Promotional Piracy

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Unauthorized reproduction of goods such as software and music can displace sales. At the same, because word-of-mouth communications alert those yet to experience a product to its existence and characteristics, individuals who copy may serve a marketing function. A simple model takes both business stealing and promotional effects into account and uncovers the sensitivity of piracy's overall profit impact to the presence and shape of conceivable relationships between product valuation and personal piracy cost. Piracy may be good or bad for business, with much hinging on the sign and curvature of this relationship. Key predictions help demystify observed differences in anti-piracy measures, such as between the markets for computer games (high protection) and office software (low protection).

1. Introduction

This paper investigates the unauthorized copying of digitizable goods, regarded by some to threaten the viability of important industries such as software, music, and film. The rise of computing and the Internet has made it possible for end-users to engage in the near perfect and instantaneous (though not entirely costless) reproduction of many creative works. Where this is done without permission, a breach of copyright arises, but detection is hard work, and the evidence suggests that digital technology is widely used to obtain products illicitly. The figures for software piracy are particulary stark: A third of all products installed on personal computers is pirated, with suggested revenue losses of $33bn for 2004.[2] Not all this piracy

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[2] http://www.bsa.org/globalstudy/

is linked to new technologies but the industry considers digitalization to have significantly escalated the problem. In the music sector, meanwhile, global annual record sales fell from $40bn to $33bn over the four years to 2004—the same period in which illegal sharing of music files across the Internet emerged from nowhere to become a serious alternative to buying.[3] And Hollywood, though it remains less affected so far (downloading a movie is too involved and time consuming for many), reportedly fears for its own revenue streams in a future with faster connection speeds and ever deeper Internet penetration.[4] Across all major piracy-affected industries, lobbyists promote the view that the proliferation in illegal copying is a manifestation of the "dark side of the net" and call for measures to reduce piracy, not only for the sake of individual copyright holders, but also jobs, tax revenues, and ultimately, the preservation of incentives for creative enterprise.[5]

With perceived losses running so high, one might expect firms to pull out all the stops to safeguard their intellectual property technologically. Certainly some appear to do just that, applying copy protection so prohibitive as to deter all but the most persistent. For instance, makers of console games such as Nintendo and Sony have thwarted the recreational end of piracy by investing huge sums in draconian anti-piracy technology.[6] At the same time, firms in many other markets seem reticent about protection. Microsoft and other business software providers refer to "casual copying" and "softlifting" of their products, seemingly admitting that these are more easily replicated.[7] There is even evidence that business software manufacturers reduced technological copy protection following the widespread introduction of personal computers in the 1980s.[8] This differential approach to piracy is curious. Why when

[3]http://news.bbc.co.uk/1/hi/entertainment/music/4720351.stm.
[4]http://news.bbc.co.uk/1/hi/entertainment/film/3985917.stm
[5]This appears to be the central thesis of recent White Papers by industry lobby body the Business Software Alliance (BSA). For instance, the December 2005 White Paper (available at www.bsa.org) asserts that "Reducing software piracy can be a strategic tool that countries use for creating high paying jobs, increasing tax revenues, expanding business opportunities, and fueling economic growth."
[6]For instance, just prior to the launch of the Xbox console, industry magazine *gamesmarketwatch.com* discussed the plan for uncompromising protection (*Copy Protection Technology to Prevent Xbox Piracy*, 9th July 2001, available at www.gamemarketwatch.com): "Xbox DVDs will also undergo a process that prevents the discs from being ripped, or copied, by pirates and pretty much everyone else."
[7]Consider the following official comments from Microsoft's website (www.microsoft.com/piracy, 8 October 2006): "An example of casual copying is if someone were to get a copy of Office XP and load it on his or her PC, then share it with a second person who loaded it on his or her PC, then share it with a third person who loaded it on his or her PC, and so on. This form of piracy is very prevalent and accounts for a large portion of the economic losses due to piracy."
[8]Shy and Thisse (1999) discuss decisions taken publicly by several providers around this time, such as the decision by MicroPro International to remove copy protection on its WordStar 2000 package in 1985.

some providers move mountains to devise and implement protection do others seem more readily to accommodate pirates?

A first step towards understanding protection differences is to recognize that not every copy must imply a lost purchase. To appreciate the basic point, assume away the possibility of piracy, and consider a standard model of monopoly sales. The important thing to note is that not everyone is a buyer in this counterfactual: Only those with valuations above the seller's optimal uniform price—the 'high types'—purchase; others—'low types'—go without. It follows trivially that only high types are relevant to an assessment of piracy's business threat; low types do not count. Temptation to copy comes down to a personal calculation, of course, reflecting equipment needs but also such things as time, experience, and psychological costs. In some markets, high types may have relatively low piracy costs, suggesting possible grounds for stiff protection. Elsewhere, copying may appeal most to low types. Variation in the susceptibility to piracy of those the seller otherwise would serve could thus be pertinent to the protection puzzle. But there is more to the story, this paper will suggest.

As well as potentially displacing sales, piracy may have helpful promotional externalities. In most markets, there are some who would buy but for lack of awareness, they have yet to discover the product exists. The seller might tap this latent demand through costly advertising, PR, and other marketing initiatives, but current consumers—buyers *and* pirates—may help for free. Family, friends, and colleagues have long traded consumption experiences in everyday conversation. And now the Internet, with its weblogs, chatrooms, and other fora, enables these to be relayed on a global scale. Social psychologists and marketeers use the terms "word of mouth" ("WOM"), "buzz," "viral marketing," and "hype" to describe such communications. WOM's significance for economic outcomes has received little attention from economists, but this is remiss. Recent empirical work attests its importance for future sales (Godes and Mayzlin, 2004, Marsden et al., 2005). According to Godes and Mayzlin (2004), who exploit online chatroom conversations to scrutinize this link for TV show success, "WOM appears to be especially important for entertainment goods." More anecdotally, the sudden rise from obscurity of British band Arctic Monkeys provides a compelling case study in the power of buzz: This year the group watched its first album break records to become the fastest selling UK debut release. Its instant impact was due not to the marketing muscle of a recording giant, but entirely to the energy of early consumers, who promoted its songs through social networking site myspace.com.[9] To the extent that piracy raises consumption (some consume who otherwise never would), consumption fuels hype, and hype in turn boosts future demand, a seller may tolerate illegal copies, even at some risk to current sales.

Pursuing matters formally, the paper works business stealing and promotional effects into a theoretical analysis of piracy. A simple two period model is constructed in which: (i) a monopolist seeks to sell her digital product to a population of individuals, not all of whom are aware of its existence and characteristics; (ii) greater total consumption in the first period (via purchase or piracy) promotes greater second period awareness;[10] and (iii) individuals have heterogeneous valuations, v, and face differing costs of piracy, c. Piracy is not always bad for business, the model predicts. The balance of business stealing and promotional effects turns on the whereabouts of potential consumers in v, c space.

A strength of the model is its generality; it permits different assumptions to be made about population location, allowing piracy's impact to be compared across a variety of settings. The paper introduces the simple idea that v and c could be monotonically related in some manner, and focuses on population locations consistent with this assumption. Behind a monotonic v, c relationship is plausibly the co-dependence of both variables on some third, perhaps age or income, and specifying the model in this way turns out to be key to empirical puzzles: When v and c are negatively related, high value sales are compromised with no promotional offset. This means profit is hurt unambiguously and the seller will wish to purge the market of piracy. Markets with youth appeal arguably fit the negative specification; consider that young people conceivably derive the greatest value from computer games, say, but also have the lowest piracy costs (not least on account of the smaller income value of their time). The business software market is more plausibly described by a positive v, c relationship, on the other hand, and there the model's predictions are quite different. With high value types experiencing the higher piracy costs, the seller can be less vulnerable to lost sales. In addition some low types, with their typically lower piracy costs, may be prepared to copy and so help

[9]The background to, and scale of, the Monkeys' success is discussed in many recent press clippings. See http://www.abc.net.au/catapult/indepth/s1570454.htm, for instance.

[10]As suggested in the main text, evidence on interpersonal communications supports a theoretical link between current consumption and future product awareness. A further justification for assuming that current consumption influences future awareness is the prevalence of charts which rank products according to their popularity with consumers. Connolly and Krueger (2005, p.30) discuss this point: "Evidently, many consumers turn to rankings to decide which music to purchase or listen to, and radio stations rely on charts to determine which music to play on air." Although for a long time rankings were compiled exclusively using physical sales data, charts based on downloads have recently begun to appear. For example, mp3charts.com tracks free music downloads.

out with marketing. Piracy's net profit impact can be substantially less detrimental, as a result, and relaxed protection, such as seen in business software, can make perfect sense.

Interestingly, when the v, c relationship is positive, the shape of the distribution seems to matter. Where income is the variable linking v and c, positive concave and convex relationships can be considered roughly to depict markets for necessities and luxuries, respectively. The paper studies both cases. With concavity, a particularly sharp pricing prediction emerges: The seller performs a u-turn as piracy becomes generally less costly, first raising price to accommodate piracy but switching to substantial price cutting if piracy costs continue to fall. Empirical work on income elasticities suggests that music products are necessities (Sessions and Stevans, 2005) and, intriguingly, this concave pricing story seems to resonate well with otherwise puzzling developments in the music industry. As the *Economist* magazine recently noted, music prices were initially raised in response to the onset of digital piracy: " ...shipments of music have fallen by 26 per cent since 1999 (though, thanks to price hikes, revenues have fallen by a slightly less worrying 14 per cent)." But as copying opportunities continued to proliferate this strategy was reversed, just as the model would predict: "Music executives seem to have realised that they cannot continue to increase prices forever [...]. In September [2003], Universal, the worlds biggest music company, cut the wholesale price of CDs to American stores, making it possible for them to sell new music for as little as $10 and still make money."[11]

The paper is organized as follows. The next section briefly reviews related literature. Section 3 sets out a basic modelling framework, derives the no piracy benchmark, and makes a note of some general insights. Sections 4 and 5 consider negative and positive v, c relationships respectively, linking findings to empirical evidence in each case. Concluding remarks are set out in Section 6, along with suggested directions for future research. Proofs omitted from the main text are contained in Appendix A.

2. Related Literature

This paper adds to a body of research which began with Plant's (1934) treatment of the economics of copying. The literature has developed in many directions since then, often connected to the advent of a new copying technology, such as the photocopier, the VCR, and most recently Internet file-sharing. The view that firms are unambiguously harmed by unauthorized copying found early support in the theoretical work of Novos and Waldman

[11] "Britney, meet Michael," *Economist*, November 7th 2003.

(1984) and Johnson (1985), among others. These contributions belong to a set of articles which assume that individuals are already perfectly informed about the product, and have valuations for this that are independent of the number of other consumers. Both assumptions are strong, and arguably particularly inappropriate for the case of digital goods.

Some authors have since worked on relaxing these modelling features. The outcome is a more ambiguous view of piracy, one which acknowledges the threat to sales but admits possibly countervailing effects. A first set of articles associates piracy with positive externalities by assuming that valuations depend on the size of the user base (for instance, Conner and Rumelt, 1991, and Shy and Thisse, 1999). This "network effects" line of thinking seems especially relevant to software markets, since learning to use an application—often a considerable investment of time and effort—is more worthwhile the greater the number of others able to interact with the output. It may also have applicability to other digital products since, for instance, consumers may value more highly music listened to by many others.[12]

The treatment offered in this paper relates most closely to a second branch of articles, known as "consumer information" studies (Duchene and Waelbroeck, 2003a, 2003b, Takeyama, 1997, Zhang, 2002, and others). In these models individuals are less than perfectly aware of the existence and characteristics of goods and unauthorized copying can help close the information gap. For instance, in Peitz and Waelbroeck (2005) consumers do not know the location of products in relation to their own pre-fixed ideal. P2P file-sharing helps a prospective buyer pin this down, allowing her to sample before committing to purchase. This in turn raises her eventual willingness to pay. Though it proceeds in the same general spirit as this "consumer information" literature, the present paper has a different approach; it posits a simple positive link between consumption this period and consumer awareness in the next, and in this setting, links the conceivably different ways in which population is likely to be distributed in v, c space to empirical puzzles related to seller behaviour.

3. Model

This section develops the basic theoretical framework. For expositional clarity, analysis is carried out in three parts. In subsection 3.1, a simple two period model of monopoly sales is introduced. Consumer awareness is assumed incomplete, which limits the size of the market. But awareness can grow over time as first period consumers generate buzz about

[12]As Peitz and Waelbroeck (2003) argue, network effects may be clearer still where file-sharing technologies are concerned, as the size of the P2P network determines the speed of downloading and probability of locating a desired track.

the product. Subsection 3.2 establishes the seller's behaviour in the 'no piracy' benchmark case, where individuals may legitimately purchase but may not otherwise come to possess the product. The monopolist is found to offer a "promotional" first period price, sacrificing some immediate margin for the sake of future product awareness. Then, in subsection 3.3, piracy is introduced as an alternative consumption channel. Two potential effects arise: (i) a "business stealing effect" (standard sales may be displaced, as some former buyers succumb to the temptation to copy) and (ii) a "promotional effect" (piracy, by boosting total consumption in the first period, may lead to greater product awareness in the next). The balance of these effects is key to piracy's overall profit impact, and hence to the matter of optimal copy protection.

3.1. **Basic Set-Up.** A monopolist brings to market a new version of her product in each of two time periods $t = 1, 2$. To fix ideas, imagine two music albums released sequentially by the same artist. With little loss of generality, marginal costs of production and distribution are assumed to be zero.[13] On the demand side, there is a population of individuals whose number is normalized to unity. Each period each person consumes zero or one unit of the firm's product, for which she has valuation v. Valuations are distributed across the population according to $F(v)$, which has full support on the unit line and satisfies the monotonic hazard rate condition (mhrc).[14] Since a person's type is private information the monopolist prices uniformly, charging p_t to all buyers of her period t release. Product awareness is limited, however, and this acts as a drag on consumption. Concretely, each period only some fraction $\alpha_t \in [0, 1]$ of the population is sufficiently aware to consider consuming; the rest abstain through ignorance, collecting zero utility.

Initial consumer awareness α_1 is chosen by Nature. To continue with the music analogy, consider that when a record label makes a new signing the artist arrives with some given level of public recognition, linked to gigs already played, previously disseminated recordings (perhaps demos circulated over the Internet), and any other promotional work already carried out. This is their α_1.[15] Second period awareness α_2 depends positively on total first

[13]The product is taken to exist already, allowing issues surrounding development incentives to be left to one side. The nature of the analysis is *ex post*, in other words.

[14]The mhrc requires that the hazard rate of the distribution $\frac{F'(v)}{1-F(v)}$ be increasing in v. The mhrc is a routine assumption within the incentives literature, and poses no problem for a number of popular distributions, including the normal, the uniform, and any distribution with nondecreasing density.

[15]In most cases an artist's initial recognition is low at the point of signing a first record deal. British band the Arctic Monkeys constitutes a notable exception, having already attained an enormous following via the Internet prior to signing with Domino Records in 2005.

period consumption q_1 and so also negatively on the seller's initial price p_1. Other influences on awareness are regarded as exogenous. The link between present consumption and future product recognition captures, in a simple fashion, the idea of word-of-mouth spillovers. Insights will be established at the general level, without the need to specify α_2 further.

3.2. **No Piracy Benchmark.** In period t, the marginal buyer has valuation $v = p_t$, and some fraction α_t of the $1 - F(p_t)$ individuals with valuations above this purchase the good. With piracy ruled out, the number of consumers is simply the number of buyers: $q_t = q_t^b = \alpha_t[1 - F(p_t)]$. How does the monopolist price her product?

Proposition 1. *"No piracy:" There exists a unique price p^M which maximizes current period profit. In the second (and final) period of the model, the monopolist implements this myopic price: $p_2^* = p^M$. In the first period, concern for future awareness leads her to set a "promotional" price: $p_1^* < p_2^* = p^M$; she 'invests' some current margin in future sales.*

Proof. Given the intertemporal linkage between first period price and second period profit, the model is solved backwards. In the second (and final) period, future sales need not concern the seller. At this stage, α_2 is but an exogenously given deflator of sales and profit, not a choice variable, and so she seeks simply to maximize undeflated current profit $\pi_2 = p_2[1 - F(p_2)]$. Just as in a standard model of monopoly sales, her optimal price solves the first order condition $p_t = \frac{1-F(p_t)}{F'(p_t)}$. Call this price p^M; the earlier assumption that $F(v)$ satisfies the monotone hazard rate condition guarantees that p^M is unique. Maximized second period profit is thus $\pi_2^* = \alpha_2 \pi^M$, where $\pi^M = p^M[1 - F(p^M)]$ is simply maximized profit in a standard model with completeness of consumer awareness. Intuitively, limited product awareness in the present model ($\alpha_2 < 1$) shrinks the seller's return.[16].

In the first period things are slightly less straightforward. A high first period price, because it discourages first period consumption, adversely affects second period awareness and so too second period profit. Being forward-looking, the monopolist seeks to maximize her total discounted profit, taking account of both periods and the externality that links them. Denoting as $\delta \in [0, 1]$ her intertemporal discount factor, she solves the following problem:

$$\max_{p_1} \Pi = \alpha_1 p_1[1 - F(p_1)] + \delta \alpha_2 \pi^M.$$

[16]To illustrate, with valuations distributed uniformly on the unit line $v \sim U[0, 1]$, demand would be linear $q = 1 - p$, and optimal price and maximized profit would be $p^M = \frac{1}{2}$ and $\pi_2^* = \alpha_2 \pi^M = \alpha_2 \frac{1}{4}$ respectively, so that with complete awareness ($\alpha_2 = 1$) the familiar textbook profit outcome results: $p_2^* = p^M = \frac{1}{4}$

A somewhat more involved first order condition results:

$$\frac{\partial \Pi}{\partial p_1} = 0 \qquad \Rightarrow \qquad p_1^* = \frac{1 - F(p_1^*)}{F'(p_1^*)} + \frac{\delta \pi^M}{\alpha_1} \frac{\alpha_2'(p_1^*)}{F'(p_1^*)}.$$

Compared to $p = \frac{1-F(p)}{F'(p)}$, the condition for single period optimization, this new optimality condition features an extra term on the right hand side, and this term, since its $\alpha_2'(p_1)$ component is negative and all other components positive, must be negative. It follows that whereas in the model's second (and final) period the monopolist optimally prices in the textbook fashion, her optimal first period price is lower: $p_1^* \leq p^M$.[17] This discounting has a straightforward interpretation: in order to exploit viral marketing the seller offers a "promotional" price. Her promotion induces low types with $v \in [p_1^*, p^M]$, provided they are aware, to purchase. This extra consumption, in turn, helps drive up product awareness. Thus some current margin is sacrificed as an investment in future demand.

By inspection of the first order condition, the monopolist offers a deeper discount: (i) the stronger the promotional effectiveness of consumption, that is, the greater in magnitude is the effect $\alpha_2'(p_1)$ and; (ii) the greater her patience, which means the higher is δ. The influence of initial awareness is ambiguous. Since α_1 appears in the denominator of the extra term and this, recall, is negative, the level of initial awareness clearly has a direct, positive impact on p_1^*;[18] However, the strength of the promotional mechanism $\alpha_2'(p_1)$ can also depend on α_1, leaving the sign of the overall effect undetermined.

It is useful to define the $1 - F(p^M)$ individuals for whom $v \geq p^M$ as 'high types' and all others (those priced out of the market at price p^M) as 'low types'.

Definition 1. *People for whom $v \geq p^M$ are high types; all others are low types.*

Thus, in the second period of the current model, where the seller sets price p^M, only *aware* high types purchase. Low types go without the product as do any ignorant high types. In the first period—the promotional phase—the monopolist serves aware high types and also some of the aware low types (those with $v \in [p_1^*, p^M]$). Appreciate, however, that serving low types is done at a cost to first-period profit (she has to lower price on all infra-marginal

[17] p_1^* is unique provided the monotone hazard rate condition is satisfied *and* $\frac{\partial\left(\alpha_2'(p_1)/F'(p_1)\right)}{\partial p_1} \geq 0$.

[18] A plausible interpretation for the positive sign is that the more informed the population to begin with, the larger the initial consumer base, and hence the costlier (in terms of foregone first period profit) any promotional pricing campaign.

units and this is costly), and thus only reluctantly, out of concern for product hype. If the seller somehow could rely on these low types otherwise to consume (and so spread awareness about) her product, so that she herself need not sacrifice current margin to entice them, then optimally she would.

3.3. **Introducing Piracy.** Suppose now that individuals have a further consumption channel: in place of buying or doing without, they might copy the product. Let $c \geq 0$ be a person's idiosyncratic cost of piracy. It could represent an amalgam of costs related to equipping oneself technologically and psychologically for the act of piracy. For instance, downloading files using P2P software can involve costly search, sometimes files will contain errors/bugs, whilst being caught reproducing copyrighted materials without permission could involve large fines or even prison sentences.

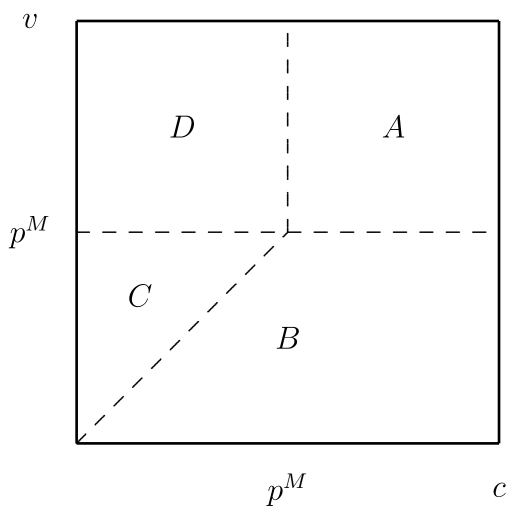
With the option to copy, and assuming she is product aware, an individual purchases one unit of the good in period t if her valuation v exceeds its price p_t unless this price is greater than her personal cost of piracy c. In the latter case she would rather copy it. Only if her v is below both p_t and her own c will she abstain from consumption altogether, receiving zero utility. Her utility is thus:

$$u = \max \begin{cases} v & - p_t, \\ v & - c, \\ & 0. \end{cases}$$

Before considering how the monopolist behaves in this new setting, the optimal price and protection choices she may make, it helps build intuition for piracy's impact to make a few diagrammatic observations. Consider that a 45^o line through the origin of v, c space divides those who potentially would pirate (upper left triangle) from those who never would (lower right triangle) and note that the standard monopoly price line p^M separates high types (those above this line, who always buy in the no piracy counterfactual) from low types (those below it). Figure 3.3 uses these two lines to create four regions labeled A, B, C and D.

Individuals located in the top right section A are high types who are not tempted to pirate. They remain happy to buy at price p^M even now that piracy is an option.

The lower right region B contains any low types not tempted to pirate. For these individuals both piracy costs and standard price p^M exceed any value they derive from the good. The monopolist's ability to sell to any such people using a promotional price remains unchanged under the possibility of piracy.



A : safe sales (high types who still buy at p^M)
B : never consume (low types unwilling to copy)
C : profit-friendly piracy (low types prepared to copy)
D : threatened sales (high types who prefer to copy)

Figure 1. Susceptibility to piracy

Anyone located in the lower left region C is of much greater interest. Such people are low types who *are* prepared to pirate. With piracy a possibility, the seller can leave such people to join the ranks of consumers through the piracy channel knowing that their piracy, since it helps stimulate product awareness without compromising high type sales, must be profit-friendly. As low types, any people in region C never would have been served in the no piracy counterfactual, except possibly in the first period, and then at a cost to immediate profitability and purely for the purposes of driving up product awareness. As noted already, the monopolist would be quite happy to lose any such 'promotional' sales to piracy.

Lastly, upper left region D is the area of biggest vulnerability for the seller. Individuals situated here are high types with relatively low piracy costs. By definition, high types are prepared buy at p^M in the no piracy counterfactual, but those in D will prefer to copy, if this is an option.

Pieced together, the above observations imply quite generally that piracy may not always be bad for business and sometimes could be good. The existence of and balance between business stealing and promotional effects depends on $\alpha_2(q_1)$ but also significantly on the location of individuals in v, c space. Consider that:

- If no one is in D, the monopolist cannot be worse off under piracy (no lost sales);
- If no one is in D but some are in both A and C, the monopolist is unambiguously better off (no lost sales, free extra promotion!);

- If some are in D but no one is in C, the monopolist is unambiguously worse off (lost sales, no free extra promotion);
- If some are in D but also in C and A, the impact is ambiguous (lost sales vs free extra promotion).

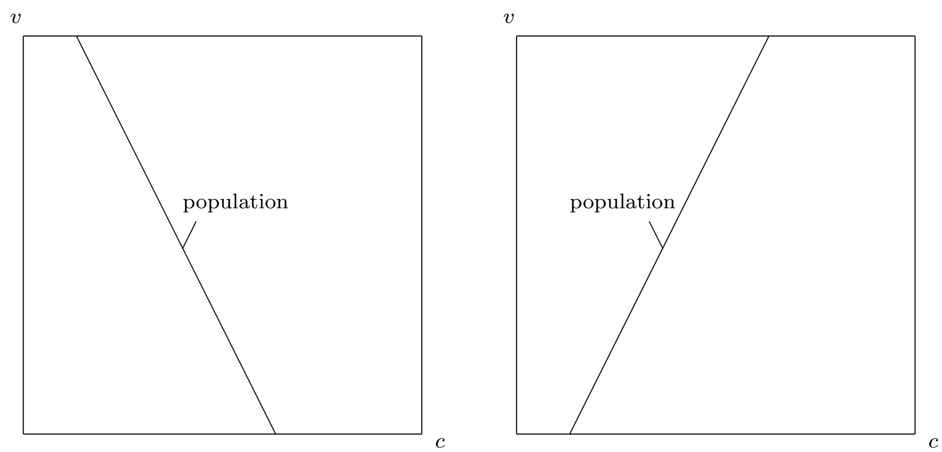
Since population location is key to outcomes, it is important to ask how people are likely to be distributed throughout v, c space. This paper introduces the plausible idea that in many markets v and c could be monotonically related through some third variable such that there exists a perfect linear relationship between their ranks. By 'perfect linear relationship between their ranks' is meant that $F(v)$ and $G(c)$ (if F and G are marginal distribution functions of v and c respectively) are perfectly correlated. Prime candidates for variables that might link piracy cost and valuation in this manner include personal income and age.[19] Consider the markets for computer games: Many games are targeted at, and plausibly most valued by, a youth market. At the same time, the piracy costs of young people are conceivably at the low end, not least because of the smaller income value of their time. The implication is a negative v, c relationship. The relationship is more probably positive in the case of business software, on the other hand, since professional users attach higher worth to office software than do teenagers, and tend also to place a higher monetary value on their time.

Taking forward this basic idea, the next two sections of the paper analyze negative and positive v, c relationships respectively. The provider's optimal pricing and protection choices, and piracy's overall profit impact, are investigated for each case.

4. Negative v, c Relationship

When a population distribution is downward sloping in v, c space, as might be the case in some computer games markets, it clearly cannot pass through A and C and thus can never be unambiguously profit-friendly. Instead, so it turns out, piracy is always (weakly) harmful

[19]The plausibility of a monotonic relationship between income and willingness-to-pay is perhaps apparent, while the fact that products are often designed to appeal particularly to people of a certain age argues for some relationship between age and willingness-to-pay. As for the link between piracy cost and income, consider that since it takes time to create an illegal copy, a rational agent factors in the income value of her time when computing piracy cost. Finally, recent research is suggestive of the relevance of age to piracy costs: In a large scale survey of music consumption, those in 18-24 age group were found primarily to use P2P and ripping methods to acquire music, while those in the 45 years and older group obtained music from store purchased CDs ("NARM Consumer Research Initiative Phase One: Consumer Profiles and Retail Experience," prepared by NPD Group for National Association of Recording Merchandisers, March 2006.)



Computer games? **Business software?**

to profit and (assuming away any costs of doing so) the provider will wish to eradicate any piracy.

Proposition 2. *Suppose v and c are negatively related. The possibility of piracy is (weakly) detrimental to profit. The seller wishes to eliminate appetite for copying.*

Proof. A straightforward argument establishes this second proposition. Begin by noting that the person with highest valuation must have the lowest piracy cost. Define this person to have valuation $\overline{v}$ and piracy cost $\underline{c}$. Two cases require consideration:

If $\underline{c} \geq p^M$ then the highest value individual does not wish to pirate and nor does anyone else (they have lower valuations and higher piracy costs). In other words, the highest value type must lie in region A and all other necessarily below and to the right of this person. But this means that all high types must be in region A (always buy) and all low types in region B (never consume). Consequently, the seller can simply go about her business as in the no piracy counterfactual, serving high types at p^M, and leaving low types to go without.

If instead $\underline{c} \leq p^M$ then piracy is unambiguously profit-damaging; it undermines sales revenue without boosting promotion. To understand why, note that with a negative relationship the population distribution crosses the 45^o line once and once only, at some valuation v^X. Demand is kinked at v^X: sales are zero for any price above this (a negative v, c relationship means that everyone with a v above the kink has a c below it). The monopolist must price below the kink ($p < v^X$) to achieve positive sales. If her price also satisfies $p \leq \underline{c}$ she can deter from piracy anyone who might be tempted. But since $\underline{c} \leq p^M$ she will in so doing be underpricing and overselling her product relative to the no piracy optimum. If, on the other hand, she goes with a higher price then always some sales are lost (some high types always pirate). Either way piracy undermines current sales and generates no extra free promotion. For any price $p < v^X$, all those who pirate would have bought her product but for the option to copy (since their valuations satisfy $v > v^X > p$) and so anyway helped promote it.

Analysis has so far referred to population distributions as though these are exogenous. If she is able to deploy copy protection technology, and possibly other anti-piracy measures, then the seller can affect the general costliness of piracy (she may affect c) and so relocate people in v, c space to her advantage. Since piracy always harms her when v and c are negatively related, she optimally sets protection so as to kill off all copying.[20]

To the extent that a negative v, c relationship broadly characterizes the market for computer games, proposition 2 helps to understand the quite draconian approach to technological copy protection applied by games makers. How, in practice, might the location of individuals through protection be effected? To illustrate, suppose that personal piracy cost takes the form $c = \kappa + \gamma y$, where κ is some fixed component to piracy cost (the price of a blank CD, for instance) and γ is the sensitivity of piracy cost to changes in some variable y which links v and c. For instance y might be hourly wage and γ could reflect the time needed produce a copy, so that γy is a person's income value of that time. If an increase in protection means it takes a person longer to pirate a product, γ rises and the distribution of individuals swings rightward away from the vertical axis in v, c space. If instead κ alone is increased because, say, protection means more expensive piracy equipment is needed, then the distribution follows a parallel rightward shift. Figure 2 illustrates both possibilities.

In either case, to rid the market of pirates at price p^M, it will do to ensure that the highest value person (who recall has the lowest cost of piracy) is just shifted into region A and so just prepared to purchase, that is, it suffices to ensure that $\underline{c} = p^M$ since this in turn guarantees that $c > p^M$ for all others, and hence that these too are disinclined to copy (all high types then in A, all low types in B). In the current example, this could be done by setting protection so high that $\kappa = \underline{c} = p^M$ or that γ is infinite.

[20]In order to focus on differences in the optimal tradeoff between piracy's business threat and word of mouth benefits, analysis ignores costs of installing protection.

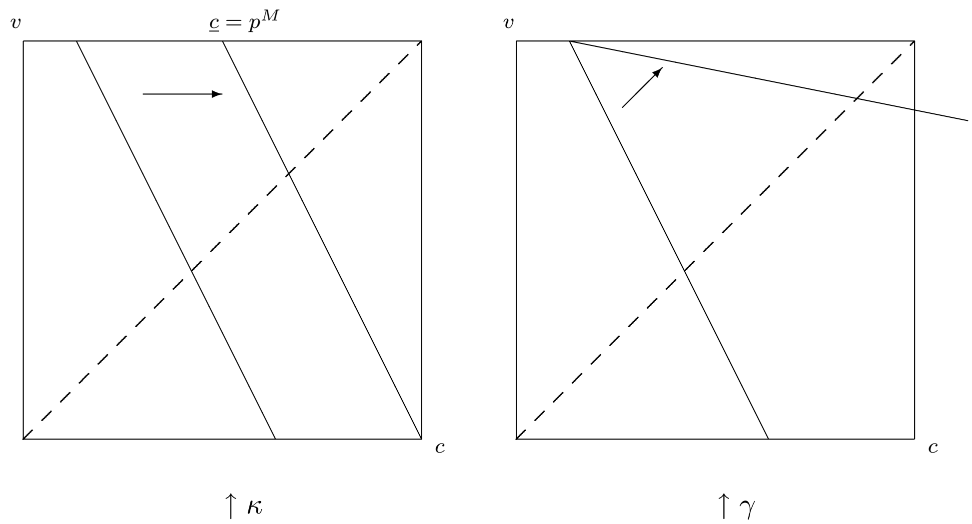


Figure 2. "Negative v, c relationship:" Protection shifts and/or rotates the population rightward. Both relocations curb enthusiasm for piracy.

5. Positive v, c Relationship

Whereas a negative v, c relationship might aptly depict markets with youth appeal, many more are probably better described by a positive relationship. Suppose that income y is the variable upon which v and c jointly depend. Where c depends positively on y, as this paper has suggested is likely (the income value of a person's time being a key component of individual piracy cost), a population distribution being upward sloping in v, c space implies that also v and y must be positively related. In other words, the product in question must be a normal good—a good for which willingness to pay is increasing in income. Realistically, many products will be normal, giving positive v, c relationships broad empirical relevance.

Intuitively, with upward sloping distributions, the possibility of piracy need not always spell bad news for the seller. In some cases, no piracy will take place at the standard price p^M. This is so if all low types are in region B of Figure 1 (and so unprepared ever to copy or to buy at price p^M) and all high types are in A (and so happy to continue buying at p^M or some lower price, regardless of the option to copy). In some other cases, piracy might occur but with ambiguous net impact on the seller's profit. This happens for populations distributed such that at least some low types are in region C, where they helpfully pirate, and at least some high types are in D, and so constitute lost sales. In other cases still, low types may be in C (profit-friendly piracy) whilst all high types are in A, so that the seller unambiguously benefits from piracy. As a corollary, maximal copy protection will not always be optimal for the seller; sometimes prescribed protection will be quite weak compared with the zero tolerance of the previous section. Proposition 3 summarizes.

Proposition 3. *Suppose v and c are positively related. Referring to Figure 1, the net profit impact of the possibility of piracy is either: (1) unambiguously positive (when all high types are in A and all low types in C) or; (2) ambiguous (when some high types are in D and some low types are in C) or; (3) non existent (when all high types are in A and all low types in B). Correspondingly, it will not always pay the seller maximally to protect against piracy.*

Very general analysis of positive relationships encounters a number of complications. For one, an upward sloping population distribution may intersect the 45^o line at multiple valuations, creating multiple kinks in demand. Furthermore, the significance of a marginal pirate (demand kink) can be quite different when compared to the case of a negative v, c relationship, and the shape of the distribution can now also matter (where with negative relationships it did not). Fortunately, to obtain some simple insights, it suffices to focus on relationships with at most two marginal pirates and hence up to two kinks in demand. Strictly concave and convex cases have at most two demand kinks and lend themselves to simple real-world interpretation: Taking as given that a positive relationship reflects the case of a normal good, and supposing that piracy cost increases linearly in income (a reasonable approximation if the costs of digital reproduction are some small fraction of income), concavity further implies that the product in question is a 'necessity'—a good for which valuation rises with income but less than proportionately. Convexity, on the other hand, would suggest a 'luxury' good—a good for which an increase in income induces a more than proportionate increase in demand. Some empirical work has sought to classify digital goods in these terms: music products are it seems necessities; some other digitizable goods, such as books, are luxuries.[21] This categorization invites comparison of the model's predictions for concave and convex cases to evidence from selected markets. The paper begins this task by considering concavity, where theoretical outcomes can be compared to particularly interesting and well documented developments in the music industry.

Before turning to this, Figure 3 helps build intuition for the basic difference curvature can make. In this illustration, v_H^X and v_L^X are the valuations of the highest and lowest marginal pirates (the highest and lowest kinks in demand), respectively. Where the relationship is

[21]Sessions and Stevans (2005) estimate income elasticity of music demand to be 0.59 over the ten years prior to 2000 rising to 0.92 in the post-2000 period. Meanwhile, a number of authors have reported income elasticities of demand above unity for books (Hjorth-Andersen, 2000, Fishwick and Fitzsimmons, 1998, and Ringstad and Loyland, 2006).

concave (left panel), all those with valuations between these marginal pirates are prepared in principle to pirate, whereas with convexity (right panel), the situation is reversed and all people *except* those in the interval $[v_L^X, v_H^X]$ are potential pirates. In either case, if the person just prepared to buy in the no piracy counterfactual (the high type with lowest valuation $v = p^M$) does not reside in the shaded region, the possibility of piracy cannot be harmful to business. Why is this? If this person does not lie in the shaded region then it must be that she is never willing to pirate. But this in turn means that *all* high types, since their piracy costs are necessarily greater than hers, must prefer to buy at p^M rather than copy. If, on the other hand, this standard marginal buyer *is* located in the shaded region then piracy's net profit impact must be ambiguous. This is because she herself now prefers to copy than to buy at p^M (she is in region D) and probably some other high types (those with valuations just slightly above p^M) then also populate area D. As a result, at least some standard sales are compromised. At the same time, probably some low types (at least anyone with valuation fractionally below p^M) will be in C, implying a costless marketing boost. Whether the seller ultimately profits or suffers from piracy will reflect the balance of these business stealing and promotional effects.

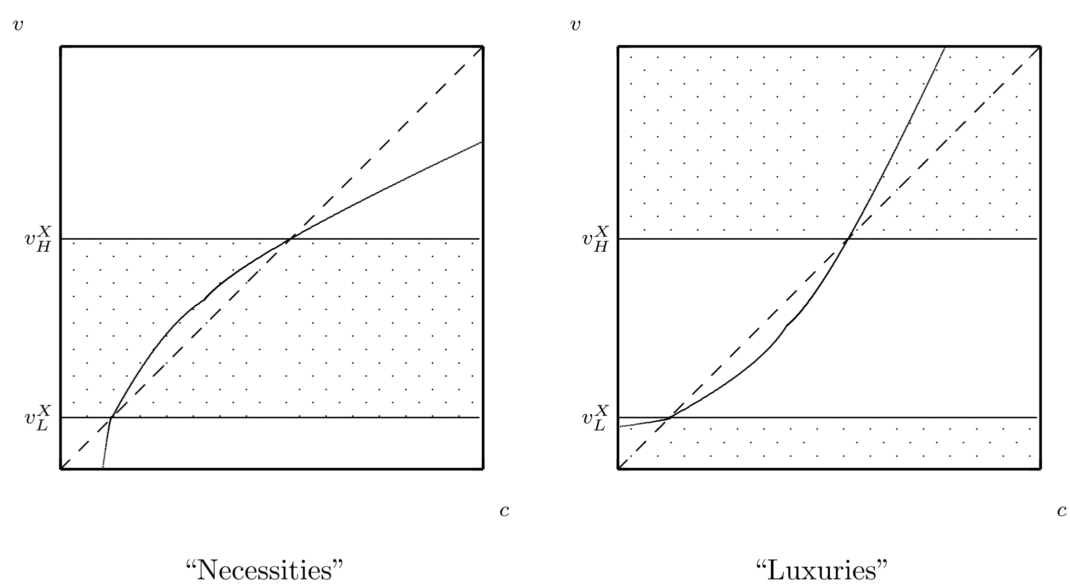


Figure 3. With concavity, potential pirates are those with valuations in the interval $[v_L^X, v_H^X]$; with convexity all except these people are potential pirates.

5.1. **Concavity ("Necessities").** This subsection considers population distributions such that there exists a positive and concave relationship between v and c. For simplicity, distributions are assumed to rise from some weakly positive intercept on the c axis. Consequently, they may intersect the 45^o line (i) just once, from below, at v_L^X or; (ii) twice: once from below at v_L^X and once from above at v_H^X, with $v_L^X < x_H^X$ or; (iii) not at all. The third case is uninteresting, meaning as it does that everyone lies below and to the right of the 45^o line and so never pirates. The first two cases are interesting and shall be considered in turn.

Begin with case (i). The net impact on the seller's profit of the possibility of piracy depends on the location of v_L^X in relation to p^M. If $v_L^X > p^M$ then, effectively, the seller finds herself in the no piracy counterfactual. She behaves as there and no piracy takes place. To understand this result, first note that anyone with valuation below v_L^X necessarily lies below and to the right of the 45^o line and so never will pirate. It follows that if $v_L^X > p^M$, then not only are low types not prepared to copy but also the standard marginal buyer (for whom, recall, $v = p^M$) never will pirate. But then all high types must prefer to buy at p^M rather than copy (their piracy costs are necessarily greater than the marginal buyer's). In terms of Figure 1, all high types necessarily lie in region A (safe sales), whereas all low types are in region B (go without), just as absent the possibility of piracy. If instead $v_L^X < p^M$ then there is a real threat to business but also promotional effects arise, so that piracy's net profit impact is ambiguous. This is because all high types must lie in region D and so would rather copy than pay price p^M, meaning standard sales are compromised. At the same time, at least some low types—those with $v \in [v_L^X, p^M]$—must lie in region C and so be prepared to pirate and so lend a free hand with marketing.

Now turn to case (ii), where a concave distribution has two points of intersection and so two marginal pirates. Provided $v_H^X < p^M$, piracy must be unambiguously profit-friendly. Anyone with valuation above v_H^X necessarily lies below and to the right of the 45^o line and so is not prepared to copy; this is true of all high types. It follows that all high types are in A, and so always buy, regardless of the option to copy. Meanwhile, at least some low types—those with $v \in (v_L^X, x_H^X)$—lie to the left of the 45^o line (in region C) and so would rather copy than go without the product. In all, the seller loses neither sales nor margin, but enjoys the additional buzz the pirates create.[22] Where instead $v_H^X > p^M$ then two possibilities arise, depending on the location of v_L^X in relation to p^M: If $v_L^X < p^M$, piracy's profit impact is

[22]Indeed if $v_L^X \in [p_1^*, p^M]$ she will find it optimal to reduce the generosity of her first period price, there being no point sacrificing margin to attract low types who could otherwise be relied upon to pirate.

once more ambiguous since then at least some high types must be in region D (compromised sales), but if instead $v_L^X > p^M$ the no piracy counterfactual again ensues.

The following proposition summarizes these insights.

Proposition 4. *Suppose that a positive concave v, c relationship begins from a weakly positive intercept on the c axis. If it intersects the 45^o line just once, from below at v_L^X, then piracy's net impact is ambiguous whenever $v_L^X < p^M$ but non-existent when $v_L^X > p^M$. If instead there are two points of intersection ($v_L^X < v_H^X$) then whenever $v_H^X \geq p^M$ piracy's profit impact is ambiguous (where also $v_L^X < p^M$) or non-existent (where also $v_L^X > p^M$), whereas when $v_H^X \leq p^M$ piracy is unambiguously profit-friendly.*

To derive further results, the rest of the section looks more closely at case (ii), under the additional simplifying assumption that the first point of intersection is the origin itself: $v_L^X = 0$. Demand is then characterized by a single kink at v_H^X. As piracy becomes generally less costly (as digital replaces analogue piracy, for instance) the v, c relationship swings back towards the vertical axis and v_H^X rises. Visual inspection of demand curves provides much intuition for what happens as v_H^X increases. Consider the three panels of Figure 4, which illustrate demand per informed individual for three progressively higher values of v_H^X.

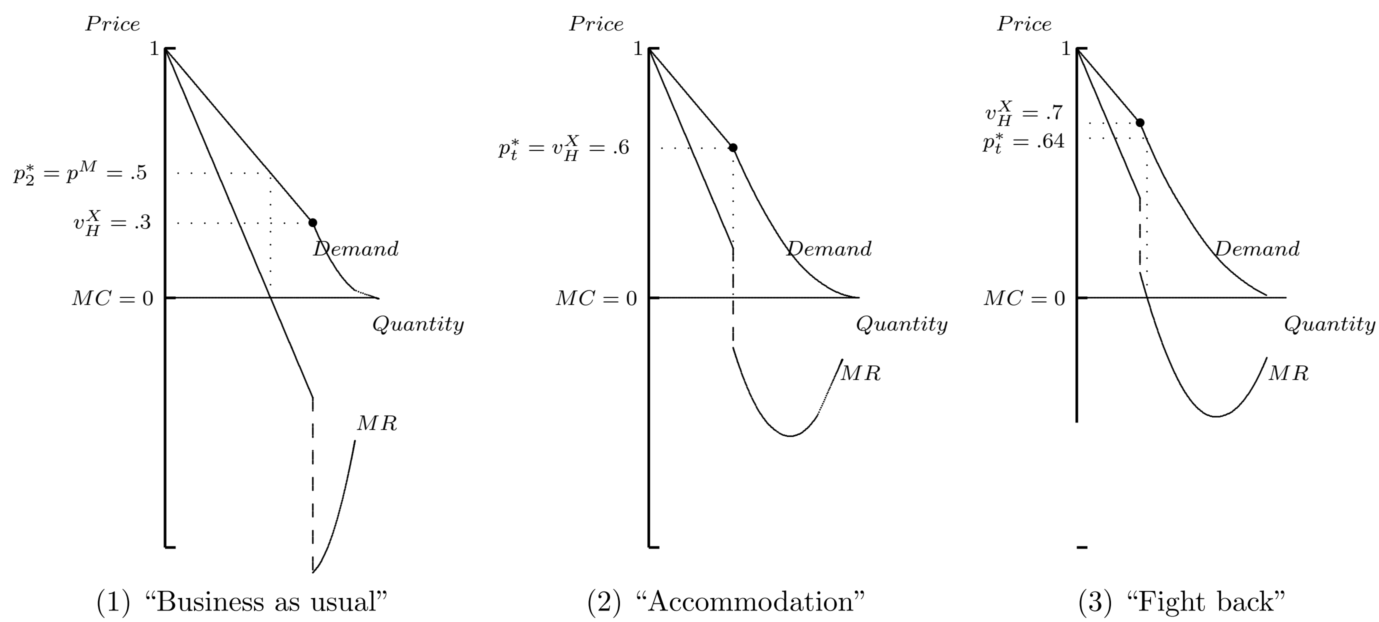


FIGURE 4. Illustrative positive concave relationship. Demand curves generated using the specification: $v = \beta y^{\frac{1}{2}}$; $c = \gamma y$ ($\Rightarrow v = \frac{\beta}{\gamma^{\frac{1}{2}}} c^{\frac{1}{2}}$); with $v \sim U[0,1]$.

This situation depicted in panel 1 is highly favourable for the seller; she can get on with things unencumbered by piracy. When $v_H^X < p^M$, as is the case here, no high type is tempted to copy, but at least some low types lie above the 45^o line and so copy and their extra WOM helps her out with marketing. Unless $v_H^X = p^M$ exactly, there are always some low types who'd rather go without than copy or buy at p^M and the seller may offer a lower price in the first period to attract some of these people, save that she will never price below the kink itself (there is no point her sacrificing margin to win the custom of low types who could be relied upon to pirate her product). In panels 2 and 3, piracy as become generally less costly (the kink has risen). The fact that in both these cases $v_H^X > p^M$ altogether obviates any need for promotional pricing (all low types lie above the 45^o line and so are guaranteed to copy rather than go without), and means that the optimal price in any period t is simply the price that myopically equates $MC_t = MR_t$. The nature of the optimal price differs in each case, however. In panel 2, the discontinuity in MR visibly passes through the $MC = 0$ line, suggesting that pricing at the kink, and so "accommodating" rather than fighting piracy, is optimal. By contrast, in scenarios where the discontinuity lies above the MC line, like that illustrated in panel 3, a "fighting price" below the kink is best. The next proposition formalises this reasoning.

Proposition 5. *Suppose a concave relationship $v = G(c)$ rises from the origin ($v_L^X = 0$) and crosses the 45^o line once more, from above, at $v_H^X \in [0, 1]$. There are three possibilities:*

(1) *"Business as usual:" if $v_H^X \leq p^M$, the monopolist carries on as in the no piracy counterfactual, setting $p_2^* = p^M$ in period two and a lower promotional price in period one, except that she will never price below the kink (anyone with valuation below this consumes regardless). Since she benefits from extra free promotion at no cost to sales, piracy is unambiguously profit-friendly;*

(2) *"Accommodation:" if $p^M \leq v_H^X \leq p^F$, where p^F satisfies $p^F = \frac{1-F[G(p^F)]}{F'[G(p^F)]G'(p_t)}$, she always prices at the kink each period $p_t^* = v_H^X$. High types with $v \in (p^M, v_H^X)$ become lost sales but low types become pirates and this helps generate buzz. Thus piracy's net profit impact is ambiguous;*

(3) *"Fight back:" otherwise, when $v_H^X \geq p^F$ she sets $p_t^* = p^F$ each period. This is a "fighting" price—a price below the kink intended to induce some of those high types tempted to pirate instead to buy. Piracy's net profit effect is again ambiguous.*

Proof of Proposition 5 is contained in Appendix A. Meanwhile, Figure 5 tracks the evolution of pricing as the general costliness of piracy decreases (as v_H^X increases).

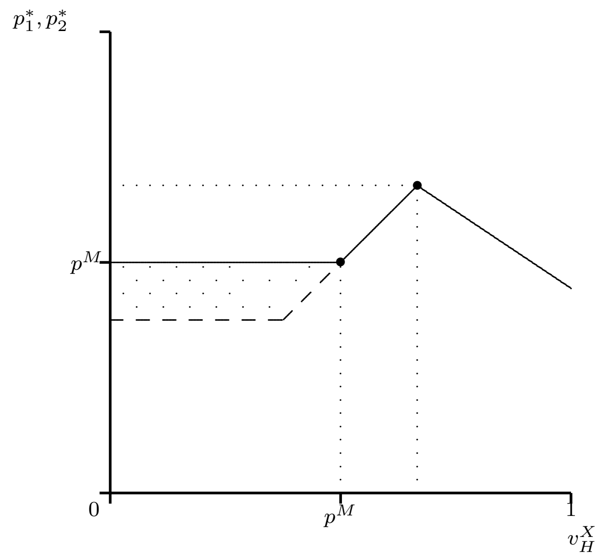


FIGURE 5. Pricing 'necessities:' As copying becomes generally less costly (as v_H^X rises), the firm "accommodates" piracy, raising price above p^M to defend margin. But if piracy's appeal continues to grow, the seller at some point switches to a "fighting price," discounting to protect volumes.

Equilibrium (1), in which piracy is still relatively expensive for high types, might be thought roughly to depict the era of analogue piracy, where copying was cumbersome and the cost or piracy encompassed a noticeable loss of product quality (vis-a-vis the original product). The model predicts that piracy takes place in such settings but that the practice is confined to low types (perhaps children taping songs from the radio). The seller responds by conducting *business as usual*, doing nothing to discourage pirates since high value business is not compromised. If piracy becomes a little cheaper from here, she has less need for a promotional price in the first period and can afford to edge p_1^* upwards, back towards p^M. However, if piracy costs continue to fall, perhaps as Internet file-sharing begins to take hold, there comes a point at which the seller enters equilibrium (2) and sales begin adversely to be affected. Price is then raised so as to defend margin in the face of ailing sales (*accommodation*). Finally, if cheap digital copying opportunities continue to lower the general costliness of piracy, the seller enters equilibrium (3) where she switches approach, seeking to lure back pirates with a low (*fighting price*).

Anecdotal evidence for music industry pricing accords surprising well with this sharp pricing prediction. In 2003, the Economist magazine discussed the tendency for the music industry initially to raise prices in response to digital piracy: "Even more worryingly for the industry, the combination of the internet and file-swapping software means that computer users can amass vast libraries of music for nothing. No wonder the record companies' shipments of music have fallen by 26 per cent since 1999 (though, thanks to price hikes, revenues have fallen by a slightly less worrying 14 per cent)." [23] But as digital piracy's threat unfolded further, music giants suddenly reversed tack and began slashing prices: "Music executives seem to have realised that they cannot continue to increase prices forever [...]. In September, Universal, the worlds biggest music company, cut the wholesale price of CDs to American stores, making it possible for them to sell new music for as little as 10 US dollars and still make money."[24]

The question arises: where would the seller prefer a population distribution to be located? Figure 6 illustrates optimal protection and the following proposition summarizes.

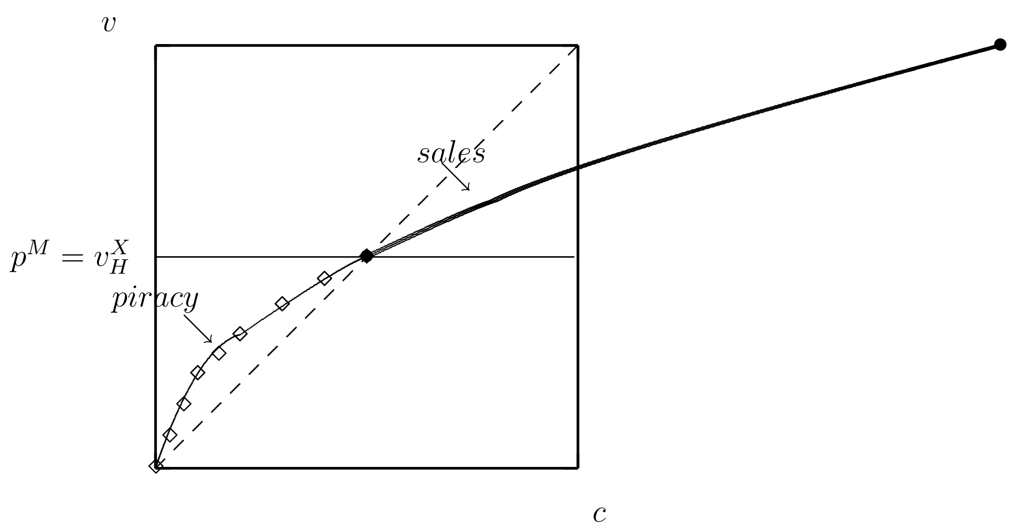


FIGURE 6. Optimal protection in the case of a positive concave v, c relationship.

Proposition 6. *"Concave positive v, c relationship:" If $v = v(y)$ is a positive concave relationship and $c = \kappa + \gamma y$ then optimal protection sets $\kappa^* = 0$ and some $\gamma^* > 0$ such that $v_H^x = p^M$. All low value individuals pirate and all high value individuals are buyers.*

[23]Elsewhere around the same time, equity analysts reported that music giant EMI had resolved to respond to piracy by concentrating on profitability as opposed to sales at any price.
[24]"Britney, meet Michael," Economist, November 7th 2003.

Note that maximal protection would be self-defeating since with a more modest application of control the monopolist can encourage low types to copy her product whilst retaining in the legal market those that she actually cares about—the high types.

5.2. **Convexity ("Luxuries").** A convex relationship that rises from the horizontal axis (to the right hand side of, and including, the origin) and does not lie entirely below the 45^o line, cuts the 45^o line from below at $v_H^X \in [0,1]$. As before, demand is kinked at this intersection but with different implications. The monopolist is unencumbered now only when she sets a price *below* the kink. In other words, the potential pirates now lie above v_H^X, not below it. This difference fundamentally affects the model's outcome.

Proposition 7. *"Convex positive v, c relationship:" Suppose the relationship begins from a weakly positive intercept on the c axis. It intersects the 45^o line just once, from below, at v_H^X. Whenever $v_H^X > p^M$ piracy's threat is spurious (no piracy takes place at standard prices) but when $v_H^X < p^M$ piracy poses a genuine threat to sales but also guarantees greater promotion, sot that the net profit impact is ambiguous.*

To demonstrate simply, suppose that the first of two intersection points is the origin itself ($v_L^X = 0$). Demand is then characterized by a single kink, corresponding to the highest point of intersection v_H^X. As piracy becomes generally less costly, the v, c relationship again swings back towards the vertical axis but now v_H^X falls (rather than rises) in the process. The next proposition identifies three pricing regimes the monopolist passes through as v_H^X declines.

Proposition 8. *Suppose a convex relationship $v = G(c)$ rises from the origin at $v_L^X = 0$ and crosses the 45^o line once more, from below, at $v_H^X \in (0,1]$. There are three equilibria:*

(1) *"Business as usual:" if $v_H^X \geq p^M$, then a monopolist carries on as in the no piracy counterfactual, setting p_2^* in period two and a lower promotional price in period one. The possibility of piracy has no impact on her business and no piracy occurs;*
(2) *"Purging price:" if $p^F \leq v_H^X \leq p^M$, where p^F satisfies $p^F = \frac{1-F[G(p^F)]}{F'[G(p^F)]G'(p_t)}$, she prices at the kink itself $p_2^* = v_H^X$. Low types with $v \in (v_H^X, p^M)$ who are not served in the no piracy counterfactual (except possibly under promotional pricing) are now served. Piracy is unambiguously harmful to profit;*
(3) *"Fighting price:" otherwise, when $v_H^X \leq p^F$ she sets $p_t^* = p^F$. This is a price above the kink. Piracy's net profit effect is ambiguous in this case, since margin is still sacrificed relative to the no piracy counterfactual but there is at least some free extra promotion—low types with $v \in (v_H^X, p^F)$ pirate and so help promote her product.*

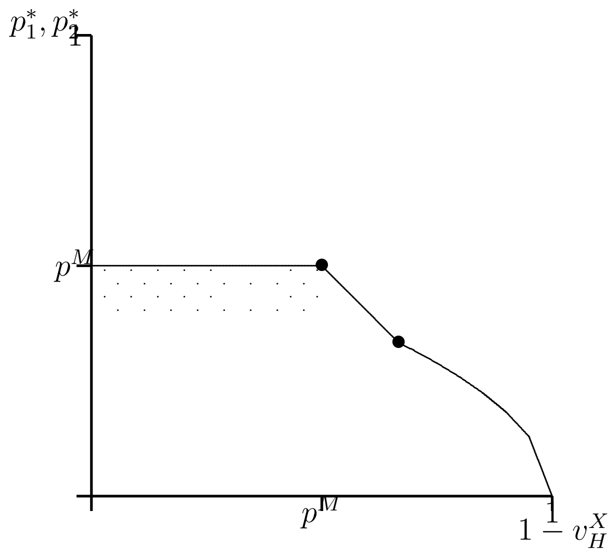


Figure 7. Pricing "luxuries:" As piracy becomes generally less costly, that is, as v_H^X falls (and hence $1 - v_H^X$ rises), the firm switches from standard pricing to tracking the kink downwards in order entirely to shut out piracy. If the typical cost of piracy falls much further the seller finds this approach too costly. Though she continues to lower price, she now keeps this above the kink, preferring to sacrifice some sales to mitigate some of the margin damage.

6. Concluding Remarks

In contrast to most economic research into piracy, the current analysis explores the possibility that pirates help spread the word about the products they copy, leading to stronger future demand. Empirical evidence suggests that word-of-mouth communications are important drivers of sales success, particularly in the digital entertainment sector.

Although not the first to admit a marketing role for illegal copies, the paper undertakes an original investigation into the sensitivity of piracy's profit impact to conceivable relationships between the distributions of willingness-to-pay and piracy cost. Specifying such relationships to reflect markets of interest, analysis yields predictions about protection and pricing that are sympathetic to empirical evidence. Insights about protection help explain the quite different strategies applied in computer games (high protection) and office software (low protection), for instance. Meanwhile, salient pricing predictions tally quite well with otherwise hard-to-explain adjustments to music pricing in the move from analogue to digital technology.

Music prices were first hiked in response to digital piracy but later slashed as cheap copying opportunities proliferated. The model's insights make this apparent u-turn more intelligible.

The basic theoretical framework could be flexed in a number of directions for greater realism. The current approach assumes that all people are equally likely to talk to all others. In reality, individuals will more probably relay recent consumption experiences to peers than to random others. Future work might address this matter. It could be of further interest to allow the seller to apply quality discrimination or 'versioning' to better exploit piracy's promotional effects. Two qualities might then be offered: (1) a well protected and high quality product and; (2) a cheaper, highly copyable 'sample', such as an inferior music file.

Appendix A. Omitted Proofs

Proofs for propositions 5 and 8 are provided in this section. Proofs of all other Propositions follow from arguments in the main text.

A.1. **Proof of Proposition 5.** Suppose a concave relationship $v = G(c)$ rises from the origin and crosses the 45^o once more, from above, at v_H^X. The monopolist faces demand per informed individual:

$$q_t^b = \begin{cases} 1 - F(p_t) & if \quad p_t \geq v_H^X \\ 1 - F[G(p_t)] & if \quad p_t \leq v_H^X \end{cases}$$

Given the kinked nature of demand, two cases require consideration.

(1) If the monopolist sets a price above the kink ($p_t > v_H^X$), she faces the standard monopoly demand $q_t = 1 - F(p_t)$. In the second period, she carries on as in the no piracy counterfactual, setting $p_2^* = p^M$ where p^M solves $p^M = \frac{1-F(p^M)}{F'(p^M)}$. In the first period she sets a promotional price below this. Note however, she will never price below the kink—there is no point sacrificing margin to coax those low types below the kink into buying (they will pirate). Thus the seller is unambiguously better off for the possibility of piracy; at least some free promotion results at no cost to profit. If $p^M > v_H^X$ is not satisfied, the boundary solution results in which she prices at the kink in both periods: $p_t^* = v_H^X$.
(2) If she prices below the kink ($p_t < v_H^X$), demand is $q_t = 1 - F[G(p_t)]$. Note that for any such price $G(p_t) > p_t \Rightarrow 1 - F[G(p_t)] < 1 - F(p_t)$, meaning demand is compromised relative to the standard monopoly case. This is piracy's business stealing effect. But

again piracy gives rise to beneficial promotional externalities. In fact, in this second case, consumption and hence promotion is automatically maximized (everyone is prepared either to buy or to pirate) and this altogether obviates the need for promotional pricing. The monopolist's optimal price in each period is the p^F that satisfies the myopic first order condition $p^F = \frac{1-F[G(p^F)]}{F'[G(p^F)]G'(p^F)}$. This is a "fighting price"—a price below the kink intended to tempt some of those who would pirate instead to buy. If this optimal price p^F does not satisfy $p^F < v_H^X$ then, again, a boundary solution results, in which she prices exactly at the kink v_H^X. The presence of both business stealing and promotional effects renders piracy's profit impact ambiguous.

We have shown that the seller may conduct "business as usual" ($p_2^* = p^M$) or may set a "fighting price" (p^F). We now show that p^M and p^F can never be exactly equal and that instead there must be a set of population distributions corresponding to some interval of kinks $v_H^X \in [p^F, p^M]$ over which she prices exactly at the kink, tracking this upwards and thereby "accommodating" piracy. To prove this by contradiction, suppose that there did exist some price p such that $p^M = p^F = p$ and $p^F \leq v_H^X \leq p^M$. Such price must satisfy the following equality:

$$\frac{1-F(p)}{F'(p)} = \frac{1-F[G(p)]}{F'[G(p)]G'(p)}.$$

Clearly such price must be the kink itself $p = v_H^X$ and it must also be the case that $G(p) = p$. The above equality could then be rewritten as follows:

$$\frac{1-F(p)}{F'(p)} = \frac{1-F(p)}{F'(p)G'(p)}.$$

Clearly, this equality is satisfied only where $G'(p) = 1$. But since the $v = G(c)$ curve cuts the 45^o line at v_H^X it cannot have a slope of unity at this point. Hence, p^M and p^F can never be the same price and instead there exists a set of population distributions such that the monopolist prices at the kink each period, those distributions for which $v_H^X \in [p^F, p^M]$ where $p^F < p^M$. Thus, there exists an intermediate set of population distributions, for which piracy is intermediately costly to individuals, over which the seller cannot conduct "business as usual" but prefers to to "accommodate" piracy rather than utilize a "fighting price."

A.2. **Proof of Proposition 8.** Suppose a convex relationship $v = G(c)$ rises from the origin and crosses the 45^o once more, from below, at v_H^X. The monopolist faces the following kinked demand function (where demand is per informed individual):

$$q_t^b = \begin{cases} 1 - F[G(p_t)] & if \quad p_t \geq v_H^X \\ 1 - F(p_t) & if \quad p_t \leq v_H^X \end{cases}$$

Again, two cases require consideration.

(1) If she prices above the kink ($p_t > v_H^X$), demand is $q_t = 1 - F[G(p_t)]$. Note that for any such price $G(p_t) > p_t \Rightarrow 1 - F[G(p_t)] < 1 - F(p_t)$, meaning demand is compromised relative to the standard monopoly case. Optimal second period price is the p^F that satisfies the myopic first order condition $p^F = \frac{1-F[G(p^F)]}{F'[G(p^F)]G'(p^F)}$. This is a price above the kink intended to protect margin—a "fighting" price. The presence of both business stealing and promotional implies an ambiguous overall impact on profit. If this optimal price p^F does not satisfy $p^F > v_H^X$ then, again, a boundary solution results, in which she prices exactly at the kink v_H^X.

(2) If the monopolist sets a price below the kink ($p_t < v_H^X$), she faces the standard monopoly demand $q_t = 1 - F(p_t)$. She carries on exactly as in the no piracy counterfactual, setting $p_2^* = p^M$ where p^M solves $p^M = \frac{1-F(p^M)}{F'(p^M)}$ and a promotional price below this in the first period. No piracy takes place. If $p^M < v_H^X$ is not satisfied, the seller again prices at the kink itself (boundary solution).

We have shown that the seller may conduct "business as usual" ($p_2^* = p^M$) or may set a "fighting price" (p^F). We now show that p^M and p^F can never be exactly equal and that instead there must be a set of population distributions corresponding to some interval of kinks $v_H^X \in [p^F, p^M]$ over which she prices exactly at the kink, tracking this downwards. In this convex specification, pricing at the kink is tantamount to acting to "purge" the market of all piracy. A proof by contradiction that an interval of "purging" prices exists, follows now familiar lines: Suppose that there did exist some price p such that $p^M = p^F = p$ and $p^F \leq v_H^X \leq p^M$. Such price must satisfy the following equality:

$$\frac{1 - F(p)}{F'(p)} = \frac{1 - F[G(p)]}{F'[G(p)]G'(p)}.$$

Clear such price must be the kink itself $p = v_H^X$ and it must also be the case that $G(p) = p$. The above equality could then be rewritten as follows:

$$\frac{1-F(p)}{F'(p)} = \frac{1-F(p)}{F'(p)G'(p)}.$$

Clearly, this equality is satisfied only where $G'(p) = 1$. But since the $v = G(c)$ curve cuts the 45^o line at v_H^X it cannot have a slope of unity at this point. Hence, p^M and p^F can never be the same price and instead there exists a set of population distributions such that the monopolist prices at the kink each period, those distributions for which $v_H^X \in [p^F, p^M]$. Thus, there exists an intermediate set of population distributions, for which piracy is intermediately costly to individuals, over which the seller cannot conduct "business as usual" but opts to to "purge" piracy from her market at some cost to margin, rather than utilize a weaker "fighting price."

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