

Promotional Piracy

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DRAFT¹

Abstract

Unauthorized reproduction of goods such as software and music can displace sales. At the same time, 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).

JEL Classification: D2, D4, D8, L1, L2, L8.

Keywords: Digital Goods, Piracy, Pricing, Protection, Word-Of-Mouth.

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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 used widely to obtain products illicitly. The figures for software piracy are particularly stark: A third of all products installed on personal computers is pirated, with suggested revenue losses of \$48bn for 2007.² Not all this piracy 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

²<http://www.bsa.org/idcglobalstudy2007/>

³<http://news.bbc.co.uk/1/hi/entertainment/music/4720351.stm>.

⁴<http://news.bbc.co.uk/1/hi/entertainment/film/3985917.stm>

⁵This appears to be the central thesis of recent studies produced or sponsored by industry lobby body the Business Software Alliance (BSA). For instance, the January 2008 report which the BSA commissioned from the IDC (“The Economic Benefits of Reducing PC Software Piracy” available at www.bsa.org) concluded that: “Reducing software piracy could create hundreds of thousands of new jobs, billions in information technology (IT) spending and economic growth, and new tax revenues to support local services.”

⁶For 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.”

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 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, disregard the possibility of piracy, and consider a standard model of monopoly sales. Not everyone is a buyer in this counterfactual: only those with valuations above the seller’s optimal uniform price (call them the ‘high types’) purchase; others (the ‘low types’) go without. It follows that only high types are relevant to an assessment of piracy’s business threat; low types should 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 modest piracy costs, suggesting possible grounds for stiff protection. Elsewhere, copying may most appeal to low types. Such variation could be a key to the protection puzzle. But potentially there is more to the story, this paper will suggest.

As well as possibly 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. At the same time, current consumers—buyers *and* pirates—may lend a hand with this 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 marketers 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 the importance of buzz for future sales (Godes & Mayzlin 2004, Marsden, Samson & Upton 2005). According to Godes & Mayzlin (2004), who exploit

⁷Consider 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.”

⁸Shy & 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.

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: recently, 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 would not), 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 awareness in the second;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).

⁹The 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.

¹⁰As 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 & 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.

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 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 good 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 relationships imply normal goods.¹¹ Where the positive relationship is also concave or convex, one can think of it as depicting a market for necessities or 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 & Stevans 2005), and, intriguingly, this concave pricing story seems to resonate well with otherwise puzzling developments in the music industry. As the *Economist* magazine noted in 2003, music prices were initially raised in response to the onset of digital piracy, but as copying opportunities continued to proliferate this strategy was reversed.¹²

“... 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).” “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.”

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 7.

¹¹Assuming, reasonably, that a person's piracy cost is positively related to their income.

¹²“Britney, meet Michael,” *Economist*, November 7th 2003.

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 & Waldman (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 (Conner & Rumelt 1991, Shy & 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.¹³

The treatment offered in this paper relates most closely to a second branch of articles, known as “consumer information” studies (Takeyama 1997, Zhang 2002, Duchene & Waelbroeck 2003, Peitz & Waelbroeck 2006, Duchene & Waelbroeck 2006). 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 & Waelbroeck (2006) 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.

¹³As Peitz & 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.

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 initial market. But awareness can grow over time as first period consumers generate buzz about 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 offers a “promotional” first period price, sacrificing some immediate margin and so overexpanding sales (relative to myopic optimization) for the sake of future consumer 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.¹⁴ 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).¹⁵ 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.

¹⁴The 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.

¹⁵The 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.

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 .¹⁶ Second period awareness α_2 depends positively on total first 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?

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 exogenous 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 . By earlier assumption that $F(v)$ satisfies the monotone hazard rate condition, this 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.¹⁷

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:

¹⁶In 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.

¹⁷To 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: $p_2^* = p^M = \frac{1}{4}$.

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

A somewhat more involved first-order condition results:

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

Compared to the standard condition for single period optimization ($p = \frac{1-F(p)}{F'(p)}$) this new optimality condition features an extra term on the right hand side, and this extra term must be negative since its $\alpha_2'(p_1)$ component is negative and all other components positive. It follows that, whereas in the second (and final) period the monopolist optimally prices in the textbook fashion, her optimal first period price is lower: $p_1^* \leq p^M$.¹⁸ This discounting has a straightforward interpretation: in order to exploit viral marketing the seller offers a “promotional” price. Her promotion induces any low types with $v \in [p_1^*, p^M]$, provided they are aware of her product, to purchase. This extra consumption, in turn, helps drive up product awareness. Thus some current margin is sacrificed as an investment in future demand. Proposition 7 follows from these arguments.

Proposition 1. *No piracy benchmark: 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.*

By inspection of the first order condition, the monopolist offers a deeper first-period price 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^* .¹⁹ 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.

¹⁸ p_1^* is unique provided the monotone hazard rate condition is satisfied and $\frac{\partial(\alpha_2'(p_1)/F'(p_1))}{\partial p_1} \geq 0$.

¹⁹A 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.

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, 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 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

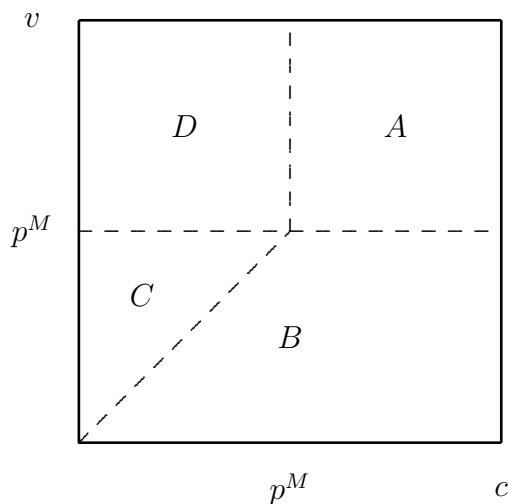
Suppose now that individuals have a further consumption channel: in place of buying or doing without, they might copy the product. Let $c \geq 0$ be a person’s idiosyncratic cost of piracy. It could represent an amalgam of costs related to equipping oneself technologically and psychologically for the act of piracy. For instance, downloading files using P2P software can involve costly search, sometimes files will contain errors or 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. 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 optimizes in this new setting and comparing this to the no piracy benchmark (in order to discern piracy’s profit impact, among other things), a few diagrammatic observations will build intuition for the eventual results. Consider, firstly,

that a 45° 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). Note, secondly, that the standard monopoly price line p^M separates high types (who lie above this price line, and so always buy in the no piracy counterfactual) from low types (who lie below it). Figure 1 uses these two lines to subdivide v, c space into four regions labeled A, B, C, and D. These are meaningful subdivisions from the monopolist's perspective.



- 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 depends on location in v, c space.

Individuals located in the top right section A are high types with relatively high piracy costs. Were the monopolist to price at p^M , these people would be happy to buy, despite the option to pirate—they are safe sales.

The lower right region B is relatively uninteresting from the seller's perspective. These people are low types who will never copy—their piracy costs are too high. As low types, they would not be served in the no piracy counterfactual and hence do not represent lost sales. Piracy does not interfere with the monopolist's ability to sell to some such people using a promotional price ($p < p^M$), should she wish to.

Anyone located in lower left region C is of much greater interest: such people are low types who *are* prepared to copy. Any piracy they undertake, since it helps stimulate product awareness without compromising sales (they are low types, they would never buy under standard pricing p^M), must be profit-friendly.

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. These people buy at price p^M

in the no piracy counterfactual but would rather copy, if this is an option. They are thus potential lost sales.

Pieced together, the above observations imply already that the existence of, and balance between, business-stealing and promotional effects depends significantly on the location of individuals in v, c space. Depending on where people are, piracy can damage profit, be profit-neutral, or be profit-friendly. 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 some are in C and A , the impact is ambiguous (lost sales vs free extra promotion).

Since population location is clearly 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 $G(c)$, where these 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.

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. Figure 2 illustrates these possibilities.

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 in each case.

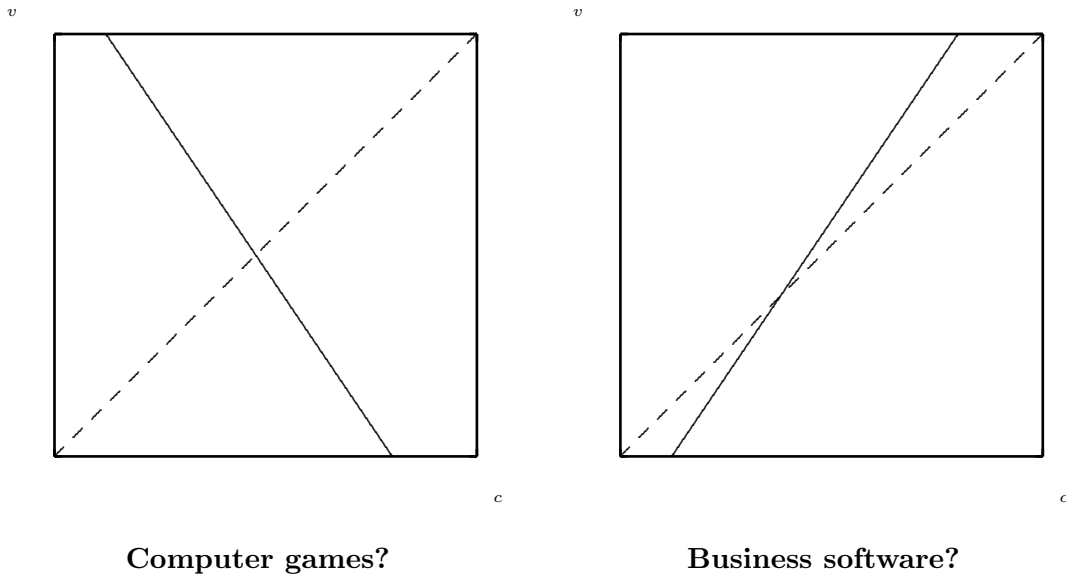


Figure 2: The v, c relationship may be positive or negative depending on the market.

4 Negative v, c Relationship

In some markets, the population distribution may be downward sloping in v, c space. Teenage computer games markets may fit this case, the previous section has argued. Downward-sloping distributions clearly cannot pass through regions A (safe sales) and C (profit-friendly piracy) of Figure 1 and so can never be unambiguously profit-friendly. Instead, so it turns out, the possibility of piracy is always (weakly) harmful to profit, and, ignoring questions of cost, the provider will wish to kill off any temptation to copy.

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 last proposition. Begin by noting that the person with highest valuation (call this \bar{v}) must have the lowest piracy cost (\underline{c}). Two cases require consideration:

1. $\underline{c} \geq p^M$: This case is straightforward. The individual with highest valuation and lowest piracy cost is not tempted to pirate at the standard price p^M and nor therefore is anyone else. Thus, the possibility of piracy has no impact on profit.

2. $\underline{c} \leq p^M$: In this alternative case, 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° line once and once only, at some valuation v^X . Demand is kinked at this valuation: for any price above v^X sales are zero (with a negative v, c relationship, everyone for whom $v > v^X$ must have $c < v^X < p$ and so prefer to copy), so price must be set below v^X in order to achieve positive sales. Supposing the seller prices below v^X , there are two subcases to consider: (i) $p < \underline{c} < v^X$, and; (ii) $\underline{c} < p < v^X$. Consider (i) first. Since $p \leq \underline{c}$ in this subcase, no one is tempted to pirate. But since $\underline{c} \leq p^M$, and hence $p < p^M$, the monopolist is here underpricing and overselling her product relative to the no piracy optimum. Turning to subcase (ii), with a higher price such that $\underline{c} < p < v^X$ then always some sales are lost relative to the no piracy counterfactual (some high types have $\underline{c} < c < p$ and so always prefer to pirate) and the piracy that arises generates no extra free promotion (for any price $p < v^X$, all those who pirate would have bought the product but for the option to copy—since their valuations satisfy $v > v^X > p$ —and so anyway helped promote it). Thus, in either subcase, piracy undermines sales or margin or both, and fails to offer promotional benefits.

□

Analysis so far has 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 that, facing price p^M , no one is tempted to copy.²⁰

To the extent that a negative v, c relationship broadly characterizes the market for computer games, proposition 8 helps understand the quite draconian approach to technological copy protection applied by games makers. How, in practice, might a seller use protection to achieve the desired relocation of people in v, c space? 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

²⁰In 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.

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 3 illustrates both possibilities.

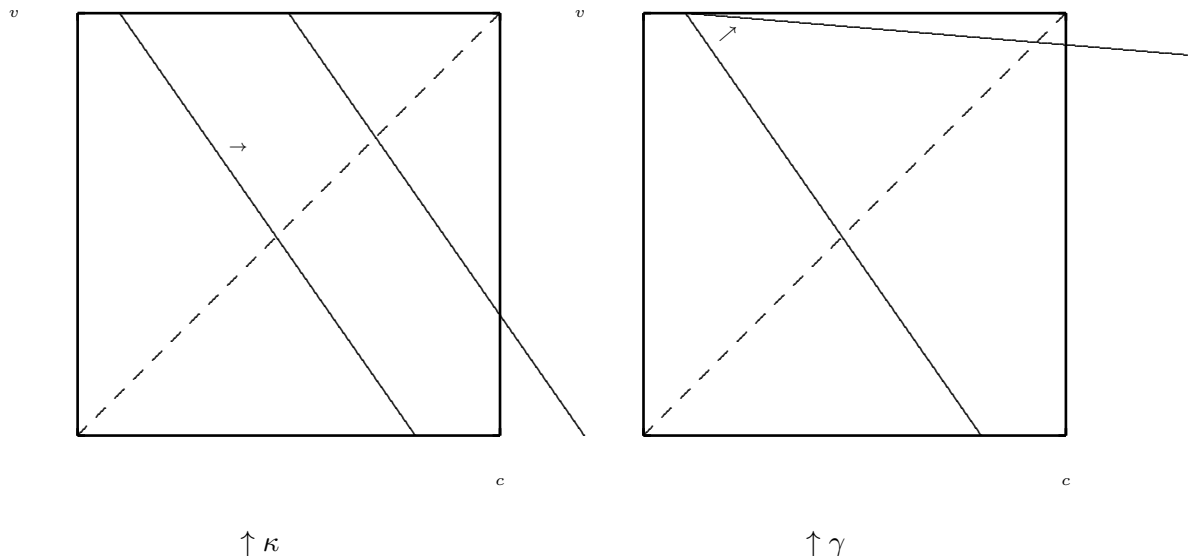


Figure 3: Negative v, c relationship: protection shifts or rotates the population.

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 of Figure 3.1 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.

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. All low types may lie in region B of Figure 3.1 (and so not consume) and all high types in A (safe sales), in which event there will be no temptation to pirate under standard pricing p^M . Or it may be that at least some low types are in region C (profit-friendly piracy) whilst at least some high types are in D (lost sales), in which case the possibility of piracy carries ambiguous consequences for the seller. In other cases still, low types may be in C 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 optimal protection will be quite weak. Proposition 3 summarizes.

Proposition 3. *Suppose v and c are positively related. Referring to Figure 3.1, 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° line at multiple valuations, creating multiple kinks in demand. Further, 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 satisfy this requirement and might be given the following real-world interpretation: Taking as given that a positive v, c relationship suggests a normal good, and supposing that piracy cost increases linearly in income,²¹ concavity implies that the product in question is also a ‘necessity’ (for which valuation rises with income but less than proportionately) whereas convexity suggests a ‘luxury’ good (for which an increase in income induces a more than proportionate increase in demand). Some existing 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.²² This categorization invites comparison of the model’s

²¹This is a reasonable approximation if the costs of reproduction are a small fraction of income.

²²Sessions & 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

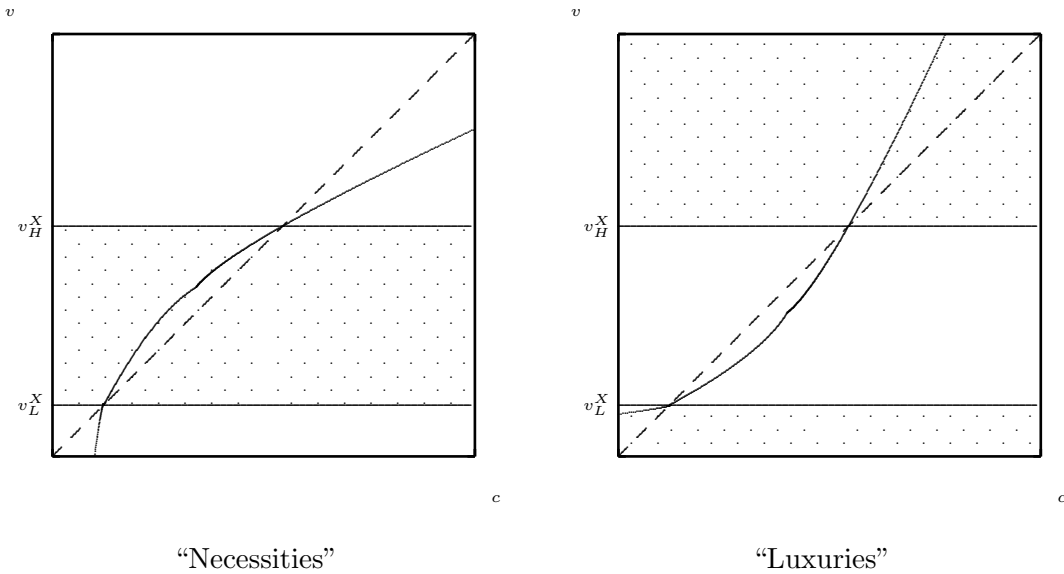
predictions to empirical evidence from actual markets. Later on in the paper, some of the theoretical insights obtained under concavity of a positive v, c relationship will be related to recent developments in the music industry.

Before moving to analyze concave and convex cases, Figure 4 helps build intuition for the basic difference curvature can make. In this diagram, v_H^X and v_L^X are the valuations of the highest and lowest marginal pirates (the highest and lowest valuations at which demand is kinked), respectively. Where the relationship is concave (left panel), all those with valuations between these marginal pirates are prepared in principle to pirate. 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 marginal high type, with $v = p^M$) does not reside in the shaded region, the possibility of piracy cannot be harmful to business. Why is this? If this person lies in the shaded region, and so is unprepared to pirate, then so too must all high types (since their piracy costs are necessarily greater than hers) prefer to buy at p^M rather than copy. If, on the other hand, this marginal high type *is* located in the shaded region then piracy’s net profit impact must be ambiguous: On the one hand, at least some standard sales are compromised since now at least this person (but probably also some others—those with valuations just above hers) would rather copy than pay p^M for the product. On the other hand, probably some low types (at least anyone with valuation and piracy costs fractionally below hers) will lie in the shaded region and so be prepared also to copy, 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.

5.1 Concavity (“Necessities”)

This subsection analyzes population distributions such that v and c are positively and concavely related. For simplicity, distributions are assumed to rise from some weakly positive intercept on the c axis. Consequently, they may intersect the 45° line: (i) just once, from below, at v_L^X ; (ii) twice—once from below at v_L^X and once from above at v_H^X , with $v_L^X < v_H^X$, or; (iii) not at all. The third case is uninteresting, implying as it does that no one faces the

elasticities of demand above unity for books (Hjorth-Andersen 2000, Fishwick & Fitzsimmons 1998, Ringstad & Loyland 2006). The incidence of piracy in the market for books appears so far to have been low by comparison with music, software, and film. However, with the arrival of electronic book reading devices, such as the Kindle, many commentators are now predicting strong future growth in the digital piracy of books. See for instance the recent BBC News article “Are we due a wave of book piracy?” published October 2009 and available online at <http://news.bbc.co.uk/1/hi/magazine/8314092.stm>.



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.

Figure 4: Positive v, c relationship: curvature can affect susceptibility.

temptation to pirate (everyone lies below and to the right of the 45° line). The first two cases are more interesting and are now considered in turn.

In case (i) the possibility of piracy is real but the implications for profit depend on the location of v_L^X in relation to p^M . If $v_L^X > p^M$ then it is as if the seller were in the no piracy counterfactual. The marginal high type (for whom $v = p^M$) does not lie in the shaded region of Figure 4, and so, by the arguments above, she and all other high types prefer to buy at p^M rather than copy. At the same time, any low type must have valuation satisfying $v < p^M < v_L^X$ and so will never pirate (they lie below and to the right of the 45° line). Thus, there is neither a threat to sales nor the prospect of any free promotion from piracy. If instead $v_L^X < p^M$ then both a threat to sales and promotional effects arise, so that piracy’s net profit impact is ambiguous. All high types will lie in region D and so would rather copy than pay price p^M . 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 lend a free hand with marketing.

In case (ii), the implications for profit depend on the location of v_H^X in relation to p^M . When $v_H^X < p^M$, piracy must be unambiguously profit-friendly: Anyone with valuation above v_H^X

is never tempted to copy (they lie below and to the right of the 45° line); this is true of all high types and so there cannot be a threat to sales. Meanwhile, since at least some low types—those with $v \in [v_L^X, x_H^X]$ —would rather copy than go without (they lie above and to the left of the 45° line—in region C), there will be some extra free buzz.²³ Where instead $v_H^X > p^M$ then the possibilities are twofold: If also $v_L^X < p^M$ then piracy’s net profit impact is ambiguous since at least some high types must be in region D (compromised sales) and at least some low types in region C (profit-friendly piracy). If instead $v_L^X > p^M$ then all high types are instead in A (safe sales) and all low types in B (never consume) so that outcomes are again the same as in the no piracy benchmark.

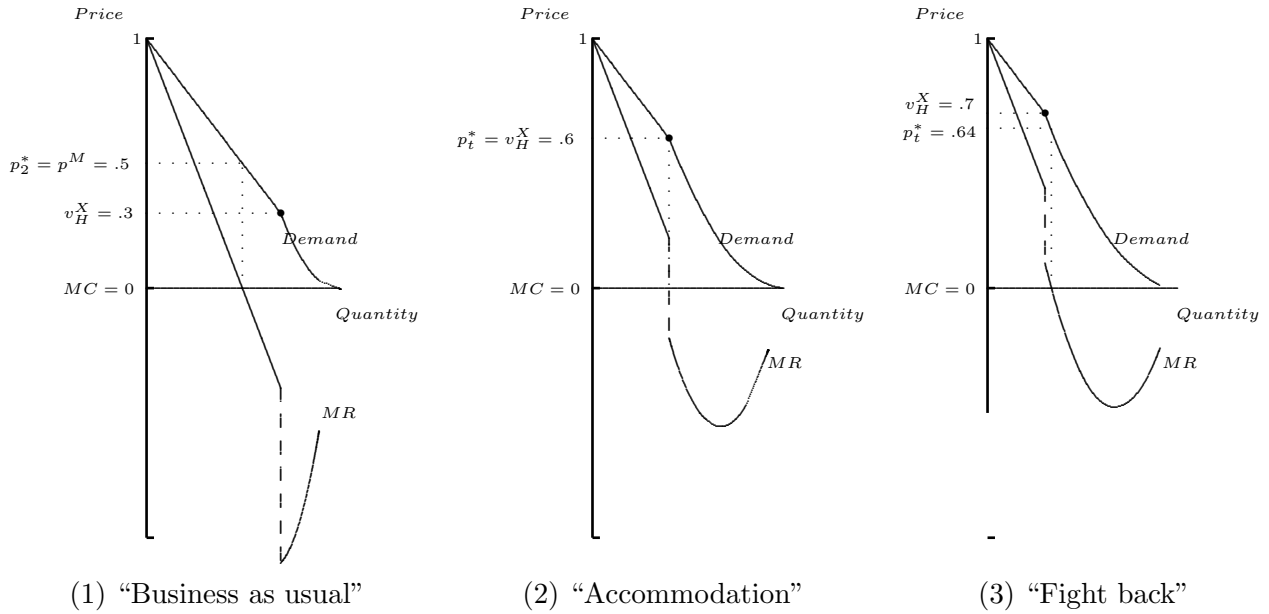
The following proposition summarizes the foregoing insights.

Proposition 4. *Suppose that a positive concave v, c relationship begins from a weakly positive intercept on the c axis and consider two cases: (i) If it intersects the 45° 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 $v_L^X > p^M$; (ii) 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 either 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.*

The rest of the section looks more closely at case (ii), studying optimal pricing decisions and outcomes under piracy, and considering how these are affected as piracy becomes generally less costly for individuals (as digital replaces analogue piracy, for instance). For further ease of exposition, it is assumed that the population distribution begins at the origin, so that $v_L^X = 0$. Demand is then characterized by a single kink at $v_H^X > 0$. As piracy becomes generally less costly the v, c relationship will swing back towards the vertical axis (pivoting leftward about the origin), causing this kink v_H^X to rise. Visual inspection of demand curves provides much intuition for how things change from the seller’s perspective as this happens. Note how in Figure 5 the kink v_H^X occurs at progressively higher valuations as one moves through the three panels, from left to right.

The situation depicted in panel 1 is highly favourable for the seller; piracy is sufficiently costly that no high type is tempted to copy (since $v_H^X < p^M$, all high types must lie below and to the right of the 45° line), but not so costly that all low types are deterred. Specifically, any low type with $v \in [0, v_H^X]$ is prepared to pirate and this extra WOM is, of course, welcome. Note that, unless $v_H^X = p^M$ exactly, there are still always some low types (those with $v \in [v_H^X, p^M]$) who would rather go without than copy. Because of this, it may still be worth it to the seller to offer a promotional first-period price in the range $v_H^X < p_1 < p^M$. Clearly, she will never

²³Indeed if $v_L^X \in [p_1^*, p^M]$ the seller will find it optimal to reduce the generosity of her first period price, there being no point sacrificing margin to attract low types who can now be relied upon to pirate.



This diagram illustrates kinked demand curves and optimal pricing for a positive and concave v, c relationship. The illustration is based on the specification: $v = \beta y^{\frac{1}{2}}$; $c = \gamma y$ ($\Rightarrow v = \frac{\beta}{\gamma^{\frac{1}{2}}} c^{\frac{1}{2}}$); with $v \sim U[0, 1]$.

Figure 5: Positive concave relationship: illustrative kinked demand curves.

price below the kink, there being no point sacrificing margin to win the custom of low types who would otherwise pirate.

It is common to panels 2 and 3 that all low types lie above and to the left of the 45° line (because $v_L^X = 0$ and $v_H^X > p^M$) and so would rather copy than go without. Thus, provided she does not price above the kink (which in the optimum she will not since at the very least she will wish to serve those high types not tempted to copy), all low and high types will become consumers (and hence promoters), regardless of the exact price she chooses. Foreseeing this the seller will not waste profit margin on promotional pricing and will instead concentrate on maximizing current period profit (as if she were myopic). She does this by setting price such that her marginal revenue and marginal cost are equated ($MC_t = MR_t$), and in situations like that depicted in panel 2 this leads her to price at the kink exactly (since there the discontinuity in MR passes through the $MC = 0$ line). In a sense she is in this case “accommodating” piracy, as she makes no attempt to fight

copying and instead raises her price in line with the kink. In situations like panel 3 (where the discontinuity in MR takes place above the MC line), it leads her instead to opt for a “fighting” price—a price that is below the kink, and which falls as piracy becomes cheaper and more convenient (as the kink rises in the illustration).

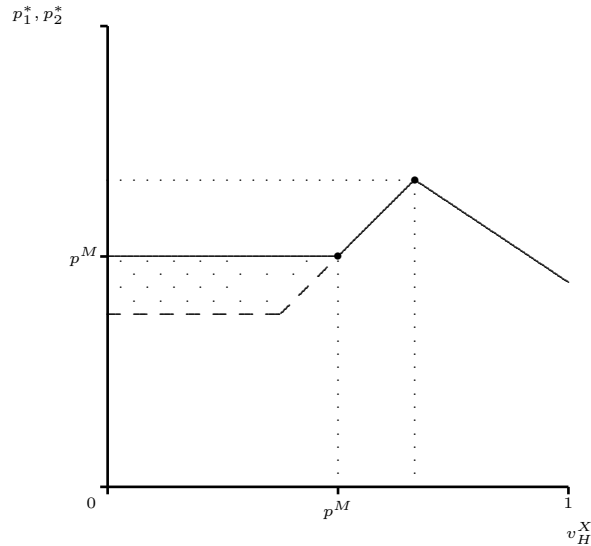
The next proposition formalizes these intuitions. For simplicity, in part 3 of the proposition, which deals with monotonicity of the “fighting price,” attention will be restricted to changes in a positive parameter γ where $c = \gamma G^{-1}(c)$. The parameter γ can be used to scale up or down the costliness of piracy in this specification, and changes in γ then correspond to changes in v_H^X .

Proposition 5. *Suppose a concave relationship $v = G(c)$ rises from the origin ($v_L^X = 0$) and crosses the 45° 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 potentially a lower promotional price in period one, save that she will never price below the kink (anyone with $v < v_H^X$ is prepared to pirate and she prefers them to do so). Overall, piracy creates some free extra promotion at no cost to sales;*
2. *“Accommodation:” if $p^M \leq v_H^X \leq p^F$, where p^F satisfies $p^F = \frac{1-F[G(p^F)]}{F'[G(p^F)]G'(p^F)}$, she always prices at the kink each period $p_t^* = v_H^X$. High types with $v \in (p^M, v_H^X)$ copy and this implies some loss of sales, but low types also copy and this creates additional costless promotion. Piracy’s net profit impact is thus ambiguous;*
3. *“Fight back:” otherwise, when $v_H^X \geq p^F$ she sets $p_t^* = p^F$ each period. This fighting price, which falls as the kink rises, retains in the legitimate market some of the high types otherwise tempted to pirate. Piracy’s net profit effect is again ambiguous.*

Proof of Proposition 5 is contained in the Appendix. Meanwhile, Figure 6 tracks the evolution of pricing as the general costliness of piracy decreases (as v_H^X increases).

In equilibrium 1, copying is cumbersome and the copied product is of noticeably lower quality than the original. Piracy takes place but the practice is confined to low types (perhaps children taping songs from the radio in the analogue era). Since high-value individuals are not tempted to pirate the seller conducts *business as usual*; she prices as if in the no-piracy counterfactual and does nothing to discourage copying. If piracy becomes a little cheaper from here, she is even better off: 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



As copying becomes generally less costly, the firm “accommodates” piracy, tracking the kink upwards (so pricing above p^M) and so prioritizing margin. If piracy’s appeal continues to strengthen, the seller at some point switches to a “fighting price” (a price below the kink) in order to defend volume. The diagram illustrates this pricing u-turn for a positive, concave specification of the form: $v \sim U[0, 1]$ with $v = \beta y^a$, $c = \gamma y$ ($\Rightarrow v = \frac{\beta}{\gamma^a} c^a$) and $a \in (0, 1)$. The dotted price line depicts a lower bound on the promotional price the seller may in period 1 offer.

Figure 6: Pricing necessities: as piracy costs fall the seller performs a pricing u-turn.

fall, perhaps as Internet file-sharing begins to take hold, the seller enters equilibrium 2 and sales begin to be affected adversely. The seller then raises price so as to defend margin in the face of ailing sales—a policy of *accommodation*. Finally, if cheap copying opportunities continue to proliferate the seller enters equilibrium 3 where, suffering a serious threat to sales, she attempts to lure back pirates with a *fighting price*.

Anecdotal evidence for the music industry accords surprisingly 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)."²⁴ 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."²⁵

For an illustration of fighting pricing, let $v \sim U[0, 1]$ and consider the following specification of the model:

$$\left. \begin{array}{l} v = \beta y^a \\ c = \gamma y \end{array} \right\} \rightarrow v = \frac{\beta}{\gamma^a} c^a.$$

β, γ are positive parameters and $a \in (0, 1)$, such that v is increasing concavely in y . y might be thought of as hourly wage income, in which case γ could reflect the time it takes to produce an illegal copy. Then, as piracy becomes generally less costly, γ will fall and so in v, c space the $v = \frac{\beta}{\gamma^a} c^a$ curve will swing back towards the vertical v axis (rotating anti-clockwise about the origin). What does p^F look like under this specification? It is straightforward to show that $p^F = \frac{\gamma}{[(1+a)\beta]^{\frac{1}{a}}}$, from which it follows trivially that $\frac{\partial p^F}{\partial \gamma} > 0$, and so p^F falls as γ falls. The illustration of optimal pricing in Figure 6 implements the specification used here.

Of course, pricing most likely is not the only instrument at the seller's disposal when responding to piracy. As was envisaged already in the previous section, she might implement technological copy protection and in so doing have some influence over the whereabouts of the population in v, c space. Where would the seller prefer a population distribution corresponding to a positive, concave v, c relationship to be located? Figure 7 sketches the seller's optimal protection policy for this case and Proposition 6 presents the result formally.

Proposition 6. *If $v = v(y)$ is a positive concave relationship rising from a weakly positive intercept on the c axis, and $c = \kappa + \gamma y$ then optimal protection sets $\kappa^* = 0$ and some $\gamma^* > 0$ such that $v_H^x = p^M$. All low types pirate, all high types buy.*

A simple argument proves that any alternative protection policy results in lower profit than, and hence is strictly dominated by, the protection choice described as optimal in this propo-

²⁴Elsewhere 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.

²⁵"Britney, meet Michael," Economist, November 7th 2003.

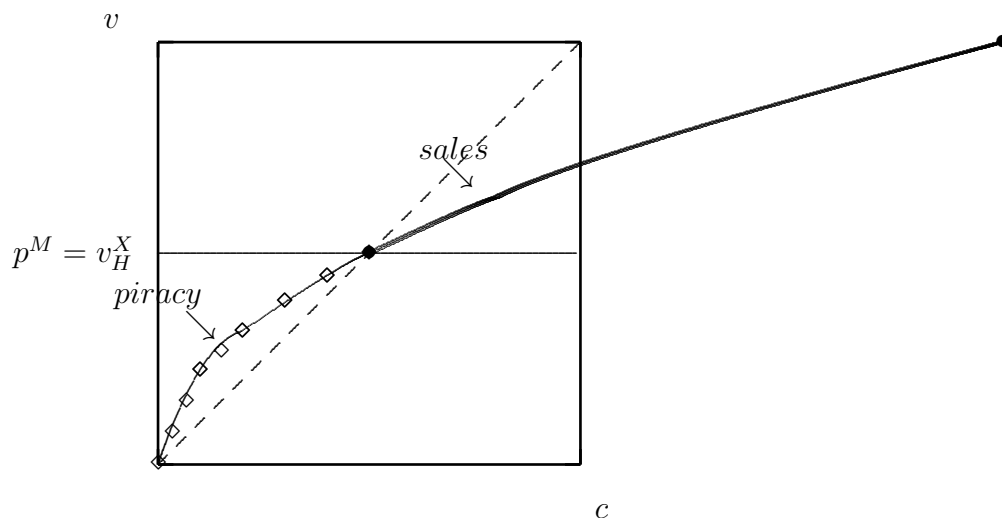


Figure 7: Protecting necessities: optimal protection is moderate (low types copy).

sition. The protection choice in Proposition 6 allows the seller to adopt standard pricing p^M in both periods, and thereby serve all high types whilst benefitting from maximal promotion (all low types copy). Any deviation from this protection policy (locating people differently in v, c space) would involve encouraging some low types to do without (and so lower promotion) and/or leave some high types tempted to pirate at the myopically optimal price p^M .

Note that maximal protection (protection stiff enough to discourage piracy by anyone) would be self-defeating since with a more modest application of control the monopolist can encourage low types to promote her product whilst retaining all high types in the legal market.

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° line, cuts the 45° 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. The following proposition summarizes.

Proposition 7. *Suppose that a positive, convex v, c relationship begins from a weakly positive intercept on the c axis. It intersects the 45° 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, so that the net profit impact is ambiguous.

To demonstrate, 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.

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

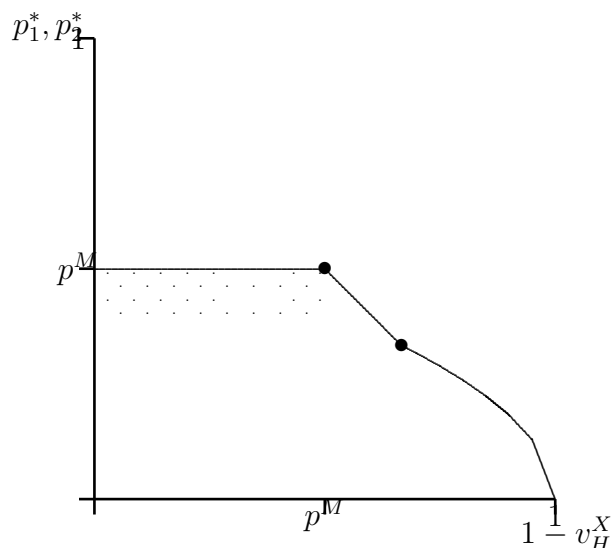
1. *“Business as usual:” if $v_H^X \geq p^M$, then a monopolist carries on as in the no piracy counterfactual, setting p_2^* in period two and a lower promotional price in period one. The possibility of piracy has no impact on her business and no piracy occurs;*
2. *“Purging price:” if $p^F \leq v_H^X \leq p^M$, where p^F satisfies $p^F = \frac{1-F[G(p^F)]}{F'[G(p^F)]G'(p^F)}$, 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 $p_i^* = p^F$. This is a price above the kink. Piracy's net profit effect is ambiguous. 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.*

Proposition 8 is proved in the Appendix. Figure 8 illustrates.

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



As piracy becomes generally less costly (as v_H^X falls and hence $1 - v_H^X$ rises in this illustration), the firm switches from standard pricing to tracking the kink downwards in order entirely to shut out piracy. She avoids lost sales but at a cost to profit margin. As the costliness of piracy continues to fall there comes a point where the seller finds this approach to be suboptimal. Though she continues to lower her price, she now keeps this above the kink, thereby accepting some loss of sales in order to contain the damage to profit margin.

Figure 8: Pricing luxuries: the seller “purges” all or some pirates from her market.

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.

7 Appendix: Proofs

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

7.1 Proof of Proposition 5

Proposition 5. Suppose a concave relationship $v = G(c)$ rises from the origin ($v_L^X = 0$) and crosses the 45° 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 potentially a lower promotional price in period one, save that she will never price below the kink (anyone with $v < v_H^X$ is prepared to pirate and she prefers them to do so). Overall, piracy creates some free extra promotion at no cost to sales;
2. “Accommodation:” if $p^M \leq v_H^X \leq p^F$, where p^F satisfies $p^F = \frac{1-F[G(p^F)]}{F'[G(p^F)]G'(p^F)}$, she always prices at the kink each period $p_t^* = v_H^X$. High types with $v \in (p^M, v_H^X)$ copy and this implies some loss of sales, but low types also copy and this creates additional costless promotion. Piracy’s net profit impact is thus ambiguous;
3. “Fight back:” otherwise, when $v_H^X \geq p^F$ she sets $p_t^* = p^F$ each period. This fighting price, which falls as the kink rises, retains in the legitimate market some of the high types otherwise tempted to pirate. Piracy’s net profit effect is again ambiguous.

Proof. The monopolist faces demand per informed individual as follows:

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

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

1. If the seller prices above the kink ($p_t \geq v_H^X$), she faces the standard monopoly demand $q_t = 1 - F(p_t)$. Her optimal second-period price is $p_2^* = p^M$, where p^M solves $p^M = \frac{1-F(p^M)}{F'(p^M)}$, just as in the no piracy counterfactual. In the first period, she may find it optimal to use a promotional price ($p_1^* < p^M$), but never a price below the kink (there being no point sacrificing margin to induce those below the kink to consume as these individuals could be left to pirate). All things considered, the seller is better off for piracy: her ability to sell to high types is not impaired and some low types (those with $v < v_H^X$) copy, and so provide free promotion. Furthermore, piracy may reduce the need for costly promotional pricing.
2. If instead she prices below the kink ($p_t \leq v_H^X$) then demand is $q_t = 1 - F[G(p_t)]$. For any such price it must be that $G(p_t) > p_t$ and so $1 - F[G(p_t)] < 1 - F(p_t)$. That is, sales are compromised relative to the standard monopoly case. But here too piracy generates beneficial promotional externalities. In fact, the possibility of piracy now ensures that in each period consumption (and hence promotion) is maximized as anyone not prepared to buy is able and willing to pirate. This obviates the need for promotional pricing. Instead optimal pricing is $p_1^* = p_2^* = p^F$, where p^F satisfies the myopic first order condition $p^F = \frac{1-F[G(p^F)]}{F'[G(p^F)]G'(p^F)}$.²⁶ This price is a “fighting price”—a price below the kink, intended to keep in the legitimate market some of those who otherwise would pirate. The presence of both business-stealing and promotional effects renders piracy’s profit impact ambiguous.

So far it has been shown that the seller may conduct “business-as-usual” or opt for a “fighting price”. Note that $v_H^X \leq p^M$ is required for the first case whereas $v_H^X \geq p^F$ is required for the second. If $p^M \leq v_H^X \leq p^F$ then a boundary solution results involving pricing at the kink exactly: $p_1^* = p_2^* = v_H^X$. It is possible to prove by contradiction that between these two cases there exists a set of population distributions (corresponding to an interval of kinks $v_H^X \in [p^M, p^F]$) for which a boundary solution is the optimal solution. Begin by supposing to the contrary that as the boundary of case 1 is reached the condition for case 2 becomes satisfied. That is, suppose that there exists a price such that $p^M = v_H^X = p^F$. Since any such price simultaneously must satisfy the first order conditions for p^M and p^F above, it must also satisfy the equality of their right-hand sides:

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

²⁶A sufficient condition for p^F to be unique is that $\frac{1-F[G(p)]}{F'[G(p)]G'(p)}$ is non-increasing in p .

Next, note that any price which is exactly at the kink must also satisfy $p = G(p)$, and hence that the above equality can be rewritten as:

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

Clearly, satisfaction of this equality implies $G'(p) = 1$. However, $G'(p) = 1$ cannot hold since the $v = G(c)$ curve cuts the 45° line at the kink and so cannot there have a slope of unity. It follows that p^M and p^F can never be the same price and that there must instead exist a set of population distributions for which $v_H^X \in [p^M, p^F]$ and for which the optimal solution is a boundary solution involving pricing at the kink exactly.

The proposition further claims that p^F , the seller's fighting price, falls as piracy becomes generally less costly to individuals. As mentioned in the paragraph preceding Proposition 11, for this third part of the proposition attention is restricted to cases where a scale parameter $\gamma > 0$ indexes the costliness of piracy. That is, $c = \gamma G^{-1}(v)$, where $\gamma > 0$. Higher γ implies a uniform increase in the costliness to individuals of piracy. Comparative statics confirms that $\frac{\partial p^F}{\partial \gamma} > 0$. To see this, begin by noting that the person just prepared to buy at price p has valuation $v = G[p/\gamma]$ and that the first order condition for optimal fighting price p^F therefore is:

$$\frac{\partial \pi}{\partial p} = 0 \Leftrightarrow 1 - F[G(p^F/\gamma)] - \frac{p^F}{\gamma} F'[G(p^F/\gamma)] G'(p^F/\gamma) = 0.$$

Since $\frac{\partial \pi}{\partial p}(p^F, \gamma) = 0$ defines p^F as a function of γ near the point (p^F, γ) , it will be possible to deploy the implicit function theorem to sign $\frac{\partial p^F}{\partial \gamma}$. Differentiating implicitly and rearranging gives:

$$\frac{dp^F}{d\gamma} = - \frac{\frac{\partial^2 \pi}{\partial \gamma \partial p^F}}{\frac{\partial^2 \pi}{\partial (p^F)^2}}.$$

Note that from the imposition of standard conditions to ensure the global concavity of the profit function, it follows that

$$\frac{\partial^2 \pi}{\partial (p^F)^2} = \frac{\partial(\partial \pi / \partial p^F)}{\partial (p^F / \gamma)} \frac{\partial (p^F / \gamma)}{\partial p^F} < 0.$$

In order to establish that $\frac{\partial p^F}{\partial \gamma} > 0$ it remains then only to prove that the cross partial $\frac{\partial^2 \pi}{\partial \gamma \partial p^F}$ is positively signed. This is easily confirmed. Note that since $\frac{\partial(p^F/\gamma)}{\partial p^F} > 0$, satisfaction of the second order condition implies $\frac{\partial(\partial \pi / \partial p^F)}{\partial(p^F/\gamma)} < 0$. Hence,

$$\frac{\partial^2 \pi}{\partial \gamma \partial p^F} = \frac{\partial(\partial \pi / \partial p^F)}{\partial(p^F/\gamma)} \frac{\partial(p^F/\gamma)}{\partial \gamma} > 0 \Leftrightarrow \frac{dp^F}{d\gamma} > 0.$$

This concludes the proof of Proposition 5. □

7.2 Proof of Proposition 8

Proposition 8. Suppose a convex relationship $v = G(c)$ rises from the origin at $v_L^X = 0$ and crosses the 45° 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.

Proof. Proposition 8 is proved in a very similar way to Proposition 5. For the convex relationship considered the monopolist faces the following kinked demand function (where demand is per informed individual):

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

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.
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.

Thus, the seller may conduct “business as usual” ($p_2^* = p^M$) or may set a “fighting price” (p^F). If neither $p^F > v_H^X$ nor $p^M < v_H^X$ is satisfied, then she again prices at the kink itself (boundary solution), we might be termed a “purging” price, since it is just low enough to prevent any piracy from arising (there are now some high types who would rather copy than pay p^M).

As before, it is possible to show that p^F and p^M 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 the seller selects a “purging” price, tracking the kink downwards. Begin by supposing that there does exist some price p such that $p^M = p^F = p$ and $p^F \leq v_H^X \leq p^M$. Again, such price necessarily is the kink and must satisfy the following equality:

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

Because such price must be the kink, it must again be the case that $G(p) = p$, and so the above equality might be rewritten:

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

Clearly, this equality is satisfied only where $G'(p) = 1$ and, as in the previous proof, this generates a contradiction: the $v = G(c)$ curve cuts the 45° line at v_H^X from below and so cannot have a slope of unity at this point.

□

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