COMPLEMENTARITIES AND NETWORK EXTERNALITIES IN CASUALLY COPIED GOODS*

DAVID BLACKBURN

Abstract

In this paper, we examine the impacts of casual copying in the market for goods that have strong network externalities and/or are strong complements with goods in another market. By allowing casual copying to occur, the monopolist triggers two effects. The "copying effect" reduces demand (and thus profits) due the introduction of a better outside alternative to consumers. However, a "network augmenting" effect works to increase demand through the larger size of a network that allows copying. We find that if the marginal network externality is large enough, the monopolist will find it profitable to allow some level of casual copying to occur among non-purchasers of the good. And in a simplified dynamic setting, we find that as time passes and the good's network becomes more mature, the monopolist will seek higher and higher levels of copy protection. This implies that firms in newly formed markets should be more willing to allow copying to occur than those in established markets.

Resumen

En este artículo, se examinan los impactos de una copia casual en el mercado de bienes, donde estos tienen una red con fuertes externalidades y/o fuertes complementos con bienes de otros mercados. Permitiendo la copia casual gatillar dos efectos en el monopolista, un efecto copia que reduce la demanda (las ganancias) a través de permitir el acceso a una mejor alternativa a los consumidores, como también, un efecto de "aumento de difusión" que incrementa la demanda a través del tamaño de la red que permite la copia, por ende, si la externalidad marginal de la red es suficientemente grande, entonces el monopolista encontrará beneficioso permitir algún grado de copia casual entre los no compradores del bien. En un planteamiento dinámico simple, se encuentra que en la medida que el tiempo transcurre y la red de bienes madura el monopolista buscará niveles más altos de protección a la copia, es decir, las firmas en mercados recién formados deberían permitir un mayor grado de copia que en aquellos mercados establecidos.

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□ Harvard University. E-mail: blackb@fas.harvard.edu

1. Introduction

In recent years, there has been much focus in the popular media on the detrimental effects that unauthorized duplication of original work, such as software piracy, and casual copying of music and film, has had on the affected industries. For example, the Business Software Alliance (BSA) estimates that over 24% of business software in the United States is unlicensed, and that in the year 2000, over US$2.6 billion in revenue was lost and over 107,000 jobs were lost due to unauthorized reproduction of software.[1]

Furthermore, the Recording Industry Association of America (RIAA), which was engaged in an infamous lawsuit regarding illegal music downloads from Napster, estimates that the recording industry loses about US\$4.5 billion per year to piracy. The estimates from the BSA and RIAA are based on the assumption that all copied good would otherwise be purchased through authorized channels, an assumption that economic logic can not support. In fact, it is possible that very few (if any) of those with illegal copies would have purchased these items if it were impossible to copy originals.

In this paper, we examine the impacts of casual copying in the market for goods that have strong network externalities and/or are strong complements with goods in another market.[2] In particular, we examine whether a monopolistic producer of a network (or complementary) good would prefer to allow casual copying of the good. We find that in circumstances where the marginal network externality to consumers is sufficiently large, the monopolist will actually increase her profits by choosing a less than full level of copyright enforcement.

Although this may seem paradoxical, the intuition is quite clear. By choosing not to enforce fully copyright enforcement, the monopolist triggers two effects. First, the potential availability of copies to consumers increases the outside alternative to purchasing a new good, thereby reducing the amount of surplus the monopolist could potentially extract, which would necessarily pushes towards a reduction in the monopolist's profits. However, a second, "network augmenting'' effect pushes the monopolist's profits in the other direction. Copying increases the size of the network beyond what it would be if it were restricted to sales. The increase in the size of the network increases each consumer's willingness to pay for the good, through the network externality (or as we shall see, through the complementary market), thereby increasing the amount of potentially extractable surplus. If this "network augmenting'' effect is strong enough, it will outweigh the traditional "copying effect'' and the monopolist will achieve higher profits through reduced copyright enforcement.

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1 However, these estimated losses are calculated under the dubious assumption that all pirated software would have been purchased. Also note, though, that these losses only consider copying of business software, and not losses from operating systems, education, or entertainment software.

2 There is an important distinction between casual copying and piracy. Piracy generally refers to copies of material being misrepresented and sold to unknowing consumers as authorized material at very low prices, with the consumer not necessarily aware that the good is not authentic. Casual copying, meanwhile, implies that both parties to the copying are aware that the transaction is illegal.

We then consider a simple dynamic game and the implications that this has on the monopolist's choices of copy protection over time. Under simple assumptions about the form of the externalities or complementarities, the dynamic aspect suggests that as time passes, and the market for the good becomes more mature, firms will increasingly seek to enforce tighter and tighter copyright protection. The intuition here is clear as well. As the market becomes more mature, the good has a smaller marginal network externality from an additional good, so the "network augmenting'' effect that suggests that a monopolist may prefer some positive level of copying is getting weaker and weaker. Thus, the monopolist will attempt to wish to make it harder for copies to spread.

Previous work by Takeyama (1994) has studied, in a discrete consumer model, the impacts of copying on static monopolist profits in the face of demand network externalities, with very similar results.[3] Takeyama (1997) also studies copying in a dynamic setting, absent network externalities, and finds that copying can allow the monopolist to overcome problems associated with the Coase conjecture.[4] Work on sharing goods (libraries, families, and rental markets) by, for example, Varian (2000), Besen and Kirby (1989), and Bakos, Brynjolfsson, and Lichtman (1999) has found that the impact that sharing has on producer profits depends critically on the assumption made about the formation of groups and the ability of the monopolist to appropriate the additional surplus that the secondary, shared uses add to the 'single-use' good. In particular, Varian and BBL find that when groups are sufficiently heterogeneous, the monopolist is able to achieve larger profits than if it was necessary to sell a single good to each user. In an empirical examination of the academic journal industry, Leibowitz (1985) found that the introduction of photocopying technology, rather than decrease profits for journal publishers, instead increased demand for journals at collegiate libraries.

In a similar vein, there exists work that suggests that it may be best for a monopolist holder of a good to license the production of the good to other firms and compete in a oligopoly. Shepard's (1987) model finds that second-souring commits the monopolist to higher quality levels, which can increase industry demand enough to offset the loss in market power, while Economides (1996), in a network externality framework like ours, finds that licensing can increase demand by committing the industry to a larger network size, whereas a monopolist would want to exert market power and withhold supply. Licensing differs sufficiently from using casual copying to expand the network size. While the technology is licensed to create a large market size, the previous monopolist

[3] Takeyama's model does not allow for variable levels of copyright enforcement, nor does it examine the effects in a dynamic setting. She finds only that given a fixed level of degradation between copies and originals that a firm which faces a large enough network externality prefers not to enforce a copyright. The model developed below extends this idea to allow firms the ability to enforce a copyright with variable degrees of vigor. Thus, a firm facing the same network externality in both models might prefer no copying in the Takeyama world while choosing to allow a low level of copying in the model below.

[4] The Coase conjecture, recall, states that the monopolist producer of a fully durable good will necessarily price at marginal cost (net of any discounting premium), as she essentially competes against future incarnations of herself.

must now compete with other firms to serve high value consumers. However, when casual copying is used, the firm retains monopoly power and faces no competitors for high value consumers.[5]

The rest of the paper proceeds as follows: First, in Section 2, we describe the set-up of the environment that the monopolist faces with network externalities and complementary goods. We describe the market for goods complementary to the monopolist's (Section 3). Then, we proceed with a description of the monopolists good and static analysis of the monopolist's market, both under an exogenous level of copying (where the firm's choice is between no copying at all or copying at the exogenous level) in Section 4, and analyzing the monopolist's optimal choice over the level of copying in Section 5. Section 6 examines a simple dynamic game which is a first attempt at examining how the choice of copy protection by the monopolist changes over time. Finally, Section 7 serves as a conclusion.

2. The Model

The model considers the monopolist producer of a hardware good. The hardware good that the monopolist produces is subject to casual copying by those consumers who do not purchase an original. Furthermore, in the spirit of Katz and Shapiro (1985), the hardware good exhibits network externalities in that the value of the good to consumers increases in the number of goods that are consumed by other consumers (the network size).

For simplicity we assume that the monopolist faces constant marginal cost, and normalize that value to zero. In addition to the direct network externality the good exhibits, the hardware good is used in conjunction with complementary software goods. The monopolist is not a participant in the software market, but the availability of third-party software impacts the utility of consumers of the hardware good. That is, consumers have zero demand for goods in the software market unless they consume the hardware good as well. The software market is assumed to not be subject to concerns about copying, though, without proof, I claim that it should not affect analysis much.[6]

While it may seem strange to think of hardware as being subject to copying, rather than software, it is not hard to think of examples which fits into the framework. For example, Microsoft Windows could be the hardware, and the software market is then the market for third-party applications. Or, a web browser

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5 Although, the introduction of copies into the market implies that the monopolist can not extract the same amount of surplus as if copying was not possible. As we shall show, though, the highest value consumers purchase original goods, while lower value consumers (attempt to) obtain copies.

6 Intuitively, it should increase the monopolist's willingness to allow copying. The monopolist would not only receive increased demand in the hardware market, but also in the software market. Of course, in the model below free entry leads to a zero-profit condition in the software market. If, however, there was some market power in the software market, then the monopolist's existence in that market should increase the willingness to allow copying of hardware.

or application (Excel) could be the relevant hardware, and software would represent add-on modules or plug-ins that are used in conjunction with the application. The exact assumed relationship between hardware and software is explained below, where it is shown that (as in Economides, 1996), the existence of the complementary third-party software market reduces down to a traditional network externality for consumption of the hardware good.

3. Software Market

The software market is assumed to be a standard differentiated product model (a circular city a la Salop) with circumference equal to 1 and uniform density equal to the size of the hardware market, *S*. We can think of each consumer of the hardware good as existing somewhere on the circular city. That is, there are more consumers in the software market the bigger the hardware market is.

Consumers in the circular city have gross surplus from a piece of software equal to *K* (large enough to ensure that all consumers will purchase software) and linear transportation cost equal to *t*. There is a fixed cost of entry into the software market of *f*, and there is zero marginal cost for production of a good. This yields a price for firm *i* of $p_i = t/n$ and a quantity of $x_i = S/n$. The profit of a firm in the industry is then $\pi = \frac{S}{n}\frac{S \bullet t}{n} - f$. The zero profit condition then implies that the number of software firms is:

$$n = S\sqrt{\frac{t}{f}} \qquad (1)$$

Thus, a larger installed hardware base implies a larger number of firms (more variety) in the software industry.

4. Hardware Market

We first consider the case of the monopolist's decision whether or not to allow copying in a static framework, where the degree of casual copying is exogenous, and represented by the parameter a, which is described below. The timing is as follows: first consumers form expectations about the size of the hardware network and the number of firms in the software market, then the monopolist prices, taking into account the expectations of consumer, and finally consumers make purchase and copying decisions, and the size of the network and the software market are realized.

4.1. Consumers

Following Katz and Shapiro (1985), consumers in the hardware market form expectations about the size of the hardware market as well as implied number of firms in the software market. Given an expected size of the hardware market of S^E and an expected number of firms in the software market of n^E, each consumer has surplus associated with consumption of the hardware good equal to $r+v(S^E)+w(S^E)$. We assume that $v',w'> 0$ v'',w'',[7] and also that $v(0) = w(0) = 0$, that is that is there is no network effects resulting from a network of size 0 Then, r can be thought of as the consumer's valuation of the hardware independent of any other consumers or the availability of any software products.

The function $v(S)$ is a standard direct network externality function, while $w(n)$ represents the increase in each consumers value of the good as the amount of variety in the software market increases. Each consumer has the same v and w, so the expected sizes of the network and the complementary market have the same effect on all consumers. However, consumers differ in their r. We assume a continuum of consumers, with values of r that are uniformly distributed from $-\infty$ to θ.[8] Thus, the value of the hardware to a consumer who pays a price p for the hardware is[9]

$$U^{\text{buying}} = r + v\left(S^E\right) + \omega\left(n^E\right) - p \tag{2}$$

The expected size of the hardware network, S^E, implies that the expected number firms in the software market in $n^E = S^E\sqrt{\frac{t}{f}}$. Letting $\tilde{w}(x) = w(x\sqrt{\frac{t}{f}})$, we can write the consumers net surplus of the hardware good as

$$U^{buying} = r + v(S^E) + \tilde{w}(S^E) - p \tag{3}$$

Then, we see that the software/hardware paradigm can be represented as an additional traditional network externality.

Consumers who decide not to purchase the hardware from the monopolist receive surplus that equals an exogenous fraction, $\alpha \in [0,1]$, of the gross surplus from buying the good

$$U^{copy} = \alpha(r + v(S^E) + \tilde{w}(S^E)) \tag{4}$$

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7 The assumption of (weakly) concave network externality functions is standard in the literature. It is sufficient that there is a network size S' and a market size n', such that for all $S > S'$ and $n > n'$, $v'(S)+w'(n)<1$, which rules out the possibility of infinite network sizes being realized.

8 This assumption will create a linear demand curve in the market. Furthermore, the normalization of marginal cost to zero somewhat alters the interpretation of r, as it can now be thought of as the consumers value of the good above marginal cost, absent any network effect. Thus, negative values of r have a natural interpretation. However, there is an implicit assumption in this set-up that the marginal cost of a copy is equal to the marginal cost of an original. For goods distributed on CDs, this is likely empirically approximately correct.

9 Although the consumers are forming expectations about network size, utility need not integrated over potential network sizes, because we will focus on rational expectations equilibrium, where expected network size is actualized. Thus, forward looking consumers know that the expected network size will be realized, and there is no uncertainty.

The fraction α can be interpreted two ways. The first interpretation is that the consumer (assumed to be risk neutral) receives a perfect copy an original, but receives it only with probability α.[10] In this case, α represents the degree to which causal copying exists in the market. A high α corresponds to a large degree of casual copying (little copy protection on the part of the monopolist), while a low α corresponds to little causal copying (or strong copy protection)[11] In the second interpretation, the consumer is always able to obtain a copy of an original, whether that is a lack of functionality or a lack of support from the monopolist. This degradation could be the result of a lack of technical support, locked features that require registration, or simple degradation from copying, such as a reduction in image or audio quality. It is assumed that this is the only price associated with a copy.[12] In either interpretation , $\alpha = 0$ represents a no-copying regime with absolute copyright enforcement. The two interpretations yield slightly different results which are discussed below, since the imply different sizes of the final network.

Given the monopolist's price p, a consumer will prefer to purchase rather than copy if.

$$(1-\alpha)(r + v(S^E) + \tilde{w}(S^E)) > p \tag{5}$$

or

$$r > \frac{p}{1-\alpha} - v(S^E) - \tilde{w}(S^E) \tag{6}$$

Thus the demand curve facing a monopolist, given consumer expectations equal to S^E and level of casual copying equal to α, is

$$D = \theta - \frac{p}{1-\alpha} + v(S^E) + \tilde{w}(S^E) \tag{7}$$

as consumers for which $r + v(S^E) + \tilde{w}(S^E) < 0$ would not purchase the hardware at any non-negative price (and thus will also not attempt to obtain a copy of an original, which has price equal to 0).

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10 It is likely that is possible to obtain an illegal copy of almost any piece of software. However, in practice, differing levels of copy protection mean that it will take longer to obtains copies of some software. Searchh and time, however, do not exist in this model, but can be thought to exist in the parameter α. Increased copyright enforcement makes it harder (in terms of realized search time) for consumers to obtain a copy. If consumers are only willing to search for finite time, then they become more likely not to be successful in their searches copy protection is increased. Thus more copy protection results in a low value of α.

11 Note that it may seem appropriate to have the probability of obtaining a copy be proportional to the amount of originals that are sold. However, given that a monopolist facing a straight-line demand curve maximizes profit by selling to half the market, it will always be that one half of consumers who have a positive gross valuation of the good purchase originals. Therefore nothing is lost (within this model) by assuming that α is independent of sales.

12 Except for the marginal cost of a copy, which is normalized out of r as discussed above.

4.2. Monopolist

The monopolist's profit function is them:

$$\pi(p, S^E) = p(\theta - \frac{p}{1-\alpha} + v(S^E) + \tilde{w}(S^E)) \tag{8}$$

Solving the FOC implies that

$$p(S^E) = \frac{1-\alpha}{2}(\theta + v(S^E) + \tilde{w}(S^E)) \tag{9}$$

$$q(S^E) = \frac{1}{2}(\theta + v(S^E) + \tilde{w}(S^E)) \tag{10}$$

$q(S^E)$ is the quantity of originals copies supplied to the market by the monopolist when consumer expectations of market size are S^E, and it follows that profit for the monopolist is

$$\pi(S^E) = \frac{1-\alpha}{4}(\theta + v(S^E) + \tilde{w}(S^E))^2 \tag{11}$$

As Katz and Shapiro noted, there are many market quantities corresponding to different expectations of network size, and thus it will be worthwhile to focus on rational expectation equilibrium where the consumers expectations about the size of the hardware network (and thus the number of software firms) are realized, $S^E = S$.

4.3. Equilibrium

The actual network size is equal to sum of the number of consumers who purchase the hardware and the number of consumers who are able to obtain a copy. Thus, $S = q(S^E)$ + quantity copied.

It is here that the two different interpretations of α yield different results. Under the first interpretation that α is a probability of receiving a copy, the total quantity copied will be $\alpha(\frac{1}{2}(\theta + v(S^E) + \tilde{w}(S^E)))$, and we have that $S_1 = \frac{1+\alpha}{2}(\theta + v(S^E) + \tilde{w}(S^E))$. Under the second interpretation that α represents a loss in quality of a copy compared to an original, everyone who would receive positive surplus from a copy will either purchase or receive a copy (half purchase, the other half obtain not fully functional copies), and $S_2 = (\theta + v(S^E) + \tilde{w}(S^E))$.

Imposing rational expectations equilibrium requires that $S = S^E$, and so we have that S_1, S_2, and S_{NC} (the network size whit no copying) solve:

$$S_1 = \frac{1+\alpha}{2}(\theta + v(S_1) + \tilde{w}(S_1)) \tag{12}$$

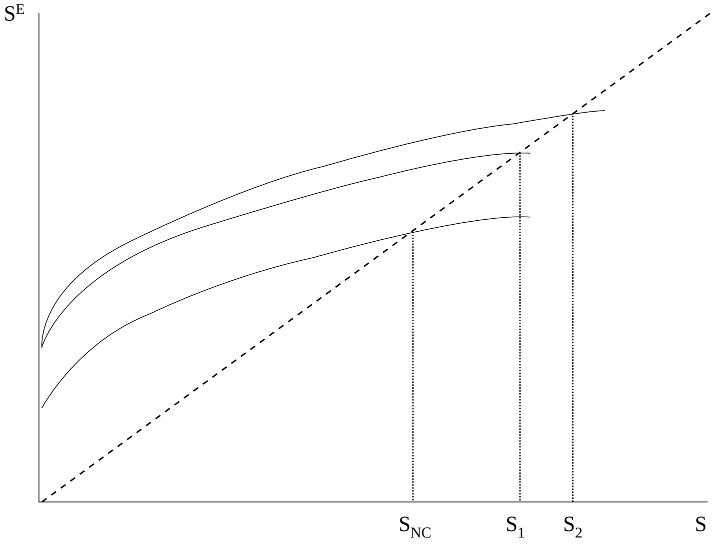
$$S_2 = (\theta + v(S_2) + \tilde{w}(S_2)) \tag{13}$$

$$S_{NC} = \frac{1}{2}(\theta + v(S_{NC}) + \tilde{w}(S_{NC})) \tag{14}$$

Given the concavity assumptions on v and w, we know that $v + w$ is also concave and thus S_1 and S_2 have unique solutions.

It is immediate from that $S_2 > S_1 > S_{NC(\alpha=0)}$, that is, the size of the network is increasing in the amount of casual copying (α).

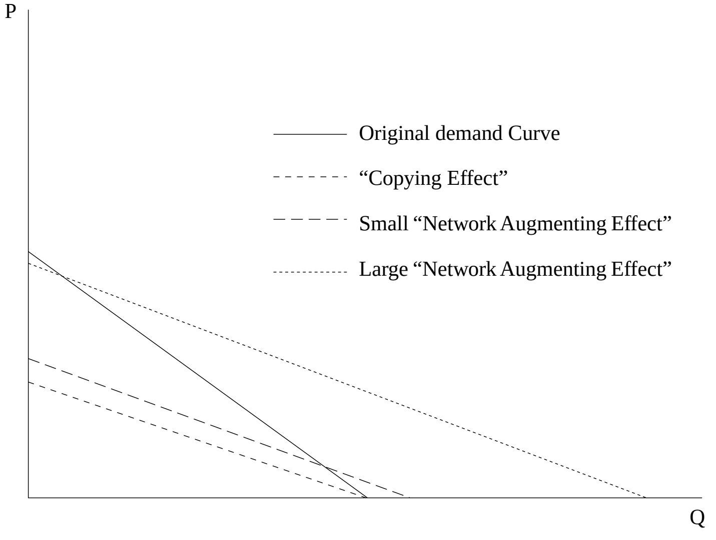
FIGURE 1
RATIONAL EXPECTATIONS EQUILIBRIUM



4.4. Copying or Not?

The question remains, should the monopolist allow casual copying? There are two effects. First, casual copying ($\alpha > 0$) implies a larger outsides option for consumers in the hardware market. This “copying effect” results in the demand curve rotating inward. By itself this implies that the firm’s profits will be lower, as sales do not decrease, but the price is reduced. However, the second effect is that the increased installed hardware base that copying creates implies a larger willingness to pay by consumers, which shifts the demand curve outward. This “network-augmenting” effect due to the fact that there are many more hardware consumers (the $v(.)$ function). Secondly, the software network (the $w(.)$ function). These two effect imply that the demand curve is shifted outward, which results in a larger price and quantity for the monopolist.

FIGURE 2
"COPYING EFFECT" AND "NETWORK AUGMENTING EFFECT"
OF CASUAL COPYING ON DEMAND



The net impact of these two effects depends on the size of α and the marginal size of the network effects $v(.)$ and $w(.)$. A larger α implies a larger inward rotation of the demand curve (as well as a large jump in *S* from copying). And larger network effects imply a larger outward shift in the demand function. If the second effect dominates (there is a large marginal "network-augmenting" effect relative to the "copying effect"), then firms will find it profitable to allow casual copying at a level α. Thus, we might expect that in a industry with large network effects, monopolists would rather turn a blind eye to casual copying. However, if the marginal network effect is small, than the inward rotation of demand will dominate and the firm will prefer to take means to prevent casual copying and restore $\alpha = 0$.

Mathematically, the difference in profits to the monopolist (which depends on how *a* is interpreted) is:

$$\pi_C - \pi_{NC} = \frac{1-\alpha}{4}(\theta + v(S_{1,2}) + \tilde{w}(S_{1,2}))^2 - \frac{1}{4}(\theta + v(S) + \tilde{w}(S))^2 \tag{15}$$

$$= \frac{-\alpha}{4}\theta^2 + \frac{1-\alpha}{2}(v(S_{1,2}) + \tilde{w}(S_{1,2}) - \frac{1}{2}(v(S) + \tilde{w}(S)) \tag{16}$$

$$+ \frac{1-\alpha}{4}(v(S_{1,2}) + \tilde{w}(S_{1,2}))^2 - \frac{1}{4}(v(S) + \tilde{w}(S))^2 \tag{17}$$

The first term $(\frac{-\alpha}{4}\theta^2)$ is the "copying effect" which represents the unambiguous loss of extractable surplus from the consumer. The second term $\frac{1-\alpha}{2}(v(S_{1,2})+\tilde{w}(S_{1,2}))-\frac{1}{2}(v(S)+\tilde{w}(S))+\frac{1-\alpha}{4}(v(S_{1,2})+\tilde{w}(S_{1,2}))^2-\frac{1}{4}(v(S_{1,2})+w(S_{1,2}))^2$ is the "network –augmenting" effect on demand which represents the larger surplus each consumers receives because of the larger network size when copying is allowed. The difference in profits is positive (and the monopolist prefers that casual copying exists) when the second effect is larger. Notice that the monopolist is more likely to allow casual copying when the second interpretation of α is taken, as this implies that the network size will be as large as possible (subject to the rational expectations equilibrium restriction), and thus the network externalities will be maximized.

As first noted in Takeyama (1994), the potential advantage here is one of price discrimination. The monopolist is able essentially to price discriminate between high and low value consumers, setting a positive price at which high the monopolist is able to induce a large network size without setting a uniformly low price which would induce low value consumers to purchase, and instead uses copying to archive this effect. It is possible (if the condition above does not hold) that the monopoly price charged to high value.

5. Choosing a level of copy protection

We now extend the model to allow the monopolist to choose a level of copyright enforcement. That is, the firm can choose a value for α. We can imagine this happening through the firm withholding support for non-registered users, locking features within the good, or employing sophisticated duplication prevention methods in production of the good, or more diligent attempts at enforcing copyrights either privately or through law enforcement. Whatever form copy protection takes, the level of copy protection associated with a good is certainly one choice variable for a firm in product design. In this framework, the monopolist is simply able to choose α. For this discussion, we assume that α represents a probability of finding a copy, and thus copy protection takes the form of making it more difficult for consumers to obtain a copy of the good. (The alternative interpretation is not as appealing in this case, because the size of the network does not depend on α, and thus the firm's optimal choice would be α as close to zero as possible, which would take full advantage of the network-augmenting effect with (essentially) zero loss associated with the copy effect.)

From above, we can see that the firms profits are purely a function of the choice of α. Given an α, the realized network size and profit level are determined from the behavior discussed above. Therefore, the firm can directly consider the effect that a change in α has on profits.

$$\frac{d\pi}{d\alpha}=\frac{\partial\pi}{\partial\alpha}+\frac{\partial\pi}{\partial S}\frac{dS}{d\alpha} \tag{18}$$

That is, the change in the monopolist's profits from a differential decrease in the level of copy protection (as α increased, the level of copy protection decreases) is composed of the two effects mentioned above. First, there is the "copying effect" which is the direct negative impact on the profit function $(\frac{\partial \pi}{\partial \alpha} < 0)$. As it becomes easier for consumers to get copies, amount of surplus that the monopolist can extract is reduced because the consumer now has a better outside alternative to purchasing the good. But it is the second effect that suggests that a monopolist might want to allow casual copying. The second term $(\frac{\partial \pi}{\partial S}\frac{\partial S}{\partial \alpha} > 0)$ is the "network-augmenting" effect that casual copying has on profits through the increased network size that copying creates. As the level of copy protection decreases, realized network size increased, which increase the extractable surplus of consumers. Now, if the "network-augmenting" effect outweighs the "copying effect", them the monopolist will find it optimal to increase α and allow an increase in level of casual copying.

From above,

$$\frac{dS}{d\alpha} = \frac{\frac{1}{2}(\theta + v(S) + \tilde{w}(S))}{1 - \frac{1+\alpha}{2}(v'(S) + \tilde{w}'(S))} > 0 \tag{19}$$

Note that $\frac{dS_1}{d\alpha} > 0$ here because at equilibrium, the concavity assumptions on v and w imply that $v'(S_1) + \tilde{w}(S_1) < 1$. So, increasing α has a bigger effect on the realized hardware base when the marginal network externality is larger.

Differentiating the profit function completely yields

$$\frac{d\pi}{d\alpha} = -\frac{1}{4}(\theta + v(S) + \tilde{w}(S))^2 + \frac{1-\alpha}{2}(\theta + v(S) + \tilde{w}(S))(v'(S) + \tilde{w}'(S))\frac{dS}{d\alpha}$$

$$= (\theta + v(S) + \tilde{w}(S))^2\left[\frac{-1}{4} + \frac{1-\alpha}{2}\frac{(v'(S) + \tilde{w}'(S))}{2-(1-\alpha)(v'(S) + \tilde{w}'(S))}\right] \tag{20}$$

So, the copying effect is proportional to $\frac{1}{4}$ while the network effect is proportional to $\frac{1-\alpha}{2}\frac{f'(S)}{2-(1+\alpha)f'(S)}$. We know immediately that the firm will not choose $\alpha = 1$, because at $\alpha = 1$, the firm makes zero profit, while any other level of a yields positive profits. Noting that $\frac{d\pi}{d\alpha}$ is monotonic decreasing in α, to determine if the firm prefers some level of casual copying to no copying at all, it is sufficient to check the sign of $\frac{d\pi}{d\alpha}$ at $\alpha = 0$

$$\frac{d\pi}{d\alpha}(\alpha=0)>0 \Leftrightarrow \frac{-1}{4}+\frac{1-\alpha}{2}\frac{f'(S)}{2-(1+\alpha)f'(S)}>0 \tag{21}$$

$$f'(S)>\frac{2}{3} \tag{22}$$

So, if the composite marginal network externality is strong enough $(f'(S)=v'(S)+\tilde{w}'(S)>\frac{2}{3})$, then the monopolist increased his profits by relaxing copyright protection somewhat. This is intuitive, because the firm will benefit from some level of casual copying if the boost in network size it gets through the increased network externality as copies proliferates is large enough to overcome the negative "copying effect".

Allowing the firm to optimize over the choice of α leads to the condition $\frac{d\pi}{d\alpha}=0$, subject to the constraint $\alpha \in$ [0,1], which yields

$$\alpha^* = \begin{cases} \dfrac{3f'(S)-2}{f'(S)} & f'(S)>\dfrac{2}{3} \\ 0 & f'(S)\leq\dfrac{2}{3} \end{cases} \tag{23}$$

Where S is determined through the rational expectations equilibrium given α.[13] So, as the marginal network externality decreases, the monopolist is willing to allow less and less casual copying. The intuition for this is straightforward: as the demand network externality becomes less and less important, the monopolist again less by allowing non-purchasers the ability to get an 'unauthorized' copy of the good, and thus desires a higher level of copy protection. Thus, for goods that have a strong marginal network externality, the monopolists should be willing to allow a (relatively) large degree of casual copying, while a good that has little (or no) marginal network externality would attempt to enforce full copyright protection. (Note that introducing some cost of enforcing a copyright would have little qualitative impact, and would just lower the bound on the marginal network externality above which the firm would allow copying. That is, the firm would be more willing to allow copying.)

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[13] If the combined network externality function is linear, $f'(S)=kS$, so that $f'(S)=k$, (with $k<1$) then we have that $\alpha^*=\frac{3k-2}{k}$ for $k>\frac{2}{3}$ and $\alpha^*=0$ for $k\leq\frac{2}{3}$. So the hardware monopolist prefers some level of copying if the marginal network effect is bigger than $\frac{2}{3}$. The corresponds exactly to linear externality case in Economides (1996), who finds that a monopolist will prefer to license to at least one other firm if $k>\frac{2}{3}$.

6. Dynamic Game

Finally, we introduce a simple dynamic game in which the monopolist sells hardware in two periods to examine what path copy protection might take over the life-cycle of a product. There are two periods t = 1,2, and the monopolist faces a distinct, but identical, set of consumers in each period. That is, consumers live for only period, while the monopolist lives for two periods. This allows us to avoid the typical problems related to monopolist pricing in dynamic settings, such as the Coase conjecture. However, we assume that some of the network externality from the network that exists in t = 1 continues on to period t = 2. In particular, we will assume that the variety of products in the software market in period 1 are still available in period 2, along with any new products that arise in software market in period 2 as a result of the hardware network in period $2(n^{t=2} = n^{t=1} + n^{new})$. A possible interpretation for this carry over is that the product in period 2 is a upgraded version of the period 1 hardware product that has backwards compatibility with the software produced for the period 1 hardware. An example would be Windows 95, which featured backward compatibility with Windows 3.11, and thus ran all software designed for the previous operating system, but offered many new features. However, one can imagine other stories where a new generation of consumers would yield benefits arising from large networks of users existing before them.

Proposition 1 In the dynamic game explained above, the level of α chosen by the hardware monopolist in period 2 is (weakly) less than the level of α chosen in period 1. That is $\alpha^{t=2} \leq \alpha^{t=1}$.

Proof. See Appendix. The intuition of the proof is simple however. In the final period, the monopolist plays a simple static game strategy as above, however, the increased base network size resulting from the period 1 network simply means that the marginal network externality is (weakly) less than in the static case, and thus there is (weakly) more copy protection in period 2 than in the static case. In the first period, however, there is a new effect that allowing copying in period 1 has. It increases the network size (and thus demand and profits) in both period 1 and period 2, while the negative aspect (easier availability of an unauthorized copy of the period 1 good) is exactly the same. Thus, the monopolist's incentive to allow copying in period 1 is greater than in the static case and there is (weakly) less copy protection in period 1 than in the static case. Therefore, there is (weakly) more copy protection in period 2 than in period 1. Thus $\alpha^{t=2} \leq \alpha^{t=1}$.

The proposition above tells us that as a good (or product-line) becomes more mature, the level of copyright enforcement chosen by the monopolist will increase. It is simple to extend the above game to more periods, and we would achieve the same result. The logic here is clear: once goods have formed established networks, there is little gain to consumers from adding other consumers to the network. Another Microsoft example may help to clarify the thought process. When Windows 3.11 was released, Microsoft Windows and Macintosh OS were both relatively widely used. The addition of another consumer to the Windows 3.11 hardware network then had a relatively strong network externality on all other uses. As the network grew, third-party software manufactures found it to be more worthwhile to focus on the Windows market, rather than the Macintosh market. However, by the time that Microsoft released Windows XP, almost all third-party software applications that are released are already focused on the Windows market, and so there is less gain in the form of additional software variety from adding another consumer to the Windows market, which is arguably already mature.

Thus we'd expect that producers of new goods would desire low levels of copyright enforcement, while producers of goods that already have established networks would (ceteris parabus) desire high levels (or a full level) of copyright protection. And this implication seems to be realistic, at least anecdotally. Again, returning to the Microsoft example, we see that over time, Microsoft has increased the level of copy protection on its operating systems. DOS and Windows 3.x, came on floppy disks and included a back-up program, Windows 95 jumped from floppy disks to CDs, which at the time were expensive to duplicate, Windows 98 required the entry of 12 digit CD-key to unlock the software, and Windows XP features a tight copy protection scheme that sends Microsoft information about the computer it is installed on, and then will not work for more than 30 days if it installed on a computer that does not match the one in the Microsoft database. The proposition above explains the rationality of such a time path given that the marginal network externality for Microsoft OS's is (arguably) far lower now than it ever has been.

7. Conclusion

The work above suggests that firms which produce goods which feature strong network externalities, or equivalently, are strongly complementary with goods in another market may benefit from the casual copying of the type that the software, music, and film industry currently claim are severely hurting them. This result stems from the fact that the additional network size that is generated by the copying may increase consumers' willingness to pay enough to counter balance the loss in extractable surplus that arises from the availability of another option to consumers. By allowing casual copying to spread the good to low value consumers that the monopolist does not want to price to, the monopolist is able to benefit from a large network size without having to resort to a single low price.

Extending the static market into a simplified dynamic setting allowed us to show that as the market for the product matures, the monopolist hardware producer will want to increase the level of copyright enforcement associated with good. This is because as the network gets larger over time, the marginal network externality is less for future generations of consumers. Because it is the increase in the network externality that causes the monopolist to desire to allow copying, a smaller externality on the margin leads the monopolist to attempt to reduce the amount of casual copying among (potential) consumers of the good. Future work could lead towards the analysis of a more complicated dynamic game with multi-generation consumers, to see how the ability of copying to help solve the Coase conjecture may interact with the mature networks tendency to reduce the desired level of copying. Similarly, it would be beneficial to examine the impacts of copying on the choice of consumers between competing technologies, such as Windows or Macintosh, or the Windows and Linux. Third, an examination of impacts of the monopolist's involvement in the third-party software market as well as introducing copying into the complementary market may well yield different implications about the role of copying. In the case where the monopolist plays a role in the complementary market, it may be that the monopolist could prefer complete copying in the hardware market, if it results in large enough increases in demand in the complementary market, which may explain why Adobe, for example, distributes Acrobat Reader for free (this is equivalent to $\alpha = 0$ in the model presented here) and sells Acrobat Writer at a high price.

8 Appendix 1

Proof. Proof of Proposition 1

To show that $\alpha^{t=2} \quad \alpha^{t=1}$, I will first show that period 2 copy protection is stronger than in the static case ($\alpha^{t=2} \quad \alpha^{static}$) and then period 1 copy protection is weaker than in the static case ($\alpha^{static} \quad \alpha^{t=1}$).

Recall the FOC for optimization in the static case:

$$\frac{d\pi}{d\alpha} = (\theta + v(S) + \tilde{w}(S))^2 \left[\frac{-1}{4} + \frac{1-\alpha}{2} \frac{(v'(S) + \tilde{w}'(S))}{2-(1+\alpha)(v'(S) + \tilde{w}'(S))} \right] \quad (24)$$

Thus we have:

$$\frac{1}{4} = \frac{1-\alpha^{static}}{2} \frac{(v'(S) + \tilde{w}'(S))}{2-(1+\alpha^{static})(v'(S) + \tilde{w}'(s))} \quad (25)$$

where S is determined by $S = \frac{1+\alpha^{static}}{2}(\theta + v(S) + \tilde{w}(S))$. Now in period 2 of the dynamic game, the profit function is:

$$\pi(S_2) = \frac{1-\alpha^{t=2}}{4}(\theta + v(S_2) + \tilde{w}(S_1 + S_2))^2 \quad (26)$$

$$S_2 = \frac{1+\alpha^{t=2}}{2}(\theta + v(S_2) + \tilde{w}(S_1 + S_2)) \quad (27)$$

Thus, we have:

$$\frac{dS_2}{d\alpha} = \frac{\frac{1}{2}(\theta + v(S_2) + \tilde{w}(S_1 + S_2))}{1 - \frac{(1+\alpha^{t=2})}{2}(v'(S_2) + \tilde{w}'(S_1 + S_2))} \quad (28)$$

and the following FOC:

$$\frac{d\pi}{d\alpha} = (\theta + v(S_2) + \tilde{w}(S_1 + S_2))^2 \left[\frac{-1}{4} + \frac{1-\alpha^{t=2}}{2} \frac{(v'(S_2) + \tilde{w}'(S_1 + S_2))}{2-(1+\alpha^{t=2})(v'(S_2) + \tilde{w}'(S_1 + S_2))} \right] \quad (29)$$

$$\frac{1}{4} = \frac{1-\alpha^{t=2}}{2} \frac{(v'(S_2) + \tilde{w}'(S_1 + S_2))}{2-(1+\alpha^{t=2})(v'(S_2) + \tilde{w}'(S_1 + S_2))} \quad (30)$$

Comparing the two FODs, we see that the change to the FOC is the inclusion of an additional S_1 in the $\tilde{w}'$ term. Since $\tilde{w}'' \leq 0$, this implies that $\tilde{w}'(S_1 + S_2) \leq \tilde{w}'(S_2)$. For all S_1, S_2. Now we can rewrite the generic FOC as:

$$1 - \frac{(1-\alpha^{t=2})}{1 - \frac{(1+\alpha^{t=2})}{2}(v' + \tilde{w}')} = 0 \quad (31)$$

and solve for $\frac{d\alpha}{d\tilde{w}'}$ and get:

$$\frac{d\alpha}{d\tilde{w}'} = \frac{-(1-\alpha^{t=2})}{(v' + \tilde{w}')^2 - (v' + \tilde{w}')} > 0 \quad (32)$$

because $(v' + \tilde{w}') < 1$ by assumption. Thus a decrease in $\tilde{w}'$ for all S_1, S_2 leads to a decreased in α and so we have that $\alpha^{t=2} < \alpha^{static}$.

To show that $\alpha^{static} \quad \alpha^{t=1}$, we follow a similar strategy. The FOC for period 1 now includes terms relating to the profit in period 2. All of these terms enter in as a (weakly) positive function of $\alpha^{t=1}$. This is the only difference between the FOC for the static case and the FOC for the dynamic case. Trust immediately follows that $\alpha^{static} \quad \alpha^{t=1}$. Putting these together we get that $\alpha^{t=2} \quad \alpha^{t=1}$, and thus (weakly) more copy-protection is sought by the monopolist in the second period than in the first period of the dynamic game.

QED.

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