

Copyright Piracy as Prey-Predator Behavior

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Abstract

The economic analysis of the piracy of copyright products has used a variety of modeling assumptions, the majority of which are set in typical industrial organization settings. The results of such models are manifold, but in general they are ambiguous as to the optimal protection strategy, and the effects of protection on the welfare of copyright holders, and on the existence of piracy. Concretely, little has been said about which types of protection mechanisms are most adequate for controlling piracy. In the present paper, we depart from the traditional industrial organization type models, and we analyze piracy in a model that is very familiar to economic dynamics – the prey-predator model. In this model, we show that publicly instigated and financed policies designed to deter piracy can have the effect of increasing the amount of piracy, while privately financed strategies (e.g. DRM) will always decrease piracy.

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1 Introduction

The economic analysis of the piracy of copyright products has relied almost exclusively on industrial organization type models, in which copies compete with originals¹ for consumption dollars (for some recent examples of such models, see Shy and Thisse, 1999; Watt, 2000; Belleflamme, 2002; Hui and Png, 2003; Gayer and Shy, 2005; and Banerjee, 2006). These models typically introduce some type of heterogeneity between copies and originals, often defined as “quality”², and it is also common to model the production functions of copies and originals differently – for a start, copies save on the variable cost of the royalty payment to copyright holders.

Here, in contrast, we appeal to the “prey-predator” literature to model piracy. This literature typically considers two populations of species, one of which subsists by preying on the other. Starting from initial given populations, the predator species grows by depleting the population of the prey, but as that population depletes, since it is the source of sustenance of the predator population, the predator population itself will begin to deplete. This in turn leads to a resurgence of the population of the prey, which again leads to a new revival of the predator species. This cyclical behaviour will, in principal, continue *ad infinitum*. Now, consider the case of a market for a copyright protected products (such as music, movies or PC programs). We can associate with the producers of originals of these products the status of the prey species. If pirated versions of these goods also circulate in the market, then we shall associate with this second type of producer the status of

¹ Note that we use the now widely accepted terminology under which a copyrighted product that is marketed under proper license by the copyright holder is known as an “original”, while a product that is marketed without such license is known as a “copy”. Of course, a copy is an illegitimate, or illegal, product under copyright law, since the copyright holder does not perceive royalty payments from the sale of copies.

² A copy can be thought of as being of inferior quality to an original for many reasons, among which it is common to see the following; it will typically not come with a guarantee or after-sales service, it may involve a risk of a fine, and it may not come with the same quality packaging.

the predator species. The analogy between the market for copyright products and the predator-prey model is clearly not as direct as in other (biological) settings, where the predator physically consumes the prey. Copies do not directly consume or destroy originals, as copyright products are by nature public goods which are non-rival. But copies do deplete the market opportunities of originals, and if this results in a reduction in the activities of creators of new originals, then we would indeed get a depletion of the population of this species (or at least, in the growth rate of this population). More directly, the availability of pirate copies will, almost certainly, deplete the number of originals that are visibly noted as final sales to consumers, and so if we consider that the species “population” is measured by sales, then clearly the growth of the pirate copy species will deplete the original species. Also, the fact that copies cannot exist unless originals do, and the more originals there are the greater are the opportunities for copiers (and the less originals there are, the fewer are the opportunities for copiers), makes the original-copy setting appropriate for analysis using the prey-predator model.

Real-world data suggests that the prey-predator model may be applicable to the case of piracy of copyright products. There is now a wealth of empirical evidence to suggest that sales of music has followed a generally increasing path over the past decade or so, but that sales have recently slowed markedly and they have possibly even gone into a phase of negative growth (see, for example, Liebowitz, 2006, Zentner, 2006). At the same time, the growth of piracy of music has also been growing, and many authors have concluded that the downturn in legitimate sales is a direct result of the increase in piracy rates (Hui and Png, 2003; Peitz and Waelbroeck, 2004; Liebowitz, 2006, Zentner, 2006. For a survey of the literature on the effects of internet piracy on sales of music, see Liebowitz and Watt, 2006). Such a situation is typical of prey-predator behavior.

Aside from its empirical relevance, the great benefit from the use of the prey-predator model to analyse copyright piracy lies in the fact that its dynamical characteristics are very well known, and are quite easy to arrive at. As we shall see, we get particularly simple descriptions of the average populations of the two species, and we can then easily study the comparative statics of the model as certain parameters are altered. This allows us to consider, with minimal difficulty, the effects on the equilibrium average populations of such things as increases in copyright protection, increases in self-protection mechanisms (e.g. DRM), and other commonly used methods of reducing the levels of piracy.

The paper continues as follows. In the next section, we outline the specific model used, and we attempt to defend it as appropriate for the study of piracy of copyright products. Following that, we compute the equilibrium of the model, and then finally we consider some obvious comparative statics exercises. Section 4 provides some conclusions and recommendations for future research.

2 The Model

In order to keep things as simple as possible, we assume a very rudimentary demand for the copyright product in question. We consider our market to be for an entire category of copyright product, say “music” in general, rather than a specific LP, or a particular song. Let N_π denote the total number of potential consumers of the product when its price is π , that is, those individuals whose willingness to pay for these goods exceeds the value π . We will assume that the market is continuously offering new products within the category, and that any potential consumer can acquire these products, either as originals or as copies. We specifically assume that the prices of each type of product (originals and copies) are *fixed parameters*. Concretely, assume that the fixed price of originals is p and that the fixed price of copies is q . We make no specific assumptions about these

two parameters, although of course the most likely scenario is that $q < p$. Note that, in the interests of both simplicity and to highlight the workings of the prey-predator model, we specifically avoid attempting to model any type of relationship between the two prices p and q – indeed even if they were to be assumed variable with no direct relationship between them, our model would become significantly more complex (see footnote 5). We also make no attempt at all to model the way in which these prices are fixed, although we could simply assume that each variety of the product (originals and copies) are simply sold at marginal price times some fixed markup.³

We assume that an individual is a consumer of originals in instant t if he has bought one original product within the period $[t - h, t]$, for some $h > 0$ fixed. In the same way we will consider that an individual is a consumer of copies in instant t if he has bought one copied product within the period $[t - h, t]$. Note that it is possible that an individual can buy more than one good in any given interval $[t_0 - h, t_0]$, or even at a given instant t_0 . If this happens, that is, if an individual acquires C goods at t_0 , we will assume that he in fact counts as C different consumers at that point of time. Moreover, note that a individual can be a consumer of originals in one moment and a consumer of copies in another, or even a consumer of both originals and copies at the same time t_0 .

Let $x(t)$ denote the number of consumers of originals at instant t , and $y(t)$ the number of consumers of copies at t . Then $x(t) \in [0, N_p]$ and $y(t) \in [0, N_q]$, where N_p is the number of potencial consumers of originals at price p (they are willing to spend at least p to acquire an original version of the product), and N_q is the number of potencial consumers of copies at price q (they are willing to spend at least q to acquire a copied version of the product).

It is important to recall that N_p and N_q are the *maximum potential numbers* of consumers

³ The fact that copies are sold more cheaply than originals would then fit well with the fact that copies save on an important marginal cost – the royalty payment to copyright holders.

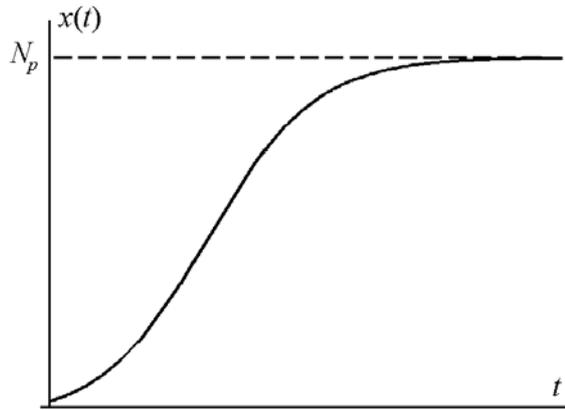


Figure 1: Logistic diffusion

of originals and of copies respectively. It is unlikely, in any real-world market, that the full potential is realized at the very first instant of sale, as is indeed the (implicit) assumption in almost any model of demand. Rather, sales grow over time as more and more potential consumers are captured as realized sales, and the rate at which this happens depends on such aspects as advertising, marketing, consumer education, availability of retail outlets, etc.. This aspect is very important to the present model, as the relationship between the two markets will be established in terms of the *growth rates* of the two variables $x(t)$ and $y(t)$, and not in terms of their absolute sizes.

Now, clearly the two markets – that for originals and that for copies – are not independent. They affect each other in a rather simple way, that is captured by looking at the rates of growth of the variables $x(t)$ and $y(t)$. Imagine for a moment that no market for copies existed. Then over time, it is reasonable to assume that the diffusion of originals, $x(t)$, would approach the value N_p from below. Specifically, let us assume a logistic diffusion process (an S-shaped growth with limit at N_p), as in Figure 1. Such a process corresponds to the rate of growth of x being given by:

$$\frac{\dot{x}}{x} = a(N_p - x)$$

Now we allow a market for copies to come into existence. The availability of a market

for copies provides an opportunity for consumers to purchase the product at a lower price, and as such it is bound to cause defection of some consumers from the market of originals to the market for copies. This effect can be simply captured by allowing the existence of a market for copies to have a negative effect on the growth rate of the diffusion of originals,⁴ i.e.:

$$\frac{\dot{x}}{x} = a(N_p - x) - by$$

Secondly, now that a market for copies is assumed to exist, consider the growth rate of $y(t)$. The market for originals feeds the market for copies with new material to copy, and so the more such new material that exists, the greater will be the growth rate of the diffusion of copies. Thus the growth rate of copies must depend positively on the value of x . Secondly, if there were no new material available (i.e. if the market for originals were to disappear, $x = 0$), then the growth rate of the diffusion of copies would be negative, until the diffusion of copies also fell to 0, which is a typical extinction process. Thus we assume that⁵

$$\frac{\dot{y}}{y} = -c + dx$$

⁴ We have made no specific assumptions about the exact relationship between the product that is available as an original and that which is available as a copy. They may be perfect substitutes, or there may be some sort of difference between them based on, for example, quality. If they were perfect substitutes, it is tempting to conclude that the existence of the copy market, where exactly the same product becomes available at a cheaper price, would immediately destroy any option of sales in the market for originals. However this is unreasonable from a real-world perspective. It takes time for the market for copies to develop, to reach a significant portion of potential customers, indeed for customers to learn where to go to buy such products (as they are likely sold in clandestine locations).

⁵ At this point, we need to re-emphasise that the two prices p and q are assumed fixed for our entire analysis. Naturally, the parameters a , b , c and d would all depend on the two prices (or perhaps better, the ratio of them as we could set one of the two goods as a numeraire product), some positively others negatively. Since we hold both prices constant, all of our growth parameters are also constant. Secondly, it should be mentioned that this model is only valid when all parameters are strictly positive. As soon as one goes to zero, the system becomes degenerate, and its solution then depends entirely upon the initial parameter values.

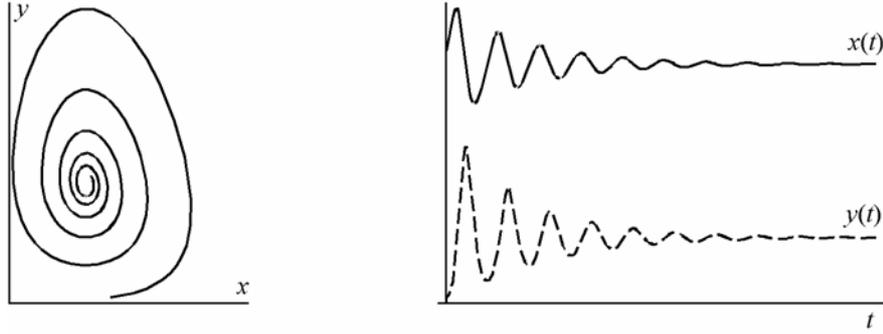


Figure 2: Solutions of system (1)

These two equations can be expressed as a Lotka-Volterra system:

$$\begin{cases} \dot{x} = (aN_p - ax - by)x \\ \dot{y} = (-c + dx)y \end{cases} \quad (1)$$

It is well known (see, for example, Smith 1976, Murray 2002-3) that the solutions of the model (1) tend to an equilibrium point (see Figure 2).

The equilibrium to which the model converges is given by $\dot{x} = \dot{y} = 0$, which from (1) can be easily calculated as

$$\bar{x} = \frac{c}{d} \quad \bar{y} = \frac{a}{b} \left(N_p - \frac{c}{d} \right) \quad (2)$$

which represents the long term population of each market.⁶

2.1 Strategies to Fight Piracy

Clearly changes in the parameters a , b , c and d will lead to a change in the equilibrium of the system. If we interpret some of these parameters as policy-type variables, we can easily consider how the effects of piracy can be mitigated by different anti-piracy strategies. Here we shall consider two such strategies – on the one hand hand public policy measures, like copyright law and taxes on blank supports, that are instigated publicly at no direct

⁶ It is interesting to note that it is not at all necessary that the long-term population of originals be greater than that of copies. For certain parameter values, we can get an equilibrium in which there are more copies than originals!

cost to copyright holders, and on the other self protection measures, like DRM, that are instigated by the copyright holders at their own cost.

Consider firstly publicly instigated and financed strategies designed to deter piracy (e.g. strengthening of copyright law in some way, application of a tax on blank supports, etc.). Such a policy has two effects on the model. Firstly, it would make it more expensive to acquire copied products, either directly in the case of a tax on the media used for delivering them, or indirectly in the case of a more effective copyright law (e.g. higher expected fines, more costly to evade detection, etc.). The greater costs involved in the market for copies would have a negative effect upon the growth rate of the diffusion of the products in this market. Secondly, the copyright holders (the market for originals) will receive money that does not originate from the sale of their own goods (the media tax payments, or the expected value of fines that the courts charge to convicted copiers designed to offset the royalty payments lost in the copy market). As previously, we can model such public policies by simply altering the basic model in a very simple way. We now write the system equations as:

$$\begin{cases} \dot{x} = [(a + \beta)N_p - (a + \beta)x - by]x \\ \dot{y} = (-c - \gamma + dx)y \end{cases}$$

where β represents the tax payments to copyright holders (or the expected compensation from fines), and γ represents the greater extinction rate of copies due to the higher costs involved. Note that if we define $\tilde{a} \equiv a + \beta$, and $\tilde{c} \equiv c + \gamma$, it is easy to see that this is formally the same Lotka-Volterra system as previously, and so the equilibrium point is given by the following average populations:

$$\bar{x} = \frac{c + \beta}{d} \quad \bar{y} = \frac{a + \gamma}{b} \left(N_p - \frac{c + \beta}{d} \right) \quad (3)$$

Under this strategy, by comparing (3) with (2), we find that:

1. The equilibrium population of originals increases. The comparison between this increase and that obtained under a self-protection mechanism depends on the relative values of δ and β .
2. The equilibrium population of copies may increase or decrease, depending on the concrete parameter set used.

Naturally, since the increase in the average population of originals comes at no cost to the sellers of originals, and since we are assuming a constant price at which these are sold, this publicly financed strategy against piracy *must* benefit the sellers of originals (read copyright holders). It is curious, however, that the public clamp-down on piracy may end up increasing the size of the market for copies! Specifically, this happens if

$$\frac{a}{b}(N_p - \frac{c}{d}) < \frac{a + \gamma}{b}(N_p - \frac{c + \beta}{d})$$

which reduces to

$$N_p - \bar{x} > \frac{a\beta}{\gamma d}$$

At first glance, it is not at all unreasonable that this condition is met, afterall, the difference between the total potential market for originals and the average size of that market (after the public policy has been introduced) is likely to be a very large number indeed (perhaps of the order of several millions), while the value of $\frac{a\beta}{\gamma d}$ is unlikely to be very great at all. In any case, this analysis clearly points out the fact that stronger copyright laws against piracy can in fact lead to more piracy (on this point, see also Harbaugh and Khemka, 2001). The logic behind this counter-intuitive result is simply that the strengthening of copyright law has a positive effect upon the population of originals,

which implies a more abundant source of prey for the copy market to draw from, which is favorable for the growth of the market for copies.

Now consider self-protection strategies. Such a strategy can be thought of as sellers of originals (read, copyright holders) using a part of their profits to cut down piracy. It is natural to assume that this would have a negative effect upon the natural growth rate of diffusion of originals (the increase in costs for fighting piracy would lead to reductions in other areas, like marketing, advertising, investment in new products, etc.), and it would also increase the extinction rate for the piracy market. To model this, let us assume that after the anti-piracy strategy has been introduced, the system (1) is altered so that it is now described by the equations

$$\begin{cases} \dot{x} = [(a - \varepsilon)N_p - (a - \varepsilon)x - by]x \\ \dot{y} = (-c - \delta + dx)y \end{cases}$$

where ε represents the loss in the natural growth rate of originals due to the increase in costs for fighting piracy, and δ represents the increase in the extinction rate for the market for copies. Again, we note that, by defining $\tilde{a} = a - \varepsilon$ and $\tilde{c} = c + \delta$, this system becomes

$$\begin{cases} \dot{x} = [\tilde{a}N_p - \tilde{a}x - by]x \\ \dot{y} = (-\tilde{c} + dx)y \end{cases}$$

which is, of course, the same Lotka-Volterra system as previously, but now with $\tilde{a} = a - \varepsilon$ and $\tilde{c} = c + \delta$. Therefore, the average size of each population would now be

$$\bar{x} = \frac{c + \delta}{d} \quad \bar{y} = \frac{a - \varepsilon}{b} \left(N_p - \frac{c + \delta}{d} \right) \quad (4)$$

Comparing (4) with the equilibrium without the self-protection mechanism installed, (2), we note that:

1. The protection mechanism increases the average population of originals.

2. The protection mechanism decreases the average population of copies.

Both of these are, of course, expected results. However, the fact that a self-protection mechanism increases the average population of originals, and decreases that of copies, does not imply that it is profitable for copyright holders to install such a mechanism. In order to conclude as to the profitability of this type of strategy, we need to consider the *optimal* investment in self-protection, as a profit maximizing strategy. We now go on to consider this more explicitly.

2.2 A Simple Analysis of The Optimal Self-Protection Strategy

As we noted above, if the copyright holders employ a self-protection strategy to fight piracy, then the average size of the market for originals increases, but at some cost to the sellers of originals. Whether or not this is a profitable strategy is unclear. Here we consider the optimal self-protection strategy, again under quite rudimentary assumptions on the profit function of sellers of originals.

Let us assume that the sellers of originals produce the good (which is sold at a fixed price p) at a constant marginal cost of m . Let us also assume that the sellers of originals use self-protection measures to control piracy: in particular we will assume that they each invest a proportion s of their profits to fight against piracy. Then, the net profits of a seller of originals is:

$$F(s) = (1 - s)(p - m) \frac{c + \delta(s)}{d} \quad (5)$$

where $\delta(s)$ is the function which describes the efficiency of the investment in anti-piracy protection for increasing the extinction rate of the copy market, that is, it measures the effectiveness of the strategy. Note that $F(0) > 0$ and $F(1) = 0$, thus the maximum of the function $F(s)$ must occur at some $s < 1$, that is, it is never optimal to spend all profits

on deterring piracy. Let us assume that $\delta(s) = ks$, then

$$\begin{aligned} F'(s) &= (p - m) \frac{k - c - 2ks}{d} \\ F''(s) &= -(p - m) \frac{2k}{d} < 0 \end{aligned}$$

Note that $F'(s) = 0$ when

$$s = \frac{k - c}{2k}$$

Thus, we obtain the following result:

1. If $k < c$ (the anti-piracy strategy is not effective enough), then $F(s)$ is a decreasing, concave function (see Figure 3, discontinuous line), and so in this case copyright holders will not be interested in investing money against piracy (i.e. the optimal investment is $s^* = 0$).
2. If $k > c$ (the anti-piracy strategy is effective enough), then $F(s)$ is a concave function with a maximum at $s^* = \frac{k-c}{2k}$ (see Figure 3, continuous line), and so copyright holders will be interested in investing this amount of money against piracy (it will increase the net profit). The value

$$\bar{y} = \frac{a - \varepsilon(s^*)}{b} \left(N_p - \frac{c + ks^*}{d} \right)$$

then represents the optimal equilibrium population in the market for copies.

Unfortunately, the present model does not allow us to consider the case in which the investment in anti-piracy strategies eliminates piracy completely. Such a strategy would imply $\varepsilon(s) = a$, but this directly involves one of the parameters of the model going to zero; $\tilde{a} = a - \varepsilon = 0$. As was mentioned above (see footnote 5), the properties of the model are altered completely when a parameter goes to zero, and so we are not able to consider this case in the current model.

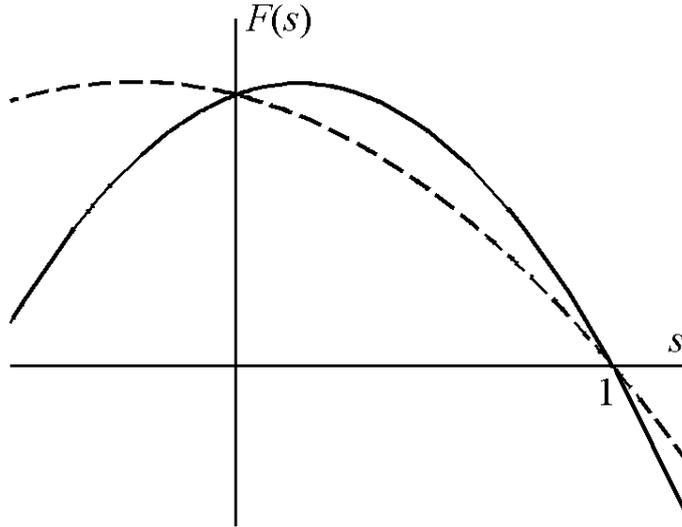


Figure 3: Net profits

3 Conclusions

In this paper we have provided a simple model of piracy of copyright products based on the prey-predator model. We have modelled original products as the prey species, and pirate copies as the predators. Under a rather rudimentary demand setting, we find that the model does behave in the manner expected of the prey-predator setting, and that there is an easily calculated equilibrium point.

The model allows us to consider the effects of different strategies against piracy. Firstly, we considered the effect of publicly instigated and financed policies, such as strengthening of copyright laws, or the introduction of taxes on blank supports to be distributed to copyright holders. We find that these policies will indeed increase the equilibrium population of originals, but curiously they may also increase the equilibrium population of pirate copies. Thus, stronger copyright protection can indeed lead to more piracy! Secondly, we considered the effect of privately instigated and financed policies, such as DRM mechanisms designed to reduce copying. We find that such policies again will unambiguously increase the equilibrium population of originals, and this time they also unambiguously decrease

the equilibrium population of pirate copies. Finally, we noted that it is not at all necessary that the optimal (from the point of view of profit maximization) privately financed strategy is positive – that is, if the privately financed strategy is relatively expensive then it is not optimal to use any such strategy.

Our model is very simplified, and allows for improvements in several dimensions. Most notably, perhaps, would be a more realistic analysis of the prices of the two products, and their effects upon the growth parameters of the model. Clearly, and as has been repeatedly modelled in the literature, the copyright holders do elect the price at which they sell originals, and that election may be considered another type of anti-piracy strategy (by setting price below the first-best optimum, sellers of originals lose profits relative to their first-best optimum, but they may also gain by becoming more competitive against pirate copies). Thus the full effects of the pricing game in a prey-predator model would be most enlightening.

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