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Abstract

This article reviews recent theoretical contributions on digital piracy. It starts by elaborating on the reasons for intellectual property protection, by reporting a few facts about copyright protection, and by examining reasons to become a digital pirate. Next, it provides an exploration of the consequences of digital piracy, using a base model and several extensions (with consumer sampling, network effects, and indirect appropriation). A closer look at market-structure implications of end-user piracy is then taken. After a brief review of commercial piracy, additional legal and private responses to end-user piracy are considered. Finally, a quick look at emerging new business models is taken.

Keywords: information good, piracy, copyright, IP protection, internet, peer-to-peer, software, music.

JEL Classification: L11, L82, L86

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1. INTRODUCTION

Over the last two decades, the fast penetration of the Internet and the digitization of information products (music, movies, books and software) have led an increasing number of consumers to copy and distribute information products without the authorization of their legal owners, a phenomenon known as ‘digital piracy’. Content industries (with record companies at the forefront) were quick to blame digital piracy for huge revenue losses and to take legal actions against file-sharing technologies and their users. Policy makers also reacted by gradually reinforcing copyright law. In general, digital technologies and the Internet have deeply modified the interaction between copyright holders, technology companies and consumers, thereby posing interesting challenges for the economic analysis of digital products. For instance, formal analysis is needed to examine the effect of digital piracy on right-holders’ profits; also, if digital piracy has a negative impact on the producers, one needs to analyze the strategies that can be used to counter piracy. As importantly, a public policy perspective has to be taken; here, the main issue is to evaluate the extent to which social interests are aligned with the interests of copyright owners.

This article reviews recent theoretical contributions on these issues. As background information, we elaborate in Section 2 on the reasons for intellectual property protection, report a few facts about copyright protection, and examine reasons to become a digital pirate. In Section 3, we provide an exploration of the consequences of digital piracy. To this purpose, we present a base model and then provide several extensions: Consumer sampling, network effects, and indirect appropriation. Section 4 takes a closer look at market-structure implications of end-user piracy. Section 5 reviews the rather short literature on commercial piracy, which has to include strategic considerations by the pirates. Section 6 discusses contributions that, in addition to price, consider alternative responses to piracy. Section 7 concludes, taking a quick look at emerging new business models.

2. THE PROTECTION OF INTELLECTUAL PROPERTY AND DIGITAL CONTENT

What is exactly digital piracy? Why is illegal? To answer these questions, we need to describe the legislation that piracy violates. We also need to understand the *raison d’être* and the recent developments of this legislation. Finally, we need to analyze what brings people to become digital pirates.

2.1. Intellectual property protection: Why and how. Intellectual property (IP) refers to the legal rights that result from intellectual activity in the industrial, scientific, literary and artistic fields. Most countries have adopted laws to protect intellectual property, with the objective to promote innovation and aesthetic creativity. The economic rationale can be summarized as follows. Intellectual creations have a public good nature: They are nonrival (their consumption by one person does not prevent their consumption by another person) and, often, nonexcludable (one person cannot exclude another person from their consumption). The latter property reduces the incentives to create, as creators face difficulties in appropriating the revenues of their creation. This causes an underproduction problem that IP law addresses by making intellectual creations excludable by legal means. That is, IP law grants exclusive use of the protected creation to the creator, which restores the incentives to create. However, by granting monopoly rights to the creator, IP

law entails an underutilization problem. Indeed, as the marginal cost of production is zero (which is a consequence of nonrivalness), any positive price induces a welfare-reducing rationing. There is thus a conflict, as pointed out by Arrow (1962), between dynamic efficiency considerations (how to provide the right incentives to create and innovate?), and static efficiency considerations (how to promote the diffusion and use of the results of creation and innovation?). In order to strike a balance between these two conflicting problems, IP law grants exclusive rights only for a limited period of time and for a limited scope.¹

The IP protection legislation generally distinguishes among four separate IP regimes, which are targeted at different subject matters. On the one hand, patents, trade secrets and trademarks are designed to protect industrial property (such as inventions, processes, machines, brand names, industrial designs,...). On the other hand, copyrights concern literary, musical, choreographic, dramatic and artistic works (such as novels, poems, plays, films, songs, drawings, paintings, photographs, sculptures, architectural designs, ...). It is with this so-called “copyright branch of IP” that we are concerned here. Piracy can indeed be defined as the *unauthorized reproduction, use, or diffusion of a copyrighted work*. Copyright applies to the expression of works, in whatever mode or form, and gives authors an exclusive right over the reproduction, performance, adaptation and translation of their work. Compared to patents, this protection is weaker (as only the expression is protected, and not the underlying ideas) but it is extended over a longer period of time.²

2.2. Recent changes in copyright law. The challenges brought by the emergence of digital technologies and the Internet have triggered many of the recent changes in copyright law.³ Digital technologies have enabled the low-cost and high-quality reproduction of copyrighted works (in particular, music and movies), leading to their complete dematerialization; the Internet has further facilitated consumers’ ability to find and redistribute digital content. These two trends have seriously limited copyright owners in their ability to control how content gets to consumers. This has undermined the existing business models, which were relying on controlled distribution and broadcast channels. In the past, as long as illegal copies were expensive to make, of drastically inferior quality, or, at least, limited in scale, end-user piracy did not pose a major threat.

Before devising new business models (see Section ??), content providers and copyright owners have tried to prevent the old ones from crashing down, mainly by pursuing copyright infringers and by using digital technologies as protective measures (see Section ??). They have also lobbied for—and obtained—more restrictive laws for their protection. In the U.S., two major changes occurred in 1998: First, the Copyright Term Extension Act (CTEA, aka Sonny Bono Copyright Act) extended the duration of existing U.S. copyrights by 20 years; second, the Digital Millennium

¹For more on this topic, see, e.g., Belleflamme and Peitz (2010, Chapter 19).

²Currently, copyright protection lasts for 70 years after the author’s death in both the European Union and the United States. For sound recordings and film, it lasts, in general, for 50 years after publication in the European Union and for 95 years in the United States—see European Parliament and Council of the European Union (2006) and Hirtle (2010). It is proposed to extend protection in the European Union to 95 years—see European Commission (2008).

³For a thorough description, see Gasser (2005a and b).

Copyright Act (DMCA) reinforced copyright protection by making it a crime to circumvent the technological measures that control access to copyrighted work.⁴

In Europe, a number of EU directives have lead EU member states to harmonize their national copyright laws in the first half of the 1990s. Worth mentioning is the European Union Copyright Directive (EUCD) of 2001, which, in the spirit of the DMCA, requires member states to enact provisions preventing the circumvention of technical protection measures (leaving, however, significant leeway to the member states to define the scope of their protections).

More recently, a number of countries have passed laws aiming at fighting Internet piracy. France opened the way by adopting in September 2009 a legislation that authorizes the suspension of Internet access to pirates who ignored two warnings to quit. The UK followed suit in April 2010 with a legislation incorporating a similar “Three Strikes” provision.⁵ In the US, the Obama administration is reported to examine this possibility as well.⁶ In Sweden, a new law allows copyright holders to obtain a court order forcing ISPs to provide the IP addresses identifying computers of illegal file-sharers.⁷

2.3. Becoming digital pirate. What brings people to engage in the illegal act of digital piracy? To answer this question, we need to separate commercial (for-profit) piracy from end-user piracy. As far as commercial piracy is concerned, the motivation is clearly criminal: The large-scale reproduction and distribution of copyrighted products generates the sort of high profit margins that criminal organizations are after. On the other hand, understanding the motivations behind end-user piracy—i.e., illegal reproduction of copyrighted work by the consumer themselves—is much more complex. It is indeed surprising to observe such large-scale violation of the laws protecting digital products by individuals who are normally law-abiding citizens.

A number of explanations have been advanced. First, the lack of clarity of the laws can be blamed. In particular, there exist limitations to a copyright holder’s exclusive rights that are not clearly defined. One such limitation is “fair use”, which permits the limited use of a copyrighted work without requiring the creator’s authorization.⁸ Fair use includes certain personal uses, but the contours of these uses are typically hard to define in the digital world where technologies are evolving

⁴Voices were raised against these more restrictive laws, arguing that they were likely to stifle rather than foster creation. For instance, seventeen economists (among them five Nobel laureates) condemned the CTEA on the grounds that the economic benefits from copyright extension were very unlikely to outweigh the costs (see Eldred *et al. vs. Ashcroft*, Attorney General, 537 U.S. 186, 2003). A more fundamental critique of copyright protection is provided by Boldrin and Levine (2008). They essentially argue that copyright protection stifles creativity and innovation and hurts consumers also in the long run.

⁵The ‘Digital Economy Bill’ has been passed by the Lords on April 6, 2010. At the time of this writing, it has not yet been examined by the Commons.

⁶See “Obama administration steps up anti-piracy plan” by A.B. Block (www.hollywoodreporter.com, June 22, 2010; last consulted on July 23, 2010).

⁷It was estimated that Internet traffic fell by one third on the day the new law came into effect (i.e., April 1, 2009; see <http://news.bbc.co.uk/2/hi/7978853.stm>, last consulted on July 23, 2010).

⁸The “fair use” doctrine is embedded in American copyright law. In the European Union the right of the rights holder are also limited, in particular, for a “private copy” (*copie privée*), which allows the copying of copyrighted material except software for personal use.

rapidly. Consumers may thus consider certain uses of copyrighted works fair, although these uses are actually illegal.⁹ Second, following Becker (1968), we can simply see end-user piracy as the normal reaction of rational agents who compare the costs and benefits of this activity. Even if they are aware of breaking the law, consumers perceive as very remote the sanctions that they may encounter if they are caught buying or making copies. The benefits, on the other hand, are obvious as free downloads and copying technologies are ubiquitous. The literature that we review in the next sections embraces this view. However convincing this economic explanation may be, it still falls short of explaining why many individuals infringe copyright law but not other laws (for which a similar pattern of low risks and high rewards could be observed). To solve this puzzle, Balestrino (2008) proposes a theoretical model of digital piracy combined with a game-theoretic mechanism of social norm formation. He argues that no social stigma is attached to digital piracy because it has no perceived social cost; as a result, there is no pressure to build a norm condemning it.¹⁰ Also, the literature typically does not explain why individuals upload copyrighted material even though that puts them at greater risk of being investigated for copyright infringement and does not give them any direct benefit.¹¹

We now move to the economic analysis of digital piracy (essentially, end-user piracy, on which the literature has mostly focused; we briefly consider commercial piracy in Section ??).

3. PROFIT AND WELFARE EFFECTS OF END-USER PIRACY

In this section, we study the impacts of end-user piracy on firms' profits and strategies.¹² We also examine how piracy affects welfare, both in the short and in the long run. We start with a basic analysis in which the monopoly producer of a digital product faces the threat of copying by the consumers. Copying undermines the producer's ability to appropriate the returns from its creation. Hence, applying the reasoning behind the protection of IP, we expect that more piracy (i.e., less effective copyright protection) will improve welfare from a static efficiency perspective but may deteriorate it if we include dynamic efficiency considerations. We move then to models that present piracy under a more favorable angle. Several reasons are put forward to explain how piracy may increase the copyright holder's profits, thereby having the potential to enhance both short- and long-run welfare. Note that the models reviewed in this second subsection (at one exception) also consider settings with a single digital product supplied by a monopolist. We defer the analysis of settings with several products and producers to Section ??.

⁹Gasser (2005a) reports survey results that partially confirm this interpretation. In a recent paper, Chiang and Assane (2009) present an empirical analysis of the factors influencing the willingness to pay for digital music downloads. They show that income and risk perceptions play a dominant role. They also review the empirical literature focusing on the determinants of piracy.

¹⁰See also Hill (2007) who looks at the behavior of individual consumers and tries to uncover why they knowingly consume pirated goods. Some of the actions of, e.g., the RIAA are intended to "educate" consumers in the sense that it is attempted to attach social stigma to digital piracy.

¹¹Uploaders in a file-sharing network contribute to a public good from the viewpoint of the other users of that network. A somewhat different but related phenomenon consists in providing user-generated content.

¹²The section partly draws on Peitz and Waelbroeck (2006b).

3.1. A first analysis. The basic analysis of end-user piracy considers the market for a digital product supplied by a single producer. The assumption of a monopoly greatly simplifies the analysis and can be justified by arguing that digital products (e.g., music titles or movies) are sufficiently horizontally differentiated to make the demand for any particular product largely independent of the prices of other products in the same category. The monopolist faces, however, another form of competition: Along the original files that the monopolist supplies, there also exist (illegal) digital copies of these files. That is, the market offers two versions of the product, the original and a copy. It is usually assumed that these two versions are vertically differentiated: The original has quality q , while the copy may be of lower quality, $q^c \leq q$. The monopolist chooses the price, and possibly the quality, of the original. As for the copy, it can be obtained at a given price, which may vary across consumers. This price may be zero; it is positive if the pirated good is costly to acquire or if there is an expected cost from being detected. The quality of the copy primarily depends on technological and legal factors. The government (through the definition and the enforcement of IP protection) and the monopolist (through technical protective measures) have the potential to affect both the price and the quality of copies.

In some situations the pirated good is of higher quality ($q^c > q$). Two examples for this: First, this can be the case in a quality dimension which may be called versatility. Such a situation arises if the original is DRM-protected, whereas the copy is not.¹³ DRM-protection often restricts the use of a product and, thus, its versatility. For instance, DRM-protected songs purchased on iTunes did not play on an incompatible mp3-device. Second, the quality dimension may be availability. Originals may only be available as bundles, as is the case for some music albums which artists refuse to make available for download per song. Also, some originals may be released later than pirated versions, as is the case for many films on DVD.

3.1.1. Basic insights. A general result that we can expect in such a framework is that piracy limits the monopoly power of the supplier of the original. As a consequence, the availability of digital copies at best leaves the firm's profits unchanged (meaning that piracy is not a real threat) or, more realistically, reduces the firm's profits. This is indeed the conclusion reached in a variety of models (see, for instance, Novos and Waldman, 1984, Johnson, 1985, and Belleflamme, 2003). When price is the only strategic variable of the firm, three types of reactions are possible: If piracy is not a real threat (because copies have too low a quality/price ratio), no reaction is necessary (piracy is said to be 'blockaded'); otherwise, the firm either reduces its price to make all active consumers prefer the original (a 'deterrence' strategy), or it sets a larger price and lets some consumers use the pirated good (an 'accommodation' strategy). Inevitably, profits are reduced in both the deterrence and the accommodation strategy. The reduction in the monopolist's profits, however, are more than compensated by the increase in consumer surplus. From a static efficiency point of view, piracy is thus welfare-enhancing.

The conclusion may differ when dynamic efficiency is taken into consideration. Reductions in profits typically affect incentives to provide quality. In a model in which original and copy have the same quality but in which consumers have

¹³DRM stands for digital rights management, which is an umbrella term for a number of technologies that inhibits uses of digital content not desired or intended by the copyright holder (see Subsection ?? for more on this topic).

heterogeneous copying costs, Novos and Waldman (1984) show how lower profits reduce, under some assumptions, the ex ante incentives to provide quality. This result is confirmed by Bae and Choi (2006) in a vertical product differentiation model with quality degradation for copies. In a multi-product framework, Johnson (1985) shows how lower profits also reduce the incentives to provide variety. This implies that although a short-term welfare analysis may see piracy in a favorable light, the long-term effects are more likely to be negative.

3.1.2. Impacts of piracy on strategies and welfare. Let us now develop the previous argument in more detail and examine the strategies that producers of digital products can adopt in the face of piracy. We follow Novos and Waldman (1984) in giving the following alternative to the consumer: She can either purchase the original or she can copy at a cost $c + z(1 + x)$, where c is the marginal cost of production, x is the extent of copyright protection, and z is the additional marginal cost of making a copy; the latter cost is assumed to be heterogeneous across consumers. What Novos and Waldman had in mind in 1984 was clearly physical copies. Yet, their specification also fits digital products. Think, e.g., of software: Downloading and installing illegally copied files require time and effort for the users (c); moreover, in the case they are caught copying files, users incur an additional cost (a fine or the disutility from having the product confiscated, z); the likelihood and the magnitude of this cost depend on the extent of copyright protection (x).

In this setting, for moderate prices of the original in a protected monopoly, those consumers with a low enough copying cost prefer the copy to the original. The firm can make copying unattractive to all consumers by setting a sufficiently low price. This deterrence strategy might, however, be too costly to the monopolist who will then prefer to raise the price and accommodate piracy. In any case, profits are lower than if piracy was not a threat. Novos and Waldman establish that the monopolist provides too low a quality compared to the social optimum; this is because piracy prevents the monopolist from appropriating all rents from quality improvements. One could therefore expect that a stronger copyright protection, making piracy less attractive, would induce the monopolist to increase the quality offered. Novos and Waldman show that this is indeed the case provided that there are relatively more consumers with higher than with lower copying costs (i.e., the density of z needs to be increasing). Note that the reinforcement of copyright protection does not hinder static efficiency in this model (an increase in x makes consumers switch from the copy to the original, thus saving the copying cost that is wasteful from a social point of view). It follows then that making copyright protection stronger and/or enforcing it more strictly is unambiguously welfare-enhancing in Novos and Waldman's model (as long as the density of z is increasing).

However, the latter conclusion is not robust to a slight modification of the setup. Novos and Waldman assume that copies have the same quality as the original, and that copying costs vary across consumers. Alternatively, we could assume that the value of the original relative to the copy is heterogeneous but that the associated disutility of copying is the same for all consumers. In that scenario, all consumers attach the same value to the original but vary in the value they attach to the copy; namely, the value of the copy for consumer z is equal to the value of the original minus $z(1 + x)$. Heterogeneity in the copying costs is thus replaced by heterogeneity in the perceived quality degradation of the copy. The setup then follows the vertical differentiation model of Mussa and Rosen (1978). Two specifications of the

heterogeneity of consumers' valuations dominate the literature: (i) Discrete types (namely two types, high-valuation and low-valuation consumers); (ii) a continuum of types (the distribution is then typically assumed to be uniform on an interval).

Yoon (2002), Belleflamme (2003), and Bae and Choi (2006) consider a single-product monopolist selling to a continuum of heterogeneous consumers. A consumer derives utility $\theta q - p$ for the original, where θ is the consumer's taste parameter, distributed on the unit interval, q is the quality of the original, and p its price.¹⁴ She derives utility $\alpha\theta q - c$ for the copy, where $1 - \alpha$ is the factor of quality depreciation and c , the copying cost. We check thus that consumers are heterogeneous in terms of the valuation of the quality differential between original and copy (i.e., $(1 - \alpha)\theta q$, which Bae and Choi call the 'degradation cost' of piracy) and homogeneous in terms of the copying cost (i.e., c , the 'reproduction cost' of piracy in Bae and Choi's terminology). We also see that pricing in the presence of piracy is the same as pricing against a firm pricing at c a product of quality αq . Obviously, in this setup the firm's profits decrease with the availability of digital copies.¹⁵

When analyzing the (short-run and long-run) welfare effects of piracy, Bae and Choi (2006) argue that Novos and Waldman's conclusion is particular to their modeling framework. They show indeed that the welfare effects of a stronger copyright protection crucially depend on how the two types of costs associated to piracy are affected. The reason is that these two costs impact the demand for a legal copy in different ways: A change in the constant reproduction cost induces a parallel shift of the demand function, whereas a change in the degradation cost makes the demand curve pivot. In particular, if we are in a situation when the monopolist finds it optimal to accommodate piracy, a strengthening of IP protection affects welfare differently depending on the piracy cost that is increased: A higher degradation cost results in higher quality and lower consumption of the original product, while a higher reproduction cost induces exactly the opposite. It may even be the case that a higher reproduction cost unambiguously reduces social welfare as both static and dynamic efficiency are negatively affected.

In Bae and Choi's analysis, a stronger IP protection is modeled as a marginal increase of either the degradation cost or the reproduction cost of piracy. This conveniently abstracts away the issues of where the increased protection comes from (legal and/or technical measures?) and how much it costs (public and/or private costs?). Yoon (2002) partially addresses these issues. In his setting, copyright protection leads to a private cost to consumers. Formally, a consumer's utility takes the form $\alpha\theta q - c - x$, where x denotes the consumers' additional cost due to copyright protection (which also constitutes a social cost). In this setting, an increase in x leads to an increase in the monopolist's profits and to a decrease in consumer surplus. As for (short-run) total surplus, it is initially decreasing in x and then, after reaching its minimum, is inversely U-shaped. Yoon then shows that the socially optimal copyright protection should be set such that the monopolist optimally reacts by deterring copying. The copyrighted product is then fully protected in the

¹⁴Yoon (2002) and Belleflamme (2003) both assume a uniform distribution of the taste parameter and an exogenously given quality of the original; Bae and Choi (2006) consider a more general class of distributions and also endogenize the monopolist's quality choice.

¹⁵Although profits are reduced in the monopoly setting, committing not to enforce copyright protection may be a profitable strategy in a market with potential entry as it may serve as an entry deterrent. The reason is that an entrant suffers if the incumbent does not enforce copyright protection.

sense that copies are driven out of the market. However, the monopolist has to lower its price compared to a situation of ‘blockaded entry’, which occurs if copying is not feasible. Thus profits generated by the copyrighted product are reduced under the social optimum.

Chen and Png (2002) also take the costs of stronger IP protection into account. In particular, they consider the social costs that arise when firms spend resources on detecting copyright infringers. They consider a setting with two groups of consumers: One group has infinite copying costs and therefore never copies, while the other group has finite copying costs and may therefore prefer to copy. Within each group, consumers have heterogeneous valuations for the good, although originals and copies are identical. The expected utility from illegal copying depends on the detection probability. This leaves two possibilities to the monopolist to eliminate copies: It can either lower its price or increase the detection probability by spending resources in some anti-piracy technology. The implications of these two strategies clearly differ from a social point of view: Short-run welfare is unambiguously improved if the price is lowered (because less effort in copying is needed) but is deteriorated if the detection probability is increased (because the technology costs are wasteful from a social point of view and because the surplus of copiers is also reduced).¹⁶

Summary. The basic models we have reviewed here consider end-user piracy under the following set of assumptions: (i) A monopoly supplies a single original product, (ii) copies are viewed as a lower-quality variant of the original product, (iii) consumers are heterogeneous (either with respect to their cost of making or acquiring copies, or to their valuation of the quality degradation between originals and copies). In these models, consumers with a low cost of copying or with a low willingness to pay for quality may prefer to consume the copy. The copy competes thus with the original, which forces the monopolist to lower its price (otherwise, the incentive constraint of too many consumers would be violated). From a static efficiency point of view, the presence of pirated copies leads to an expansion of the market and, thereby, to an increase in consumer surplus. This has to be balanced, in a dynamic efficiency perspective, with the reduced incentives to improve the quality of the original product (as a result of the reduction in the copyright holder’s profits). Moreover, the analysis of total welfare must also incorporate a number of costs associated to piracy: The costs for consumers of making copies compared to the marginal cost of production of originals; the costs for firms of technical measures to protect products against copying; the costs for governments to enforce copyrights. If these costs are high, society may prefer to adopt little or no protection (because of the low performance, at least in a short-run view, of the combination of protection policies and the profit-maximizing behavior of copyright owners).

As we now show, some of these conclusions may not carry over in environments where original products are made available in several versions.

3.1.3. Price discrimination. So far, it has been assumed that original digital products are offered in a single version. Although pirated versions are available on the market, these versions are imposed upon the copyrights holder. In many instances,

¹⁶Chen and Png then analyze the socially optimal government policy consisting of a tax on copies and recording equipment, subsidies to originals, and penalties in case of copyright violations.

however, producers of digital products deliberately offer the original in different versions in an attempt to capture a larger share of consumer surplus through (second-degree) price discrimination.¹⁷ It is therefore important to analyze the link between end-user piracy and the firms' versioning strategies.

Alvisi, Argentesi and Carbonara (2002) analyze the incentives of a firm facing piracy to offer a downgraded version.¹⁸ They adopt a vertical differentiation setting à la Mussa and Rosen (1978) and choose parameters in such a way that the monopolist prefers to offer a single quality in the absence of piracy. The question is whether the introduction of copies (which are assumed to have the same quality as originals) drives the monopolist to offer a second quality. In their model, consumers are heterogeneous in two respects. First, as in the Mussa-Rosen setting, consumers differ by their taste θ for quality increases. Second, they also differ in their reproduction cost. The authors assume a positive correlation between the two sources of heterogeneity: Consumers with a high preference for quality (high values of θ) sustain a high copying cost c_H ; consumers with a low preference for quality (low values of θ) sustain a low copying cost c_L . Under these assumptions, a high quality product can be offered at a higher price to consumers with a high preference for quality. The authors then show that the monopolist's optimal response to piracy may be to introduce an extra version of lower quality. This lower quality version is targeted at consumers with a low copying cost (and a low preference for quality); its purpose is clearly to divert them from the pirated good to the original one. The authors also show that a stricter enforcement of copyright protection reduces the incentive to differentiate, which reinforces the idea that vertical differentiation is a reaction to piracy.

Cho and Ahn (2010) study a related, though slightly different, issue. In their setting, the monopolist optimally offers two qualities in the absence of piracy. What they study, then, is how piracy affects the choice of these two qualities. Like Alvisi *et al.*, they adopt a Mussa-Rosen setting and assume that copies have the same quality as originals. They make, however, different assumptions regarding consumers: Instead of a continuum of consumer types, they assume two classes; moreover, they assume that all consumers share the same copying cost. In this framework, they show that the presence of piracy induces the firm to choose a lower level of quality for the high-end version, and a higher level of quality for the low-end version relative to decisions made in the absence of piracy (i.e., the firm reduces vertical differentiation under piracy). These results need to be put in perspective with the results drawn from the basic models that we reviewed above. Novos and Waldman (1984) and others show that piracy causes an underprovision problem as it induces firms to create digital products with an inefficient low quality. They also suggest that strengthening copyright protection may alleviate this problem. Cho

¹⁷For an overview of versioning of information goods, see Shapiro and Varian (1998) and Belleflamme (2006).

¹⁸The argument is similar to the decision by a monopolist to introduce a low-quality variant in response to the introduction of a generic drug in the pharmaceutical industry (see Valletti and Szymanski, 2006). More generally, recent work has considered conditions under which it is profit-maximizing for a monopolist to introduce a low-quality variant (see e.g. Johnson and Myatt, 2003). In our piracy context, the argument also relates to King and Lampe (2003), as described in the subsection on network effects below. In addition, a number of articles have looked at the incentives to provide downgraded goods without piracy but with network effects. These include Hahn (2001, 2004), Csorba (2002), and Csorba and Hahn (2006).

and Ahn’s contribution is to show that when several versions of the same digital product are offered, the underprovision problem only carries over to the high-quality version. These results need to be kept in mind when discussing the optimal level of copyright protection.

3.2. A more favorable view of piracy. We now move beyond the previous basic models and consider a number of reasons why copyright owners’ profits may actually *increase* with piracy. Piracy could then improve welfare not only in the short run but also in the long run. We consider three reasons: Sampling, network effects, and indirect appropriation.

3.2.1. Consumer sampling. As we have just seen, the basic models of end-user piracy focus on an important feature of digital products, namely their public good nature. The non-excludability of digital products is synonymous with the potential for piracy, leading to appropriability problems for the producers. This section addresses another important feature of digital products. Digital products (music and movies in particular) belong to the category of experience goods, for which the quality or suitability can only be observed after purchase. This poses yet another problem for producers of digital products who may find it hard to start selling a new product because consumers lack information about it. One obvious answer to this problem is to allow consumers to try out the product (listen to an extract from a song, watch the trailer of a movie, browse a book in a bookshop or on the web, test a beta version of a video game or a software).

In terms of experimentation, the digitalization of content products comes as a mixed blessing. On the one hand, it is more dangerous for producers to release “samples” of a digital product as these can quickly be copied and shared, thereby jeopardizing the sales of the “full” original product. On the other hand, in an increasingly interconnected world, the sharing of digital copies also largely reduces the producers’ costs of transmitting information to the consumers. The information contained in pirated copies may be about the product fit to the consumer taste, or about the product quality. In the former case, copies are a form of sample while in the latter, they can solve an adverse selection problem. We consider these two views in turn.¹⁹

The sampling effect. The idea that copies can benefit the sales of an original product through an exposure or sampling effect was already present in the ‘analog’ world; Liebowitz (1985) made indeed this point for photocopies of books or journals. Digital technologies have naturally revived this idea as they make copying and spreading digital products much less costly. This has led a number of authors to analyze the informational role of unauthorized copies on the copyright holders’ profits and strategies, as well as on welfare.

One path to model the informational role of digital copies is to extend the basic single-product models that we reviewed above. Recall the vertical differentiation model used by Yoon (2002), Belleflamme (2003) and Bae and Choi (2006). In this

¹⁹In a different, though related, approach, Wang and Zhang (2009) consider samples of digital products that, unlike pirated versions, cannot be used as substitutes to the original product. Hence, samples do not jeopardize the sales of the legitimate product. However, digitalization prevents the firm from controlling free samples, as could be done with physical goods. It is, therefore, impossible to target a particular category of consumers with samples (as samples become immediately accessible to anyone once they are provided). The authors show that the firm may nevertheless find it profitable to use free samples.

model, a consumer with taste parameter θ derives utility $\theta q - p$ from the original and $\alpha \theta q - c$ from the copy (where $1 - \alpha$ measures the quality degradation and c , the cost of acquiring or making a copy). In this framework, Ahn and Yoon (2009) assume that digitalization and sampling affect a consumer's utility in the following way: The utility from an original becomes $(1 + s)\theta - p$, where $s > 0$ denotes the sampling effect of an original; the utility from a copy becomes $(1 + t)\alpha'\theta - c'$, where $t > 0$ denotes the sampling effect of a copy, and α' and c' are the new quality degradation parameter and consumers' reproduction cost, respectively. Typically, digitalization contributes to reduce both the quality degradation and the reproduction cost of copies; we expect thus $\alpha' > \alpha$ and $c' < c$. The authors then carry out comparative statics exercises to evaluate the impact of digitalization and sampling on profit, consumer surplus and (short-run) social welfare. As far as profits are concerned, Ahn and Yoon confirm that the positive informational effect of copies attenuates their negative business-stealing effect. Unsurprisingly, the impact of digitalization on the consumer surplus is unambiguously positive. Finally, they find that the impact on social welfare is ambiguous in general, but they show that the impact may be positive.

Gopal, Bhattacharjee, and Sanders (2006) also examine the effects of sampling in a single-product model with an exogenous price. In their setting, downloading (of illegitimate files) may increase the attractiveness of the original product by helping consumers find out that they like the product. This sampling effect can be decisive for consumers with intermediate valuations for the product. The authors show indeed that these consumers buy the original if downloading is available, but otherwise refrain from doing so. This allows the firm to increase its profits.²⁰ The authors further show that sampling, by reducing consumer uncertainty, is likely to benefit more producers of niche products rather than 'superstars'.²¹

The informational role of digital copies available on P2P networks is further analyzed in Duchene and Waelbroeck (2005, 2006), with the same basic model of end-user piracy as a starting point (a single firm, an original providing additional value compared to the copy, and heterogeneous consumers with respect to the opportunity cost of spending time online searching for files). Here, the firm's distribution and protection strategies are explicitly taken into account and the focus is on the effects of extended copyright protection. The authors assume that consumers can purchase a new product only after they have downloaded a digital copy that provides information on the characteristics of the product. They also assume that technological protection increases the consumers' disutility of a copy but at the same reduces the fair use value of the original product (although the former effect is assumed to dominate the latter; the fair use value is due to information

²⁰A similar situation is described by Chellappa and Shivendu (2005) in a two-stage model in which consumers can use pirated copies to update their perception of a digital product's fit to their tastes. The firm's profits may increase if some pirates who, on the basis of their initial perception, did not consider purchasing eventually decide, on the basis of their updated perception, to discard the pirated version and purchase the original.

²¹Zhang (2002) also makes this point in a different setting. In a similar vein, Alcalá and Gonzalez-Maestre (2010) show that piracy reduces superstars' earnings and the incentives to invest in their promotion, which tends to increase the market share and the number of niche and young artists. The view that digital information transmission has reduced the skewness in the distribution of content products—i.e., that niche products have found a larger audience, has been popularized and coined the "long tail" by Anderson (2004).

transmission through downloading. As for legal protection, it affects copiers' utility through the expected penalty if caught copying. In this framework, Duchene and Waelbroeck show that a stronger IP protection negatively affects both copiers and buyers: The effect on copiers is direct through the increased expected penalty; the effect on buyers is indirect and stems from the fact that a stronger legal protection leads the firm to increase both its technological protection and its price, which unambiguously reduces consumer surplus.

In contrast with the above papers, it is in a multi-product environment that Peitz and Waelbroeck (2004, 2006a) analyze the informational role of copies and their possibly positive effect on profits. They propose a multi-product monopoly model in which products are located on the Salop circle and in which consumers regard each original as superior to its copy. To model sampling, the authors assume that if consumers are not able to download copies on P2P networks, they completely lack information about the products and choose therefore at random among them. In contrast, if copies are available, consumers can use them to obtain information on the horizontal characteristics of products. That is, P2P allows users to sample and, thereby, to obtain a very precise signal concerning the location of the products with respect to their own taste.²² As the number of products increases and as they become more differentiated, this sampling effect becomes more powerful; consumers have then a higher willingness to pay for the original and, as Peitz and Waelbroeck show, the firm eventually benefits from the availability of digital copies.

Copying and adverse selection. In situations of asymmetric information, copies can provide information on the quality of the original product and, thereby, they have the potential to solve an adverse selection problem. This is the argument developed by Takeyama (2003). In her model, a monopolist sells, over two periods, a durable digital product that can have two exogenous qualities (high and low). There is asymmetric information insofar as quality is known to the producer but not to the consumers. It is assumed that consumers have no value for low quality, have unit demand and are present in both periods. This benchmark setting is designed in such a way that the adverse selection problem prevents a high-quality firm from making profits.

However, the situation may be improved in the presence of piracy. A consumer who copies in the first period will indeed learn the quality of the product and may then decide to purchase the original in the second period (as it is assumed that the original provides a higher value to consumers than the copy). Using our previous notation, we can write the utility from a copy as $\alpha_i \theta q - c$. As before, c denotes the reproduction cost. As for the quality degradation parameter, it is assumed that it can take two values: One group of consumers receive a low value from copies (α_L) and the other group, a higher value ($\alpha_H > \alpha_L$). Takeyama imposes some parameter restrictions to make sure that the group of consumers with parameter α_L never copy; for these 'captive consumers', the reproduction cost is higher than the benefits of the copy, whatever the true quality and the price of the original. In contrast, the other group may decide to copy in the first period and, upon learning that the product is of high quality, purchase in the second.

²²The mirror image of such information pull is the information push strategy of a producer to reveal relevant product characteristics to consumers. Such a strategy may consist of content advertising, as investigated by Anderson and Renault (2006).

Different types of equilibria are possible in which the presence of copies allows a high-quality firm to make profits. A first possibility is a pooling equilibrium in which the firm intertemporally price-discriminates. In the first period, the firm sells to captive consumers and lets the group with a high value for copies copy; in the second period, the firm sells to the latter group at a price equal to the value that they attach to the quality differential between the two versions (i.e., $(1 - \alpha_H)\theta q$). Copying solves the adverse selection problem for high quality by bringing an informational gain that the high-quality firm can capture.

There also exists a separating equilibrium with copies in which the quality may be revealed to consumers prior to purchase and the low quality original may not be available on the market. A natural extension of this result is to let the firm decide whether copies should be available or not (by enforcing copyright or not). Takeyama (2003) shows that the firm may strategically decide to make copies available (i.e., not to enforce copyright) as the existence of copies serves as a signal of high quality. Takeyama (2009) explores more deeply this idea that a producer of digital products can signal product quality via its copyright enforcement decision. To this end, she explicitly models copyright enforcement and allows it to be partial (instead of the all-or-nothing assumption of the previous model). In this extended model, she shows that a high-quality firm may be able to choose a level of partial copyright protection that a low-quality firm would never find profitable to mimic. There exists therefore a separating equilibrium in which high quality is revealed.²³ Note that if there was perfect information, a high-quality firm would opt for full copyright protection. We see thus here that asymmetric information may make partial enforcement of IP protection (i.e., some tolerance of piracy) profitable for copyright holders.

Summary. Digital goods are complex experience goods: Consumers face uncertainty whether a particular variety exists, and they have heterogeneous tastes for them. Sampling by consumers can be highly beneficial for such goods. Information-pull technologies, such as P2P networks, social networks and other Web 2.0 technologies, greatly facilitate such sampling, especially for new or niche firms (and artists). This suggests that sampling has the potential to generate positive welfare effects both in the short and in the long run. This also explains why business models based on traditional information-push technologies are slowly making way, under the pressure of end-user piracy, to new business models and industry structures (see Section ?? for a brief review).

3.2.2. Network effects. A large majority of digital products exhibit network effects in the sense that they give a utility to their users that increases with the number of other users of that product. Hence, the utility derived from consumption depends directly or indirectly on the consumption decision of other consumers. Software is the prime illustration: The usefulness of a software often directly increases with the number of users because (in case of incompatibility or only partial compatibility with other products) a user can more easily exchange files generated with that software; also, it often indirectly increases with the number of users because more complementary products and services are offered (due to increasing returns). Music, books and movies also exhibit network effects: The more they are consumed, the

²³As a deliberate low enforcement of copyright protection is analogous to charging a low introductory price of zero (or of distributing free samples), we notice a clear parallel between Takeyama's adverse selection story and the sampling story of the previous models.

more people are knowledgeable about them and the more they become attractive (because of word-of-mouth recommendation, or because of the social prestige they confer).²⁴

When it comes to piracy, the key point is that network effects are generated by both legitimate and pirated copies of a particular product. That is, pirated copies contribute, through network effects, to raise the attractiveness of the original product. It follows that not enforcing copyright protection may, in some market environments, be privately and socially beneficial in the presence of network effects.²⁵ This point was first made by Conner and Rumelt (1991). A number of other studies have developed the argument in a monopoly setting (we defer duopoly settings to the next section). In contrast with the basic analyses of end-user piracy, these papers reject the idea that piracy necessarily reduces the monopolist's profits.

As we did for sampling, we start by extending the basic model to allow for network effects. Belleflamme (2003) does so in the following way. Recall that in the basic model, utilities were $\theta q - p$ and $\alpha\theta q - c$ for an original and a copy respectively. Now, with network effects, these utilities become $(\theta + \mu N)q - p$ and $(\theta + \mu N)\alpha q - c$, where N is the consumer mass with an original or a copy, and μ measures the strength of the network effect. Repeating the analysis of the monopolist's optimal pricing decision under these new assumptions, Belleflamme shows that piracy continues to reduce profits as long as network effects are not too strong.

Contrastingly, Takeyama (1994) shows, in a different model, that piracy can benefit the monopolist. Like Belleflamme (2003), she assumes that users only receive a share α of the utility associated with the original when using an illegal copy. Her assumptions about consumers and network effects, however, differ with Belleflamme's. First, instead of considering a continuum of user types, she takes a two-type distribution: There is a group of high-valuation users and a group of low-valuation users. Second, while Belleflamme assumes that only the fixed utility depends on the network size, she assumes that it is the type-dependent utility that depends on the network size. It follows that under Takeyama's specification, the network effect is more pronounced for the original than for the copy. This is best seen by looking at consumers' utilities. Supposing that N users consume the product (in either form), high-valuation users derive utilities $N - p$ and $\alpha N - c$, respectively from an original and a copy. As for low-valuation users, these utilities are $\varepsilon N - p$ and $\alpha\varepsilon N - c$, with $0 < \varepsilon < 1$.

Let us now sketch Takeyama's main result in a simple example where we set the reproduction cost c to zero and where we assume that each group of users is of mass 1. When copies are not available (because, e.g., copyright protection is fully enforced), a monopolist who sets a uniform price faces the following alternative: It sets either $p = 2\varepsilon$ if all users are served, or $p = 1$ if only high-valuation users are served. The former option yields a profit of 4ε and the latter, a profit of 1. Hence, the firm chooses to serve all users if $\varepsilon > 1/4$, and only high-valuation users

²⁴Akin to network effects are *addiction effects* that create a positive inter-temporal link between a consumer's own consumption of a digital product. Silva and Ramello (2000) note that low-valuation consumers can become high-valuation ones thanks to previous consumption. As Regner et al. (2009) observe, a kind of sampling effect may then arise insofar as current consumption of a copy can lead to future purchases of the same product or artist when consuming the copy has created sufficient pleasure over time.

²⁵In this section, we focus on the effects on the firm's profit and only make a few remarks on welfare effects.

otherwise. Suppose now that piracy is an option (which all users prefer to not consuming as copies are free). If the firm targets only high-valuation users, the maximal price it can charge is $2(1 - \alpha)$, as a mass 2 of users consume the product and as $(1 - \alpha)$ is the additional value attached to an original with respect to a copy. The associated profit is $2(1 - \alpha)$. On the other hand, if the firm wants to sell to all users, the maximum price is $2(1 - \alpha)\varepsilon$ and the associated profit, $4(1 - \alpha)\varepsilon$. It is thus optimal to serve only high-valuation users if $2(1 - \alpha) > 4(1 - \alpha)\varepsilon$ or $\varepsilon < 1/2$. It follows that for $1/4 < \varepsilon < 1/2$, piracy leads the monopolist to switch tactics: It serves all users without piracy but only high-valuation users with piracy. And if the monopolist can choose between the two regimes, it prefers not to enforce copyright protection if $2(1 - \alpha) > 4\varepsilon$ —i.e., if the original is sufficiently superior to the pirated version.

To summarize, we have that under certain conditions, the firm prefers to set a low price when piracy is not possible so as to sell to all users and fully exploit network effects. However, when piracy is possible, the firm can benefit from full network effects while, at the same time, setting a high price to target high-valuation users. As low-valuation users generate network effects even when they copy instead of purchasing the original, the firm foregoes less profit from not serving this group of users when piracy is present. There exist thus parameter configurations for which profits without enforcement are higher than profits with full enforcement of copyright protection.²⁶

Gayer and Shy (2003a) obtain similar results. They consider a monopoly model in which original and copy are horizontally differentiated and in which the original may give higher fixed utility and stronger network effects. The authors show that if network effects for the original are sufficiently strong, the monopolist's profits are larger with the availability of copies.

It must be noted that the previous results might not carry over to situations where the monopolist uses versioning strategies. In particular, King and Lampe (2003) show that a monopolist who offers a downgraded version himself (in order to exploit network effects) may suffer from end-user piracy. The reason is that it is often optimal to sell the downgraded version at a low but positive price. It is only if creating a low-end version is sufficiently costly for the monopolist that it is not in its interest to use this strategy.

Summary. When network effects are taken into account, one observes that copyright holders may welcome end-user piracy. This is likely to be the case if firms manage to price discriminate between users of originals and copiers (and if they do not have any superior discrimination strategies available). The policy implication is that weak IP protection should be favored because it makes both consumers and firms better off in the short run (and it also fosters incentives to create or improve quality in the long run).

3.2.3. Indirect appropriation. Indirect appropriation refers to the idea that the ability to make copies may increase the consumers' willingness to pay for originals and, thereby, allow producers of originals to capture (partially or even fully) the value of these copies. This idea has been put forward by Liebowitz (1985) in the case of photocopies of books and other printed material. The argument is in fact an

²⁶Takeyama (1994) also shows that piracy can lead to a Pareto improvement compared to the setting in which copies are not available. This occurs when the monopolist only sells to high-valuation users with and without copyright enforcement and when profits increase with copying.

application of (third-degree) price discrimination. Groups of consumers differ by their willingness to pay for the original product and the source of the difference is the value that they attach to the ability of copying. Thus, if the producer is able to identify those consumers who purchase the originals that serve as models for subsequent copies, he can increase his profits by charging a higher price to these consumers than to other consumers. The difference between the prices for the two groups is nothing but the value of copies; it is thus as if the producer had been able to charge directly the consumers of copies.

It is important to note that this result relies on three restrictive assumptions: (i) It must be possible for the producer to assess the amount of copying that will be done from a single original; (ii) the population of buyers of the original must be homogeneous; (iii) as in any price discrimination story, arbitrage must be prevented. Liebowitz argues that these assumptions are largely satisfied for the particular case of photocopying of academic journals. Libraries may indeed be expected to copy more and they are easily identified. The theory is appealing as it can be invoked to explain the shift from books (weak complement with photocopiers) to journals (strong complements) in the academic profession.²⁷

Liebowitz's paper has been very influential and has inspired a number of subsequent studies on the issue of indirect appropriability. Besen and Kirby (1989) make a link between indirect appropriability and the issue of a monopolist facing a second-hand market. In a model with small-scale copying, they show that direct appropriability arises when the marginal cost of copying is constant and indirect appropriability when the marginal cost is increasing in the number of copies. The main message of their analysis is thus that the technology of copying and the substitutability between originals and their copies are crucial to assess the advantage of direct versus indirect appropriation. Besen and Kirby also show that strong substitutability between originals and copies, combined with increasing marginal cost of copying, lead to a situation of clubs who share the cost of the original among their (copying) members. The notion of sharing copies within clubs has been further analyzed by Bakos, Brynjolfsson, and Lichtman (1999) and by Varian (2000). The issue is to determine under which conditions selling to clubs rather than to their members directly is more profitable for the copyright owner.

The next question that arises naturally is whether indirect appropriation is applicable to any copying environment. Serious doubts can be raised when looking at how digital technologies have increased the speed and quality with which copies can be made and distributed. As Watt (2005) nicely puts it, "indirect appropriability has been shown to work well enough for the very special case of publishing of academic journals, but surely it would take a rather bold man indeed to seriously suggest that it can also provide a robust form of remuneration for copyright holders when music is burned from one CD to another, when mp3 files are shared by 50 million individual Internet users from their own homes world wide, and when bootlegged copies of Microsoft Office 2003 show up on the back streets of Bangkok."

²⁷Liebowitz tests for indirect appropriability by analyzing the change in the relative price of an economic journal charged to institutions and individuals between 1959 and 1982 as a function of its usage (measured by citations). After controlling for journal age and commercial journals, Liebowitz finds a positive relation between the usage and the relative price of copyrighted good. Also, price discrimination increased after the introduction of photocopy machines and demand for material that is easy to copy (such as journal articles) increased compared to other materials (such as books that are more difficult to copy).

Johnson and Waldman (2005) share Watt's skepticism about the wider applicability of indirect appropriation. They identify two reasons why the indirect appropriation argument can break down in markets for digital products. First, if copies flood the market, their price falls to marginal cost, which is essentially zero for digital products. It follows that there is no profit associated with selling copies and thus no indirect appropriability component of the price of original. Second, as digital copies are close substitutes for originals, the price at which copies are available limits the price the monopolist can charge for originals. Moreover, this price is necessarily low if consumer valuation for copies is low. For these two reasons, the ability of indirect appropriation does not seem to offer an escape route by which copyright holders could benefit from end-user piracy in digital markets.

Note that Johnson and Waldman's arguments apply more to the initial argument of Liebowitz (1985) and Besen and Kirby (1989) than to the sharing version of Bakos et al. (1999) and Varian (2000). However, one can also be skeptical about the applicability of the sharing argument to digital products. Indeed, as the marginal production costs of digital products are negligible, it cannot be profitable to sell them through clubs. It can be argued, however, that the definition of costs should be broadened to include marketing and distribution costs, which may well be non-negligible even in a digital world. In this case, private copying (done within clubs) may enhance the copyright holder's profit. This may explain, for example, the practice of site licenses for software. When these marketing and distribution costs are due to an asymmetric information problem between firm and consumers, the sampling argument that we exposed above complements the explanation.

A more convincing case can be made for indirect appropriation in digital markets if one considers that indirect appropriation does not apply across consumers for a given digital product but *across complementary goods for a given consumer*. The idea is simple: If illegal copies are consumed together with private goods that cannot be copied, the potential problem of end-user copying for copyright owners is much less pronounced. We briefly return to this argument in Section ?? where we describe new business models designed to tackle end-user piracy.

Summary. Indirect appropriation works when it is possible to assess the value of the uses made from a legally purchased product. Producers can indirectly appropriate revenues from homogenous consumers who share its products within a club or community if the marginal cost of copying is increasing. Digital technologies, however, seriously undermine the feasibility of this strategy as high-quality copies can quickly flood the market.

4. END-USER PIRACY AND MARKET STRUCTURE

So far in this survey, we have considered environments where a single digital product is offered by a monopoly producer.²⁸ It may be argued that a single-product monopoly setting is a reasonable approximation for markets with a high degree of horizontal product differentiation (like music, books or movies). There exist, however, a number of situations where this assumption proves restrictive and inappropriate. Even if digital products are highly differentiated and, therefore, hardly

²⁸There are two exceptions in the papers we have reviewed in the previous sections: First, Johnson (1985) studies a monopolistic competition framework in which a number of copyright holders produce each a single original; second, Peitz and Waelbroeck (2004, 2006a) consider a multiproduct monopolist.

compete directly with one another, some form of indirect competition may nevertheless appear. First, indirect competition stems either from the presence of a common substitute (namely copying) to otherwise independent originals, or, secondly, from the durability of the digital product that puts the monopolist in competition with its future selves. Thirdly, some digital products present higher levels of substitutability, at least on some market segments; think, e.g., of business software that offer similar functionalities and are, therefore, close substitutes.²⁹ We examine these three situations in turn.

4.1. Indirect competition caused by copying. Related to Johnson (1985), the idea that copying generates a form of indirect competition between horizontally differentiated digital products has been studied by Belleflamme and Picard (2007). In a multi-product framework, they show how increasing returns to scale in the copying technology create an interdependence between the demands for digital products, which would be independent otherwise. Increasing returns to scale in copying typically arise if consumers incur a high initial fixed cost to be able to copy (for example by breaking the ‘moral barrier’ to illegal copying or by purchasing a DVD burner). It follows that a firm benefits from low prices of the other firms because this makes consumers less prone to install the copying technology, thereby reducing the threat of piracy. As a result, there exists in this setting a range of prices for which prices are strategic substitutes.

In a two-product duopoly, Belleflamme and Picard show that this strategic substitutability generates free-riding behaviors with respect to the threat of piracy: If the two firms take this threat seriously by quoting low prices, then there exists an opportunity for a firm to take advantage of this situation and to raise its price. If the fixed cost of copying is low enough, such free-riding can lead to the absence of an equilibrium in pure strategies. Firms may then randomize between several prices, leading to price dispersion.³⁰ Interestingly, when the fixed cost of copying is not too small, the market can yield a symmetric equilibrium with prices that are larger than the (average) price that would be set by a multi-product monopoly controlling the two digital products.³¹

The interactions between copyright holders under the threat of piracy also yield surprising welfare implications. From a static efficiency perspective, concentration may be preferable to competition; this result is an application of the ‘Cournot effect’ according to which a merger between two monopolies producing complementary goods is welfare-enhancing. Regarding dynamic efficiency, the multi-product setting makes it possible to assess the incentives to create new digital products (rather than the incentives to improve the quality of existing products, as is done in the literature using monopoly settings). To this end, Belleflamme and Picard measure

²⁹Even in the music and film industries, it can be argued that production and pricing decisions are concentrated in the hands of a small number of major players.

³⁰Price dispersion is commonly observed in markets for digital products. For instance, Brynjolfsson and Smith (2000) observe prices for a matched set of 20 books and 20 CDs sold through conventional and Internet outlets, and report average price differences ranging from 25% for books to 33% for CDs. The explanation usually advanced in the literature does not rely on piracy, though, but on asymmetric information and search frictions (see, e.g., Varian, 1980 and Baye and Morgan, 2001).

³¹Belleflamme and Picard even show that there exist parameter configurations for which the duopoly prices are larger than the price of a monopoly that faces no threat of piracy.

the (gross) incentives to create a new digital product by comparing their two-product framework with an economy where only a single digital product is available. Whether those incentives are larger for an entrant or for an incumbent firm is not clear a priori. On the one hand, the entrant's incentives are reduced by the free-riding effect observed in a duopoly; on the other hand, the incumbent's incentives are reduced by a cannibalization effect (copying becomes more attractive as the number of goods increases). Yet, it is possible to conclude in this model that incentives to create are always higher for an entrant—i.e., if the ex post economy is organized as a duopoly. Therefore, ex post competition can be seen as a necessary evil that enhances ex ante incentives to create (which is the exact opposite of the traditional argument underlying IP protection, as recalled in Section ??).

Clearly, the previous results are derived from a set of restrictive assumptions and should, therefore, not be taken at face value. They suggest, however, that under the threat of piracy, copyright holders impose on each other a number of externalities that may significantly alter the equilibrium outcome (and the welfare implications) compared to what is obtained under a one-good monopoly setting.

4.2. Durable goods and commitment problem. Digital products such as software are durable goods—i.e., consumers can benefit from the purchase of these goods over a number of periods. An important issue for firms selling durable goods is whether they can commit to future prices. In the absence of commitment, a monopolist selling a durable good is, in effect, in price competition with itself over several periods, which might force it, at the extreme, to offer a competitive price in the first period—this is the Coase conjecture that has been formalized by Stokey (1981), Bulow (1982), Gul, Sonnenschein (1986).³²

Re-considering end-user piracy, Takeyama (1997) assumes that a copyright holder suffers from this Coasian commitment problem and shows that piracy may hurt the monopolist even more when dynamic effects are taken into account.³³ She develops a two-period model with two types of consumers, who buy up to one unit in the two periods: 'High types' have a high valuation for the good and no propensity to copy, while 'low types' have a low valuation for the good and a strong propensity to copy. Without copying, high types anticipate a lower price in the second period, which is set to make low types indifferent between buying and not buying. Therefore, the monopolist has to offer a price strictly below the valuation of high types in the first period so as to satisfy their incentive constraint. The problem gets

³²In many markets for digital products, it is not clear whether firms actually lack commitment power. Indeed, since most firms offer multiple products, they may not give steep mark-downs over time for reputation reasons. As is well-known in the literature on the durable goods monopoly, reputation concerns may give the firm commitment power. Planned obsolescence, which is common for software, may also be used to reduce the durability of the product.

³³In related papers on versioning by a durable goods monopolist, Hahn (2006) and Inderst (2008) consider an environment with two consumer types and discrete time in which a firm can sell different versions of a product over time. Here, the firm faces a commitment problem in price and quality. They show that a firm may optimally decide to sell a low- and a high-quality version in the first period (and trade only occurs in this period). The firm may optimally sell the low-quality version below marginal cost in the first period. By serving low-valuation consumers in the first period, it avoids price concessions in later periods to high-valuation consumers. This result can be interpreted in terms of piracy as follows: illegal copying (which resembles a low-quality version) may mitigate the Coasian commitment problem so that copies that are distributed for free actually increase the firm's profit. Hahn (2006) also provides detailed conditions for the monopolist to introduce a low-quality version simultaneously or with a delay.

worse when copying is possible: Now, the monopolist has to lower the second-period price to make low types indifferent between buying *and copying*. This leads to a reduction in profits that is equivalent to what would be obtained in an atemporal model. However, what makes things worse is that the lower second-period price affects the incentive constraint of high types in such a way that the monopolist also has to lower the first-period price. This second, dynamic, effect leads to a further reduction in first-period profits.

It is thus shown that the dynamic problem typically amplifies the negative effect of piracy on profits. However, Takeyama also identifies cases where copying actually increases profits: If the monopolist cannot avoid copying in the second period without making losses in that period (i.e., if the marginal costs of production and selling of the good are above the private copying cost of low types), then the availability of copies in the second period serves as a commitment not to offer the good in the second period. As a consequence, in the first period, the participation constraint and not the incentive constraint of high types becomes binding. In other words, the monopolist can extract the full surplus from high types.

4.3. Competitive effects. What happens when two producers of substitutable and piratable digital products directly compete with each another? Shy and Thisse (1999) address this issue by extending to a duopoly framework the analysis of piracy in the presence of network effects (in the spirit of Conner and Rumelt, 1991, and Takeyama, 1994). In their model, two firms are located at the extreme points of the Hotelling line. Two types of consumers are distributed along the line: Using the same terminology as in the previous model, ‘high types’ have a strong preference for originals, while ‘low types’ are indifferent whether the good is an original or a copy. In particular, the benefit from purchasing the original is $r > 0$ for high types and 0 for low types.³⁴ Both types of consumers enjoy network benefits, which are generated by the total number of users of a particular software (be they consumers of the original or of a copy). Denoting this number by N and considering the product located at 0, we have the following utility functions for a consumer located at $x \in [0, 1]$: When purchasing the original, the consumer gets $r + \mu N - x - p$ if her type is high and $\mu N - x - p$ if her type is low; when copying the product, the consumer gets $\mu N - x$ whatever her type (μ measures the strength of network effects and copies are assumed to be free and to be perfect substitutes to originals).

Shy and Thisse impose parameter restrictions to make sure that the firms never compete for low types. Under this assumption, they compare the types of equilibria that obtain when (full) copy protection prevails or when consumers can copy. Under copy protection, they show that there exist up to two types of symmetric equilibria: If network effects are sufficiently strong, the equilibrium is such that both firms price low so as to sell the good to some low types; if network effects are sufficiently weak, the firms prefer at equilibrium to set prices so as to sell only to high types.³⁵ In contrast, when consumers can copy, the argument already put forward by Takeyama (1994) may apply: Firms can exploit network effects without selling to low value consumers. This is true as long as network effects are strong enough. Then, firms do not need to price low to take advantage of network effects (as they had to under copy

³⁴The difference in value between an original and a copy is thus independent of the network effect, contrary to Takeyama (1994).

³⁵For this result, see Peitz (2004) who corrects a mistake made by Shy and Thisse in their original analysis.

protection). When copies are freely available, they can concentrate on high value consumers and still reap the benefits from network effects, which leads to higher prices and profits. On the other hand, when network effects are weak, it turns out that sales are not affected by the copy protection policy. What changes, however, in a duopoly framework is that price competition gets fiercer and, consequently, profits fall.

The analysis of Shy and Thisse (1999) has been extended in a number of directions. Jain (2008) refines the analysis of copyright protection by assuming that firm i can choose a level of copyright protection, noted α_i , such that only a proportion α_i of low types (who are, by assumption, the only consumers interested in copying) can copy its product (that is, α_i represents the level of piracy for firm i 's product). Another important difference with Shy and Thisse's framework is that Jain lifts the restriction on the absence of competition for low types. Jain assumes instead that low types have a sufficiently higher valuation for the product such that firms compete for them. It turns out that results change significantly under this alternative assumption. In the absence of network effects, Jain shows that piracy can change the composition of the market and, thereby, reduce price competition between firms. This is because copying by low types, who are more price-sensitive, enables firms to credibly charge higher prices on the segment of consumers that do not copy. Furthermore, this positive effect of piracy on firms' profits can sometimes outweigh the negative impact due to lost sales. So, even in the absence of network effects, firms may prefer weak copyright protection in equilibrium. The existence of network effects, however, somewhat blurs the picture. Actually, the opposite result may hold when network effects are strong enough: It is copyright enforcement that helps firms to reduce price competition. This is because when firms compete for low types and network effects are strong, allowing piracy by both firms can intensify price competition. Therefore, in such situations, strict copyright enforcement by one firm can serve as a coordination device to reduce price competition. The main message that can then be drawn from Jain's analysis is that, in a duopoly framework, the role of copyright protection depends on the strength of network effects: Absent network effects, weak copyright protection allows firms to increase prices, while the opposite prevails in the case of strong network effects.

Minnitti and Vergari (2010) also consider a differentiated-product duopoly framework. Their goal is to analyse how the presence of a (private, small-scale) file-sharing community affects the pricing behaviour and profitability of producers of digital products. It is assumed that consumers can download one of the two goods by joining a file-sharing community, with the restriction that consumers can join only if they buy and share a digital good with the community.³⁶ Their model differs from the above two models in a number of ways. First, consumers are assumed to be homogeneous (except for their location on the Hotelling line); they all value originals in the same way but their copying cost depends on their location. Second, there are no network effects. Third, consumers are allowed to consume both goods: They may buy one and copy the other.³⁷ Finally, the intrinsic benefit from using the first digital product may not be large enough for all consumers to be willing to participate. Minnitti and Vergari show that the latter assumption is key: Market

³⁶This initial purchase requirement seems a reasonable assumption within small, private communities where consumers share only the files they own.

³⁷As long as piracy is feasible, purchasing both goods is a dominated option for all consumers.

coverage is indeed crucial in determining firms' attitude towards piracy. In particular, when the market is not completely covered, firms are shown to benefit from piracy. We are indeed in the presence of two monopolies that see the downloading option as a way to enlarge their market share without increasing competition. This is because downloading is made through file-sharing communities that can only be joined by consumers who have purchased a digital product. Hence, the downloading possibility makes the goods more attractive, which drives some consumers to use both goods. Firms take thus advantage of a form of indirect appropriation. Naturally, this argument only holds when there are consumers still to be conquered. In fully covered markets, the positive demand effect is indeed missing and file-sharing is harmful to firms; they would therefore prefer to be protected from piracy.

5. COMMERCIAL DIGITAL PIRACY

We have been concerned so far with end-user piracy. In this section, we consider briefly commercial (or for-profit) piracy—i.e., piracy achieved by organizations that illegally reproduce and sell copyrighted products at a large scale. Commercial piracy is a form of counterfeiting, which, following Grossman and Shapiro (1988a, 1988b), can be defined as illegally copying authentic goods with a brand name. It can take one of two forms: Either the copied product is a perfect substitute of the original one and, insofar as the two products are sold at the same price (which is usually the case), consumers cannot distinguish between them; or the counterfeited product is an imperfect substitute of the original one and consumers knowingly make a choice regarding which product to buy.³⁸ These two forms are called, respectively, 'deceptive' and 'non-deceptive' counterfeiting in Grossman and Shapiro's terminology.

Although commercial piracy is a major concern to the producers of digital products (software, music and movies), mainly in developing countries,³⁹ this form of piracy has received little attention in the economics literature. There is in fact only a handful of papers that explicitly study commercial piracy. However, commercial piracy can largely be studied by using the models developed in the literature on end-user piracy. As far as consumer decisions are concerned, nothing really differs between the two forms of piracy: Copying from a friend or buying a counterfeited product are essentially modelled in the same way. Now, what clearly differs in the case of commercial piracy is the presence of an additional category of (possibly strategic) players, namely the counterfeiters. Yet, from a modelling point of view, including these players is not fundamentally different from including competing legitimate producers, as is done in the models reviewed in the previous section.

³⁸Consumers know (or strongly suspect) that they are buying a counterfeit, either because they observe the product's low quality after close inspection, or simply because of the place of purchase. For instance, in the case of music, we can think of CDs bought from street peddlers, or of downloads from a file-sharing service such as the Russian site AllofMP3, which charged significantly lower prices than those of mainstream services (although this site claimed that it operated in accordance with Russian copyright law, it was closed down in 2006 under American pressure).

³⁹Estimates of the effects of piracy on the profits of copyright owners are notoriously hard to make; distinguishing between commercial and non-commercial forms of piracy is fraught with even more difficulties. Kiema (2008, p. 304-305) reports that "the International Federation of the Phonographic Industry (IFPI) has estimated that approximately 37% of all the [music] CDs that were purchased in 2005 globally were pirate copies. However, in the case of the software industry, it is more difficult to find estimates of the prevalence of commercial piracy."

Banerjee (2003, 2006) studies competition between an incumbent copyright owner and one potential pirate entrant. Consumers are assumed to be able to distinguish legitimate from pirate products, for which they have a lower willingness to pay—i.e., Banerjee considers non-deceptive counterfeiting. He uses the Mussa-Rosen model of vertical product differentiation, with consumers being heterogeneous with respect to the utility derived from the quality difference between the original and the copy. The main difference with the models reviewed in Subsection ?? is that the price of the copy is set by a profit-maximizing counterfeiter. In this context, Banerjee analyzes what attitude a government (caring about static efficiency) and the copyright owner take in the face of piracy. The government may decide to monitor and penalize commercial piracy, while the copyright owner may combine entry-deterrence strategies and investments in protective devices against copying.⁴⁰ Jaisingh (2009) performs a similar analysis in a slightly different framework: The heterogeneity with respect to quality differences is replaced by heterogeneity with respect to the copying costs (which can be increased by anti-piracy measures). The analytical reasons as to why the policy implications drawn from Jaisingh's and Banerjee's analyses differ are clearly explained in Bae and Choi (2006).⁴¹

The above analyses share the often unrealistic assumption that only one counterfeiter can enter the market. In reality, counterfeiters tend to remain relatively small. As copying and distributing digital products do not require heavy investments, entry in the counterfeiting business is relatively easy and the number of counterfeiters tends thus to be large on a given market. Being small also reduces the risk for the pirate to be detected by a public authority. It is also observed that pirated copies are priced above marginal cost (which is close to zero for digital products). One needs then to address the question why Bertrand competition between the counterfeiters (rather than between them and the copyright owner) does not drive prices down to zero.

Yao (2005) proposes the following answer: Although counterfeiters have zero marginal cost of production, they face an expected cost resulting from the risk of being caught by the authorities. In particular, counterfeiters are caught with probability $\phi \in [0, 1]$, and have to pay a fine, which is fixed at some proportion t of the price of the legitimate product, p_m . Letting p_c denote the price of a pirate copy, we have that the net expected payoff due to counterfeiting is equal to $(1 - \phi)p_c - \phi tp_m$. Because of free entry and exit of counterfeiters, this should be equal to zero at the long-run equilibrium. It follows that $p_c = (\phi tp_m) / (1 - \phi)$, which increases with p_m , the price of the legitimate product and with ϕ , which can be seen as the monitoring rate to detect counterfeits and thus, as an indicator of the strength of IP rights enforcement.⁴²

⁴⁰Martinez-Sanchez (2010b) considers (movie) piracy in a vertical product differentiation model with sequential pricing and shows that the pirate, if it enters, decides to offer the illegal copy prior to the release of the original. Maximizing short-run welfare the government does not fully protect the copyright holder and, similar to the work on end-user piracy, the government designs its policy such that the incumbent decides to set a price below the monopoly price that successfully deters the pirate from entering the market.

⁴¹Banerjee *et al.* (2008) address the same questions in the case of deceptive counterfeiting (originals and copies are seen as perfect substitutes by the consumers).

⁴²Yao (2005) further assumes that the original product and the pirate copies are vertically differentiated à la Mussa-Rosen (counterfeiting is thus non-deceptive). In this framework, he analyzes the effect of changes in the extent of IP rights enforcement on total social welfare (dynamic efficiency is considered by endogenizing the copyright owner's choice of quality). The main result

Kiema (2008) proposes a related explanation for the positive price of pirate copies. Counterfeiters are assumed to have zero marginal cost of production but to face some positive ‘advertising cost’. To make positive sales, counterfeiters have to inform consumers of the availability of their products; they do so, by sending advertisements to consumers at random. Although the physical cost of sending an ad is close to zero in a digital world, each additional sending increases the expected cost of punishment for the counterfeiter, which makes the advertising cost positive. As a result, the competition between the counterfeiters resembles the classical model of advertising by Butters (1977), which leads to equilibrium price dispersion.⁴³

6. PRIVATE AND PUBLIC MEASURES AGAINST END-USER PIRACY

In the preceding sections, we considered the rightholder’s reaction to piracy and mostly focused on the pricing decision, taking the enforcement policy and public measures in the face of piracy as given. Public debate has been dominated by the actions that should be taken, especially by the government, in response to piracy. In this section, we report on some recent efforts on this issue. One can distinguish three categories of actions: (1) legal actions; (2) technology-based actions and (3) alternative remuneration schemes. Concerning the first category, one may want to distinguish between actions against platforms on which piracy is taking place—i.e., legal actions against file-sharing platforms such as the old Napster—and actions against individual uploaders and downloaders. Concerning the second category, in the context of digital files this comes under the name of digital rights management (DRM). Concerning the third category, it is a bit odd to talk about piracy, since levies on hardware intend to give returns to rightholders under a fair-use regime—i.e., to justify levies end-user copying cannot be seen as illegal, but would need to be considered fair use.

6.1. Legal actions.

6.1.1. *Facts.* It is fair to say that it is the introduction of Napster (a peer-to-peer-P2P-file-sharing system) in 1999 that turned the issue of digital piracy into a topic of intense debate. The fear was great in the music industry that illegal file-sharing would quickly destroy profits. The first legal actions were thus targeted against file-sharing platforms. In 2001, the Recording Industry Association of America (RIAA) obtained the closure of Napster but the victory proved short-lived as a number of other file-sharing systems (such as Kazaa, Limewire, and Morpheus) quickly replaced Napster. The industry started then a campaign of litigation against individual P2P file sharers: Between 2003 and 2008, legal proceedings were opened against about 35,000 people. In parallel, the industry also lobbied to obtain stronger protection of copyrights and stiffer penalties for infringement. Yet, these tactics did not prove very effective in combating online music piracy. At the end of 2008, the industry decided then to shift its efforts to a model known as ‘graduated response’.

is that the government should monitor counterfeiting only if the degree to which counterfeiters are able to imitate the original product is above some threshold.

⁴³Combining these assumptions with the usual Mussa-Rosen framework, Kiema (2008) analyzes the role of government policy and of DRM systems in preventing commercial piracy. One interesting result is that when there are several counterfeiters on the market, an increase in the price of legitimate copies increases price dispersion in the market for pirate copies and decreases their minimum price.

As we already mentioned in Section ??, a widely publicized form of graduated response (in Europe and in the United States) is a “three strikes” rule according to which the user’s ISP suspends or terminates Internet access after three successive notices of copyright infringement. At the time of this writing, it is too early to assess the effectiveness of such measures.

6.1.2. Analysis. In the basic analysis of the effects of digital piracy that we described in Section ??, we already examined how stronger legal actions against copyright infringement may affect the right holder’s profit and the consumer surplus. Recall that legal actions were modeled through either a marginal increase in the copying cost or a marginal decrease in the quality of copies (see, e.g., Novos and Waldman, 1984, Yoon, 2002, or Bae and Choi, 2006). We complete here this preliminary analysis by reviewing a couple of papers that have a closer look at how copyright protection is chosen.

In the analyses of Section ??, it was assumed that the copyright holder does not distinguish between different types of users—i.e., we considered a *broad-based enforcement policy* that affects all consumers in the same way. A copyright holder may, however, prefer a *targeted* enforcement policy and focus instead on some specific user groups. In particular, the monopolist may want to concentrate on high-valuation consumers. Harbaugh and Khemka (2010) analyze this option in a model of vertical differentiation with a continuum of consumer types. Targeted enforcement is modeled as a costly device that allows the firm to create two distinct groups of consumers: Those consumers who are targeted are willing to pay a high premium on originals, while the others do not face any risks and are essentially not willing to pay a premium for originals. This means that a model with a continuum of types and targeted enforcement becomes a model with essentially two types, the group sizes being determined by the scope of the enforcement policy. The interesting finding in such a framework is that the optimal monopoly price with targeted enforcement may be above the monopoly price without piracy, p^M . As Harbaugh and Khemka (2010) explain, the reason is that with targeted enforcement and positive enforcement costs, the monopolist may not want to apply enforcement up to the level of the demand that would be served by the monopolist without piracy but may want to choose a more limited scope. Then, if enforcement is sufficiently effective to deter the targeted consumer segment from copying, prices are above p^M since only high-valuation consumers can be “convinced” to buy the original.

In Cremer and Pestieau (2009), a monopolist sells a digital product in two versions. These versions are targeted at two different types of consumers (which the firm cannot observe): High-valuation ($j = 1$) and low-valuation consumers ($j = 2$). Facing the price-quality pairs (p_L, q_L) and (p_H, q_H) , consumers derive utility $u_j(q_i) - p_i$, $i = L, H$. Low-valuation consumers may also make a copy and achieve some quality $q < q_H$. The quality of the copy is the solution to $\max_q \theta u_2(q) - x(q, e)$, where x is the individual cost from copying. This cost increases in the chosen quality q and the level of copyright protection e . The level e can be seen as chosen either by the monopolist or by the government (or a regulator appointed by the government): In the former case, it corresponds to private legal actions or attempts of technical protection (like the DRM systems we consider in the next section); in the latter case, it corresponds to public measures of IP protection (e.g. those established in the Digital Millennium Copyright Act).

The authors suppose first that the government is in charge of the pricing policy as well as the level of copyright protection. In that case, they show that it can be socially optimal (in a second-best sense—i.e., respecting the incentive constraints of consumers) to sell only to high-valuation consumers and to let all low-valuation consumers copy the product. Then, high-valuation consumers fully finance the product. Although a private firm could replicate such a strategy, it could find it more profitable to implement a positive level of copyright protection and, thereby, to sell to both types of consumers. It follows that the private firm implements a higher level of copyright protection than the government.

In a second scenario, Cremer and Pestieau consider that e is a government policy determining the strength of IP protection. Suppose that we are in a situation in which the socially optimal government policy (again in a second-best sense) requires to sell to both consumer groups and to choose a positive level of IP protection. If the firm controls the pricing, the best government policy may be not to provide any IP protection at all. Thus, although IP protection is too low compared to the socially optimal government policy when the government also controls the pricing policy, it is the best not to provide IP protection given that the product is sold by a profit-maximizing firm.

6.2. Technology-based actions.

6.2.1. *Facts.* Copyright holders may resort to technology-based actions to complement their IP rights so as to prevent unauthorized duplication of their work. Digital products are often protected by digital rights management (DRM) systems, which is an umbrella term for a number of technologies that inhibits uses of digital content not desired or intended by the content provider.⁴⁴ DRM systems have thus the potential to fight digital piracy but also, in a more general way, to manage how digital products can be used. Well-known examples of DRM systems are the Content Scrambling System (CSS) employed on film DVDs since 1996, so-called ‘copy-proof’ CDs introduced by Bertelsman in 2002 (which could not be played on all CD players and were later abandoned), and the FairPlay system used by Apple on its iTunes Store. Recent development in digital distribution suggest that DRM is on a losing path since not only Apple but also Amazon and Walmart have started selling DRM-free digital music files.

6.2.2. *Analysis.* The basic analyses of digital piracy can again be used to assess the impacts of DRM systems when they are simply viewed as a way to increase the copying cost. However, it can be seen from the above description that the effects that DRM systems have on the production, distribution and consumption of digital products go beyond the reduction of illegal copying. We review here some of these effects.

Besides hindering piracy, DRM systems may also increase the copyright holder profits by allowing him to implement various price discrimination tactics (versioning, group pricing and even personalized pricing). DRM tools allow indeed the producer to define who can do what with the digital product. This possibility is particularly interesting for new artists, as Duchène, Peitz and Waelbroeck (2006)

⁴⁴As Kiema (2008, p. 305) explains, “digital rights management tools can, broadly speaking, be divided into cryptography (i.e. the distribution of information goods in an enciphered format) and watermarking (i.e. embedding information into a digital product in such a way that each copy of the good becomes different).”

argue. Because they make it easier for new artists to expose their products to consumers, DRM should not simply be considered as a tool to protect against piracy, but rather as a key to opening up the market.

A potential downside of DRM systems is that they may decrease the value that the consumers attach to the original product (for an illustration, think of the copy-protected CDs that could not be played on all CD devices). The producer faces then a trade-off between making the demand for the digital product less elastic (as DRM systems hinder copying) and, at the same time, dampening the demand (as DRM protection reduces the attractiveness of the original). Sundararajan (2004) analyses this trade-off and shows that the producer may find it optimal to choose an intermediate protection level. In a similar vein, although in the main part assuming that DRM leaves the quality unaffected, Ahn and Shin (2010) find that DRM-free is optimal when copyrights enforcement is strong or when the antipiracy function in DRM is not very effective due to the severe free rider problem. Otherwise, they show that the use of DRM is optimal for the firm, with the legitimate products having lower quality than unauthorized copies. Ahn and Shin obtain implications for the optimal design of copyright law that takes into account the substitution possibility through DRM.

In a competitive context, the choices of DRM systems also raise issues related to compatibility and interoperability. For instance, several incompatible DRM systems coexist for the distribution of digital music; similarly, on the e-book market, each platform comes with its own incompatible DRM protection. Park and Scotchmer (2005) examine whether firms prefer proprietary systems or a shared system, and whether their choice coincides with efficiency. The answers to these questions are ambiguous as the two options may have countervailing effects on prices and costs. Regarding prices, proprietary systems have the advantage of being a less attractive target for circumvention attempts, which reduces firms' incentives to lower their prices so as to avoid circumvention. On the other hand, a shared system may facilitate collusion through cost sharing. Regarding costs, the transition from a shared system to proprietary systems lowers costs as the required level of protection is lower, but raises them because of duplication.

A related issue is the effect of strategic interaction among producers of digital goods on their choice of DRM protection. In the spirit of Johnson (1985) and Belleflamme and Picard (2007), Choi, Bae and Jun (2010) consider a framework in which the interdependence between the firms comes from their strategies against piracy rather than from direct competition on prices. In particular, the degree of similarity between the DRM systems of the two firms (i.e., the extent to which cracking one system allows users to crack the other system) is key to determine the type of strategic interaction between the firms: If the two systems are relatively dissimilar, the DRM protection levels of the two firms are seen as strategic substitutes as they tend to move in the opposite direction; in contrast, when the two systems are quite similar, the protection levels move in the same direction and are seen as strategic complements. The authors derive the optimal DRM levels, prices, and demand functions for the original for each type of strategic interaction. They examine then the interaction between public and private protection against piracy. In particular, they show that when the firms consider their DRM levels as strategic substitutes, a crowding-out effect is observed: A stronger public copyright protection tends to

reduce the equilibrium level of private DRM protection and to increase piracy. The opposite prevails when DRM levels are seen as strategic complements.

6.3. Alternative remuneration schemes.

6.3.1. *Facts.* As we explained in Section ??, an important limitation to a copyright holder's exclusive rights is "fair use", which permits the limited use of a copyrighted work without requiring the creator's authorization. In particular, using the European terminology, "private copies" are permitted (i.e., users are allowed to copy copyrighted material as long as it is for their personal use). In most European countries, Japan and Canada, this allowance has been coupled with the imposition of so-called "copyright levies". These levies are intended to compensate copyright holders for the economic harm done by legal private copying. The logic is thus the following: As acts of private copying cannot be licensed for practical purposes by the relevant rights holders, an alternative remuneration scheme, involving lower transaction costs, has to be found. The chosen solution is to place surcharges on digital recording equipment and media, and to let collecting copyright societies collect the fees and pass them back to copyright holders.

6.3.2. *Analysis.* Although copyright levies are not intended to compensate for illegal copying (they do not constitute a sort of "piracy tax"), we mention them here because they are likely to have indirect impacts on piracy. Levies, like any sales tax, create market distortions. By making hardware devices more expensive, they have the potential to reduce copying, be it legal or illegal.⁴⁵ On the supply side, levies represent an alternative source of revenues for producers and may therefore affect their attitude towards piracy.⁴⁶

It is along these lines that Gayer and Shy (2003b) study the effect of hardware taxation on the demand for software. They postulate that consumers cannot use the software (either the original or a copy) without purchasing the hardware. Therefore, by making the hardware/software bundle more expensive, a tax on hardware reduces both copying and the demand for the legitimate software. Yet, if the proceeds of the hardware tax go to the software producer, a tax increase may benefit the producer. The authors compute then the profit-maximizing tax rate and show that it falls short of the tax rate that eliminates piracy.

Alcala and Gonzalez-Maestre (2010) compare the consequences of different levies on copy equipment and analyze alternative schemes for allocating their yields. To do so, they extend the conventional analysis of digital piracy by including three key aspects of artistic markets that are usually neglected: The predominance of superstars, the importance of promotion expenditures, and the dynamics of talent sorting. They start with a short-run analysis where they take the number of superstars as exogenously given and assume that there is free entry into the sub-market of niche and young artists. Piracy is shown to hurt superstars (by reducing their

⁴⁵Arguably, levies may contribute to blur the boundary between legal and illegal use of copyrighted work (users may have the wrong impression that the payment of an upfront tax on the hardware grants them extensive rights on the content).

⁴⁶Obviously, using 'producers' as a general term is an oversimplification in this context. Copyright levies have indeed contrasting impacts on the various players in the value chain of digital products. Roughly put, rights holders and collecting societies (acting on their behalf) like the levies, whereas the consumer electronics industry hates them. Accordingly, the industry welcomed the European Commission's initiative to reform the copyright levies system in the EU. Yet, despite a large consultation of all stakeholders, no such reform has been implemented so far.

earnings and the incentives to invest in their promotion) at the benefit of niche and young artists (whose market share and number increase). Using an overlapping-generations model of artists, they study then the dynamics of the market and its long run equilibrium. The number of superstars is now endogenous: Only a fraction of young artists starting the artistic career show talent and become superstars later in their career. Hence, as piracy helps more young artists start their career, it also increases the number of highly talented artists in the long run.

In this setting, the authors uncover two potential negative impacts of copyright levies on artistic creation. First, by hindering the promotion of niche and young artists, levies hamper artistic creation in the long run. Second, when levy yields are distributed in proportion to market sales (which is the most common policy followed by Western countries), levies strongly favor superstars and, thereby, reduce artistic diversity in the short run, as well as high-quality artistic creation in the long run. The latter problem could be alleviated, the authors argue, by allocating levy yields on the basis of non-linear (in sales) schemes that strongly favor young artists.

To close this section and link it with the previous one, let us recall that the logic of the copyright levy system relies on transaction costs: The system was introduced because there were no effective means to monitor (and therefore authorise) acts of copying by consumers. However, the advent of DRM technologies should lead policy-makers to question this argument. Indeed, as Regner et al. (2009) note, it is now (technologically and economically) feasible to design DRM-based licensing contracts on which individualized monitoring and compensation schemes can be based.

7. CONCLUSION

In this article, we have extensively reviewed the theoretical literature on piracy of information products. This literature, which started in the mid-1980s, really mushroomed at the turn of the 21st century when digital piracy became a topic of intense debate. Our analysis has been mainly focused on end-user piracy, which acts as an illegal source of competition for right-holders. One therefore expects piracy to have a negative impact on right-holders' profits. In terms of welfare, piracy is likely to improve welfare in the short run (as the deadweight loss of monopoly is reduced) but to deteriorate it in the long run (as lower profits imply lower incentives to create and to improve products). These conclusions were established in a number of seminal papers considering a simple monopoly framework.

Subsequent analyses extended this basic approach in several directions. First, it was suggested that piracy also had the potential to increase the right-holders' profits, thereby counteracting its negative competition effect; a number of ways were described by which pirated copies could increase the value of original products either by solving an experience good problem (sampling), by increasing network benefits, or simply because the ability to make copies raises the consumers' willingness to pay for originals (indirect appropriation). It was then shown that there exist circumstances where right-holders favor piracy and where fighting piracy could prove welfare-detrimental. A second line of extension was to examine the effects of piracy in environments where several digital products compete with one another. Competition between digital products either stems directly from their substitutability, or indirectly because end-user piracy is a common substitute for otherwise independent products (durability may also create intertemporal competition for the

same product). These analyses showed that competition may significantly alter copyright holders' strategies towards piracy (and the corresponding welfare implications) compared to what can be drawn from the basic monopoly approach. Finally, we discussed contributions that consider other responses to piracy than actions through prices, namely legal actions, technical measures and copyright levies.

To close this survey, we should say a few words about new business models that have recently emerged in digital markets. A number of papers have described these new models: For instance, Dubosson-Torbay, Pigneur, and Usunier (2004) review business models for music distribution in a post-Napster world; Duchène, Peitz, and Waelbroeck (2006) examine the potential of DRM for creating new markets. More recently, Regner, Barria, Pitt and Neville (2009) survey and categorize emerging digital media business models. Interestingly, they categorize the models according to the extent to which payment and rights are decoupled from the actual distribution of content. On one end of the spectrum, one finds the conventional models that we have reviewed in this survey: These models are based on strong DRM and imply a strong link between payment, rights and distribution (basically, it is the conventional offline retail model that is translated online). As an alternative, various industry players have tried subscription-based business models, which, however, also tend to rely on strong DRM. When one moves along the spectrum, payment and rights become increasingly decoupled from distribution. A recent trend seems indeed to let consumers access digital products without asking for an immediate payment or, even, without asking for any payment at all. In some models, payment may be made on a voluntary basis.⁴⁷ In other models, the content is free but revenues come from complementary products and services, or from advertising.

The latter type of models exploit the idea of indirect appropriation that we explored at the end of Section ???. Recall, however, that indirect appropriation applied across consumers for a given product. Here, what is suggested is to exploit indirect appropriation across products for a given consumer. Indeed, if illegal copies are consumed together with private goods that cannot be copied, end-user piracy may be seen as less harmful for copyright owners. In this logic, digital products can be used as loss leaders that boost the demand for complementary products or services; for instance, free downloads of an artist's music can be used as a promotional device that increases the demand for concert tickets or for ancillary products (ringtones on mobile phones, T-shirts, caps, etc.). A number of formal analyses of such complementary product and service-based models have been proposed.⁴⁸

As these business models are recent and are developing in a fast-changing technological landscape, it is not surprising that they have only received limited attention in the literature so far. Yet, given the importance of digital media industries, the academic interest in these emerging models is deemed to grow. The present survey may thus have to be significantly complemented in a few years from now.

⁴⁷Regner and Barria (2009) analyze the payment behavior of customers of the online music label *Magnatune*; Kim, Natter and Spann (2009) analyze factors that influence prices paid under the 'Pay What You Want' model and show that this model can lead to an increase in seller revenues.

⁴⁸See Curien, Laffond, Lainé, and Moreau (2004), Gayer and Shy (2006), Curien and Moreau (2009); see also Krueger (2005), and Connolly and Krueger (2006), who document the increasing importance of concert revenues.

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