Network Externalities and the Myth of Profitable Piracy

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Abstract: Recent papers have argued that a firm might be able to raise its profit by allowing some customers to steal its product. In particular, with network externalities, so that customers value the product more highly the more widely the product is used, it is claimed that piracy can be profitable. In this paper we analyze these claims when the producer can freely choose the degree of piracy prevention. We show that piracy can never be profitable if the producer can directly price discriminate between potential-pirates and other customers. In the absence of price discrimination, piracy will only raise profits when the ability to pirate is inversely related to customer willingness-to-pay. Even in this situation, there is no profit maximizing equilibrium where some potential pirates buy while others pirate the product. Thus, even though potential pirates differ in their ability to illegally gain the product, the profit maximizing outcome involves either no piracy or complete piracy.

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1 Introduction

The idea that a firm can raise its profits by allowing some consumers to steal its product seems perverse. But when considering patents, copyright and the protection of intellectual property (IP), the case for ‘profitable piracy’ has been forcefully made in a number of recent papers beginning with Conner and Rumelt (1991).

Of course, if complete prevention of piracy is very costly, it will usually be optimal for firms to allow some piracy. Whenever there are high enforcement costs, there will be an optimal level of any illegal activity.\(^1\) However the ‘profitable piracy’ claims go further than this, arguing that allowing some piracy can positively increase profit.

Three reasons for ‘profitable piracy’ have been presented in the literature. First, piracy can increase profits whenever there are network externalities between customers.\(^2\) Because piracy increases the user base of the product, non-pirates are willing to pay more. By allowing some piracy, the seller can raise the price to paying customers and more than make up for any lost sales (see Conner and Rumelt, 1991; Takeyama, 1994; Slive and Bernhardt 1998). Alternatively, piracy can be a commitment device for a firm. Allowing piracy today can alter the firm’s incentives in the future and can limit the standard problems that face a durable goods monopoly (Takayama, 1997). Finally, piracy can be used strategically as a device to undermine the appeal and market share of competitors (Shy and Thisse, 1999).

In this paper we examine the first of these claims. Can piracy raise a single firm’s profit when there is a positive externality between the number of consumers and the private valuation of each individual consumer (i.e. a network externality)? And if

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\(^1\) The optimal level of illegal activity has been extensively studied in the literature on law and economics. See Kaplow (1990); Polinsky and Shavell (1992); and Shavell (1991). Garoupa (1997) provides a survey of the literature.

\(^2\) Network effects or network externalities occur among customers of a product whenever the value of the product to one customer increases when more customers use the product. The idea was initially developed by Katz and Shapiro (1985).
allowing piracy can raise profits what are the minimal requirements for this to occur? In other words, is ‘profitable piracy’ a myth and, if not, when will it be observed?

Understanding the case for ‘profitable piracy’ is important because it flies in the face of observed business behavior. The piracy of intellectual property and illegal copying of copyright material is a major issue in international commerce and relations. Companies are developing and adopting sophisticated anti-piracy technologies to protect their copyright material. For example, music and video companies have introduced new protection devices to prevent copying of their product by computer. Sony has recently begun selling digital televisions with a Digital Video Interface that limits home recording. Piracy concerns have led to tighter laws and high profile court cases. The most prominent of these is the legal action against the music-sharing company, Napster. The Digital Millenium Copyright Act in the US has been used to prosecute a Russian programmer and Elcomsoft, his employer, for writing software that circumvents security procedures in Adobe e-books. If breaching copyright and piracy of IP can be profitable, then why are firms spending so much time and effort trying to reduce it?

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3 For example, the United States has put considerable diplomatic pressure on China to reduce software piracy. See asia.cnn.com “China urged to intensify piracy crackdown”, January 23, 2002. Also The Economist, “The politics of piracy”, February 18, 1999.

4 John Davidson, “CD buyers have been Dion like a dinner”, Australian Financial Review, April 23, 2002.


6 While much of the concern relates to software, music and video, these are not the only types of intellectual property that face piracy concerns. For example, the Canadian Hydrographic Service (CHS) successfully convicted an individual for illegally copying, selling and distributing CDs containing copyrighted nautical charts (Fisheries and Oceans Canada, “Illegal copying of nautical charts ends in conviction” News Release, February 16, 2000). The Associated Press (August 1, 2000, “An Emerging Pattern Needlepoint Industry Latest Online Copyright Battlefield”) reported growing piracy in needlepoint patterns.
To understand the relationship between ‘profitable piracy’ and network externalities, consider a simple application from the standard literature on price discrimination. Suppose there are two consumer groups – customers with a high willingness-to-pay for the relevant product (high-type customers) and customers with a low willingness-to-pay (low-type customers). If a seller is unable to price discriminate between the two groups and there are relatively few customers with a low willingness-to-pay then (even in the absence of piracy) profit maximization can involve the seller setting a price above the maximum willingness-to-pay of the low-type customers. Lowering the price to sell to some of the low-type customers means lowering the price to all customers and while sales will rise, profit can fall. Now, suppose that (a) there is a network externality so that high-type customers are willing to pay more if low-type customers also have the product and (b) the low-type customers can pirate the product but the high-type customers cannot pirate. It then pays the seller to allow all low-type customers to pirate the product even if piracy could be freely prevented. After all, the customers who pirate the product were not going to buy it anyway, while increasing the customer base raises the willingness-to-pay of non-pirates. The seller can allow piracy, increase prices and raise profits. Piracy is profitable.

This simple interaction between price discrimination and piracy lies at the heart of the papers by Conner and Rumelt (1991), Takayama (1994) and Slive and Bernhardt (1998). It is based on four specific assumptions:

- Customers have a differential ability to pirate;

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7 Varian (1989) provides a survey of the relevant literature.

8 The interaction in Conner and Rumelt (1991) differs slightly from the other papers. In particular, Conner and Rumelt do not that the ability to pirate is inversely correlated with customer willingness-to-pay. The Conner and Rumelt model shows that there exists a large enough network externality so that it is desirable to allow those customers most capable of pirating to pirate. However, the logic is still based on simple price discrimination and the four assumptions given below in the sense that piracy allows the seller to selectively provide the product to some potential buyers (including some who would not otherwise buy the product) and if the feedback to purchasers’ product demand is sufficient, then piracy can be profitable.
• The seller does not have an ability to directly price discriminate between different customers;

• The number of potential pirates is relatively small; and

• The ability to pirate is inversely correlated with customer willingness-to-pay.

In this paper we develop a simple model to show that these four assumptions are not simply convenient but are necessary for piracy to be profitable. If any one of these four assumptions breaks down then the argument for profitable piracy can fail. In other words, not only is the simple price discrimination logic one way for a single firm to make piracy profitable in the presence of network externalities, it is the only way that piracy can be profitable.9

Our model involves two types of customers, each characterized by a distribution of consumer values and ability to pirate. The seller can freely prevent piracy.10 There is a network externality in that consumers’ values are rising in the number of people who have the product. In this framework we show:

1. If customers are ex ante identical then allowing piracy can never raise profits;

2. If some customers have a greater ability to pirate but the seller can price discriminate between customers then allowing piracy can never raise profits;

3. If some customers have a greater ability to pirate, the seller cannot price discriminate, but the ability to pirate is independent of willingness-to-pay, then allowing piracy can never raise profits;11

9 As noted above, our focus is on the case for profitable piracy for a single firm in a static market with customer network externalities. We do not analyze the strategic benefits of piracy or the time-commitment benefits of piracy considered by Shy and Thisse (1999) and Takayama (1997) respectively.

10 This simply avoids having ‘optimal’ piracy because it is too costly to prevent all piracy.

11 Although the seller may maximize profits by setting a zero price for some customers.
4. If some customers have a greater ability to pirate, the seller cannot price discriminate, the ability to pirate is inversely related to the willingness-to-pay, and there are sufficiently few potential pirates, then allowing piracy can raise profits. However, in this case, the seller will allow piracy by all potential pirates, even though they may differ \textit{ex post} in their ability to pirate and their willingness-to-pay. There is no profit maximizing equilibrium where some potential pirates buy the product while others pirate the product.

This paper makes a number of contributions. It clarifies the relationship between ‘profitable piracy’ and network externalities that have emerged in the literature. In particular, by establishing the minimal conditions for profitable piracy in a simple model, we allow both a better theoretical understanding of profitable piracy and provide pointers for empirical analysis of industry. In doing this, we resolve the apparent conflict between ‘profitable piracy’ and the strong reactions of many firms against copyright violation and IP piracy in industries where we would expect network externalities to be present.

Our work joins a number of others who have questioned the ‘profitable piracy’ claims. Hui and Png (2001) estimate the relationship between the demand for music CDs and piracy. While they find that the effect of piracy on music sales is lower than industry claims, their results also suggest that piracy has, overall, an adverse impact on music companies. Tze and Poddar (2001) develop a model where firms can either completely eliminate piracy or allow a rival firm to sell an imperfect copy. In their framework, allowing piracy is never desirable. Their model is not, however, designed to capture the simple price discrimination logic that underlies the claims of profitable piracy. In this sense, their results go too far to dismiss profitable piracy. Rather, we show that piracy can be profitable, but only in highly specific circumstances when it simply reflects well-known results regarding price discrimination.

The remainder of this paper is organized as follows: the next section develops the model of piracy. Two further sections then analyze the potential for profitable piracy when price discrimination is and is not possible. A final section concludes.
2 A model of piracy and give-aways.

The monopoly owner of an item of intellectual property (IP) can realize and sell that IP by selling a particular product. The product might, for example, be computer software or recorded music. Standard IP laws that prevent illegal copying or other forms of ‘piracy’ that undermine the owner’s IP rights protect the product. For simplicity we assume that the marginal cost to the owner of producing the product is zero.\(^{12}\)

We present the model by first considering the different types of customers faced by the IP owner, the alternatives for software prevention, the formal timing of moves and then the characterization of equilibrium.

2.1 Customers

The IP owner faces a population of potential customers. For convenience, we normalize the size of this population to unity. Within this population, there are two classes of customers, called groups \(A\) and \(B\). A proportion of the population \(\lambda \in [0,1]\) belongs to group \(A\) while the remaining proportion \(1 - \lambda\) belongs to group \(B\). The owner sets a price for the product to each group of customers. We denote the price to customers in group \(A\) by \(p_A\) and the price to customers in group \(B\) by \(p_B\). If the owner can determine a customer’s group \textit{ex ante} then the owner can set group specific prices for the product so that \(p_A\) and \(p_B\) can be set independently. If the owner cannot determine a customer’s group \textit{ex ante} then group-specific price discrimination is impossible and the owner must set \(p_A = p_B\).\(^{13}\)

The two groups differ by (1) their expected willingness-to-pay for the product; and (2) their potential to engage in activities that undermine IP protection. Any particular consumer will choose to buy the product only if (a) they prefer buying the product to an

\(^{12}\) For both music recordings such as CDs or computer software, the relevant marginal cost is very low.

\(^{13}\) Other than a customers group, the owner never has any other customer specific information.
alternative option that might undermine IP protection and (b) given the price faced, the consumer expects to gain a value from the product that is at least as high as the price.

### 2.1.1 Customers’ value and the network externality

First, consider customers’ willingness-to-pay. We assume that each group of customers involves a continuum of consumers and that each consumer has an ‘intrinsic’ or personal value for the product, $v$. For group $A$, $v$ is distributed uniformly on $[0, 1]$ while for group $B$, $v$ is uniformly distributed on $[0, \eta]$ where $\eta \leq 1$.\(^{14}\)

The actual value that a customer receives from consuming the product depends on both their personal value of the product and on a network externality. The approach to customer value adopted here embodies a simple form of network externality that arises from a matching model.\(^ {15}\) After deciding whether or not to purchase the product, each consumer is randomly matched with one other consumer. For any matched pair, if both consumers have the product then they each receive their individual values. But if one of the consumers does not have the product then neither that consumer nor the consumer that they are matched with, receive any value.

Suppose that each consumer expects that $N$ individuals in total will have the product (either by purchasing the product or pirating the product). Then from an individual consumer’s perspective, the probability that they will be matched with another individual who has the product is given by $N$. In other words, given that we have

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\(^{14}\) This structure allows us to vary the degree of correlation between ability to pirate and personal value. Suppose customers in group $B$ are more likely to pirate the product than customers in group $A$. Then if $\eta = 1$ there is no difference in expected valuation between the members of group $A$ and group $B$ so that expected customer value and piracy are uncorrelated. If, however, $\eta < 1$, then ability to illegally copy and expected customer valuation are inversely correlated. As we show below, the degree of correlation, as captured by $\eta$, is critical to the owner’s incentives to allow either piracy or give-aways of the product.

\(^{15}\) Most of the existing literature on piracy includes an *ad hoc* network externality by simply adding a term to each customer’s willingness-to-pay that increases in the number of buyers. In contrast, our model derives the interaction between the externality and willingness-to-pay endogenously.
normalized the population size to unity, $N$ is both the number of consumers who have the product and the proportion of the population who have the product. Thus, \textit{ex ante} a consumer with personal value $v$ only expects to receive value $vN$ if they purchase the product.$^{16}$

In summary any consumer’s actual value from consuming the product depends both on their personal value and on the number of other consumers who own the product, $N$. A specific consumer’s individual benefit from consuming the product is given by $vN$. Thus a consumer from group $A$ will only ever buy the product if $vN \geq p_A$ and similarly for a consumer in group $B$.

\subsection*{2.1.2 Customer piracy}

A customer will only buy if they expect to gain benefit from the purchase and if they prefer purchasing the product to undertaking another activity that enables them to obtain the product. For example, in the case of software, a customer might have the ability to copy the software and they will only buy the product if they prefer legitimate purchase to piracy. Alternatively, the producer might decide to give away a specified number of units of the product. A consumer will not purchase if they receive the identical product for free.

We assume that customers in group $A$ are never able to gain the product except through purchase. In contrast, if it is possible to gain the product other than by purchasing, such as through piracy or an owner-sanctioned product ‘give-away’, then this option will be available to customers in group $B$. In the literature, this division of customers is justified as representing different groups, such as business and home users of software. See for example Slive and Bernhardt (1998).

\footnote{This type of network externality is particularly relevant for products that involve the sharing of system-specific information such as computer software or video games. It should be noted that the value of $N$ is not just the number of people who purchase the product, but rather the number who have gained access to the product either through purchase or other means, such as illegal copying. Note that in our framework a pirated version of the product is equivalent to a purchased version. There is no degradation of pirated copies that might make pirating less desirable for customers.}
As noted in the introduction other papers have analyzed piracy where it is costly for the IP owner to perfectly protect their product. Our aim here is to show if and when limited piracy might be desirable for the owner even when piracy can be freely prevented. Thus we allow the owner to freely set any level of protection for the software between zero and unity. We denote this value by $c$ where $c = 0$ means that any consumer in group $B$ is able to gain the product by copying at no personal cost while $c = 1$ means that no consumer can pirate the product. An intermediate value of $c$ means that a proportion $(1 - c)$ of customers in group $B$ will be able to pirate the software, and hence will not buy the product, while the remaining customers in group $B$ only have the option of buying the product.\(^\text{17}\)

For example, with computer software, the value of $c$ can represent the degree of encryption. A low value of $c$ represents a product that can easily be copied and used on different machines. A high level of $c$ might represent machine-specific registration, where even a licensed user can only use the software on one machine at a time and where internet registration with computer specific details are required. Such high level encryption has been used by software such as Mathematica and, more recently, for Windows XP.

Our approach can also be used to consider a product give-away. The owner can set $(1 - c)$ as the proportion of group $B$ customers who will receive a free copy of the product. As the marginal cost of each unit is zero, setting a low value of $c$ has no direct cost to the owner. Of course, it has an indirect cost to the degree that it reduces the pool of potential buyers.

\(^{17}\text{In other words, we can think of consumers in group } B \text{ as having two characteristics, their personal value and their ability to pirate software. Consumers in group } B \text{ are uniformly distributed over } [0, \eta] \times [0, 1] \text{ where an individual consumer has characteristics } (v, C). \text{ A consumer can only illegally copy the software if, from their perspective, it is ‘easy enough’, i.e. } c < C. \text{ Thus, given the value of } c \text{ set by the owner of the product, a proportion } (1 - c) \text{ of consumers in group } B \text{ will pirate the product while the others will only have the option of buying the product.} \)
2.1.3 Timing

The formal timing of the game is as follows.

At t=1: The owner of the product simultaneously sets both the degree of product protection \( c \) and the prices for each customer group, \( p_A \) and \( p_B \). Also a proportion \( (1-c) \) of group \( B \) customers gain the product at no cost to themselves through either piracy or a give-away.

At t=2: The group \( B \) customers who do not have the product and the group \( A \) customers simultaneously choose whether or not to buy the product.

At t=3: All consumers are matched in randomly chosen pairs. Customers allocated to pairs where both consumers have the product receive a payoff of their personal value less the purchase price (if any). Customers allocated to pairs where at least one consumer does not have the product receive a payoff zero less the purchase price (if any). The owner receives a payoff given by total profit which is simply the sum of the profit that he or she makes on sales to each group of customers.

2.1.4 Prices and equilibrium

Before we can analyze the optimal strategy for the owner, we need to consider how the prices set by the owner will affect sales. Given their belief about the number of people who will gain the software, \( N \), a consumer from group \( A \) will only purchase the software if \( p_A \leq vN \). Thus, given the price faced by a group \( A \) customer, we can define a critical personal value \( \theta_p \) such that \( p_A = \theta_p N \). This critical value represents the cut-off for consumers who will buy the product. A member of group \( A \) whose personal value is at least \( \theta_p \) will purchase the product while a member whose personal value is less than \( \theta_p \) will not buy. We can similarly define \( \theta_{\bar{p}} \).

For any set of prices chosen by the IP owner, the existence of network externalities leads to multiple equilibria. To see this, note that for any positive price levels, \( \theta_p = \theta_{\bar{p}} = 0 \) is always a potential equilibrium outcome. A customer only gains utility if he or she is matched with another customer who also has the product. As such, if everyone believes that no-one else will purchase, then it is always individually optimal
not to purchase. The belief that no-one will purchase is consistent and individually optimal so long as the price faced by the customer is positive. Clearly, the IP owner can never make positive profits in the face of such an equilibrium.

Multiple equilibria arise because the IP owner can only set prices, and cannot directly set the critical values \( \theta_p \) and \( \theta_g \). Rather, it is the price(s) together with the beliefs of customers that will determine the equilibrium outcome. In this paper we will only consider the stable ‘fulfilled expectations’ equilibria (Economides, 1996). In other words, we will only consider those equilibria where consumer expectations are satisfied in equilibrium and where the equilibrium is ‘stable’ to small changes in consumers’ expectations.
3 Piracy and give-aways with a single customer group

We begin our analysis by considering the case of a single group of customers. Hence, we consider the ‘extreme values’ of \( \lambda = 0 \) and \( \lambda = 1 \).

When \( \lambda = 0 \) (i.e. no type-A customers) all customers have the potential to either pirate the IP product or to receive a product give-away. This situation provides a useful base-case. If it is optimal for the IP owner to either allow piracy or to give the product away in this situation, then it seems likely that such free provision of the product will remain optimal when there are some ‘type-A’ customers. Further, it could be claimed that allowing some otherwise identical customers to receive the product for free might be optimal in the presence of network externalities. In fact, for the simple network externality analyzed here, the claim is false. As proposition 3.1 shows, if the IP owner only faces one type of customer, allowing some customers to freely gain the product is never profit maximizing.

**Proposition 3.1.** If \( \lambda = 0 \) then it is profit maximizing to set \( c = 1 \).

**Proof:** In the fulfilled expectations equilibrium, the IP owner sets \( \theta_0 \) indirectly by setting the product price. If \( \lambda = 0 \) then the IP owner’s profit is

\[
\pi = p_h \frac{c}{\eta} (\eta - \theta_0). \quad \text{But} \quad p_h = \theta_0 N \quad \text{where the number of consumers who have the product in equilibrium is} \quad N = \frac{1}{\eta} [\eta - c\theta_0].
\]

Thus, when \( \lambda = 0 \) the IP owner will set \( c \) and \( \theta_0 \) to maximize profit, \( \pi = \frac{Nc\theta_0}{\eta} (\eta - \theta_0) \), subject to \( N = \frac{1}{\eta} [\eta - c\theta_0] \).

Noting that it can never be profit maximizing to set \( \theta_0 \) equal to either 0 or \( \eta \), or to set \( c \) equal to 0, the first order conditions for the IP owner’s problem with respect to \( \theta_0 \) and \( c \) respectively are given by:

\[
\frac{\pi}{\eta} \left( N (\eta - \theta_0) + \gamma - N\theta_0 \right) = 0 \quad \text{and} \quad \frac{\partial \pi}{\eta} \left( N (\eta - \theta_0) + \gamma \right) = 0 \quad (> 0 \text{ if } c = 1)
\]

where \( \gamma \) is the Lagrange multiplier on the population constraint.
From the first order condition for $\theta_p$, $N(\eta - \theta_p) + \gamma > 0$. But substitution into the first order condition for $c$ shows that this condition is greater than 0 for all $c \in [0,1]$ so that $c = 1$ is optimal. Thus, when $\lambda = 0$ then it is profit maximizing to set $c = 1$.

If the IP owner only faces type-$B$ customers, then it is never optimal to allow either piracy or give aways. The intuition behind this result is simple. Allowing piracy or a give-away is just as likely to deliver the product to a high-value customer as it is to a low-value customer. The effect of losing the ability to charge such a customer more than outweighs any potential profit gains by raising value to other customers. In this situation, it is optimal to set $c = 1$. Substitution into the profit equation shows that the optimal value of $\theta_p = \frac{\eta}{2}$ with a price $p_B = \frac{3\eta}{5}$ and profit of $\frac{4\eta}{27}$. Two-thirds of customers buy the product in equilibrium.\(^{18}\)

An implication of proposition 3.1 is that, in the absence of costs of IP protection, piracy or give aways will only ever be observed if there are at least some members of both customer groups. If the population of potential buyers is identical in all respects then the simple existence of a pure network externality will not make it desirable for the IP owner to undermine her IP rights.

The case of $\lambda = 1$ trivially follows from the above. If there is only type-$A$ customers who never pirate, the profit maximizing outcome for the IP owner is to set $\theta_p = \frac{1}{3}$ with a price $p_B = \frac{2}{3}$ and profit of $\frac{4\eta}{27}$ and two-thirds of customers buy the product in equilibrium.

\(^{18}\) It is easy to confirm that this equilibrium is stable. The proofs of stability in both the cases presented in this section are identical to the proof given in Example 4.2.
4 Price discrimination between customer groups

We now consider the situation where the IP owner faces two distinct types of customer. There are two possibilities. The IP owner might be able to distinguish between the two customer groups and to set different prices for these customers. Alternatively the IP owner might be unable to price discriminate. We consider the first of these situations in this section. Section 5 then considers the case without price discrimination.

If the owner can set different prices for the two groups then need not equal . In this situation, setting equal to zero is equivalent to setting . In other words, the owner can price discriminate and can simply set a zero price for the product to group customers rather than, say, allowing all customers in group to illegally copy the product. As such, the situation where the IP owner allows all type-B customers free access to the product does not involve a diminution of IP rights. Rather, it simply reflects a zero price to a select group of customers.

Two questions arise:

1. Does the owner ever finds it optimal to allow meaningful piracy by group B customers or to have selective product give-aways, in the sense that both and ? Proposition 4.1 shows that such meaningful allowance of piracy or selective giveaways is never optimal for the owner.

2. Will the IP owner ever find it profitable to give away the product to all group B customers in the sense that it is profit maximizing to set ? Proposition 4.3 shows that if both the proportion of type-B customers and their maximum willingness to pay are sufficiently low, then it is optimal for the owner just to give the product to all customers in group B.

First consider the problem that faces the IP owner. Given the value of set by the owner, the total number of customers who will gain the product – either through purchase or through other means – is given by . The owner does
not sell to all of these people so that the owner’s profit is given by

\[ \pi = p_A \lambda (1 - \theta_B) + p_B (1 - \lambda) \frac{c}{\eta} (\eta - \theta_B) . \]

Note that whenever \( c < 1 \) some group-B customers will pirate the product. Substituting in for price, the owner will set \( c, \theta_B \) and \( \theta_B \) to maximize:

\[ \pi = \theta_B N \lambda (1 - \theta_B) + \theta_B N (1 - \lambda) \frac{c}{\eta} (\eta - \theta_B) \]

subject to:

\[ N = \lambda (1 - \theta_B) + (1 - \lambda) \left( \eta - c\theta_B \right) \frac{1}{\eta} \]

The first-order Kuhn-Tucker conditions for this maximization are given by:

\[ N \lambda (1 - \theta_B) - \theta_B N \lambda - \gamma \lambda = 0 \quad (> 0 \text{ if } \theta_B = 1; < 0 \text{ if } \theta_B = 0) \]

\[ N \frac{c}{\eta} (1 - \lambda)(\eta - \theta_B) - N \frac{c}{\eta} (1 - \lambda) \theta_B - \gamma \frac{c}{\eta} (1 - \lambda) = 0 \quad (> 0 \text{ if } \theta_B = 1; < 0 \text{ if } \theta_B = 0) \]

\[ \theta_B N (1 - \lambda)(\eta - \theta_B) \frac{1}{\eta} - \gamma \theta_B (1 - \lambda) \frac{1}{\eta} = 0 \quad (> 0 \text{ if } c = 1; < 0 \text{ if } c = 0) \]

where \( \gamma \) is the multiplier on the constraint.

**Proposition 4.1.** It is never optimal for the owner to set \( c \in (0,1) \) unless it is also optimal to set a zero price for all group B customers.

**Proof:** Suppose that the optimal value of \( \theta_B \) is strictly greater than zero, so that \( p_B > 0 \).

By the first order condition with regards to \( \theta_B \), if \( \frac{c}{\eta} (1 - \lambda) \neq 0 \) then

\[ N (\eta - 2\theta_B) - \gamma \neq 0 . \]

But, if \( N \neq 0 \), this implies that the first order condition with regards to \( c \) is always positive for \( c \in [0,1] \) (i.e. the optimal value of \( c \) is equal to one). As \( N = 0 \) cannot be profit maximizing as the owner makes no profit, this implies that either the optimal value of \( c = 1 \) with \( \theta_B > 0 \) or that the optimal value of \( \theta_B = 0 \). However, \( \theta_B > 0 \) requires that group B customers face a positive price. Thus, if it is optimal for the owner to set a positive price for the product, then the owner will optimally set \( c = 1 \). \( QED \)
Proposition 4.1 shows that when the owner can price discriminate between potential ‘pirates’ and other customers, then it is never desirable to allow any piracy. Rather it is always more profitable to sell to the potential pirates. In other words, while allowing limited piracy or selective ‘giveaways’ will raise the customer base and, with network externalities, can raise the price charged to buyers, such a strategy is always dominated by simply lowering the price to all members of group $B$. In this sense, selective diminution of IP rights is not an efficient way for an owner to exploit network externalities under price discrimination.

To see a specific example, suppose that $\eta = 1$. In this situation, the two customer groups are identical from the seller’s perspective, except that one group can pirate if this is allowed by the IP owner, while the other group can never pirate. From proposition 4.1, the IP owner will either want to set $c = 0$ or $c = 1$. Example 4.2 shows that the optimal solution involves never allowing type-$B$ customers to pirate.

**Example 4.2.** Suppose that $\eta = 1$. Then the profit maximizing solution for the owner is to set $c = 1$ with $p_A = p_B = \frac{2}{9}$ and two-thirds of all customers purchasing the product.

**Proof:** From proposition 4.1 we know that either $c = 0$ or $c = 1$ is optimal for the IP owner. First, suppose that $c = 1$ and $\theta_B > 0$. From the owner’s perspective, there is no difference between the two groups of customers and it is optimal to set $\theta_A = \theta_B = \theta$. To see this, note that the first order conditions for $\theta_A$ and $\theta_B$ are identical when $\lambda \in (0, 1)$. Further, $N = 1 - \theta$ and $\pi = \theta^2 (1 - \theta)^2$. Solving, $\theta = \frac{1}{3}$, $N^* = \frac{2}{3}$, $p_A^* = p_B^* = \frac{2}{9}$ and $\pi^* = \frac{4}{27}$.

Alternatively, suppose that $\theta_B = 0$, with either $c = 0$ or equivalently $p_B = 0$. The owner’s profit in this situation is given by $\pi = \theta^2 (1 - \theta) + \lambda (1 - \theta^2)$. Taking the derivative with regards to $\lambda$, $\left(\frac{\partial \pi}{\partial \lambda}\right) = \theta^2 (1 - \theta)$ which is strictly positive for $\theta^2 \in (0, 1)$. The optimized value of $\theta_B$ must lie between zero and unity for positive profit, so we know that the owner’s maximum profit is strictly increasing in $\lambda$. But, if it were possible to have $\lambda = 1$, then the firm would face...
just one type of consumer with no piracy or give away. The owner’s optimization problem in this case is identical to the case of \( c = 1 \) and \( \theta' > 0 \) and the owner would gain maximized profit of \( \pi^* = \frac{4}{27} \). Thus the owner’s profit when \( \theta' = 0 \) is bounded below \( \left( \frac{4}{27} \right) \).

As the owner always makes less profit by setting \( \theta' = 0 \) rather than by setting \( c = 1 \) and \( \theta' > 0 \), the owner will always prefer to set \( c = 1 \) and \( \theta' > 0 \). In this situation, the unique profit maximizing solution for the owner involves \( p_A = p_B = \frac{2}{9} \) and two-thirds of all customers purchasing the product. Finally, we need to show that this outcome is a stable equilibrium. Note that there are two other equilibria when the IP owner sets \( p_A = p_B = \frac{2}{9} \) and \( c = 1 \). First, there is an equilibrium where no customer buys. As noted in section 2, this outcome is always an equilibrium of the game. Second, there is an equilibrium where one-third of all customers purchase the product. In this case \( \theta_0 = \frac{2}{3}, N^e = \frac{1}{3} \) and \( \pi^* = \frac{2}{27} \).

To test for stability, note that for the marginal consumer who buys from group \( A \), \( \theta'_e = \frac{P_A}{N^e} \) where \( N^e \) is the expected total number of buyers and this expectation is correct in equilibrium. Given that \( c = 1 \) and both types of consumer face the same price in this example, we can write \( \theta_e = \frac{P}{1 - v^e} \) where \( v^e \) is the expected value of the marginal consumer and \( \theta \) is the actual value of the marginal consumer. In equilibrium these two values coincide. An equilibrium will be stable if a small change in the expected value \( v^e \) leads to a smaller change in the actual marginal value \( \theta \). The opposite is true for an unstable equilibrium. Noting that \( \frac{\partial \theta_0}{\partial v^e} = \frac{p}{(1 - v^e)^2} \) and substituting in for the equilibrium values it is easy to confirm that the profit maximizing equilibrium with two-thirds of consumers purchasing the product is stable. In contrast, the equilibrium with only one-third of consumers purchasing the product is unstable. Hence, of those equilibria where some consumers purchase the product, the stable profit maximizing equilibrium has \( c = 1 \) with \( p_A = p_B = \frac{2}{9} \) and two-thirds of all customers purchasing the product.

QED
With price discrimination, the IP owner will always prefer to use differential pricing rather than allow for a diminution of IP rights through either piracy or selective give-away to some type-B customers. But does the owner ever wish to give-away the product to all type-B customers, by setting a zero price to these customers? Proposition 4.3 shows that if both the number of group B customers is sufficiently small, and the value that they place on the product is relatively low, then it is optimal to simply give all type-B customers the product. The benefits of ownership by that group – in the sense of increasing the willingness-to-pay of other customers – makes it desirable for all members of group B to freely gain the product.

**Proposition 4.3.** Given the proportion of group A members in the population, \( \lambda \), it is optimal for the owner to set a zero price to members of group B if the maximum willingness-to-pay of members of group B, \( \eta \), is less than

\[
\frac{1}{3\lambda} \left( \lambda - 2 + 2\sqrt{\lambda^2 - \lambda + 1} \right).
\]

**Proof:** From proposition 4.1, we can simply consider the situation where \( c = 1 \). Substituting this into the population of consumers, \( N \), gives profit level

\[
\pi = \left[ \lambda (1-\theta) + (1-\lambda) \frac{1}{\eta} (\eta - \theta) \right] \left[ \frac{\theta \lambda (1-\theta) + \theta (1-\lambda) \frac{1}{\eta} (\eta - \theta)}{\theta} \right].
\]

Taking first order conditions with regards to critical values, note that if the optimal \( \theta \) is equal to 0 (i.e. the optimal price to type-B consumers is zero) then

\[
\frac{\partial \pi}{\partial \theta} < 0.
\]

This implies that

\[
\left[ \frac{\theta \lambda (1-\theta) + \theta (1-\lambda) \frac{1}{\eta} (\eta - \theta)}{\theta} \right] \left[ \frac{\lambda (1-\theta) + (1-\lambda) \frac{1}{\eta} (\eta - \theta)}{\theta} \right] \left[ \eta - 2\theta \right] < 0.
\]

Noting that it can only be optimal to set a zero price for members of group B if members of group A face a positive price and some type-A customers buy the product, it can be seen that \( \frac{\partial \pi}{\partial \theta} < 0 \) is only consistent with \( \frac{\partial \pi}{\partial \theta} = 0 \) if

\[
(\eta - 2\theta) < (1-2\theta).
\]

Substituting in \( \theta = 0 \) gives \( \eta < 1-2\theta \).

Substituting \( \theta = 0 \) into the first order condition for \( \theta \), solving for \( \theta \) and noting that the optimal value of \( \theta \) must lie strictly between zero and unity, we find that
\[ \vartheta_\theta = \frac{1}{3\lambda}(1 + \lambda - \sqrt{\lambda^2 - \lambda + 1}) \]  
Substituting back into the equation for \( \eta \) gives  
\[ \eta < \frac{1}{3\lambda}\left(\lambda - 2 + 2\sqrt{\lambda^2 - \lambda + 1}\right) \] 
as required. \[ \text{QED} \]

For a given value of \( \lambda \) we can define the critical value of \( \eta \), denoted \( \eta_c \), by  
\[ \eta_c = \frac{1}{3\lambda}\left(\lambda - 2 + 2\sqrt{\lambda^2 - \lambda + 1}\right) \] 
Hence, given \( \lambda \), if \( \eta < \eta_c \) then the IP owner will set \( p_B = 0 \). Otherwise, the IP owner will set \( c = 1 \) so that there is no piracy and \( p_B > 0 \).

By L’Hôpital’s rule, as \( \lambda \) approaches zero, \( \eta_c \) also approaches zero. Also, as \( \lambda \) approaches one, \( \eta_c \) also approaches one-third. Table 4.4 presents values of \( \eta_c \) for other values of \( \lambda \).

<table>
<thead>
<tr>
<th>( \lambda )</th>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.8</th>
<th>0.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \eta_c )</td>
<td>0.026</td>
<td>0.055</td>
<td>0.086</td>
<td>0.12</td>
<td>0.15</td>
<td>0.19</td>
<td>0.23</td>
<td>0.26</td>
<td>0.30</td>
</tr>
</tbody>
</table>

As expected, \( \eta_c \) increases as \( \lambda \) increases. In other words, as the proportion of group B customers in the population falls, the IP owner is willing to set a zero price for these customers even if they have a higher maximum willingness-to-pay. As they make up a smaller fraction of the population, the foregone income from setting a zero price to group B customers falls as \( \lambda \) rises while the importance of the network effect on group A customers from any group B customer gaining the product tends to rise.

In summary, proposition 4.1 shows how price discrimination can dominate either ‘give aways’ or piracy even with the presence of network externalities. Price discrimination is a substitute for piracy or give-aways but also generates revenue for the IP owner. Thus, if some customers have a greater ability to pirate but the seller can price discriminate between customers then allowing piracy can never raise profits.
5 No price discrimination

In the absence of price discrimination, the owner must set a single price to both groups of customers, so that $\theta_A = \theta_B = \theta$. Again, our interest here is on whether it is ever optimal for the owner to allow (in a non-trivial situation) some, but not perfect, copying of the product.

It is obvious that if $\eta$ is sufficiently small, then the owner will set $c = 0$. There are two reasons that relate to this. The first reason is standard price discrimination. If there are two groups of customers but the owner can only set a single price then, as one customer group’s willingness-to-pay falls sufficiently low, it is profit maximizing to just serve the other group. Thus, for $\eta$ sufficiently small, the owner will set a price $p > \eta$ and no members of group $B$ will buy. The second reason involves network externalities. If the owner decides not to serve group $B$ then it is always optimal to simply give all group $B$ customers the product by setting $c = 0$. This does not affect costs or revenue but does raise the price that the owner can charge group $A$ customers, and so raises maximum profit.

We are interested in situations where the owner does, in fact, serve both groups of customers but allows some piracy. As such, we limit attention to those situations where $\eta$ is sufficiently large so that it is profit maximizing for the owner to make some sales to group $B$ customers. Thus, in what follows, we consider situations where the profit maximizing price, $p$, leads to a critical value $\theta_p \in (0, \eta)$. We are interested in non-trivial levels of piracy in the sense that it is optimal for the IP owner to set $c \in (0,1)$. Proposition 5.1 however shows that this is never profit maximizing. In other words, if it is profit maximizing for the IP owner to make sales at a positive price to both types of customer then she will never allow any piracy. As such the profit maximizing solution for the IP owner will be to either prevent all piracy or to allow all type-B customers to receive the product for free, either through piracy or a give-away.

In the absence of price discrimination, the owner will set $\theta = \theta_A = \theta_B$ and $c$ to maximize $\pi$ subject to $N = \lambda (1 - \theta) + (1 - \lambda) (\eta - c \theta) \frac{\lambda}{\eta}$. Substitution gives
\[ \pi = \frac{\eta}{\sigma} \left( \eta - c v + (c - \eta) \lambda v \right) \left( c (1 - \lambda) (\eta - v) + \eta \lambda (1 - v) \right) \]

where \( c \in [0, 1], v \in (0, \eta) \) and \( \eta \in [0, 1] \).

The first order conditions are:

\[ \frac{1}{\eta} \left( c \theta (3 \theta - 2 \eta) (\lambda - 1)^2 + \eta \lambda (1 + 3 \theta \lambda - 2 \theta (1 + \lambda)) - c \eta (\lambda - 1) (\eta + 6 \theta \lambda - 2 \theta (1 + \lambda + \eta \lambda)) \right) = 0 \]

and

\[ \frac{1}{\eta} \left( (\theta (\lambda - 1) (2 \theta (\theta - \eta) (\lambda - 1) + \eta (\theta - \eta + \theta (1 - 2 \theta + \eta))) \right) = 0 \quad (> 0 \text{ if } c = 1, < 0 \text{ if } c = 0) \]

**Proposition 5.1.** It is never optimal for the owner to set \( c \in (0, 1) \) when setting a price such that \( v \in (0, \eta) \).

**Proof:** We prove this by contradiction. By assumption the optimal price results in \( v \in (0, \eta) \). Suppose it is optimal to set \( c \in (0, 1) \). Then by the first order condition for \( c \),

\[ c = \frac{\eta (v \lambda + 1 - 2 v \lambda) + \eta (v \lambda - 1)}{2 v (\eta - v) (\lambda - 1)} \]

Substituting into profit and taking derivatives with regards to \( v \) gives:

\[ \frac{\partial \pi}{\partial v} = -\frac{1}{4 (v - \eta)^2} \left[ (v - \eta + v (\eta - 1) \lambda) (v - \eta + (v - 2 \eta) (\eta - 1) \lambda) \right] \]

and

\[ \frac{\partial^2 \pi}{\partial v^2} = \frac{(\eta - 1)^2 \eta^2 \lambda^2}{2 (\eta - v)^3} \] But note that the second order derivative is strictly positive for all \( v \in (0, \eta) \), so that the optimal price results in a value of \( v \) outside our assumed range (either \( v = 0 \) or \( v \geq \eta \)). Thus, we have a contradiction and if the owner sets a price such that \( v \in (0, \eta) \) it cannot be optimal to simultaneously set \( c \in (0, 1) \). \( QED \)

Proposition 5.1 shows that it is inconsistent with profit maximization for an IP owner to simultaneously sell some product to type-B customers and allow some type-B customers to either pirate the product or receive a give-away. Consider the intuition behind this result. First, suppose that there are only type-B customers. It follows directly from proposition 3.1 that it is never optimal to allow any piracy. Now, suppose that the relative number of type-B customers falls. From the IP owner’s perspective, all type-B
customers are *ex ante* identical. Suppose that it is worthwhile giving the product to one

type-B customer. This might be profitable because it raises the willingness-to-pay of the

remaining type-B customers and the type-A customers. But the IP owner cannot ‘choose’
a type-B customer with a low personal value for the give-away. The IP owner is just as
likely to give the product to a type-B customer with a relatively high value as one with a
relatively low value. It is because of this that proposition 3.1 showed that it is never

optimal to give away the product to a member of one customer group in order to raise the
value of the product to other members of the same customer group. In other words,

section 3 showed that it can only be worthwhile to give away the product to one member
of group-B then if this raises profit by raising the willingness-to-pay of type-A customers.

As such, if it is worthwhile to give the product away to one type-B customer, this must
reflect that the cost of the lost type-B customer is more than offset by the rise in the

willingness-to-pay of type-A customers. However, as all type-B customers are *ex ante*
identical, if such a give-away is desirable for one member of group B then it must be
desirable for all members of group B. The IP owner either allows all group B customers
free access to the product – by either a give away or by a lack of protection against piracy
– or requires all members of group B to pay for the product. There is no profit-

maximizing ‘intermediate’ case where some type-B customers pay and others do not.

We would expect that as either the maximum willingness-to-pay by group B falls
or the proportion of customers who are in group B falls, it is more likely to be profit
maximizing to allow free access to the product to type-B customers. Consider for any
value of $\lambda$ the critical value of the maximum willingness-to-pay of group B, denoted by
$\eta_c$, such that for any lower maximum willingness-to-pay it is optimal to allow all type-B
customers free access to the product. While $\eta_c$ can only be implicitly defined, the table
5.2 presents a variety of values of $\eta_c$ for different population proportions.\footnote{Table 5.2 is constructed by calculating the IP owner’s profit when $c = 0$ and $c = 1$ and then determining the value of $\eta_c$ that equates these two profits given $\lambda$.}

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\footnote{Table 5.2 is constructed by calculating the IP owner’s profit when $c = 0$ and $c = 1$ and then determining the value of $\eta_c$ that equates these two profits given $\lambda$.}
Table 5.2

Critical values of $\eta_c$ without price discrimination

<table>
<thead>
<tr>
<th>$\lambda$</th>
<th>0</th>
<th>0.01</th>
<th>0.1</th>
<th>0.25</th>
<th>0.5</th>
<th>0.75</th>
<th>0.85</th>
<th>0.99</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\eta_c$</td>
<td>0</td>
<td>0.0166</td>
<td>0.147</td>
<td>0.307</td>
<td>0.481</td>
<td>0.592</td>
<td>0.625</td>
<td>0.664</td>
</tr>
</tbody>
</table>

Table 5.2 shows that, as expected, when type-B customers make up a relatively smaller proportion of the population, the IP owner is more likely to allow all of these customers to violate IP rights and pirate the product. Similarly, if we read the table the other way, if the type-B customers are less willing to pay for the product, then it is profit maximizing to let them gain the product for free even if they are a more substantial proportion of all customers.

Comparing table 4.4 and table 5.2, the critical values of $\eta$ tend to be higher for any given value of $\lambda$ when there is no price discrimination than when price discrimination is possible. In both cases, when $\eta$ is below the critical value the type-B customers gain the product at no cost. But without price discrimination, if the IP owner wants to sell to type-B customers as $\eta$ falls, then this involves lowering the price to all customers rather than just to type-B customers. Hence, in the absence of customer-group specific pricing, allowing a give-away or piracy becomes profitable ‘sooner’ than if the IP owner can selectively lower the price to type-B customers.

In summary, if price discrimination is not possible, then a firm might allow piracy. But the conditions for this are stringent. In particular the ability to pirate must be inversely related to the willingness-to-pay and there must be sufficiently few potential pirates, before allowing piracy can raise profits. Even under these conditions, however, there is no profit maximizing equilibrium where some potential pirates buy while others pirate the software. In equilibrium, either all type-B consumers pirate the product or none of these consumers pirate the product.
6 Conclusion

In this paper we have developed a simple model to analyze the proposition that, in the presence of network externalities, a firm’s profits can increase if that firm allows some consumers to undermine the intellectual property rights associated with the firm’s product. We have shown that the concept of ‘profitable piracy’ depends critically on certain assumptions about both the customers’ and the firm’s behavior. In particular, piracy, from the perspective of a single firm, is always dominated by price discrimination. If the firm can differentiate customer prices on the basis ability to pirate, then this is always preferred to allowing piracy. Price discrimination allows the firm to exploit any network benefits from spreading use of their product while also raising revenue. In this sense, piracy is, at best, an inferior alternative to price discrimination.

We also showed, even in the absence of price discrimination, that piracy provides a very ‘blunt instrument’ for the relevant firm. Piracy may be profitable, but if it is profitable to allow any customer to pirate then it is also profitable to allow all other similar customers to pirate. In this sense, piracy is more like an organized product ‘give way’ aimed at buyers with a low intrinsic value for the product. There is no non-trivial piracy in the sense that some low value consumers purchase and others pirate.

Our results show that the claims for profitable piracy must be carefully examined. The underlying logic behind profitable piracy is simply the logic of price discrimination. Unless there is a reason to believe that potential pirates will systematically value a product less than other buyers and that there are relatively few pirates, then allowing IP rights to be degraded will not be in a firm’s interest.
References:


