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Abstract: Digital products such as movies, music and computer software are protected both by self-help measures such as encryption and copy controls, and by the legal right to prevent copying. We explore how digital rights management and other technical protections affect the pricing of content, and consequently, why content users, content vendors, and antitrust authorities might have different views on what technical capabilities should be deployed. We discuss the potential for "collusion through technology."

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1. Copyright Enforcement by Technical Protection Measures

Digital products such as movies, music and computer software are protected both by self-help measures such as encryption and copy controls, and by the legal right to prevent copying. The purpose of this paper is to understand how digital rights management and other technical protections affect the pricing of content, and consequently, why content users, content vendors, and antitrust authorities might have different views on what technical capabilities should be deployed.

We begin by giving examples of the varied systems that have been tried or are currently in use. Protection for digital content has been evolving since the 1980's, with the legally mandated Serial Copy Management System for digital audio tape. This system caused the quality of copies to degrade, so that, as with analog audio tapes, it was hard to make faithful copies of copies. The solution was inelegant at best, but in any case, has become obsolete due to the proliferation of other digital mediums. In the late 1980's, vendors began to sell software for personal computers with a one-installation feature. These measures were cumbersome, restricted fair use, and were rapidly circumvented.

As content distribution has moved to the internet, watermark and encryption technologies have developed. A watermark, by analogy with a watermark on paper stationery, is a piece of software code embedded in a program. If illicit copies of the software circulate, the watermark can identify the original buyer or licensee of the copy that is circulating. This may or may not be useful, depending on whether the original buyer or licensee can be held liable. Encryption systems attempt to make digital content uninterpretable or inaccessible without use of a code key. The code key generally authorizes playing the content on a specific piece of hardware. For example, the movie industry has developed digital versatile disks (DVDs), which are protected by a technology called the Content Scrambling System (CSS). CSS authorizes access by matching a code embedded in disks to a code embedded in DVD players. Among other purposes, this system ensures that movies released for viewing in one region of the world cannot be viewed in another that may have a later release date.

Although it may be possible for each content provider to implement its own protection system, there are many proposals for coordinated industry-wide standards. However, standardization of technical protections does not imply standardization of media players or vice versa. A technical protection system can be implemented on different media players, and a media player can implement different technical protection systems. For example, since the personal computer is currently the primary device used to play and organize digital media, calls for protection are influencing its design. Intel introduced a controversial serial number on its Pentium III chip that could potentially identify specific computers for watermarking or encryption purposes. The Microsoft-led Trusted Computing platform promises to provide a "hack-proof" environment that can restrict the viewing or playing of content to authorized computers. MPEG4, the updated standard for digital video encoding, provides "hooks" for a technical protection system, and does not specify a particular implementation.

Technical protection platforms raise a host of issues regarding ownership, licensing, and price control over players as well as content. For DVDs, both the hardware and software are proprietary, and jointly licensed. On the hardware side, Toshiba administers the licenses, charging per-unit license fees on the sale of DVD media, players, and decoders. The collected fees are then distributed to the patentholders (Hitachi, Matsushita Electric, Time Warner, Toshiba, and Victor) proportionally to each member's holdings in the patent portfolio. On the software side, the Motion Pictures Expert Group (MPEG), which includes device manufacturers, content companies, and others, use similar terms to license the digital video and audio algorithms (called "codecs") used on DVDs and digital television. Finally, the DVD Copy Control Association (DVD-CCA), controlled primarily by the content industry, licenses the technical protection measure known as the Content Scramble System (CSS). These license fees are linked to players rather than to usage of digital content.

The license on DVD hardware is for a "pool" of patents. Patent pooling for standardization is generally thought to be pro-competitive, barring practices that are anticompetitive or not necessary for the dissemination of intellectual property (Shapiro 2001). The Department of Justice Antitrust Division issued favorable review letters on both the DVD and the MPEG licensing agreements. Notably, however, the review of these agreements focused almost entirely on the competitive effects in device markets. As the licensing fees were only at the encoding/decoding level in the physical media, the effect on the content market was assumed to be minimal, and only briefly considered. This, however, is the focus of our paper.

Much of the emphasis below will be on the cost of circumvention, and how it affects the pricing of digital content. From that perspective, the issue is not whether content providers implement different protections, but whether a circumvention reduces the cost of the next circumvention. If the means of circumvention are substantially similar, in the sense that circumventing one system is tantamount to circumventing all of them, then for our purposes, the content providers are using the same system. We will first stylize the problem as if content providers use different systems, in the sense that there are no such cost advantages, and then as if they use the same system, in the sense that a single circumvention gives access to all content. A shared system makes circumvention more attractive. This is key to our analysis.

In section 2 we assume that each content provider has its own technical protection system, and show that technical protections lead to lower prices for content than perfect legal enforcement, at least when each vendor provides his own protection system. Surprisingly, lower prices might lead to the result that technical protection is better for providers as well as users, as compared to perfect enforcement of legal protection. This is essentially because, even if per-period profit is smaller, there is no legal end to protection by technical means.

Even more surprisingly, we show in sections 3, 4 and 5 that jointly owned and implemented industry standards – which obviously have a potential for collusion – can lead to lower prices for content than independently deployed systems. This depends both on the degree of substitutability in vendors' digital products and on the cost structure for technical protection. In sections 6 and 7, we investigate how the competitive environment is affected by technical capabilities, from the point of view of both consumers and vendors.

2. Technical Protections and Proprietary Pricing

Probably the most severe criticism of intellectual property as an incentive mechanism is that, in allowing content creators to raise prices to the monopoly level, it creates deadweight loss by excluding users. Will technical protections exacerbate this problem or serve as an antidote? One reason the answer is not obvious is that the strength of protection is an optimizing choice. Even if it is possible to exclude all unauthorized users, the vendor will not typically find it profitable to do so. It may be cheaper to price so that circumvention is deterred rather than to bear the high costs of implementing a hackproof protection system. The incentive to avoid circumvention and to avoid the high cost of protection will have a moderating influence on price.

The assumption here, following Conner and Rumelt (1991), is that a user will buy a legitimate copy instead of circumventing the protection system whenever the price of the legitimate copy is lower than the cost of circumvention. The vendor's optimizing strategy takes account of this. We also assume that, although individual circumventors can circumvent without detection, they cannot make the content freely available on the internet, or sell a circumvention tool. Those activities would be easily detectable and would put the circumventor in jeopardy under the Digital Millenium Copyright Act. The issues surrounding unprotected existing content currently

In this section we show that technical protection will generally result in a lower market price than the monopoly price that would be charged with perfect legal enforcement. In the Appendix, we show that dispersion in the costs of circumvention may exert yet another downward influence on price.

To be more concrete, index agents by $\theta \in [0,1]$, uniformly distributed, and suppose that the willingness to pay of agent θ is θ. Figure 1 shows a willingness to pay (WTP) curve, also called the inverse demand curve, for copies of a work. For each price p, the number of potential users with willingness to pay θ greater than p is $1-p$. At price p, the consumers' surplus of buyers is

$$s(p) = \int_p^1 (\theta - p)\, d\theta = \frac{1}{2}(1-p)^2 \qquad (2.1)$$

We assume that the marginal cost of copying is zero. Thus, if copying can be controlled, the monopoly price will be $p^* = 1/2$, which maximizes per-period profit,

$$\pi(p) = p(1 - p).$$

However, if the copies cannot be controlled, the demand curve for legitimate copies falls to zero. Technical protection measures can mitigate this problem.

Index the strength of protection by $e \in \mathbf{R}_+$, and interpret e as the cost of circumvention. Formalizing the intuition that the cost of protection increases superlinearly in the cost of circumvention, denote the cost of implementing protection level e by $K(e) > 0$, where K and K' are increasing. We shall first suppose that the cost of circumvention is the same for all users, which we will also take to be e. After the rightholder has chosen the strength of protection, e, he must set a price. If $e > p^*$, then the optimal price is p^*. It is therefore wasteful to implement a protection $e > p^*$, since the proprietor does not need such strong protection in order to charge the monopoly price. If $e < p^*$, the optimal price is $p = e$, the cost of circumvention. At that price, no users will circumvent the technical protection measure in equilibrium.

Thus, for any $e \leq p^*$, the firm's profit as a function of e is $\pi(e) - K(e)$, where both π and K are increasing, and π flattens out for $e > p^*$. The profit-maximizing level of protection, say $\hat{e}$, maximizes the difference between profit and cost, and must be lower than p^*. Thus,

Remark 1. If each user's cost of circumvention is e when the protection level is e, the profit-maximizing level of protection $\hat{e}$ satisfies $\hat{e} < p^*$, where p^* is the profit-maximizing price with perfect legal enforcement. The profit-maximizing price satisfies $\hat{p} = \hat{e} < p^*$. There is no circumvention in equilibrium.

Now suppose that there is dispersion to the costs of circumvention. For this case we must define an "effective" demand curve that recognizes that some agents may circumvent rather than buy legitimate copies. To define the effective demand curve, assume that each user will buy if both his willingness to pay and his personal cost of circumvention, say c, are higher than the price. Agent θ will buy if $\theta, c \geq p$. He will circumvent if both his willingness to pay and the price are higher than his cost of circumvention, $\theta, p \geq c$. Suppose that the costs of circumvention are distributed according to a distribution function G with density g, independently of θ, such that, if $e > e'$, then $G(\cdot; e)$ stochastically dominates $G(\cdot; e')$.[1] At the price and protection (p, e), the demand for legitimate copies is

$$(1-p)(1-G(p;e))$$

The term $(1-p)$ represents the fraction of consumers for whom willingness to pay is higher than the price, and the term $(1-G(p;e))$ represents the fraction for whom the circumvention cost is higher than the price.

The proprietor's profit is

$$\Pi(p,e) = p(1-p)(1-G(p;e)) - K(e) \tag{2.2}$$

For each e, let $p(e)$ be the price that maximizes $\Pi(p, e)$. Given this setup, we prove the following result in the appendix:

Remark 2: When the costs of circumvention are dispersed, for every e, $p(e) < p^*$. Suppose that the costs of circumvention are uniformly distributed with expected value e when the protection level is e. If $\hat{e}, \tilde{e}$ are respectively the profit-maximizing protection levels when circumvention costs are not dispersed and when dispersed uniformly, then $p(\tilde{e}) < \hat{e} < p^*$.

Thus the threat of circumvention lowers the price of content, and dispersion in circumvention costs may lower it even more.

While the price and profit are lower in each period, the technical protection can continue forever, and may thus end up being more profitable than perfect legal enforcement, which eventually expires. This may even be true if the costs K are taken into account. Moreover, it is not obvious that the threat of circumvention increases consumer welfare, even though it reduces the per-period price. This is again because the technical protection can continue indefinitely, rather than expiring, as an intellectual property right does. In fact, a technical protection system can increase both consumer welfare and the proprietor's profit, as compared with perfect legal enforcement for a limited duration.

[1] That is, $G(c; e') > G(c; e)$ for every c in the support of G.

We will show this in an example, but first we make a preliminary comment on the optimal structure of rewards to creation. For each p, let $DWL(p)$ be the lost consumers' surplus at the price p (deadweight loss). Remark 3 says that if a lower price is coupled with longer protection to just the extent that total profit is preserved, and if this has the effect of reducing the deadweight-loss-to-profit ratio, consumers are better off. This ratio test is satisfied for linear demand curves, as assumed here.

By assuming that revenue is held fixed, Remark 3 focuses on the optimal structure of rewards ex post. It allows us to consider ex post efficiency without considering the ex ante incentive to create. In the remainder of this paper, where we consider governance structures for sharing technical protections, the ex ante and ex post efficiency issues are not so easy to disentangle.

Remark 3:[2] Suppose a legal regime lasts T^* discounted years[3] with monopoly price p^*, and suppose a technical protection regime lasts $T(e)$ discounted years, $T(e) > T^*$ with price $p(e)$ that satisfies $p(e) < p^*$. Suppose that the revenue earned in both regimes is the same, $\pi(p(e))T(e) = \pi(p^*)T^*$. Then consumers are better off if and only if

$$\frac{DWL(p^*)}{\pi(p^*)} > \frac{DWL(p(e))}{\pi(p(e))} \tag{2.3}$$

Proof: Since $p(e) < p^*$, the per-period consumers' surplus is higher, $s\left(p(e)\right) > s\left(p^*\right)$. With perfectly enforceable copyrights, total consumers surplus is

$$s\left(p^*\right)T^* + (\frac{1}{r} - T^*)s(0),$$

[2]The ratio test for whether a simultaneous price reduction and lengthening of protection helps consumers was introduced in the antitrust context by Kaplow 1984 to evaluate the desirability of licensing practices, and in the patent design context by Tandon (1982) and many subsequent authors (see Scotchmer (2005), chapter 4) to evaluate the desirability of making patents broad or narrow. The notable feature of the ratio test is that the comparison is reduced to a static one. Even though deadweight loss lasts longer in the technical protection regime, we only have to observe that the ratio of deadweight loss to profit is reduced in each period in order to know whether in total the technical protection regime is better for consumers.

[3]The length of protection T is taken to be already discounted. If the statutory length of protection is τ, and the discount rate is r, then $T = \int_0^\tau e^{-rt}dt$. The discounted length of protection, T, cannot be larger than $1/r$, which corresponds to $\tau = \infty$.

where $s(0) = \frac{1}{2}$ is the per-period consumers' surplus after the protection ends, when the product will be "sold" at the competitive price, zero. Analogously, we shall write

$$s\left(p(e)\right)T(e) + (\frac{1}{r} - T(e))s(0)$$

for consumers' surplus with the technical protection in place. Consumers are better off with technical protection of length $T(e)$ if and only if:

$$\left(s\left(0\right) - s\left(p^*\right)\right)T^* - \left(s\left(0\right) - s\left(p(e)\right)\right)T(e) > 0 \tag{2.4}$$

Remark 3 follows from the observation that the consumers' surplus that is lost due to higher than competitive prices is equal to profit plus deadweight loss. Therefore,

$$s\left(0\right) - s\left(p^*\right) = \pi(p^*) + DWL(p^*)$$

$$s\left(0\right) - s\left(p(e)\right) = \pi(p(e)) + DWL(p(e))$$

Then, using $T^*\pi(p^*) = T(e)\pi(p(e))$, the inequality (2.4) holds if and only if (2.3) holds. □

However, this conceptual experiment is not quite the right one for comparing costless enforcement of copyrights with technical protections. Technical protections can continue forever – protection will not end at the duration $T(e)$ required for the profit equivalence. Further, technical protections are costly. Nevertheless, this line of reasoning correctly suggests that technical protections can sometimes make both creators and consumers better off. We show this with an example.

Example: As argued above, if there is no dispersion of circumvention costs, the optimal price with a technical protection is $p(e) = e$. Thus, consumers' surplus per period of time with technical protection is $s(p(e)) = \frac{1}{2}(1-e)^2$.

Social surplus is greater with technical protection than with perfect legal enforcement if

$$T^*s(p^*) + \left(\frac{1}{r} - T^*\right)s(0) \leq \frac{1}{r}s(p(e)) \tag{2.5}$$

Profit is greater with technical protection than with perfect legal enforcement if

$$T^*\left(p^*\left(1-p^*\right)\right) \leq \frac{1}{r}\left(e(1-e) - K(e)\right) \tag{2.6}$$

Let the cost function K be given by

$$K(e) = \begin{array}{ll} \frac{1}{80} & \text{if} \quad e \leq 1/4 \\ e^2 - \frac{1}{20} & \text{if} \quad e > 1/4 \end{array}$$

The level of protection that maximizes $e(1-e)-K(e)$ is $e = 1/4$. The conditions (2.6) and (2.5) on profit and social surplus are satisfied if the discount rate and length of legal protection satisfy

$$\frac{7}{12} < rT^* < \frac{7}{10}$$

3. Independent Technical Protections and Competition

We now turn from monopoly to competition, and consider how the pricing of digital content depends on the protection system. Prices will depend on whether the content providers implement separate systems or share a common one. Our objective is to develop several benchmarks, as a prelude to discussing collusion. However, as will become clear, one of the difficulties is in knowing how to define collusion.

The table below lays out the cases for comparison, partly as a guide to notation. Vendors may implement separate systems for their content or a shared one, and they can price independently or collude. When vendors share a protection system, they must somehow cover their shared protection costs. Much of what follows is directed at the question of how to apportion the costs without giving the firms an opportunity to coordinate pricing, especially since the level of protection must depend on prices.

Pricing:	Protections:		
	None Legal Enforcement	Independent System	Shared System
Independent	$\hat{I}$	I	
Joint		C	J

A finding below is that prices may be higher with separate systems and independent pricing than with a shared system and collusive pricing. This is due to the moderating effect that a threat of circumvention has on price. A shared system is more tempting to hackers, since a single hack gives access to more content. To deter circumvention, the shared protection must be stronger, hence more costly. Instead of bearing the high cost of joint protection, it may be cheaper for the content providers who use the shared system to deter circumvention by lowering prices instead.

Even though protection must be stronger for a shared system than for separate systems, the total cost of shared protection may be lower, since setup costs are only paid once instead of twice. Balanced against the saving in fixed costs is the fact that marginal costs of deploying more protection will be higher in a shared system. Thus, a welfare comparison between the two benchmarks depends both on the cost structure for providing technical protections and on the substitutability of content, which affects the degree to which content prices are affected by collusion.

Suppose that the digital content of each provider is an imperfect substitute for the other. The firms face demands $D_1(p_1, p_2), D_2(p_1, p_2)$, each decreasing in its own price and increasing in the other price (the products are substitutes). The cost of protection will again be given by a positive function K, which has fixed costs and increasing marginal costs as the strength of protection increases. For simplicity we revert to the assumption that there is no dispersion in circumvention costs, and assume that the cost of circumvention is the level of protection, e. (In the more specific model in section 5 we will assume that K is defined by $K(e) = k + \kappa e^2$.)

We will find it useful to define revenue functions

$$\begin{aligned} R_1(p_1, p_2) &= p_1 D_1(p_1, p_2) \\ R_2(p_1, p_2) &= p_2 D_2(p_1, p_2) \end{aligned}$$

To isolate the strategic issues, we will assume that the two vendors of digital content are exactly alike, and will focus on symmetric equilibria. We make the following assumptions. Assumption R1 ensures, among other things, that the goods are substitutes. Assumption R2 ensures that the Nash equilibria below are unique.

Assumption R1 [The firms' prices are strategic complements.]

$$\frac{\partial^2}{\partial p_1 \partial p_2} R_1(p_1, p_2) > 0, \frac{\partial^2}{\partial p_1 \partial p_2} R_2(p_1, p_2) > 0$$

$$\frac{\partial^2}{\partial p_1 \partial p_2} \left[R_1(p_1, p_2) + R_2(p_1, p_2) - K(p_1 + p_2)\right] > 0$$

Assumption R2 R_1 and R_2 are strictly concave and K is strictly convex.

We first consider the case of competition with perfect legal enforcement, as that will become a benchmark for considering collusion in section 6. We also consider competition with separate technical protections.

The prices $(p^{\hat{I}}, p^{\hat{I}})$ are an *equilibrium with perfect legal enforcement* if

$$R_1(p^{\hat{I}}, p^{\hat{I}}) \geq R_1(p, p^{\hat{I}}) \text{ for all } p \geq 0$$

$$R_2(p^{\hat{I}}, p^{\hat{I}}) \geq R_2(p^{\hat{I}}, p) \text{ for all } p \geq 0.$$

The prices (p^I, p^I) are an *equilibrium with separate technical protections* if

$$R_1(p^I, p^I) - K(p^I) \geq R_1(p, p^I) - K(p) \text{ for all } p \geq 0$$

$$R_2(p^I, p^I) - K(p^I) \geq R_2(p^I, p) - K(p) \text{ for all } p \geq 0.$$

Since we have assumed that the prices are strategic complements, it follows that each of these equilibria exists (Milgrom and Roberts, 1990, Theorem 5, or Milgrom and Shannon, 1994, Theorem 12). Further, they are unique.[4]

Now suppose that the firms collude, even though they implement separate protections and have no "legitimate" right to collude. Joint profits are given by

$$R_1(p_1, p_2) + R_2(p_1, p_2) - K(p_1) - K(p_2) \tag{3.1}$$

[4]Because R_1 is strictly concave, $(\frac{\partial R_1}{\partial p_1 \partial p_1}(p_1, p_2))^2 > (\frac{\partial R_1}{\partial p_1 \partial p_2}(p_1, p_2))^2$ at each (p_1, p_2), which implies that $\frac{\partial R_1}{\partial p_1 \partial p_1}(p_1, p_2) + \frac{\partial R_1}{\partial p_1 \partial p_2}(p_1, p_2) < 0$. Suppose, for example, that there are two equilibria with perfect legal enforcement, $(\hat{p}, \hat{p})$ and $(\tilde{p}, \tilde{p})$. Then $\frac{\partial R_1}{\partial p_1}(\tilde{p}, \tilde{p}) = \frac{\partial R_1}{\partial p_1}(\hat{p}, \hat{p}) = 0$, so $\frac{\partial R_1}{\partial p_1}(\tilde{p}, \tilde{p}) - \frac{\partial R_1}{\partial p_1}(\hat{p}, \hat{p})$ $=0= \int_{\hat{p}}^{\tilde{p}} \left[\frac{\partial R_1^2}{\partial p_1 \partial p_1}(t,t) + \frac{\partial R_1^2}{\partial p_1 \partial p_2}(t,t)\right] dt$, but this is a contradiction, due to assumption R2.

The prices (p^C, p^C) are *collusive prices with separate protections* if they maximize (3.1).

Proposition 1: Suppose that R1 and R2 hold. Then $p^{\hat{I}} > p^I$ and $p^C > p^I$.

Proof: We use Corollary to Theorem 6 of Milgrom and Roberts, 1990 and Theorem 13 of Milgrom and Shannon, 1994. For $p^{\hat{I}} > p^I$, write $R_1(p_1, p_2)+tK(p_1)$ for firm 1's profit function (symmetrically, firm 2's profit function), and let $t \in [-1, 0]$. Then $t = -1$ is the profit function for equilibrium with separate technical protections, and $t = 0$ is the profit function for equilibrium with perfect legal enforcement. The class of games defined by $t \in [-1, 0]$ are supermodular and the profit functions satisfy the single crossing property. Therefore the (unique) equilibrium prices of the games defined by t are increasing in t. This proves the result.

For $p^C > p^I$, consider a game in which firm 1 and firm 2 respectively have the following payoff functions

$$\pi_1(p_1, p_2, t) = R_1(p_1, p_2) - K(p_1) + t(R_2(p_1, p_2) - K(p_2))$$

$$\pi_2(p_1, p_2, t) = R_2(p_1, p_2) - K(p_2) + t\,(R_1(p_1, p_2) - K(p_1))$$

and $t \in [0, 1]$. If $t = 0$, the equilibrium is an equilibrium with separate protection systems and if $t = 1$, the equilibrium is the optimum of (3.1). The class of games defined by t are supermodular and the maximands have increasing differences in own price and t, for a fixed value of the other price. □

4. Shared Protections

The previous section considered pricing by two firms implementing their own individual technical protections. However, the firms may do better by deploying a single system. Although a single system may create benefits for users that are not modeled here, and cut costs, it will also create a better target for hackers. Therefore the level of protection e must be higher than with separate systems. The higher e creates an enhanced burden because of increasing marginal cost, but that may be offset by the elimination of duplicated fixed costs.

Continuing with the same model, if the vendors sell at prices (p_1, p_2), they will need protection level $e = p_1 + p_2$ to deter a coordinated circumvention. The prices (p^J, p^J) are *collusive prices with joint protections* if they maximize joint profit:

$$R_1(p_1, p_2) + R_2(p_1, p_2) - K(p_1 + p_2) \tag{4.1}$$

Proposition 2: Suppose that R1 and R2 hold. Then $p^C > p^J$.

Proof: Consider the following family of maximands, parameterized by $t \in [0, 1]$

$$R_1(p_1, p_2) + R_2(p_1, p_2) - [K(p_1 + p_2) + t\,(K(p_1) + K(p_2) - K(p_1 + p_2))]$$

By assumption R1, the maximand is supermodular in (p_1, p_2) for each t. Since the maximand also has increasing differences in $(p_1, p_2; t)$ (Milgrom and Shannon, 1994, Theorem 6), the maximum is monotonic in t (Milgrom and Shannon, 1994, Theorem 5). The optimum of (3.1) is the maximum where $t = 1$, and the optimum of (4.1) is the maximum when $t = 0$. The result follows. □

We make the following remark as a prelude to our discussion of competition policy. By competition we mean independent pricing, using separate protection systems. By collusion we mean coordinating prices, using a shared protection system. When we say that the content providers will prefer one system to the other, we mean that the revenue minus costs are greater. When we say that one system is socially more efficient than the other, this is from an ex post point of view, namely, that the deadweight loss plus the cost of the protection system is smaller. As previously noted in section 2, however, reducing profit may reduce the ex ante incentives to create content, which also entails a social cost. In this remark, we are not taking this cost into account.

Remark 4: [Ex post efficiency, and the choice among protection systems]

(a) If $p^I > p^J$ and $2K(p^I) < K(2p^J)$, the content providers prefer competition to collusion, although collusion might be socially more efficient.

(b) If $p^I > p^J$ and $2K(p^I) > K(2p^J)$, the content providers might prefer competition to collusion, although collusion is socially more efficient.

(c) If $p^I < p^J$ and $2K(p^I) > K(2p^J)$, the content providers prefer collusion to competition, although competition might be socially more efficient.

(d) If $p^I < p^J$ and $2K(p^I) < K(2p^J)$, the content providers might prefer collusion to competition, although competition is socially more efficient.

5. Comparing Competitive and Collusive Prices

We have not made enough assumptions to know whether p^J is greater than p^I or $p^{\hat{I}}$. Because the products are substitutes, collusion has a tendency to raise price relative to independent pricing with perfect legal enforcement, $p^{\hat{I}}$. But because joint protection is more costly than separate protection, there is an offsetting effect. Perhaps counterintuitively, it may occur that $p^J < p^I$or $p^J < p^{\hat{I}}$. Therefore, consumers can benefit from consolidation of pricing control in a single firm that deploys a single protection system.

For this discussion we examine a more fully specified model. Consider two firms $1, 2$, each facing a demand for its content that depends negatively on its own price and positively on the competitor's price. Let firm 1's demand be defined as

$$D_1(p_1, p_2) = \max\{1 - p_1 + cp_2, 0\} \tag{5.1}$$

where $0 \leq p_1, p_2 \leq 1$, and $0 \leq c \leq 1$. The parameter c determines the degree of substitutability between the two products. Firm 2's demand is symmetrically defined.

Let the costs of protection be defined by

$$K(e) = k + \kappa e^2$$

so that k is a fixed cost and $2\kappa e$ is the marginal cost of increasing the cost of circumvention.

When the firms compete using separate protection systems, firm 1's best response function is $\frac{1+cp_2}{2+2\kappa}$ (symmetrically for firm 2), and the symmetric Nash equilibrium prices and per-firm profits are given by:

$$p^I = \frac{1}{2 + 2\kappa - c} \tag{5.2}$$

$$\pi^I = \frac{1 + \kappa}{(2 + 2\kappa - c)^2} - k \tag{5.3}$$

As noted previously, technical protection moderates the price of content (with $\kappa > 0$), compared to perfect legal protection. The equilibrium price with perfect legal enforcement would be $p^{\hat{I}} = 1/(2-c)$, which is higher than p^I.

Suppose now that firms own a technical protection system as a joint monopolist. The level of protection must satisfy $e \geq p_1 + p_2$, and this inequality will be satisfied as an equality. The firms maximize joint profit (4.1). The symmetric profit-maximizing prices, quantities, and total profits are:

$$p^J = \frac{1}{2 + 4\kappa - 2c} \tag{5.4}$$

$$\pi^J = \frac{2(1-c)}{(2 + 4\kappa - 2c)^2} - k \tag{5.5}$$

Proposition 3: In the context of the above model with linear demand and quadratic protection costs, the profit-maximizing prices with a shared protection system, (p^J, p^J), are higher than the competitive prices with separate protection systems, (p^I, p^I), if $2\kappa < c$, and otherwise are lower.

The proof follows directly from comparing the expressions (5.2) and (5.4). The price-moderating effect of the shared protection is increasing in κ, but the collusive effect of joint pricing is increasing in c. The latter effect dominates if $2\kappa < c$.

Aside from any strategic benefit due to coordinating prices, vendors have an incentive to share a technical protection system in order to save fixed costs. This incentive is offset by the higher marginal costs of protection in a shared system, which will also cause the price to be lower. Depending on the relative magnitudes of these effects, a shared protection system may be beneficial to both consumers and vendors.

Example 1: To illustrate, suppose first that the demands for the content are independent ($c = 0$) and marginal costs for protection are positive, ($\kappa > 0$.) As stated in the proposition, the equilibrium prices (p^I, p^I) given by (5.2) are higher than the collusive prices (p^J, p^J) given by (5.4). Now consider the firm's profits given by (5.3) and (5.5), noting that each firm's share of joint profits is $\frac{\pi^J}{2}$. Vendors prefer a joint system if

$$\frac{1}{2(1+\kappa)} - \frac{1}{2(1+2\kappa)^2} < k \tag{5.6}$$

Total consumer surplus at a given symmetric price level p is $s(p)$, defined in (2.1). Clearly, $s(p^J) > s(p^I)$. Therefore, if (5.6) holds, vendors and consumers both prefer shared protection. From an aggregated standpoint, shared protections are better when $2s(p^J) + \pi^J > 2s(p^I) + 2\pi^I$, which holds if

$$\frac{(1+2\kappa)^2}{4(1+\kappa)^2} - \frac{(1+4\kappa)^2}{4(1+2\kappa)^2} + \frac{1}{2(1+\kappa)} - \frac{1}{2(1+2\kappa)^2} < k \tag{5.7}$$

Because the difference between the first two terms of (5.7) is negative, (5.7) holds if (5.6) holds, but not necessarily vice versa. Thus, for a wide range of parameter values, firms will be too reluctant to share a system, relative to what is efficient.

Example 2: Suppose now that $c > 0$ and $\kappa = 0$. Then consumers are unambiguously worse off with collusion than competitive pricing and separate protections, that is, $p^J > p^I$. Comparing (5.3) and (5.5), for all $k \geq 0, c > 0$, we find that $\pi^I < \frac{\pi^J}{2}$. Since the collusive prices are higher than the competitive prices, and the total costs are smaller, profits are higher with joint protection. However vendors have more incentive to create joint protections than is optimal from the consumers' point of view. Vendors do not account for the reduction in consumers' surplus due to the higher prices.

Perhaps the most surprising conclusion is that, depending on the relative magnitude of the collusive effects and cost advantages, collusive pricing with a shared protection system may be socially and privately preferable to the competitive outcome with separate protections.

6. Joint Ownership of a Protection Subsidiary: Is it Collusive?

So far we have assumed that when the content providers share a technical protection system, they somehow manage to coordinate their prices and achieve what we have called a collusive outcome (p^J, p^J). However, such collusion might be avoidable with a suitable antitrust policy. But which of the prices $p^{\hat{I}}$, p^I or p^J is a reasonable antitrust objective? If p^I or p^J is lower than $p^{\hat{I}}$, we cannot necessarily conclude that consumers are better off, since the technically-facilitated price p^I or p^J can continue indefinitely, whereas the proprietary price $p^{\hat{I}}$ will expire. As we showed for the monopoly case in section 2 (and is also true more generally), both consumers and firms can be better off with lower prices that last forever.

It can only happen that $p^{\hat{I}} < p^J$ if the digital products are substitutes, and close substitutes at that. But even if consumers would have lower prices with perfect legal enforcement than with a shared protection system, this does not necessarily mean that the collusive price lowers welfare. Given that the firms must pay for technical protections, they may earn less profit with the collusive price p^J than with perfect legal enforcement. Profit may also be so low that it thwarts investment in content.

As noted above, we will not resolve the question of the right antitrust objective, since we are focusing on ex post efficiency, and not on the incentives to create. Instead, as a tool to understand how (or if) a particular policy objective could be implemented, we address the more limited question of how prices depend on the ownership and governance of the shared technical protection system. The one case we have already analyzed, complete merger leading to prices (p^J, p^J), might be challenged on a first-principles theory that the owners of competing proprietary goods should not be allowed to merge. We therefore consider weaker forms of cooperation among the firms, where they share the costs of a technical protection system, but retain their individual marketing identities. Even so, the firms will often be able to support the "collusive" price p^J.

The simplest profit- and cost-sharing scheme is to delegate authority for pricing and protection to a jointly owned subsidiary, which is owned in fixed shares α_1, α_2. That organizational structure will clearly lead to collusion, since firm 1's profit is

$$\alpha_1 \pi^J(p_1, p_2)$$

and likewise for firm 2. Both firms favor the prices that maximize joint profit, namely, (p^J, p^J). The content providers will have no incentive to undermine this outcome.

A natural conjecture is that the market will be more competitive if the firms can share costs but not revenues. We consider (i) independent pricing with fixed cost shares, (ii) independent pricing with cost shares equal to revenue shares, and (iii) a wholly owned subsidiary that sets prices to maximize profit and distributes the profit according to revenue shares. The third option will by definition lead to collusive prices, just as complete merger will. It is mainly a benchmark for a further inquiry in the next section: What if the subsidiary sets prices, but the content providers can charge supplemental prices (or give rebates) off the subsidiary's books, thus affecting the revenue shares?

We will see that among the three options, option (i) with fixed cost shares is most likely to result in prices lower than the collusive price p^J. Option (ii), with cost shares proportional to the revenue provided, may also lead to prices below the collusive price, but not as reliably as fixed shares.

(i) Suppose the fixed cost shares are (α_1, α_2). The only coordination of prices that the protection system facilitates is that the sum of prices cannot exceed the level of protection, $p_1 + p_2 \leq e$. With the level of protection e fixed by the subsidiary, firm 1's profit is the following if $p_1 + p_2 \leq e$, and otherwise is $-\alpha_1 K(e)$.

$$R_1(p_1, p_2) - \alpha_1 K(e) \tag{6.1}$$

Suppose that the firms try to support the price (p^J, p^J) by choosing a protection level $e = 2p^J$. Then provided $p^J > p^{\hat{I}}$ and the assumptions R1, R2 hold, the unique unconstrained equilibrium in prices is $(p^{\hat{I}}, p^{\hat{I}})$. The firms will therefore achieve that outcome for any protection level e larger than $2p^{\hat{I}}$. Anticipating this, the firms will choose $e = 2p^{\hat{I}}$, and achieve prices $(p^{\hat{I}}, p^{\hat{I}})$.

Thus, fixed cost shares will not support the collusive price p^J when the competitive price $p^{\hat{I}}$ is lower. This might look good to the antitrust authorities, but the fixed cost shares present two problems. First, in the case that the content providers are not symmetric, low-volume content providers may pay so much relative to their revenue that they drop out of the market. Fixed cost shares cannot guard against this unless the relative popularity of the content is known in advance. Even then, choosing the cost shares may constitute a disabling ex ante bargaining problem. The second problem is that, wanting to avoid competition, the firms may prefer another form of governance. It is of interest to know whether competition is inevitable in the case $p^{\hat{I}} < p^J$, or whether other "reasonable" forms of governance will avoid it. This question goes to whether the antitrust authorities need to intervene. They may (or may not) want to disallow a form of governance that supports the collusive outcome p^J.

(ii) Suppose that the cost shares are equal to revenue shares instead of being fixed. Define the revenue share provided by firm 1 (symmetrically, firm 2) as:

$$\alpha_1(p_1, p_2) = \frac{R_1(p_1, p_2)}{R_1(p_1, p_2) + R_2(p_1, p_2)} \tag{6.2}$$

Conditional on the level of protection e, firm 1's profit is the following, provided $p_1 + p_2 \leq e$.

$$R_1(p_1, p_2) - \alpha_1(p_1, p_2)K(e) \tag{6.3}$$

The owners of the subsidiary must first agree on the level of protection e, knowing that they will then compete on price subject to the constraint that $p_1 + p_2 \leq e$. (When the firms are symmetric, as here, they will not disagree on e, although this will be an issue more generally.)

To see whether the firms can support the profit-maximizing prices (p^J, p^J) with revenue-based cost sharing, we ask whether $p_1 = p^J$ maximizes (6.3) when $p_2 = p^J$. The cost share α_1 increases in R_1, and since $R_2(p^{\hat{I}}, p^J) < R_2(p^J, p^J)$, it follows that $\alpha_1(p^J, p^J) < \alpha_1(p^{\hat{I}}, p^J)$. Thus, the revenue consideration, that reducing price increases firm 1's revenue, is offset by the cost consideration, that the reduced price increases firm 1's cost share. Sharing the cost proportionally to revenue will dampen any incentive that the firm has to reduce price from the collusive price p^J, at least relative to fixed cost shares. There will be circumstances in which the collusive outcome (p^J, p^J) can be sustained by merger, but not by revenue-based cost sharing, and there will be circumstances in which revenue-based profit sharing will not cause firms to compete to the competitive price $(p^{\hat{I}}, p^{\hat{I}})$ when profit sharing with fixed shares would have that effect.

(iii) In the third form of governance, we assume that the subsidiary sets the prices $(p_1, p_2) = (p^J, p^J)$ that maximize joint profit, π^J. Firm 1 (symmetrically, firm 2) has no direct control over its profit, but its profit is

$$\alpha_1(p^J, p^J)\pi^J(p^J, p^J)$$

In the next section we point out that, depending on the technology, the firms might be able to reclaim some control over price by making price rebates directly to users. We consider the content providers' incentive to constrain their own behavior in this regard through the technical aspects of the protection system they use. If the technology preserves some mechanism by which content providers can provide supplements or rebates to the royalties chosen by the subsidiary, they will find it very hard to resist using those capabilities, and this has an impact on competition. The connection between technology and competition is an important one, so we address it further in a separate section.

7. Collusion through Technology

We said in the previous section that the pricing consequences of complete merger can be achieved technologically by delegating all pricing authority to a subsidiary that sets prices to maximize profit. In fact, a user of content might pay prices to two parties: the content provider and the subsidiary. Although the consumer cares only about the sum of these two prices, and might be unaware that he or she is paying two prices for each piece of content, control over the prices will determine whether the total price is collusive. Our point in this section is that technology constrains who controls prices. The protections may or may not allow content providers to supplement prices or make rebates. Hence, neither the content providers nor the antitrust authorities will be indifferent as to the technology that is deployed.

Suppose that the subsidiary chooses prices (royalties) (p^J, p^J), and that firm 1 finds some way to provide a supplement ϵ to its price. Since the subsidiary's optimal policy will be to choose $e = p^J + p^J$, the firm's only option is to give a rebate, $\epsilon < 0$. A positive supplement would lead to circumvention.

If firm 1 makes no supplements or rebates to the price, its profit can be written as

$$\alpha_1(p^J, p^J)\pi^J(p^J, p^J) = R_1(p^J, p^J) - \alpha_1(p^J, p^J)K(p^J + p^J)$$

The supplement $\epsilon < 0$ does not have the same effect on firm 1's profit as if the subsidiary administered the price change. First, the rebate will not result in a cost saving on the technical protections, since the level of protection e stays fixed. Second, the rebate will change the firm's revenue share, hence cost share, but not in the same way as if the price reduction were administered and accounted by the subsidiary. We assume that the rebates on price are not taken into account in calculating cost shares, although the changes in usage are taken into account.

If firm 1 adds a supplement ϵ to its price, firm 1's revenue share, including only the part accounted for by the subsidiary, becomes

$$\tilde{\alpha}_1(p^J, p^J, \epsilon) = \frac{p^J D_1(p^J + \epsilon, p^J)}{p^J D_1(p^J + \epsilon, p^J) + p^J D_2(p^J + \epsilon, p^J)} \tag{7.1}$$

Comparing (7.1) with (6.2), which is the revenue share when all revenue passes through the subsidiary, it holds that

$$\tilde{\alpha}_1(p^J, p^J, \epsilon) > \alpha_1(p_1, p^J)|_{p_1 = p^J + \epsilon} \quad \text{for every } \epsilon < 0$$

That is, a rebate *outside* the subsidiary will increase firm 1's revenue share, hence cost share, more than a decrease in price paid *through* the subsidiary.

Assuming that the subsidiary administers the collusive prices (p^J, p^J), and sets the protection level at $e = p^J + p^J$, the profit of firm 1, as a function of its supplement ϵ, is

$$R_1(p^J + \epsilon, p^J) - \tilde{\alpha}_1\left(p^J, p^J, \epsilon\right) K(e) \tag{7.2}$$

and symmetrically for firm 2.

The price reduction of size ϵ will be profitable under the cost-sharing schemes, respectively, if

$$R_1(p^J + \epsilon, p^J) - \alpha_1(p^J + \epsilon, p^J)K(e) \;>\; R_1(p^J, p^J) - \alpha_1(p^J, p^J)K(e) \tag{7.3}$$

$$R_1(p^J + \epsilon, p^J) - \tilde{\alpha}_1(p^J, p^J, \epsilon)K(e) \;>\; R_1(p^J, p^J) - \alpha_1(p^J, p^J)K(e) \tag{7.4}$$

For any level of protection e, and for any $\epsilon < 0$, the profit (6.3) is larger than the profit (7.2) when firm 1's price is equal to $p^J + \epsilon$:

$$R_1(p^J + \epsilon, p^J) - \alpha_1(p^J + \epsilon, p^J)K(e) > R_1(p^J + \epsilon, p^J) - \tilde{\alpha}_1\left(p^J, p^J, \epsilon\right)K(e)$$

Thus (7.4) implies (7.3), but not vice versa, implying that content providers pricing within the subsidiary would want to drop their prices, but not content providers who can only drop their prices by making rebates on the side. This observation, together with the considerations in the previous section, leads to parts (c) and (d) of Remark 5. (Parts (a) and (b) are trivial, as explained above, but are included for completeness.)

Remark 5: Suppose that $p^{\hat{I}} < p^J$. Then

(a) Suppose the content providers delegate pricing authority to a subsidiary that maximizes joint profit π^J. Then regardless of how the profits are shared, the subsidiary will implement the collusive prices (p^J, p^J).

(b) If the content providers pay fixed shares of the cost and price independently, they will price as they would with perfect legal enforcement, namely, $(p^{\hat{I}}, p^{\hat{I}})$.

(c) If the content providers price independently through a subsidiary with revenue-based profit sharing, the collusive prices (p^J, p^J) may not be sustainable.

(d) If the subsidiary sets the prices and distributes profits based on revenue shares, not accounting for unverifiable rebates on the side, the collusive price may not be sustainable, but will be sustainable in more circumstances than in (c).

We thus arrive at a result which is not very surprising. The best strategy for supporting the collusive price p^J is for the firms to relinquish all pricing authority to the wholly owned subsidiary. If there is anything subtle about this result, it is that firms must renounce their ability to make rebates on the side, and that this capability might be implemented through technology.

Suppose, for example, that the following systems are observed in the market: (1) Content is given away for free, but a protection system charges a royalty to use it.

Content providers do not deal directly with users, but earn shares of the subsidiary's profit, possibly fixed, but possibly proportional to revenue. (2) Users pay content providers, and do not pay the subsidiary that administers the technical protection system. However, the revenues are verifiable, and the cost shares are proportional to revenue. (3) Users pay the subsidiary to use the content, but the subsidiary tracks usage in order to facilitate a "frequent-user" program allowing rebates. The net profit is shared according to revenue earned through the subsidiary, which does not include the rebates.

The market structure (1), where content is given away for free, is likely to support the collusive outcome. The market structures (2) and (3) preserve independent pricing, so the collusive price might be undermined, but market structure (3) might nevertheless keep collusion intact in circumstances where (2) would not.

Which of these market structures are feasible depends on the technology of the protection system. The content providers and antitrust authorities may have different views as to what is appropriate. The content providers will clearly prefer the system (1) that supports the collusive outcome. Conversely, the antitrust authorities might want to undermine the collusive price p^J whenever $p^{\hat{I}} < p^J$. If so, they may favor a governance structure in which the firms price independently and the costs are shared according to accurately accounted revenue shares – if the firms choose lower prices, that has to be done within the subsidiary's accounting system so that the cost shares are accurate. However option (1) would not be their first choice, as option (1) does not preserve any independence in pricing.

8. Conclusions and Open Questions

Our main message is that technical protections can reduce prices for digital content whether the protections are separate or shared. Content providers will choose their technology with this in mind – technology can be collusive.

We have explored the divergence between the private incentive to create a shared system and the circumstances in which that would be efficient. There are two incentives for content providers to share a system. One is that it saves the fixed costs of implementing and administering the system. The other is that it may give them an opportunity for coordinated or collusive pricing. One of these is in the public interest, and the other may not be. But collusive pricing is less a threat than it appears because a shared system is an attractive target for circumvention, and the firms can reduce circumvention by lowering prices.

Of course, the welfare implications are ambiguous. Technical protections are expensive. The expense is a social waste, as compared to perfect legal enforcement. Content providers are burdened in two ways: by the cost of protection and by the lower prices they receive for access to the content. In the end, smaller rewards for content providers will mute the creative impulse. Nevertheless, we have found a silver lining, namely, that users will pay lower prices.

The pricing options we have investigated do not exhaust the possibilities suggested in the introduction. The systems we have considered govern the pricing of content, rather than devices, and content itself can be priced in different ways, depending on how use can be metered. Content today can be purchased on physical media, giving the right to unlimited or only a few viewings, or it can be purchased on a per-viewing basis such as video-on-demand. Subscription services like cable television bundle these services in yet another way, by giving unlimited viewings per unit time. Basing royalties on usage has the virtue of taxing the more popular content and the higher-demand users more highly. It may thus reduce distortions as compared, for example, to putting the royalty on media players or charging a fixed royalty per unit time. Taxing the media players will presumably create distortions at the "extensive margin," that is, in the number of users in the market. The competitive effects of what is priced have not yet been explored.

Although we have studied shared systems, competition among third-party intermediaries may be the better market structure. Bergemann, Feigenbaum, Shenker and Smith (2004) have proposed to study "trusted systems" as intermediaries in two-sided markets (Rochet and Tirole, 2003, 2004), focusing on competition. In the framework of this paper, perfect competition is hard to define, because the strategies (prices) of the content providers using a common system are constrained by the strategy (level of protection) of the trusted system. For example, a content provider will not necessarily sign up with the cheapest intermediary, because the prices that the content provider can charge depend on the level of protection provided by the system, but also, importantly, on the prices charged by the other content providers who are using it. At the same time, the intermediary recognizes that the level of protection it provides will determine the number of content providers it attracts. Both the level of protection and the prices charged by the other vendors using the system determine the attractiveness of the system to any given vendor.

9. Appendix: Prices with Dispersion in Circumvention Costs

Return to the content provider's profit function with dispersion in circumvention costs, given by (2.2).

Since $\Pi(p, e) < p(1-p)$ at every p, e, profit is smaller with technical protection than with perfect legal enforcement. The optimal proprietary price, say $p(e)$, maximizes (2.2), conditional on the level of protection e, and satisfies

$$\frac{\partial}{\partial p}\Pi(p,e)|_{p=p(e)} = \left[(1-G(p;e))\ \frac{\partial p(1-p)}{\partial p} - p(1-p)g(p;e)\right]|_{p=p(e)} = 0 \quad (9.1)$$

Since the derivative is negative whenever $\frac{\partial p(1-p)}{\partial p} \leq 0$, the optimal price $p(e)$ is lower than the monopoly price, $p^* = 1/2$, regardless of e.

The proprietor also optimizes with respect to the level of protection e. The derivative of Π with respect to e is

$$\frac{\partial}{\partial e}\Pi(p,e)|_{p=p(e)} = -p(1-p)\frac{\partial G(p;e)}{\partial e} - K'(e) \quad (9.2)$$

The first term, which is positive since $\frac{\partial G(p;e)}{\partial e} < 0$, represents the saved revenue due to a decrease in circumvention if e is increased, and the second term represents the marginal cost. Combining with (9.1),

$$\frac{\partial}{\partial e}\Pi(p,e)|_{p=p(e)} = \frac{-(1-G(p;e))}{g(p;e)}\frac{\partial G(p;e)}{\partial e}\frac{\partial p(1-p)}{\partial p}|_{p=p(e)} - K'(e) = 0 \quad (9.3)$$

It is easy to see in an example that dispersion in circumvention costs can cause the proprietor to charge a lower price than without dispersion. Suppose that K' is increasing and that the distribution of circumvention costs is uniform on an interval around the strength of protection e :

$$G(p;e) = \begin{array}{lll} 0 & \text{if} & p < e - 1/2 \\ p - e + 1/2 & \text{if} & e - 1/2 < p < e + 1/2 \\ 1 & \text{if} & p > e + 1/2 \end{array}$$

$$g(p;e) = 1 \quad \text{for} \;\; e - 1/2 < p < e + 1/2$$

It follows from (9.2) that the optimal (p, e) entails both circumvention and purchases, so that $0 < 1 - G(p;e) < 1$. It follows from (9.1) that $p(e)$ is increasing with e. In (9.3), $\frac{(1-G(p;e))}{g(p;e)} \frac{\partial G(p;e)}{\partial e}$ is less than one. It then follows from (9.3) that the optimal strength of protection is smaller when circumvention costs are dispersed than when not, as follows.

Let $\tilde{e}$ be the optimal protection when circumvention costs are dispersed, and $\hat{e}$ when not. Then $\frac{\partial p(1-p)}{\partial p}|_{p=\hat{e}} = K'(\hat{e})$. It follows from (9.3) that $p(\hat{e}) < \hat{e}$. (In fact, at any given protection level e, not only $\hat{e}$, the optimal price is lower with dispersed circumvention costs than with no dispersion.) Then if $\tilde{e} < \hat{e}$, it follows that $p(\tilde{e}) < p(\hat{e}) < \hat{e}$; the optimal price is lower with dispersed circumvention costs than not. Suppose instead that $\hat{e} \leq \tilde{e}$, which implies that $K'(\hat{e}) \leq K'(\tilde{e})$ and $p(\hat{e}) \leq p(\tilde{e})$. Then using (9.3), it follows that $\frac{\partial p(1-p)}{\partial p}|_{p=p(\tilde{e})} > \frac{\partial p(1-p)}{\partial p}|_{p=\hat{e}}$ which again implies that $p(\tilde{e}) < \hat{e}$.

Thus, in a plausible example, dispersion in the costs of circumvention decreases the price of content, but also decreases the proprietor's profit. In addition, there will be consumers who circumvent the protection in equilibrium, adding to social costs.

Consumers' surplus plus profit in each period, designated $W(p, e)$, is

$$\begin{aligned} W(p, e) &= s(p) + p(1-p) + \int_0^p \theta \; G(\theta; e) \; d\theta - C(p, e) \\ &= \int_p^1 \theta d\theta + \int_0^p \theta \; G(\theta; e) \; d\theta - C(p, e) \end{aligned}$$

where $C(e;p)$ is the total cost of circumventions that occur in equilibrium:

$$C(p, e) = \int_0^1 \left(\int_0^{\min\{p,\theta\}} c \; dG(c; e) \right) d\theta$$

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