kihlstrom and Riordan [1984].

17. If  $(V^H + \beta D^{II,H} - c^L)\gamma - F^L > 0$ , the high quality firm must use some alternative mechanism such as wasteful advertising expenditures to signal its product's quality.

Observe, however, that the presence of copying makes such additional signaling possible when it might not otherwise be possible in the absence of copying (e.g., repeat purchases are required and the distribution of firm–produced copies is infeasible).

18. From the previous section we saw that when  $(V^H + \beta D^{H,H} - c^L)\gamma - F^L < 0$ , the low quality firm is unable to earn positive profits with copying. Given  $\Pi_s^H > 0$ , the high quality firm will obviously choose not to enforce the copyright and the low quality firm does not produce. The assumption that  $\Pi_s^L > 0$  also allows for the more interesting possibility that separating equilibria exist in which both firms produce and the copyright is enforced only by the low quality firm.

19. The analysis assumes that copyright enforcement is costless for the firm. Obviously, as the cost of enforcement is higher, the less likely such enforcement will be employed.

20. Obviously, this is for illustrative purposes only, since  $\gamma = 0$  begs the question of from whom copiers copy. Admittedly, this paper, as do most papers that model unauthorized copying, has abstracted from the additional complication of explicitly modeling the dissemination of copies by implicitly assuming that copies are available (at a cost of  $P_c$ ) to anyone who wishes to consume one (provided the number of originals sold is positive). More generally, the extent of copying should be increasing with the number of originals sold.

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