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*D*igital *R*ights *M*anagement or *D*iscard *R*estrictions on *M*usic? DRM, Peer-To-Peer Piracy and the Pricing of Digital Music

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Digital Rights Management (DRM) has been widely viewed by the music industry as an effective strategy for reducing digital piracy. DRM systems aim to prevent unauthorized copying and reduce the overall rate of piracy. Therefore, the recent move towards offering DRM-free music by some major online music sellers appears paradoxical. In this paper, the authors propose a model that conceptualizes and estimates the concept of hardcore piracy in an attempt to resolve this apparent paradox.

The model results, based on two large empirical studies and one validation exercise with a large sample of over 2000 college students, indicate that the music industry can benefit from removing DRM because such a strategy has the potential to convert some pirates into paying consumers. In addition, a DRM-free environment enhances both consumer and producer welfare by increasing the demand for legitimate products as well as consumers' WTP for these products. The authors also find that producers could benefit by lowering prices from currently observed levels. The paper concludes by discussing the practical implications of the findings for managers within the music industry.

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The Recording Industry Association of America (RIAA) estimates that music sales declined from $13.7 billion in 1998 to $8.5 billion in 2008 (RIAA 2009). The music industry has been unequivocal in blaming this trend on online piracy. While music piracy is not a new phenomenon, what is new is the industry's focus on individual consumers like college students as pirates (Devaney 2008). Technology has been one of the key strategies to combat such piracy through systems like Digital Rights Management (DRM). DRM strives to make it difficult, if not impossible, to reproduce and distribute copies of legally purchased digital music. However, it is also possible that cumbersome restrictions imposed by DRM have contributed to the slow growth in digital music sales. Since DRM-encoded music files limit many aspects of a consumer's ability to listen to music, it should not be surprising if DRM also limits the market for such products.

In February 2007, Apple's CEO, Steve Jobs, called for the elimination of DRM protection from all legally sold digital music files, stating "DRM (systems) haven't worked, and may never work to halt music piracy" (Jobs 2007). In June 2007, iTunes started selling part of its catalog DRM-free and exactly a year later, the online music store Rhapsody teamed up with Verizon, Yahoo Music, MTV and iLike to strip DRM entirely from its catalog. More significantly, in what has been heralded by some as the death knell for DRM, on January 6, 2009 Apple announced that it had signed agreements with all the major music labels to offer their music in a DRM-free format on its iTunes store. Given the extreme measures taken by most major producers to curb piracy through DRM and legal enforcement, this recent strategy of offering DRM-free songs poses an interesting paradox that is worthy of further exploration.

In this paper, we investigate the impact of DRM restrictions on the demand for music downloads. We do this by developing a new model that introduces the concept of "hardcore pirates" and estimates the impact of DRM on consumers' willingness to pay

(WTP) for songs (favorites as well as non-favorites) and on the producer revenues and profits. Our results, based on two studies of over 2000 college students suggest that despite the potential advantages offered by some DRM restrictions, on balance the elimination of DRM has a net positive impact on both producer profits and consumer welfare. The reasons for these surprising results are twofold: (a) a decrease in the propensity to pirate due to the removal of DRM (as explained later, this is due to the fact that DRM removal results in some hardcore pirates converting to paying customers) and (b) an increase in market participation by low value consumers due to the impact of an increase in their utility and WTP. We believe that these results provide an interesting and important rationale for the emerging trend towards a DRM-free environment for music. In addition they also provide support to the notion that under certain circumstances, consumers may prefer to pay for a product, even if they could obtain it for free.

Our research contributes to the literature in at least three ways: (a) It provides a consumer-based rationale for the paradoxical trend of removing DRM controls (b) It considers piracy from a demand perspective and offers a new and unique method for conceptualizing and measuring piracy in terms of willingness to pay (WTP) and (c) It allows us to examine how different DRM and pricing strategies impact the levels of piracy, producer profits, and consumer welfare. While the popular press contains numerous articles regarding the impact of DRM, the academic literature has yet to produce any empirical work examining how various DRM strategies might affect music sales and piracy rates. Additionally, our research addresses the limitation of many previous studies of the relationship between music sales and piracy which were based on supply-side estimates.

The paper is organized as follows. The next section describes DRM and the manner in which it impacts the music industry. This is followed by our conceptualization of music piracy and the empirical model used for estimating the relationship between DRM and piracy.

The following section estimates and validates the model based on two studies that focused specifically on the type of DRM reduction strategies that have the most beneficial impact on reducing piracy and increasing consumers' WTP. The next section considers the welfare effects of DRM removal and optimal pricing strategies. The concluding section summarizes the main findings of the paper, reviews key limitations, and discusses relevant managerial implications.

DIGITAL RIGHTS MANAGEMENT

Digital Rights Management (DRM) is a term used to refer to the technical systems and technologies that digital publishers and copyright holders use to exert control over how digital works may be used by consumers. DRM systems offer several potential benefits to both music publishers and consumers. For publishers, DRM offers the technical means to control the distribution and use of digital music. In theory, DRM allows music publishers to sell digital music which is difficult or impossible for end users to duplicate. These technologies can not only limit unauthorized copying, but can also enable new business models beyond just purchasing individual songs or albums.

The Impact of DRM on Consumers

For consumers, the benefits of DRM primarily result from being able to legally purchase music and music services that might not otherwise be offered. Music publishers were initially slow to offer digital music for purchase and download on the Internet due to fears of increasing the unauthorized use of their music offerings. It was not until viable DRM protected music services such as Apple's iTunes were launched that consumers had a brand name outlet to purchase music for download from the major music publishers. DRM can also offer consumers new ways to purchase music such as Microsoft's Zune Pass which offers unlimited music downloads for $14.99/month (Microsoft 2007). Without DRM, music publishers would be unlikely to allow retailers such as Microsoft to offer services like these.

It is worth noting, however, that reducing the DRM protection on a particular music file does not automatically give consumers the freedom to copy these files indiscriminately. For example, while Apple now sells music that has no DRM restrictions (iTunes Plus), the terms of use still specify purchasers are "authorized to use the Products only for personal, noncommercial use" (Apple iTunes Terms of Service 2009). So, reducing or eliminating DRM need not imply that users are free to pirate purchased music. It should also be noted that relaxing DRM restrictions does not necessarily mean there are no technical restrictions on use. Microsoft's Zune music player, for example, allows sharing of music with friends via a relaxed version of the traditional DRM restrictions. This relaxed DRM only allows sharing in person with other friends, limits burning of CDs or DVDs, and prevents users from uploading music to file sharing networks, for example.

While the benefits of DRM protection to consumers and music publishers appear clear, it is not entirely obvious that these benefits outweigh the limitations of DRM systems on balance. For consumers, DRM has the potential to impose stricter technical controls on their use of purchased digital music than even copyright statutes dictate (Lichtman 2006). These restrictions may limit the utility consumers realize when purchasing music that has DRM controls. For example, where "fair use" legislation may allow consumers to create a private copy, DRM can take away that ability. In this way, DRM can impose many restrictions that consumers might find unfair or inconsistent with their desired ability to use purchased music. Finally, DRM also raises the issue of data privacy given some types of DRM controls have the ability to track individual consumer usage of music files (Cohen 2003). All these factors taken together may limit the utility of digital music for legitimate consumers.

The Impact of DRM on Music Producers

Thus, given the ambiguity surrounding DRM restrictions, an important but unanswered question is how a producer should decide on whether to offer DRM restricted or DRM free files. It would appear that there are three main requirements for there to be a sustainable business model if the absence of DRM restrictions on music files increases file sharing activities. First, there should not exist any significant, negative impact of file sharing on the sales of alternative music formats from which the industry derives substantial revenues (for example, CDs primarily but also vinyl records and music videos). Second, file sharing should enhance the demand for complementary, revenue generating goods and services such as other digital songs and concerts. Third, lifting DRM restrictions should enhance consumers´ utility and increase overall sales of digital music files. This may be achieved via files that are more flexible (transportable, customizable, playable, shareable with friends) as well as by converting a certain segment of non-purchasers or pirates into paying customers. Naturally, these increased revenues have to be sufficient to exceed or at least cover any potential losses in direct sales of digital files on account of lifting DRM restrictions. We present theoretical and empirical arguments drawn from the literature as well as from our own original empirical results to provide evidence that all these conditions may indeed exist in the current world of digital music. Each of these requirements is discussed in detail below.

Regarding the first issue of the potential negative impact of file sharing on CD sales, the generally held view in the music industry has been that the lack of DRM controls increases piracy and leads to declining album sales. However, the empirical relationship between piracy and declining album sales has not been clearly established. While some studies have found evidence linking piracy and declining album sales (Liebowitz 2006; Rob and Waldfogel 2006; Zentner 2006), others have not (Bhattacharjee et al 2007; Oberholzer and Strumpf 2007; Smith and Telang 2008; Tanaka 2004). Furthermore, it is important to

note that the latter four studies were the only ones that used actual file sharing data and none of them found any negative impact on CD sales (Oberholzer and Strumpf 2009). Thus, on balance, it is difficult to argue that DRM removal would have a significant negative effect on CD sales. Plausible alternative explanations for the observed decline in CD sales include variable economic cycles and the increasing competition from substitute forms of entertainment such as digital games, movie, TV-shows and concert DVDs, etc (Oberholzer and Strumpf 2009).

Second, regarding the increased sales of complementary goods as a result of file sharing, recent evidence from the economics literature shows that as DRM restrictions are lifted and music availability increases, the price of complementary goods (such as concerts) also increases, thereby enhancing "sales" and revenues for many artists (Krueger 2005; Mortimer and Sorensen 2005; Schulz 2009).

Finally, regarding the issue of enhanced consumer utility for DRM-free files, the principal focus of our research, the existing literature has identified factors that may cause legal digital music sellers to benefit from consumer piracy, and therefore optimally choose a low or zero level of DRM protection. These reasons include:

- *Restrictions on product usage*: DRM is "capable of controlling, monitoring, and metering almost every conceivable use of a digital work" (Burk and Cohen 2001) . Therefore, to the extent that it imposes restrictions on the access, portability and use of legally bought digital products, DRM may also reduce the value of such products for consumers (Helberger et al. 2004). Desai, Purohit and Vernik (2009) state that the most limiting restriction for consumers was the requirement of limiting songs to only one device and that this lowered utility for all consumers.
- *Product sampling***:** Since many digital goods are often experience goods, digital copies may also act as product samples, allowing consumers to find out which products fit their

own preferences more closely (Chellappa and Shivendu 2005). In turn, allowing consumers to gain information about product fit can positively impact profits by letting firms design appropriate pricing strategies to match this information (Shapiro 1983). In a multi-product monopoly setting, Peitz and Waelbroeck (2006a) showed that, due to the sampling role of music piracy, the introduction of file-sharing technologies leads to higher profits in the presence of product diversity and consumer heterogeneity.

- *"Social" network effects***:** Previous research has shown that the value of possessing products does not reside only in the direct utility and enjoyment that consumers derive from their use, but also in their importance in forming social relationships and their role in expressing the sense of self (Richins 1994). These types of social network effects are recognized as being very important for music consumption. For example, activities such as sharing, displaying and swapping music can be important ways of self-expression and social interaction (Bassoli et al. 2006; Brown et al. 2001; O'Hara and Brown 2006). An influential study by Salganik, Dodds and Watts (2006) demonstrated that the success of digital songs depended to a large extent on the knowledge of what other customers were downloading. Thus, removing restrictions on the ability to share files with friends may increase the "social network effects" of music consumption, thereby increasing consumers' WTP for legal downloads.
- *Indirect appropriability***:** Indirect appropriability (Liebowitz 1985) refers to the fact that the ability to copy increases the value that purchasers place on originals, thereby increasing their willingness to pay and allowing sellers of originals to incorporate and capture the value of these copies while pricing originals. Thus, it provides legal suppliers a tool to mitigate the potential negative effects of DRM removal. Liebowitz (1985) argued that the price of CDs reflected the value of cassette copies that purchasers made for personal use, just like libraries paid significantly more than individual subscribers. In

the case of music, between 2007 and early 2009 iTunes sold DRM-free songs at a higher price than DRM-encoded songs ($1.29 vs. $0.99), in what can be interpreted as an attempt to indirectly appropriate the benefits of file copying.

The significance of these factors and the net impact of removing DRM is an interesting and relevant empirical issue. However, to the best of our knowledge, no study has investigated the effects of DRM removal on piracy, consumer demand, industry profits and welfare. Our attempt to fill this hiatus is described below. In our study, we demonstrate the advantages of DRM-free policies, but acknowledge that the cross-sectional nature of our design limits these potential benefits to the short term. The investigation of potential long-term benefits of DRM implementation, if they do exist, is left to future research.

MODEL: CONCEPTUALIZING DRM AND PIRACY IN TERMS OF WTP

Our model uses a demand based approach to estimate the impact of DRM removal on piracy by measuring consumers' WTP for downloaded music. We allow for the existence of an endogenously estimated group of "hardcore pirates" or consumers whose WTP for downloaded songs is always zero. In order to do so, we build on the contingent valuation method (CVM) that originated in the economics literature (Cameron and James 1987; Hanemann 1994; Hanemann, Loomis and Kanninen 1991).

Alternative techniques for estimating WTP have been proposed and used in the marketing literature, including the so-called BDM lottery procedure and choice based experiments such as conjoint analysis among others. Suffice it say here that while each approach has its own advantages and disadvantages, along with their own set of detractors (Diamond and Hausman 1994; Hausman 1993) and supporters (Hanemann 1994), there is no consensus that any one method is clearly preferable to the other (Foster and Mourato 2003; Hanley, Mourato and Wright 2001; Stevens et al. 2000). However, there is now increasing evidence that carefully designed CVM studies, following the protocols established in recent

work (Carson et al 1996, 2001) and the recommendations made by the National Oceanographic and Atmospheric Administration's blue ribbon panel of economists headed by Kenneth Arrow (Arrow et al. 1993) yield both reliable and valid estimates of WTP (Carson et al. 2001). Accordingly, we use the CVM approach in order to develop our model of hardcore piracy, the details of which are described below.

Contingent Valuation and WTP

CVM studies, including the dichotomous choice model, have been used extensively for the purpose of estimating WTP (Bishop and Heberlein 1979; Hanemann 1994; Mitchell and Carson 1989). In this model, respondents are presented with a sequence of two bids and asked if their willingness to pay equals or exceeds that bid. The magnitude of the second bid depends on the answer (yes/no) to the first bid. Denoting the initial bid as B_1, respondents are asked whether or not they would purchase the product if it were priced at B_1. If the answer is 'yes", these respondents are presented with a new bid B_H, such that $B_H > B_1$. However, if the response to the initial bid is negative, they are presented with $B_L < B_1$. Typically multiple bid sets (B_1, B_L, B_H) are developed based on extensive pre-testing of appropriate price ranges and then distributed equally across respondents. The four outcomes may be represented as: (*No-No)* if $WTP < B_L$, (*No-Yes)* if $B_L \leq WTP < B_1$, (*Yes-No)* if $B_1 \leq WTP < B_H$ and (*Yes-Yes)* if $B_H \leq WTP$. Based on the responses to these questions it is possible to estimate the cumulative distribution functions of a variety of distributions and estimate the WTP based on parametric and nonparametric techniques. One of the main attractions of this closed-ended approach is that it mimics choices faced by buyers in actual markets and results in improved efficiency of the estimated mean WTP.

An important issue in contingent valuation surveys is one of optimal bid design. Clearly, the distribution of the chosen bids impacts the efficiency of the estimators (the bids enter as regressors and determine the variance-covariance matrix), and should therefore be

chosen after careful deliberation. A number of studies have derived optimal bidding mechanisms (Alberini 1995; Kanninen 1995), but they all require some prior knowledge of the WTP distribution. However, the consensus in the recent literature is to utilize as much information as may be available or inferred about the distribution and to then set the bids around this inferred distribution. For example, these bids may be designed based on focus groups and pretests (Cameron and Quiggin 1994) or, as is likely in the case of new products, they may be based around the price of existing products. In our case, we based our bids on the results of extensive pretests with college students regarding their WTP for digital songs. The five bid sets were consistent with prices for a single downloaded song at the time of our studies (Spring 2007 and Fall 2008) and ranged from approximately 10 cents at *allofmp3.com* to 99 cents at the *iTunes* music store. Accordingly, the five bid sets were in the range \$0.05 to \$1.50 as follows: (0.10, 0.05, 0.25), (0.25, 0.10, 0.50), (0.50, 0.25, 0.75), (0.75, 0.50, 1.50), (1.00, 0.75, 1.50), where each number represents (bid1, subsequent lower bid, subsequent higher bid).

Piracy Model

Our conceptualization of hardcore piracy involved a two-step procedure.

Step A: estimating WTP. First, we asked all respondents in the (*No-No*) group whether they would be willing to "pay anything at all". All hardcore pirates belong to the "*No-No-No*" group of respondents (i.e. those respondents who said "No" to the initial bid presented to them, "No" to the subsequent *lower* follow-up bid and finally also "No" to the follow-up question asking them whether they would pay anything at all for a favorite song). Hence, for individual *j*,

(1) $\Pr(\text{No-No}) = \Pr\{WTP_j \le B_{1j} \text{ and } WTP_j \le B_{Lj}\}$

$= \Pr\{WTP_j \le B_{1j} \mid WTP_j \le B_{Lj}\} \Pr\{WTP_j \le B_{Lj}\}$

$= \Pr\{WTP_j \le B_{Lj}\}$, since $B_{Lj} < B_{1j}$

$= F(B_{Lj}, \theta)$, where $F(B_{Lj}, \theta)$ is the cumulative distribution function (cdf) of a chosen parametric distribution for WTP with parameter vector θ. Similarly,

(2) $\Pr(\text{Yes-Yes}) = \Pr\{WTP_j > B_{1j} \text{ and } WTP_j > B_{Hj}\}$

$= 1 - F(B_{Hj}, \theta)$

(3) $\Pr(\text{Yes-No}) = \Pr\{WTP_j > B_{1j} \text{ and } WTP_j \leq B_{Hj}\}$

$= F(B_{Hj}, \theta) - F(B_{1j}, \theta)$, and

(4) $\Pr(\text{No-Yes}) = \Pr\{WTP_j \leq B_{1j} \text{ and } WTP_j > B_{Lj}\}$

$= F(B_{1j}, \theta) - F(B_{Lj}, \theta)$

Equations (1) – (4) represent the probabilities of observing the different responses to each of the individual bids and yield the likelihood function for estimating the mean WTP for the sample.

Step B: Jointly Estimating WTP and Hardcore Piracy. In order to jointly estimate WTP and hardcore piracy, we define two groups of consumers as follows:

a) Group ***A*** consists of individuals whose WTP is "always zero". These are the "hardcore pirates" and are observed with probability $\mathbf{p_j}$. This probability may be modeled as a function of individual and/or firm covariates $\mathbf{X}_{ij}$. In our application, the primary covariate of interest is the presence or absence of DRM restrictions.
b) Group $\tilde{\boldsymbol{A}}$ consists of individuals whose WTP is "not always zero". These individuals may or may not purchase a song and are observed with probability $(1- \mathbf{p_j})$.

We do not know which group a randomly drawn individual belongs to, but we do know that $\Pr(WTP = 0 \mid \mathbf{A, X_{ij}}) = 1$ and that $\Pr(WTP = k \mid \mathbf{A, X_{ij}}) = 0, k > 0$. Hence,

(5) $\Pr(WTP = 0 \mid \mathbf{X_{ij}}) = \Pr(WTP = 0 \mid \tilde{\mathbf{A}}, \mathbf{X_{ij}}) * \Pr(\tilde{\mathbf{A}}) + \Pr(WTP = 0 \mid \mathbf{A, X_{ij}}) \Pr(\mathbf{A})$

$= \Pr(WTP = 0 \mid \tilde{\mathbf{A}}, \mathbf{X_{ij}}) * \Pr(\tilde{\mathbf{A}}) + \Pr(\mathbf{A})$

$= \mathbf{p_j} + (1 - \mathbf{p_j}) \Pr(WTP = 0 \mid \tilde{\mathbf{A}}, \mathbf{X_{ij}})$

$$(6)\quad \Pr(WTP = k \mid \mathbf{X_{ij}}) = \Pr(WTP = k \mid \tilde{\mathbf{A}}, \mathbf{X_{ij}}) \Pr(\tilde{\mathbf{A}}) + \Pr(WTP = k \mid \mathbf{A}, \mathbf{X_{ij}}) \Pr(\mathbf{A})$$

$$= \Pr(WTP = k \mid \tilde{\mathbf{A}}, \mathbf{X_{ij}}) \Pr(\tilde{\mathbf{A}})$$

$$= (1 - \mathbf{p_j}) \Pr(WTP = k \mid \tilde{\mathbf{A}}, \mathbf{X_{ij}})$$

Letting *nnn*, *nn*, *ny*, *yn* and *yy* represent dummy indicators for the (*No-No-No), (No-No), (No-Yes), (Yes-No)* and *(Yes-Yes)* group respectively, equations (1)-(6) yield a sample log-likelihood of:

$$(7)\quad LL = \sum_{j=1}^{N} \left[\begin{array}{l} (nnn)\ln(p_j) + (nn - nnn)\ln\left[(1-p_j)F(B_{Lj},\theta)\right] \\ +(ny)\ln\left[(1-p_j)\left\{F(B_{1j},\theta) - F(B_{Lj},\theta)\right\}\right] \\ +(yn)\ln\left[(1-p_j)\left\{F(B_{Hj},\theta) - F(B_{1j},\theta)\right\}\right] \\ +(yy)\ln\left[(1-p_j)\left\{1 - F(B_{Hj},\theta)\right\}\right] \end{array} \right]$$

A variety of distributions such as the Lognormal, Normal, and Weibull have been suggested for modeling WTP. The parameters of these distributions can be specified as functions of covariates. Consequently, our model is able to incorporate the differential impact of covariates on both the probability of hardcore piracy ($\boldsymbol{p_j}$) and the distribution of WTP for "non-pirates". This feature will be used in the empirical application for ascertaining the impact of DRM restrictions on piracy and WTP. In the following sections, we describe the results of validating our model based on two empirical studies.

THE EFFECTS OF DRM ON HARDCORE PIRACY, WTP AND WELFARE: EVIDENCE FROM THE COLLEGE STUDENT SEGMENT

In this section, we analyze the impact of DRM technology on hardcore piracy, optimal pricing, and welfare. In order to do so, we conducted two studies involving a diverse group of undergraduates at a major public university. The results of these studies are described below. In both the studies, subjects were recruited on a voluntary basis in

undergraduate classes representing diverse disciplines such as business, liberal arts, sciences and engineering. All but one student agreed to participate in our surveys.

Study 1

The first experiment was conducted with 849 students during Spring 2007. In this experiment, we varied the levels of DRM based on the prevalent restrictions on sharing and individual use and estimated their impact on both hardcore piracy and consumers' WTP. This study used a 2x2 between-subjects design in which we varied the level of two factors. The first factor, *individual DRM*, was varied using two different levels (absent versus present *individual DRM* restrictions). The second factor, *shared DRM*, was also varied using two different levels (absent versus present *shared DRM* restrictions). We presented the respondents in each condition with a scenario in which they were asked for their opinion about the attributes of a new online music store. The new store was presented generically to avoid any potential brand effects of using an existing online music store. Specifically, we told the participants we were interested in knowing how much they were willing to pay to download their favorite songs given the new store's attributes which were varied in each of the four conditions.

In addition to the paper-and-pencil questionnaire that each participant completed, we began the experiment with an extensive presentation where we carefully described the experimental task and the condition-specific attributes of the new online music store using the same wording that was contained in the questionnaire. The participants were given an opportunity to ask questions and clarify any doubts regarding the characteristics of the store and the accessibility and portability of the songs. In order to maximize the believability of the setup of the experiment, we included example screenshots of a web site we developed to represent the new, fictional online music store. These screenshots were identical across

conditions except for the attributes listed on the web page which were changed in each condition to correspond to the two levels of each factor.

Individual and Shared DRM Factors

Technically, DRM controls two types of transactions by consumers of digital music: music usage and music distribution (Kwok 2002). DRM enforces particular rules of a consumer's music usage through only allowing decryption of purchased music files in accordance with the rights granted to a music purchaser. These uses include frequency of access, transfer to other devices, allowable playback devices, and copy permission, among others (Liu et al. 2003). Beyond an individual's use, DRM can also control how a consumer can share music, termed "superdistribution" because it applies not to individual use but how the consumer can share purchased music with others (Kwok 2002; Liu et al. 2003; Mori and Kawahara 1990). Following this logic, we constructed two factors that represented the different levels of DRM restrictions on: (a) individual usage (product usage limited exclusively to the purchaser) and (b) shared usage (product usage that included sharing with other consumers i.e., "superdistribution").

We varied the level of the first factor, *individual DRM*, by including attributes that were more or less restrictive based on actual levels of DRM associated with digital music files. The two different levels of this factor only varied the attributes of DRM that had to do with the purchaser's individual use of a digital music file. For operationalizing this *individual DRM* condition, we used the then most current attributes enforced by the Apple iTunes Fairplay DRM system and the associated terms of service for the iTunes music store. Therefore, the present *individual DRM* condition only authorized the song to play on a specific brand of digital music player and on a specific branded software player on the user's personal computer, only offered a single quality of song for download (128 Kbps sampling rate), and did not allow the purchaser to re-download the song if the song were ever lost. The

saliency of these attributes were validated in extensive one-on-one interviews with knowledgeable online music users who were asked to discuss the differences between DRM encoded and DRM free digital songs.

We varied the level of the second factor, *shared DRM*, by including attributes of the purchased music file that were more or less restrictive of the purchaser's ability to share their purchased music with their friends. As with *individual DRM*, we based the present *shared DRM* factor on the existing iTunes DRM systems and terms of service which do not explicitly allow a music file purchaser to share that song with others. The absent *shared DRM* condition did allow for sharing purchased songs with friends only by transferring them to their digital music players. Thus, it is clear that other forms of sharing such as uploading files on peer-to-peer networks or making copies from another copy of a digital file would still be in violation of copyright laws. As with *individual DRM*, the external validity of the attributes associated with non-DRM music formats was tested in interviews with experienced digital music users.

Data and Model Estimation

In order to estimate the model, the 849 respondents were presented with the bid sets described earlier. We randomly presented respondents within each condition with all five sets of bids in roughly equal numbers.

After cleaning the data and performing consistency checks, we were left with a sample of 827 respondents. These 22 deleted observations represented cases with obviously incorrect entries for age (12 cases) and inconsistent responses for the contingent valuation survey (10 cases) where respondents filled out responses for both high and low bid values when they were supposed to enter responses for one or the other.[1] In order to avoid a

[1] One potential is the possibility of respondents anchoring their responses on the prevailing market prices, such as iTunes prices. We have been conducting studies of WTP for digital music since 2001, well before the launch of iTunes and our estimates have never been either consistently higher or lower than the current estimates. This provides some evidence that the presence of anchoring is not systematically biasing our estimates.

potential overestimation of hardcore piracy we further eliminated 11 respondents who checked the box "I am not a music fan" as a reason for reporting a zero willingness to pay. It is likely that for these individuals, their unwillingness to pay any positive amount for a legally sold music file reflects the fact that they derive no benefits from music consumption (as opposed to a proclivity for pirating the same file at zero price). This left us with a final sample of 816 respondents[2]. 58% of the sample was male, the average age of the sample was 19.7 years, 91% owned a portable music player, 44% attended concerts regularly and 27% visited music stores regularly. These statistics confirm that the surveyed population has a strong propensity to consume music-related products and digital music in particular.

In order to investigate whether changes in DRM policies affect the consumers' propensity for piracy and the distribution of WTP for music downloads, we estimated the most general version of our empirical model, where we used the pooled set of data from all conditions (816 observations), but the model parameters were allowed to vary across conditions. More specifically, we created the following dummy variables:

D_{indv}. - dummy variable that takes the value of 0 if *individual DRM* conditions are absent and 1 *individual DRM* conditions are present.

D_{shrd}. - dummy variable that takes the value of 0 if *shared DRM* conditions are absent and 1 if the *shared DRM* conditions are present.

Of particular importance is the fact that we allowed these variables to impact both the levels of piracy as well as the WTP distribution of the "non-pirates". Consequently, we estimated the following varying parameter Weibull model, where $F(y, DRM_i)$ is the cumulative WTP distribution and y represents the bid sets:

$$(8)\quad F(y, DRM_i) = 1 - \exp\left[-\left(\gamma_0 + \gamma_1 DRM_{shrd} + \gamma_2 DRM_{indv}\right) y^{-\left(\alpha_0 + \alpha_1 DRM_{shrd} + \alpha_2 DRM_{indv}\right)}\right]$$

[2] Re-estimating the model by including the 22 deleted observations had virtually no impact on the magnitude of any of the estimated coefficients and did not change any of the results.

The probability of observing hardcore pirates was modeled as a logit function:

$$p = \frac{\exp\left(\beta_0 + \beta_1 DRM_{shrd} + \beta_2 DRM_{indv}\right)}{1 + \exp\left(\beta_0 + \beta_1 DRM_{shrd} + \beta_2 DRM_{indv}\right)} \quad (9)$$

We estimated equation (7) based on the Normal, Lognormal and Weibull distributions. Using the Akaike Information Criterion (AIC), we found clear evidence in favor of the Weibull model (AIC = 1700.01, 1368.26 and 1271.15 for the Normal, Lognormal and Weibull respectively). We also used a number of demographic and individual level variables related to ethics, involvement, music ownership and experience with file sharing services as covariates. None of these had any impact on piracy and are not reported here for the sake of brevity. The main parameter estimates are reported in table 1.

Insert table 1 about here

The results obtained for model 1 show that neither parameter associated with the individual DRM dummy variable is significant. Therefore, *individual DRM* conditions (being able to reproduce downloaded songs on any player, to download multiple copies of the purchased songs for personal use, and to download files of different music quality) do not impact either the probability of being a hardcore pirate or the consumers' WTP. On the other hand, *shared DRM* conditions (being able to share downloaded files with friends) have a statistically significant impact on both the levels of hardcore piracy as well as on the distribution of WTP of the non-pirates. This result is consistent with the results from our own survey, in which respondents directly declared they attach a high level of importance to the ability to share music with friends (in response to a 7 point importance scale question "You are allowed to share your songs with any number of your friends. The songs can be streamed to your friends' computer when they visit your page at the online store", the mean response was 5.23 (1=Least Important, 7=Most Important) with 70% of the respondents checking the top three boxes, 53% checking the top two and 35% checking the top box).

Drawing on these results, we re-estimated our model without including the individual DRM variable[3]. The results, also reported in table 1, show that all but one of the parameter estimates are significant. Specifically, the presence of *shared DRM* increases the likelihood of piracy and lowers WTP. The parameter estimates translate to a decline of $0.06 per song relative to the absent *shared DRM* case and is statistically significant ($z = 2.36$, $p < .02$). Thus, Study 1 established the deleterious impact of imposing *shared DRM* controls on consumer utility for digital songs. In order to further evaluate the reliability of the main conclusions of this study and investigate their implications in terms of optimal DRM and pricing strategies in greater detail, we conducted a second study during the Fall of 2008, the details of which are reported below.

Study 2

This study had two principal objectives. First, we wanted to assess the extent to which our estimates vary when the model is applied to a different scenario regarding the good to be valued. While Study 1 pertained only to favorite songs, in Study 2 we assessed consumers' WTP and piracy potential for both favorite songs as well as for less preferred songs (described in the questionnaire as "a song that is not your favorite, but still a song you would like to own"). One would, of course, expect the conditional distribution of WTP to differ between favorite and non-favorite songs. However, given our definition of hardcore piracy, we expected that the piracy rate estimates would not differ significantly between the two types of songs. In other words, while non-pirates must have a higher WTP for favorite songs than for non-favorites, we expected hardcore pirates to exhibit the same (zero) WTP for both types of songs. If this is true, it would represent an additional validation of our hardcore piracy measure.

[3] The interaction term between individual and shared DRM was also included in the model but since it was not significant and did not impact the other estimates it was dropped from the final model and is not reported in the table.

Second, one could argue that although the ability to share a song with a friend increases consumers' WTP, this positive effect may be partially or even totally offset by a second order (negative) effect resulting from the opportunity to legally copy the same song from a friend[4]. In other words, a DRM-free environment may also increase the possibility of obtaining songs from friends and possibly lower the sales and WTP for downloads. As mentioned earlier, in the absent *shared DRM* condition of study 1, both the possibility of sharing a song with a friend and of getting it from a friend were explained to the respondents. More specifically, the scenario description used was the following: "You are also allowed to share songs with any of your friends. You can share your songs with your friends by transferring your songs to their digital music players. Additionally, your friends can share any songs they purchase by transferring their songs to your digital music player". Therefore, one would expect the measured impact of DRM removal on the distribution of WTP to be the net effect of the two opposing forces described above. However, it is possible that our scenario description in Study 1 did not make the possibility of copying the song for free (conditional on a friend having bought it) salient enough in the minds of respondents. If this were the case, our model would overestimate the benefits of DRM removal. In order to address this issue we introduced three alternative conditions for the absent *shared DRM* factor. These conditions differed in only one critical respect i.e., the likelihood that the respondents had a friend who had previously bought the song.

Thus, in the first condition (referred to as the certain opportunity of copying condition or COC), each respondent was told that since one of their friends had already bought their favorite song, they were free to ask that friend to transfer that song to their own digital music player. Similarly, in the other two conditions, the respondents were told that (a) there is a good chance that one of your friends has already bought the song (uncertain opportunity of

[4] We thank two anonymous reviewers for pointing out the possible existence of this second order effect.

copying or UOC) and (b) none of your friends have your favorite song (no opportunity of copying or NOC). The details of the stimuli are contained in the Appendix. If the above described second order effect of DRM removal has a significant impact on WTP, one would expect the parameters of the WTP distribution (γ, α and β) to vary significantly across these conditions.

In addition to these three "absent *shared DRM*" conditions, our between-subjects experimental design also included a "present *shared DRM*" condition. The survey was administered to 1312 students and the respondents were split about equally across all four conditions (324, 302, and 325 respondents for COC, UOC, and NOC respectively and 361 for the present *shared DRM* condition).

Data and Model Estimation: Second Order Effects of DRM Removal

We started our analysis by estimating a model from only the three absent *shared DRM* conditions (951 observations) in order to specifically gauge the impact of the three opportunity of copying conditions on piracy and WTP. More specifically, we included dummy variables associated with the "certain opportunity to copy" and "no opportunity to copy" conditions (D_{COC} and D_{NOC} respectively) and estimated parameters for both the favorite and the non-favorite song scenarios. These estimates are reported in table 2.

Insert table 2 about here

For the base scenario (favorite song) only one of the six dummy variable parameters is statistically significant. The only significant parameter is the shape parameter of the conditional distribution of WTP pertaining to the NOC condition. These estimates imply that while the piracy rates do not differ across the three conditions, the distribution of WTP for the NOC condition differs significantly from the WTP distribution for the UOC and COC conditions. The parameter estimate translates to a 6 cents difference in WTP between NOC and UOC. However, this difference is in the opposite direction of what one would expect if

the second order effect of DRM removal on WTP was significant, since it implies that the inability to copy a song from a friend actually *lowers* the mean WTP for a song (from 85 cents to 79 cents). Furthermore, none of the six parameters is significant for the non-favorite song scenario, implying that for these songs there are no differences across conditions for both piracy and for the conditional distribution of WTP. Thus, it is reasonable to conclude that our demand estimates are not subject to these second order effects of *shared DRM* on piracy and WTP.

Piracy and WTP Estimates for Favorite and Non-Favorite Songs

In comparing the results for favorites with non-favorites, we find that while the significant parameter values of the conditional WTP distribution (γ and α) differ markedly, the piracy parameters (β) are very similar in both models with the differences being statistically insignificant (z =.13, p = .66 and z = .18, p = .58 for COC and NOC conditions respectively). Therefore, these results provide strong evidence in support of our contention that while the WTP varies across different types of songs for non-hardcore pirates, it does not differ among hardcore pirates, who consistently refuse to pay a positive amount for any type of song. The fact that piracy rate estimates do not differ significantly across different types of songs also provides evidence in favor of validating our proposed method for estimating hardcore piracy.

Next, we estimated a model with the complete data set (1312 observations) where we compare the pooled absent *shared DRM* conditions (across which no significant differences were found) with the present *shared DRM* condition, both for favorite and non-favorite songs. The model estimates are provided in table 3. The results show that all the parameters have the appropriate signs and most of them are significant. The model for favorite songs strongly reinforces the previous findings of study 1.

Insert table 3 about here

More specifically, the presence of *shared DRM* increases piracy and reduces the mean WTP of non-pirates. The estimated piracy rates are 6.8% for the absent *shared DRM* condition and 9.7% for the present *shared DRM* condition while the (unconditional) mean WTP estimates are 83 cents and 69 cents, respectively. Both these differences are statistically significant ($z = 1.74$, $p = .04$ and $z = 2.36$, $p = .01$). The results for non-favorite songs are similar though the parameter β_1 (related to the impact of DRM on piracy) is no longer significant. Estimated piracy rates are 6.2% for the absent *shared DRM* and 7.5% for the present *shared DRM* conditions, respectively. This difference is statistically insignificant ($z = .83$, $p = .21$). Mean WTP estimates for these non-favorite songs across the absent *shared DRM* and present *shared DRM* conditions were 67 cents and 54 cents, a statistically significant difference ($p < .01$). Thus, we conclude that the removal of shared DRM restrictions has the dual impact of lowering hardcore piracy and increasing WTP for digital music.

Validation of Hard Core Piracy Estimates

We validated our estimates of hard core piracy through three independent methods. First, we conducted an independent survey of 102 students who were explicitly asked if they would pay anything at all for downloading a song of their choice in the presence of DRM. The results, which were very consistent with the earlier estimates of hardcore piracy, suggested that 11.6% of the respondents would not be willing to pay any price at all for downloads. Second, as reported in the previous section, hardcore piracy rates are robust across song types and did not differ for favorite and non-favorite songs. Finally, in order to control for the possibility of respondents providing untruthful answers in order to prevent threats to their self-esteem or image (socially desirable responding or SDR) we used the Randomized Response Model to estimate hardcore piracy.[5]

[5] We are grateful to an anonymous reviewer for suggesting this validation technique.

The Randomized Response Model (RRM) is based on guaranteeing the anonymity of responses so that subjects have no incentive to provide distorted responses to sensitive questions (see de Jong, Pieters and Fox, forthcoming for a review). While there are numerous variants of the RRM, the most efficient version asks respondents to answer the sensitive question based on a coin toss without the outcome being observed by the interviewer. Respondents answer the sensitive question if the outcome of the toss is a Head but are instructed to simply indicate "Yes" or "No" (depending on whether the sensitive answer is the former or latter) if the outcome is a Tail. Since the interviewers do not know the outcome, they have no way of knowing whether respondents´ answers were innocuous or based on the sensitive question. This procedure then yields an estimate of the proportion of the sample that would respond truthfully.

This model, estimated on a sample of 145 students, yielded an estimate of 6.2% for favorite songs in the absence of DRM, which is very similar to our model estimate of 6.8% for the same condition (the details of this estimation procedure are available from the first author upon request). Thus, we conclude that (a) our hard core piracy estimates are robust and (b) do not suffer from SDR, which is also consistent with the findings in Sinha and Mandel (2008) that most college students do not think that free downloading is wrong in any way.

Welfare Effects of DRM Removal and Optimal Industry Pricing

Using the estimates of table 3 we now analyze the effects of DRM removal on demand and optimal pricing. More specifically, in order to further analyze the impact of DRM we consider: (a) the impact of removing *shared DRM* at the currently prevailing market price of $0.99 for most digital songs (for example, at the Apple iTunes store) and (b) the impact of simultaneously removing DRM and adjusting prices to the optimal level for favorite songs.

We initially make these calculations under the assumption of a zero marginal cost of production (so that revenues are equivalent to producer surplus), because the music industry's cost structure is characterized by very high fixed costs and very low marginal costs. For example, marketing a potential hit song may cost more than $100,000 (Vogel 2007). In contrast, the variable costs of distributing and selling one additional copy tend to be very low. According to industry executives, the manufacturing and distribution costs of a CD amount to about $1.00 (10% of the price to retailers), which corresponds to about $0.10 per song . With digital music, such costs are much lower, since digital files can be produced and distributed over the internet with virtually zero incremental costs. Therefore, the zero marginal cost assumption appears to be a reasonable one. However, in order to ensure that our results are not solely driven by this assumption, we relax it later based on an extensive cost analysis of the music industry. In table 4, we show how removing *shared DRM* would affect demand, revenue/profits and consumer surplus, under the current price policy of charging $0.99 cents per song.

Insert table 4 about here

Removing DRM, while keeping prices at current levels, increases producer revenue by about 34% and consumer surplus by 56%. As a result, overall welfare rises by 41%.

Based on the estimated demand curve, the revenue/profit maximizing price without DRM enforcement was 75 cents per song. For each price point in the $0.01-$2.50 interval we obtained demand levels (both for DRM-free and DRM protected files) by multiplying the estimated piracy rate by the estimated conditional probability of being willing to pay that price. Total revenue was obtained by multiplying price by quantity demanded and the price point with the highest revenue/profit was selected. Table 4 also reports the welfare effects of an optimal price adjustment. Not surprisingly, our results suggest that a price reduction from