1998

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ISSN:0318-725X
ISBN:0-7714-2124-9

RESEARCH REPORT 9808

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September 1998

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Abstract

Modern consumers of intellectual property, and especially software, find that the products they buy are protected by ever more sophisticated forms of copy protection. This occurs despite the presence of legislative protection. The economics literature within the area has begun to take note, yet there has been very little formal modelling to date. This paper sets up a model for analyzing the impact of alternative forms of copy protection on works subject to copyright protection. It outlines a model of intellectual

I would like to thank John Palmer, Jeff Smith and Tai-Yeong Chung for helpful comments. I would also like to thank participants at the 1998 Canadian Law and Economics Association conference in Toronto. I am grateful to the Social Sciences and Humanities Research Council of Canada for financial support. email: pcurry@julian.uwo.ca

property creation with endogenous protection choice as well as legislative copyright and examines the welfare implications. It also relates the results to two court cases and discusses the impact they may have on future copyright law.

It is widely recognized that intellectual property poses an unusual problem for legislators and economists alike. The problem stems from the high fixed costs often incurred in a creative endeavour and the ease with which such a work can be copied. Works of intellectual property generally require some form of protection from copying in order to ensure that the author of an original work will appropriate enough of a return in order to undertake the creation process in the first place. To date, formal models of intellectual property have examined only legislative forms of protection. This paper examines some implications of other forms of copy protection. It looks at the profit maximization problem facing producers of intellectual property when they can invest in protection themselves and looks at the welfare implications. Although the welfare implications are ambiguous, there are some positive statements that can be made when relating to the model to two recent copyright cases.

Section 1 describes what copy protection is and gives the motivation for modelling the problem. Section 2 outlines a model of intellectual property creation

with endogenous protection choice and discusses the optimal levels of copy protection as a function of exogenously given levels of copyright. Section 3 discusses welfare implications while relating the findings to some specific examples. Finally, Section 4 summarizes the findings and discusses possible extensions of the paper.

1. What is Copy Protection?

On a very basic level, copy protection is anything that makes it more costly to copy a creative work. This paper looks at forms of intellectual property that are subject to copyright law, such as novels or software. In this case, there are generally two kinds of copying that can occur: literal copying, such as photocopying a journal article or copying the diskettes for a computer program; and derivative copying, such as making a novel into a movie. A complete description of the amount of protection afforded a work would give the costs associated with all forms of copying at all points in time after the work's release. Landes and Posner[1] were the first to propose that all such information could be incorporated into a single-dimensional index. This paper follows that approach.

There are many ways to increase the costs of copying, one of which is leg-

[1] Landes, William M. and Richard A. Posner, 1989. "An Economic Analysis of Copyright Law", *Journal of Legal Studies*, Vol. 18, June 1989.

islative. Throughout this paper, legislative copy protection will be referred to as copyright protection while all other forms will be referred to as simply copy protection. These two forms will be separated within the index representing the level of protection. The amount of protection derived from copyright will be denoted by z and the amount of protection derived from copy protection will be denoted by i.

Given that copyright exists, it is natural to ask to what extent authors of intellectual property invest in their own copy protection. A quick look around makes it quite clear that producers (especially in the software industry) have been exploring other means of protection quite extensively. Typically, these alternative forms of protection have either used technology to make copying more difficult, or have used alternative forms of legal protection. For example, program code and databases can be encrypted and many computer games these days will not run unless the associated CD-ROM is in the carousel. These are both examples of technologies that make copying more difficult. In addition, many programs now require the consumer to agree to an end-user, or "shrinkwrap" contract before using the product. This is an example of authors making use of alternative forms of legal protection.

How do these alternative forms of copy protection compare with copyright

protection? Is it a complement or a substitute? A first look might lead one to believe that it is mostly complementary. One of the problems with legislative protection is that of monitoring costs. Although copyright can prohibit an individual from selling a copy of computer programs to friends while retaining the original, in practice there is actually very little protection afforded. Such innovations as rendering a program inorperable unless the CD-ROM is in the carousel can help reduce this form of copying. However, this paper takes the stance that it is fruitful to analyze copy protection as a substitute to legislation.

The motivation for this stance arises from the decision in *Feist Publications Inc. v. Rural Telephone Service Co. Inc.*[2] and its aftermath. In *Feist*, the Supreme Court decided that databases, or compilations of facts, did not necessarily meet the creative requirements for copyright protection[3]. Compilations, however, are very similar to creative works in that there are often high fixed costs associated with their creation and, once released, they can be very easy to copy. With the removal of legislative protection, some[4] predicted that the incentive to

[2]111 S. Ct. 1282 (1991)

[3]This decision has been quite controversial. Even before the ruling, arguments were made to promote copyright protection for databases, as in Palmer, John, 1983. "Copyright and Computer Data Bases", *International Review of Industral Property and Copyright Law*, Vol. 14, Spring 1983.

Even since the ruling, the decision has come under attack to the point where it may be overturned by the proposed Collections of Information Antipiracy Act. I thank Thomas Cotter for bringing this to my attention.

[4]For example, Hayden, John F., 1991. "Copyright Protection of Computer Databases After

create these databases would be significantly reduced, resulting in less than the socially optimal amount of creation.

However, is this the case? It has been six years since the *Feist* ruling and its impact should have been felt by now. Have we seen a significant reduction in the creation of databases? A casual surf around the Internet would certainly suggest not. However, there has been a marked change in the compilations we do see. More and more often a consumer of a database is required to agree to an end-user contract, whereby the consumer promises not to disseminate the information. For example, CANSIM (Canadian Socio-Economic Information and Management database) has made use of both technological and contractual forms of protection. In order to access the database, a university must buy a license and sign an agreement stating that only students and faculty at that university may access the data. The faculty and students wishing to use CANSIM data may do so over the Internet, but they can enter the site only if they use a computer whose domain corresponds to thier university.

Effectively, the consumer must now agree to a contract that affords the same

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Feist", *Harvard Journal of Law and Technology*, Vol. 5, Fall Issue, 1991.). However, Siebrasse alludes to the results obtained here that the implications for welfare are ambiguous if there are alternative methods of protection. Siebrasse, Norman, 1997. "An Economic Analysis of Copyright of Facts and the Idea/Expression Dichotomy", University of New Brunswick, Faculty of Law Working Paper, 1997.

protection that copyright law used to provide. Furthermore, these contracts have been recognized as a viable alternative. In the case *ProCD, Inc. v. Matthew Zeidenberg and Silken Mountain Web Services, Inc.*[5], it was found that the dissemination of data contained on CD was in violation of the "shrinkwrap" contract that Zeidenberg had agreed to by using the product. Thus ProCD had found a method of protection equivalent to that of copyright law. As such, it would seem that copy protection is best viewed as a substitute to legislative protection.

2. The Model

The basic model builds on that of Landes and Posner[6]. In their model, the author of a creative work acts as a dominant firm in the market and copiers act as fringe firms. The author acts as a monopolist in that he\she has price as a choice variable, but some of the demand will be satisfied by copiers. The copiers' supply is increasing in the price that the author chooses and decreasing in the amount of copyright protection. The amount of protection is given by the index,

[5] 86 F.3d 1447 (7th Cir. 1996)
[6] *supra* note 1.

z, outlined above. The author's gross profits are given by

$$(p-c)\left[q(p)-y(p,z)\right]$$

where c is the (constant) marginal cost of reproducing the work, $q(p)$ is the demand for the work and $y(p,z)$ is the copiers' supply.

In addition, however, the author incurs a cost in producing the original work. This cost, denoted by $e(z)$, is called the cost of expression. This cost includes time and effort expended in creating something original. It is a function of copyright in that the more copyright protection there is, the less an author can borrow from existing works. That is, the author will have to expend more time and energy ensuring that the work does not infringe upon any existing copyrights. The author's net profits are then given by

$$\Pi(p)=(p-c)\left[q(p)-y(p,z)\right]-e(z)$$

and price is the lone choice variable. Also note that it is assumed that the author faces no uncertainty. That is, the author knows how much effort it will take to create a work before undertaking the project, and the author knows the demand

for the work as well as the copiers' supply function.

2.1. Copy Protection as an Input

In this model, the author now has the option of choosing some level of copy protection, i. This copy protection can be viewed as an input to production that affects the copiers' supply. In this paper, it will be assumed that copy protection enters the cost function as a one-time cost. The reason for this is that many forms of protection, such as encryption or on-screen end-user contracts, involve additional programming but do not noticeably affect the costs of duplicating the prototype. As with Landes and Posner's cost of expression, this cost is probably one of time and effort. In the case of encryption, the author must develop an algorithm sufficiently difficult to decrypt and in the case of end-user contracts, the author expends time and effort in developing a contract that covers all the relevant eventualities.

Thus the author incurs a cost of $k(i)$ for implementing level i of copy protection, where $k_i > 0$. In addition, I assume that $k_{ii} > 0$, so that the author incurs an increasing marginal cost of protection.

2.2. The Effect of Copy Protection on Copiers' Supply

As mentioned above, the reason an author would invest in copy protection is to reduce the supply of copies. That is, the copiers' supply curve is now given by $y(p, z, i)$ where $y_i < 0$. In this model, copy protection is treated as a *perfect* substitute to copyright. The rationale for this is that, as mentioned above, both types of copy protection affect the supply of copies by changing the expected cost of copying. Although the cost can either be the expected punishment for being found guilty of infringement or the cost of hacking through some other type of protection, such as encryption, any such cost can be measured by a single index. However, it need not be the case that the two types of protection have the same cost function.

The assumption of perfect substitutes has the additional advantage that it simplifies the model significantly. One of the implications of perfect substitutes is that the total amount of protection afforded to a work is then given by $z + i$. Mathematically, this means that $y_i = y_z$ for all levels of p. As in Landes and Posner, it will be assumed that $y_{zp} = y_{ip} = 0$. In other words, the marginal impact of a small increase in the amount of protection does not depend on the price of the work. Furthermore, it seems reasonable to assume that copy protection has a decreasing impact on copiers' supply. Since i and z are perfect substitutes,

this yields $y_{ii} = y_{zz} = y_{iz} = y_{zi} > 0$. Nothing in the model depends on these assumptions, but they do allow for easier analysis.

Also note, as Landes and Posner assume no uncertainty in their paper, it is assumed in this one that the author knows exactly what impact an investment on copy protection will have on the copiers' supply.

2.3. Profit Maximization

Now that the choice over copy protection has been defined, the profit maximization problem of the author can be written:

$$\max_{p\geq 0, i\geq 0} \Pi(p,i) = (p-c)\left[q(p) - y(p,z,i)\right] - e(z+i') - k(i) \qquad (2.1)$$

Note that the cost of creation, $e(z+i')$, now incorporates the investment of others in copy protection. It is assumed that authors draw upon other works, and do so legally. If i' denotes the amount of copy protection an author of an existing work has chosen, then the total amount of protection afforded that work is $z+i'$. All current authors that draw upon that work must then incur a cost associated with that total amount of protection, $z+i'$. Also note that it is assumed that the level

of copy protection chosen does not affect demand[7].

For a given level of z, the profit maximizing price and investment in protection are given by

$$\frac{\partial \Pi}{\partial p} = [q(p) - y(p,z,i)] + (p-c)[q_p - y_p] = 0 \tag{2.2}$$

$$\frac{\partial \Pi}{\partial i} = -(p-c)\, y_i - k_i \leq 0 \tag{2.3}$$

Note that for all positive levels of investment in protection, (2.3) will hold with equality. The second order sufficient conditions are

$$\frac{\partial^2 \Pi}{\partial p^2} = 2(q_p - y_p) + (p-c)(q_{pp} - y_{pp}) < 0 \tag{2.4}$$

$$\frac{\partial^2 \Pi}{\partial i^2} = -(p-c)\, y_{ii} - k_{ii} < 0 \tag{2.5}$$

$$\frac{\partial^2 \Pi}{\partial p^2} \cdot \frac{\partial^2 \Pi}{\partial i^2} > \left(\frac{\partial^2 \Pi}{\partial i \partial p}\right)^2 = y_{ii}^2 \tag{2.6}$$

Solving the system of equations given by (2.2) and (2.3) will result in an optimal price and level of investment as a function of z, i.e. $p^*(z)$ and $i^*(z)$.

[7] This need not be the case. Recall that $y(p,z,i)$ represents the supply of *legal* copies. If protection reduces the amount of illegal copying, then this might be represented by an increase in demand. I thank Norman Siebrasse for pointing this out.

Differentiating with respect to z[8] yields

$$\frac{dp^*}{dz} = \frac{k_{ii}y_i}{y_i^2 - \frac{\partial^2\Pi}{\partial i^2}\frac{\partial^2\Pi}{\partial p^2}} \tag{2.7}$$

$$\frac{di^*}{dz} = -\frac{y_i^2 + (p-c)\,y_{ii}\frac{\partial^2\Pi}{\partial p^2}}{y_i^2 - \frac{\partial^2\Pi}{\partial i^2}\frac{\partial^2\Pi}{\partial p^2}} \tag{2.8}$$

Note that $k_{ii}y_i < 0$ by assumption, and from (2.6) we know that $y_i^2 - \frac{\partial^2\Pi}{\partial i^2}\frac{\partial^2\Pi}{\partial p^2} < 0$. Therefore it must be that the sign of $\frac{dp^*}{dz}$ is positive. Furthermore, since

$$y_i^2 + (p-c)\,y_{ii}\frac{\partial^2\Pi}{\partial p^2} = y_i^2 - \frac{\partial^2\Pi}{\partial i^2}\frac{\partial^2\Pi}{\partial p^2} - k_{ii}\frac{\partial^2\Pi}{\partial p^2}$$

and $k_{ii}\frac{\partial^2\Pi}{\partial p^2} < 0$ it must be that the sign of $\frac{di^*}{dz}$ is may be either negative or positive.

An important detail is that in the case where $\frac{\partial i^*}{\partial z} < 0$, as z increases, total protection $(z+i)$ increases even though i decreases. This can be seen in two ways. From a technical viewpoint, if $\frac{\partial i^*}{\partial z} < 0$, then it must be that $y_i^2 - \frac{\partial^2\Pi}{\partial i^2}\frac{\partial^2\Pi}{\partial p^2} - k_{ii}\frac{\partial^2\Pi}{\partial p^2} < 0$. Since $k_{ii}\frac{\partial^2\Pi}{\partial p^2} < 0$, we have that $\left|\frac{\partial i^*}{\partial z}\right| < 1$ and the change in investment is less than the change in z.

Intuitively, we can see that what is driving this is the assumption that the au-

[8]The equations for $\frac{dp^*}{dz}$ and $\frac{di^*}{dz}$ hold only for interior solutions to i^*. That is, when $i^* > 0$, then (2.3) holds with equality and $\frac{dp^*}{dz}$ and $\frac{di^*}{dz}$ can be found via a system of simultaneous implicit functions.

thor has monopoly power. For a given marginal cost, the profit maximizing price is increasing in demand. Since $\frac{dp^*}{dz}$ is positive, it must be that the demand that the monopolist faces $(q(p) - y(p, z, i))$ increases. This happens when $y(p, z, i)$ decreases. So, if $\frac{dp^*}{dz}$ is positive, it must be that total the copiers' supply decreases, which means that $z + i$ increases.

Note that it is possible to have $\frac{\partial i^*}{\partial z} > 0$ even though i and z are perfect substitutes. When this occurs, we say that i and z are *strategic* complements. When, $\frac{\partial i^*}{\partial z} < 0$, then i and z are *strategic* substitutes.

3. Welfare Implications

At this point, it is convenient to restrict attention to one of the above scenarios. Specifically, this paper will focus on the case where $\frac{di^*}{dz}$ is negative. The rationale for this stems from the *Feist* and *ProCD* cases. As mentioned above, the *Feist* case had the effect of reducing the level of copyright protection. As evidenced by the *ProCD* case, the response of at least some producers of databases was to increase their own investment in copy protection. In light of this, it would seem natural to focus on the welfare implications when $\frac{di^*}{dz}$ is negative.

3.1. Number of Works Created

An important argument in any welfare function dealing with intellectual property is the number of works generated. Let N be the number of works created. The above analysis of p^* and i^* of course assumes that they generate non-negative profit. That is, an author will produce a work only if

$$\Pi^* = (p^* - c)\left[q\left(p^*\right) - y\left(p^*, z, i^*\right)\right] - e\left(z + i'\right) - k\left(i^*\right) \geq 0 \qquad (3.1)$$

It is assumed that as net profits increase (decrease), the number of works created likewise increases (decreases). Also note that i' represents the amount of protection on a work used by the author. Since i' was determined by another profit maximization problem, it is therefore a function of z. Furthermore, since both p^* and i^* are also functions of z, this means that the number of works produced should be given by $N\left(z\right)$.

The number of works, then, will vary as Π^* varies. Taking the derivative with respect to z yields

$$\frac{dp^*}{dz}\left[q\left(p^*\right) - y\left(p^*, z, i^*\right)\right] + (p^* - c)\left[q_p\frac{dp^*}{dz} - y_p\frac{dp^*}{dz} - y_z - y_i\frac{di^*}{dz}\right] - e_z - e_i\frac{di'}{dz} - k_i\frac{di^*}{dz}$$

Combining the terms and noticing that

$$\begin{aligned} q(p^*) - y(p^*, z, i^*) + (p^* - c)[q_p - y_p] &= 0 \\ -(p^* - c)\, y_i - k_i &= 0 \end{aligned}$$

by equations (2.2) and (2.3) yields

$$\frac{\partial \Pi^*}{\partial z} = -(p^* - c)\, y_z - e_z - e_i \frac{di'}{dz} \tag{3.2}$$

As in Landes and Posner, the assumptions that $y_z < 0$ and $y_{zz} > 0$ along with $e_i = e_z > 0$ and $e_{zz} > 0$ suggest that profits are increasing in z when z is small and decreasing when z is large. In other words, profits are roughly concave in z. It seems reasonable to assume that the number of works created behaves in a manner similar to profits and is also roughly concave.

How does the number of works generated in this model compare to the results of Landes and Posner? Unfortunately, this relationship cannot be pinned down. Note that with copy protection, the cost of expression, $e(z + i')$ is equal to the cost without copy protection when the level of copyright is $\tilde{z} = z + i'$. The cost to the author is therefore higher when there is copy protection. However, the

author has the option of investing in protection as well. This means that at a given level of copyright, z, both cost and revenue are higher when there is copy protection and one cannot tell whether profits will be higher or lower. However, since at low levels of z the marginal cost of expression is small and the marginal decrease in copiers' supply is large, we would expect that when z is small, the number of works produced is greater when copy protection is present. Likewise, at high levels of z, the marginal cost of expression becomes high and the marginal decrease in copiers' supply becomes small, so the number of works created ought to be fewer when copy protection is possible. Finding the point at which the number of works created is equal with and without copy protection would require further assumptions on the cost and copiers' supply functions.

Furthermore, we cannot compare the levels of z that maximize the number of works. The number of works created will be maximized when Π^* is maximized. With no copy protection, this occurs at z^*_{LP} such that

$$[p^*_{LP} - c] \cdot y_z\left(p^*_{LP}, z^*_{LP}\right) = -e_z\left(z^*_{LP}\right) \tag{3.3}$$

If we try to determine the sign of equation (3.2) when evaluated at z^*_{LP}, we find that it is indeterminate. We know that allowing copy protection increases

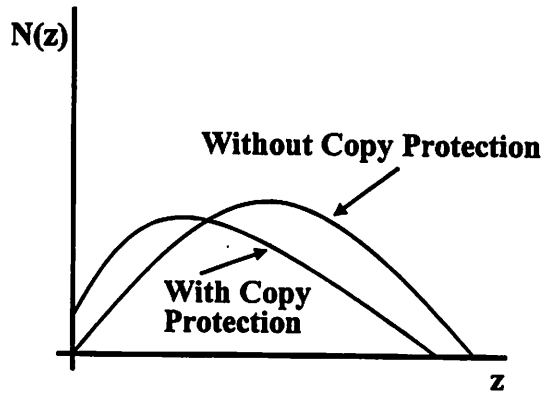


Figure 3.1: Example a): The number of works created is maximized at a lower level of copyright when copy protection is possible.

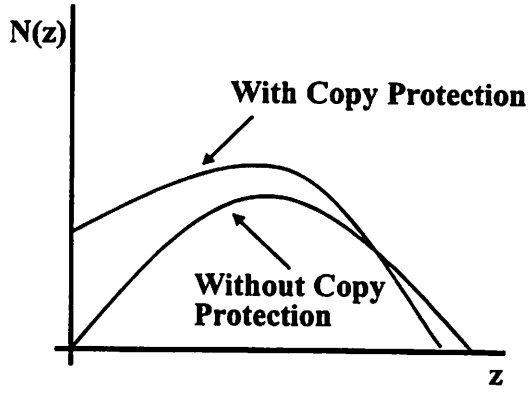


Figure 3.2: Example b): The number of works created is maximized at a higher level of copyright when copy protection is possible.

monopoly power, so that p^* is higher than when there is no copy protection. However, we also know that when $i > 0$, $y_z(p, z_{LP}, i)$ is less negative than $y_z(p, z, 0)$. Therefore we cannot tell what happens to marginal revenue when copy protection is allowed for. Furthermore, the effect on marginal costs is also ambiguous. Note that the assumption that $e_z = e_i$ allows us to write the marginal cost as $e_z\left(1 + \frac{di'}{dz}\right)$. Furthermore, since $e_{zz} > 0$, we have that allowing for copy protection increases e_z. However, since $\frac{di'}{dz}$ is negative and less than one, we cannot tell what happens to marginal costs. Figures (3.1) and (3.2) depict two possible relationships between the number of works produced with and without copy protection.

3.2. Optimal Copyright

In order to determine the optimal level of copyright protection, it is necessary to have a welfare function. Again, the one used in this paper will be a slight modification of the one in Landes and Posner. Total welfare, W, is a function of the number of works created, the welfare generated by each work and the total costs of creating the works. The welfare generated by each work in this case is very similar to that in Landes and Posner. The addition of copy protection yields

the following expression:

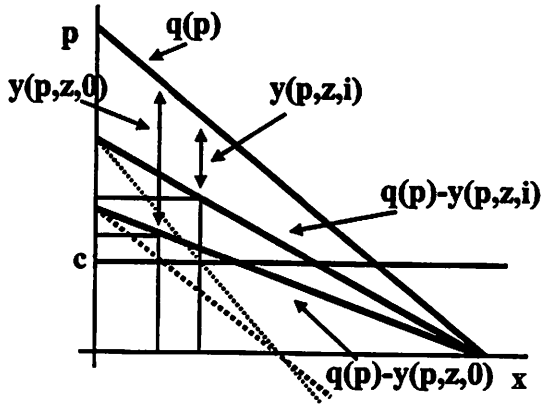
$$w = \int_{p^*}^{\infty} q(p)\,dp + (p^* - c)\left[q(p^*) - y(p^*, z, i^*)\right] + \int_{p^0}^{p^*} y(p^*, z, i^*)\,dp \qquad (3.4)$$

where p^0 is the minimum price at which copiers' are willing to produce a copy. Note that this expression is welfare before the deduction of cost of expression and investment in copy protection. At this point, it becomes necessary to specify the relationship between i^* and i'. If we assume that i' comes from an identical profit maximization problem, then the effect of an increase in z on i' will be identical to the effect on i^*. Net welfare is therefore given by $w - e(z + i^*) - k(i^*)$.

In comparison to Landes and Posner, note that allowing investment in copy protection can reduce the net welfare of a given work. The reason for this is that when authors invest in copy protection, they increase their monopoly power. They can then charge a higher price while increasing output, which will increase their profits but decrease consumer surplus per unit. The net effect of an increase in price and an increase in protection will be to decrease the copiers' supply. However, the total amount supplied will fall. The intuition for this is given by Figure (3.3).

The net result of the increase in profits and the decrease in consumer surplus

Figure 3.3: Change in Copiers' Supply as i Changes



and copiers' profits on welfare is ambiguous. However, assuming that the result is a reduction in net welfare is consistent with the assumption in Landes and Posner that net welfare is decreasing with respect to z.

The change in net welfare with respect to a change in z is given by

$$\begin{aligned}\frac{d\left[w-e\left(z+i^{*}\right)-k\left(i^{*}\right)\right]}{dz} &= -q\left(p^{*}\right)\frac{dp^{*}}{dz}+\frac{dp^{*}}{dz}\left[q\left(p^{*}\right)-y\left(p^{*},z,i^{*}\right)\right] \\ &\quad +\left(p^{*}-c\right)\left[q_{p}\frac{dp^{*}}{dz}-y_{p}\frac{dp^{*}}{dz}-y_{z}-y_{i}\frac{di^{*}}{dz}\right]+y_{p}\left(p^{*},z,i^{*}\right)\frac{dp^{*}}{dz} \\ &\quad -y\left(p^{0},z,i^{*}\right)+\int_{p^{0}}^{p^{*}}\left(y_{z}+y_{i}\frac{di^{*}}{dz}\right)dp-e_{z}-e_{i}\frac{di^{*}}{dz}-k_{i}\frac{di^{*}}{dz}\end{aligned}$$

Collecting terms and using the assumption in Landes and Posner that $y\left(p^{0},z,i\right)=$

0 yields

$$\frac{d\left[w-e\left(z\right)-k\left(i^{*}\right)\right]}{dz} = \left(p^{*}-c\right)\left[q_{p}\frac{dp^{*}}{dz}-y_{p}\frac{dp^{*}}{dz}-y_{z}-y_{i}\frac{di^{*}}{dz}\right] + \int_{p^{0}}^{p^{*}}\left(y_{z}+y_{i}\frac{di^{*}}{dz}\right)dp-e_{z}-e_{i}\frac{di^{*}}{dz}-k_{i}\frac{di^{*}}{dz} \quad (3.5)$$

which is very similar to the expression derived in Landes and Posner[9]. As mentioned above, they assume that this is likely to be negative. Note that (3.5) should be greater than the case without copy protection. This is because $\left(y_{z}+y_{i}\frac{di^{*}}{dz}\right) > y_{z}$ and $e_{i}\frac{di^{*}}{dz}+k_{i}\frac{di^{*}}{dz} < 0$. Thus we have that $\frac{d[w-e(z+i^{*})-k(i^{*})]}{dz} \geq \frac{d[w-e(z+0)-k(0)]}{dz}$[10] for all levels of z. This means that although the welfare of an individual work is lower when copy protection is present, as copyright protection increases, welfare per work drops at a slower rate. The reason for this slower decline is the "crowding out" effect that an increase in copyright has on investment in copy protection. For unit increase in copyright, total protection goes up by less than one unit as investment copy protection falls.

Total welfare, then, will be modified from that in Landes and Posner as fol-

[9]The expression in Landes and Posner is $\frac{\partial[w-e(z)]}{\partial z} = (p^{*}-c)\left[q_{p}\frac{dp^{*}}{dz}-\left(y_{p}\frac{dp^{*}}{dz}+y_{z}\right)\right]+\int_{p^{0}}^{p^{*}}y_{z}dp-e_{z}$. The difference between the two is the the additional change in costs $(e_{i}\frac{di^{*}}{dz}+k_{i}\frac{di^{*}}{dz})$ and the additional change in the supply of copies $(y_{i}\frac{di^{*}}{dz})$.

[10]This holds with equality if and only if $i^{*}=0$.

lows[11]:

$$W = f(N)[w - k(i^*)] - E(N, z)$$

where $E(N, z)$ is the total cost of creating works. It includes the total cost of expression as well as administrative and enforcement costs. Note that the gross welfare produced by the existing works is not simply Nw. The welfare from the individual works is multiplied by $f(N)$ where $f_N > 0$ and $f_{NN} < 0$ in order to reflect diminishing net welfare per work. Maximizing total welfare with respect to z yields

$$\frac{\partial W}{\partial z} = f_N N_z [w - k(i^*)] + f(N)\left[w_z - k_i \frac{di^*}{dz}\right] - E_N N_z - E_z = 0 \qquad (3.6)$$

How does the solution to this problem compare to the welfare maximizing amount of copyright when there is no copy protection? Unfortunately, we cannot say that the optimal amount of copyright is unambiguously larger or smaller. We can see this by comparing the two equations. Let z^* be the amount of copyright that maximizes welfare when there is no copy protection. The first order condition

[11] Welfare in Landes and Posner is given by $W = f(N)w - E(N, z)$.

in Landes and Posner is given by

$$\frac{\partial W}{\partial z} = f_N N_z w + f(N) w_z - (E_N N_z + E_z) = 0$$

To begin with, recall that with copy protection, the net welfare per work is smaller for all levels of z than without. In addition, the change in the number of works from a small increase in z, N_z, is also smaller. However, we do not know whether more works are created at z^* when there is copy protection or when there isn't (see section 3.1, figure 3.1). So, although we know that the change in welfare per work created is smaller with copy protection, we do not know what happens to the number of works created.

It is possible that the number of works slowly tails off, in which case we would expect to see a higher level of copyright. In this case, although copyright and copy protection are substitutes in preventing the supply of copies, they happen to be strategic complements in the welfare function. If the number of works drops off sharply, then copyright and copy protection are strategic substitutes.

4. Conclusion and Discussion

The relation between this model and the two court cases, *Feist* and *ProCD*, raises many interesting issues. To begin with, one result of the model is that $\frac{dp^*}{dz}$ must be positive. It was also assumed that $\frac{di^*}{dz}$ is negative. Both of these hypotheses are testable. Certainly any policy maker that wanted to use this model should test at least the second of these hypotheses. Welfare analysis might be quite different in the case where $\frac{di^*}{dz}$ is positive.

Another interesting point is that although the model cannot give the optimal level of copyright, it can give some insight into whether or not the decision in *Feist* was welfare reducing. Recall that total welfare was a function of the number of works created and the welfare from each of those works. In section 3.2 it was noted that net welfare per work was decreasing in z. In section 3.1 it was noted that the number of works was a concave function of z. The decrease in z brought about by *Feist* would therefore have the result of increasing the net welfare per work, while decreasing the number of works (see footnote 6). A rough estimation of the impact of *Feist* on total welfare could then be obtained by examining the drop in price and the drop in the number of works. Again, although I do not have any data on this, it certainly does not appear that the number of works has

declined too severely. This may suggest that the decision in *Feist* was welfare increasing.

An issue not raised here is the development of the technology used in copy protection. As mentioned in section 2.1, copy protection can be thought of as an input to production. Something that might be interesting to consider is the scenario of a software firm conducting its own research into copy protection. This would be analogous to vertical integration in the traditional industrial organization literature.

Related to this, is the issue of the development of technology on behalf of the *copiers* in order to reduce costs. This idea was addressed by Liebowitz[12] in the context of improved photocopying technology for academic journals. Certainly if the effectiveness of technology-based protection is expected to erode over time, this would suggest that such forms have a lower index rating than legislative forms of protection. Whether this model ignores any incentives for the copiers is open question.

Finally, although this model cannot predict whether the introduction of copy protection increases or decreases the optimal level of copyright, the optimal level is

[12]Liebowitz, S. J., 1985. "Copying and Indirect Appropriability: Photocopying of Journals", *Journal of Political Economy*, Vol. 93, October 1985.

almost surely not zero. This has been a constant in the copyright literature since Plant[13] and Hurt and Shuchman[14]. This result is generated in this model from the assumption that both types of protection have increasing marginal costs. Thus, even if the cost curve for copy protection lies below the cost curve of copyright, eventually the marginal cost of one more unit of copy protection will be more than the marginal cost of the first unit of copyright protection.

This has important implications for the role of copyright in the future. Even if it is determined that the decrease in copyright by *Feist* was welfare increasing, copyright will not be totally be replaced by copy protection. It may turn out, however, that copyright law will be relegated to the status of a default contract for the situations in which there is no end-user contract.

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