The Impact of Digital File Sharing on the Music Industry:

A Theoretical and Empirical Analysis

by

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Abstract

The first file-sharing software, Napster, was shut down in 2001, but the copying technology's impact on the music industry is still passionately debated. This paper develops a simple theoretical model of interactions between artists who create original musical compositions, record labels that distribute them, and consumers who have the option of copying music rather than buying it. The model provides testable price and demand equations and suggests that file sharing may have been undertaken by consumers who were previously not in the market for music. Using household-level data from the Consumer Expenditure Survey, we are unable to reject this hypothesis.

Introduction

The impact of new copying technology on the music industry has been hotly debated since the launch of the first file-sharing software, Napster, in 1999. Music industry representatives have charged that indiscriminate copying decreases compact disc (CD) sales, while supporters of free file sharing have alleged the practice is mostly innocuous.[1] Although several researchers have examined the impact of copying in other contexts, relatively little theoretical work exists that allows for the presence of a profit maximizing industry as an intermediary between the creators of intellectual property (artists) and the consumers of their output. The music industry serves in such an intermediary role, and this paper attempts to

[1] On September 17, 2002, the President of the Consumer Electronics Association (CEA) gave a speech in which he said that file sharing is both "legal and moral." A copy of the speech can be found on the CEA's website at http://www.ce.org/press_room/speech.doc. For a different perspective, see Brad King (2002). Nothing in this paper should be construed to suggest that the author endorses or condones illegal file sharing.

develop a simple theoretical model that captures the essential interactions of the music industry, artists, and consumers. We use micro-level consumer data to test a key implication of the model.

We imagine a process in three stages. In the last (third) stage, consumers choose between copying, purchasing music, and staying out of the market altogether. Prior to this choice, the music producer (record label) picks the profit maximizing price for a unit of music (a CD). In the first stage of the model, the record label bargains with an artist to obtain permission to reproduce the original creation. Consumers have access to a copying technology (such as Internet copying) that allows them to obtain music without paying the record label. Copying consumers do, however, incur a transaction cost. Depending on their tastes, transaction costs of copying, the market price of music, and the relative quality of legitimate CDs and copies, consumers choose whether to purchase music, copy, or stay out of the market completely.

As the transaction cost of copying falls and the relative quality of copies rises, the model predicts that more consumers will *enter the market through copying*; these are consumers who formerly viewed music as not worth buying. This finding suggests, given the recent dramatic increase in copy quality and decrease in the transaction costs of copying (provided by various file-sharing services), that some Internet file sharing may have been undertaken by consumers who previously did not buy significant amounts of music. We test this prediction using micro-level data from the Consumer Expenditure Survey and are unable to reject the hypothesis. Still, even if it can be shown that file sharing has not yet seriously impacted record sales, this does not constitute evidence against future harm to the music industry, given that digital downloads are likely to become the dominant mode of distribution. That is, if originals and copies are near perfect substitutes, and copies are widely available at no charge, labels (and artists) may not be able to charge positive prices for music.

The new Internet technologies may force record labels to significantly alter their methods for selling to consumers, as well as how they provide intermediary services to artists. The labels' main source of bargaining power with artists has been their ability to provide large-scale distribution of the artists' product, and digital technologies threaten this source of strength. Yet, a paradox concerning digital Internet technologies is that they simultaneously threaten to end the labels' distribution advantage (a boon to artists) and the ability to charge positive prices for music (an obvious disadvantage to artists).

Our model provides a simple formalization for the bargaining arrangement between the record label and the creative artist, an aspect of the music industry that has received little attention in the literature. Peterson and Berger (1975), Belinfante and Johnson (1982), Baker (1991) and Klaes (1997) examine the music industry, but they focus almost exclusively on industry structure issues such as label competition, pricing, and concentration. We employ the Nash bargaining solution (Nash (1950)) and then derive the implications of the artist-label bargaining for the pricing and sales of music. Much of the existing literature on the economics of copying bolsters the idea that small-scale sharing can increase the welfare of both consumers and producers provided that the producers can price discriminate (see, e.g., Liebowitz (1981), Liebowitz (1985), Besen (1986), Besen and Kirby (1989) and Bakos, Brynjolfsson, and Lichtman (1999)). Our model does not explore this notion but contributes to the literature by more fully describing consumers' choices and by simultaneously considering the interactions of firms, consumers, and artists.

Earlier models of the demand for music (Belinfante and Davis (1979), Anderson, Hesbacher, Etzkorn and Denisoff (1980), Alpert (1983) and Crain and Tollison (1995)) focus largely on specific demand characteristics of music, such as price, song type (genre), and lyrical content. In contrast to this approach, our model relies on the idea that consumers have different tastes for music, and focuses more directly on consumers' choice between buying, copying, and staying out of the market. Similar to Johnson (1985), we apply a Hotelling-type model of spatial differentiation (according to consumer tastes) to illustrate the consumer decision problem and to derive demand functions. The two key differences between Johnson (1985) and the present model are that Johnson (1985) modeled firms locating at a point on a circle and did not consider the relationship of such firms with creative artists. We consider this additional factor and employ the standard linear Hotelling-type location model.

The remainder of this paper is structured as follows. Section I introduces the last two stages of the model (the consumer and firm interactions), Section II discusses the artist-label bargaining agreement, and Section III summarizes the theoretical results. Section IV empirically tests an implication of the model, namely that some file-sharing consumers were formerly not in the market for music, and Section V concludes.

I. Consumer Demand and Firm Profit Maximization

A. Basic Assumptions for the Consumer

We assume that consumers are able to satisfy their taste for music through both purchasing compact discs (CDs) and obtaining copies. We assume that consumers buy "music" as CDs, a homogenous product without any reference to a particular genre, and that copying falls into one general category of "copying." Currently, consumers can choose between several forms of copying, such as using a CD recorder to copy a friend's CD, or using a file-sharing service to download digital copies of songs from the Internet. Of these types, Internet-based copying is likely to remain the most serious concern for the music industry. The number of consumers who can potentially copy one original is far greater than under older technologies because consumers do not need any sort of relationship with the individual who owns the "first" copy.[2] Because the industry's main method of distribution is (currently) to sell physical CDs in stores, our assumption that copying falls into one general category of "copying" appears non-problematic. For the consumer demand and firm profit maximization stages of the model, all derivations and comparative statics not described in the main text can be found in Michel (2003), Ch. 4.

B. Utility Function

We use a Hotelling-type model of spatial differentiation to illustrate each consumer's choice and to derive demand functions for music CDs and copying. Consumers are distributed uniformly along a line segment of length one, with each consumer identified by *ability type*, $x \in [0,1]$. The consumer of ability type $x = 0$ is one who has no ability to grasp the copy technology, while a consumer of type $x = 1$ is one who grasps the technology perfectly.[3] Consumers can buy music (CDs) at price p or they may copy at transaction cost $t(1-x)$ (>0), which reflects the "distance" of the consumer of type x from those who grasp the copy technology perfectly ($x = 1$).[4] Additionally, a *taste parameter*, θ, is used to show that consumers with a high preference for music will consume large quantities of CDs, and those with a low preference for music will consume relatively smaller quantities. The parameter θ is distributed uniformly between zero and one, and is independent of ability type (x).

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[2] The music industry appears to have used this distinction to their advantage, choosing to bring lawsuits against individuals who make large numbers of songs available to sharing services, and largely ignoring those who make copies of their friends' CDs. (See Smith (2003))

[3] We expect that even a consumer with "perfect" knowledge of the copy technology will still have a small opportunity cost associated with making the copy.

[4] Transaction costs include all marginal opportunity costs associated with copying (the opportunity cost of time for making the copy and of learning about the technology). The implications of the model remain unchanged if either a fixed component is added to transaction cost or if transaction costs are quadratic (see Michel (2003), pp. 130-133).

The parameters q^{CD} and q^{COPY} (between zero and one) are introduced to denote the *quality* of a legitimate CD and an illicit copy, respectively. In the case of q^{CD}, quality represents any set of characteristics which *only* the firm can include with the CD, with a value of one being the highest quality and a value of zero being the lowest quality. In the case of q^{COPY}, quality represents the degree of substitutability between the original and the copy. A value of one represents a perfect substitute for a CD (a "high" quality copy) and a value of zero signifies a completely worthless copy. Additionally, the parameter q is used (without superscripts) to denote the difference in quality between the CD and the copy, i.e., $q = (q^{CD} - q^{COPY})$, with $q > 0$.[5]

Given the above assumptions, the consumer's utility function from choosing to buy, copy, or stay out of the market is taken to be of the following form[6]

$$(1)\ U_x = \begin{cases} \theta q^{CD} - p & \textit{if the consumer buys the CD,} \\ \theta q^{COPY} - t(1-x) & \textit{if the consumer copies,} \\ 0 & \textit{if the consumer does neither.} \end{cases}$$

In the first case, the consumer whose ability type and taste parameter are x and θ pays the price p for any CD purchased. By purchasing the CD, the consumer obtains the surplus utility $\theta q^{CD} - p$, which is affected by the quality of the CD, q^{CD}. If $q^{CD} = 1$, then the consumer's utility is only reduced by the price of the CD. The consumer who copies incurs cost $t(1-x)$, the magnitude of which depends on ability type. The copying consumer's utility is reduced by any lack of copy quality, with $q^{COPY} = 1$ when the copy is a perfect substitute for the CD and $q^{COPY} = 0$ when the two are completely different. If the quality difference between the CD and the copy,

[5] If $q = 0$, the two goods are perfect substitutes. However, even in the case of two identical digital goods, one offered by the firm and one obtained through copying, we could expect some small, positive difference, perhaps from some nominal feeling of guilt from consuming an illegal copy. Since both q^{CD} and q^{COPY} are between zero and one, and since q is restricted to being positive, $q^{CD} > q^{COPY}$.

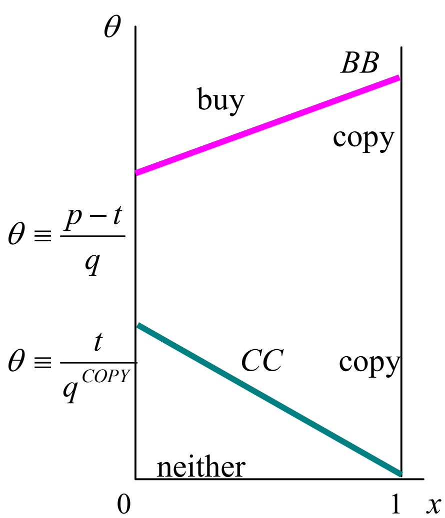
[6] The utility function in (1) is a modified version of Tirole (2001), p. 96. Analogous utility functions are discussed in Shy (1995), pp. 150-163.

q, is close to zero (the CD and the copy are very close substitutes), then the consumer's choice will depend largely on which cost, p or $t(1-x)$, is smaller. This notion corresponds to the standard interpretation of the (linear) Hotelling model in which the consumer buys from the least cost supplier of a (homogenous) product.

C. Market Demand for Music CDs and Copying

The utility expressions of the three groups of consumers (those who buy, those who copy, and those who do not consume music at all) are now used to derive the demand for CDs for all pairs of taste parameter, θ, and ability type, x. Figure 1, which is drawn in (x, θ)-space, shows the parameter combination regions that correspond to CD purchasing, copying, and no consumption of music in any form. The upward sloping line BB in Figure 1 that separates the

Figure 1, Demand for Music (Copy vs. Purchase)



music buying consumers from the copiers is obtained by setting the utility of buying and copying equal to each other; this line separates the choices of buying and copying music for the complete range of ability types, x.

When the taste parameter θ is greater than the critical value identified by the line BB, the consumer of any ability type x will buy the CD rather than copy. Below BB, consumers will copy, unless their taste for music is so low that they forgo consumption altogether. The downward sloping line CC in Figure 1 corresponds to those (x, θ) combinations for which the utility derived from copying is equal to the utility from not consuming (zero). The line CC divides the consumers, for any ability type x, into those who will copy music (above the line CC) and those will not consume music (below the line). Both the BB and CC lines shift in response to changes in model parameters.

The BB line, for instance, shifts upward as the price of CDs (p) rises, such that the "buy" region will shrink and the "copy" region will grow. Similarly, the BB line shifts upward as copy transaction costs (t) and the quality difference between the copy and original (q) decrease. The CC line shifts downward as t decreases and copy quality (q^{COPY}) increases, thus contracting the "neither" region. Thus, from Figure 1 we obtain a key hypothesis of the model, i.e., that Internet file sharing, with its lower transaction costs and higher copy quality, could have induced consumers from the "neither" region of Figure 1 to move into the "copy" region. The decision to copy by *these* consumers does not result in an immediate economic loss to music sellers because the consumer tastes for these individuals were such that they previously stayed out of the market altogether.[7]

Figure 1 is drawn assuming that t / q^{COPY} is less than $(p - t)/q$. When $t / q^{COPY} = (p - t)/q$, the two lines, BB and CC in Figure 1, cut each other on the (vertical) θ axis. In this case, consumers of the highest ability type ($x = 1$) only buy or copy. This case poses stark

[7] This prediction does not have unambiguous implications for the future viability of the music industry if file sharing remains pervasive. For a thorough discussion of opposing views, see Liebowitz (2004).

implications for the music industry, given that digital downloading is predicted to become the main distribution platform. In this scenario, consumers may choose between near perfect substitutes, with only originals offered at a positive price. Since the market demand equation for buying CDs is the same in either of these cases (whether t / q^{COPY} is less than *or* equal to $(p - t)/q$), only the case in which t / q^{COPY} is less than $(p - t)/q$ is discussed here.[8]

Using Figure 1, we obtain the demand equation for music CDs in two steps. First, we fix the taste parameter θ at a given level (as long as $\theta \geq (p - t) / q$) and use the BB curve to determine the proportion of consumers who will buy, given the CD price, *p*, the quality difference, *q*, the transaction cost, *t*, and the fixed taste parameter, θ. This proportion of consumers equals

(2) Demand for CDs with θ given = $\dfrac{t - p + \theta\, q}{t}$.

Next, in order to obtain *the market demand for CDs*, we integrate equation (2) with respect to the taste parameter θ. The lower integration limit for equation (2) is found from the requirement that the demand for CDs is nonnegative (i.e., θ must be at least as large as $(p–t) / q$) and the upper integration limit equals unity. Thus, the market demand function for CDs is as follows:

(3) Market Demand for CDs = $\displaystyle\int_{\frac{p-t}{q}}^{1} \frac{t - p + \theta q}{t} d\theta = \frac{1}{2qt}(q - p + t)^2 \equiv y^{CD}(p; q, t).$

The demand equation for CDs given in (3) responds negatively to a change in the price of a CD, *p*, positively to a change in the quality difference of the copy and the CD, *q*, and positively to a

[8] If $t / q^{COPY} > (p - t)/q$, the difference in the quality of the CD and the copy is such that some consumers will either buy or stay out of the market altogether. This case seems rather unrealistic because it requires that the quality of copies must be grossly inferior to the quality of CDs. For a graphical representation, see Michel (2003), p. 52.

change in the transaction cost of copying, t.[9] (The integration limits in (3) impose the restriction $p - t/q < 1$ on the price of a CD and the cost of copying.) Equation (3) implies that we would expect the market demand for CDs to have decreased with the introduction of Internet file sharing, a technology that substantially increased copy quality (thus reducing q) and decreased copy transaction costs (t).

D. Basic Assumptions for the Firm

The firm (the music producing label) is assumed to be a profit maximizing monopolist, and the product supplied to consumers is viewed as a "music" CD, a homogenous product without any reference to a particular genre. The terms "label" and "firm" will be used interchangeably. By assuming the firm sells a homogenous product, we are implying that prices of other types of music do not affect the demand for this specific type of music. According to industry surveys, most consumers of a given style of music do tend to buy from within that particular genre.[10] As for the monopoly assumption, the music industry currently consists of a handful of "major" labels and countless "independent" labels. The major labels, firms such as Sony and Vivendi-Universal, are responsible for the majority of album sales in the U.S., while the independent labels typically fill niche markets. Regardless of this structure, each label always has a monopoly on, at the very least, a particular version of an album (or song). Since we are examining one firm that sells one type of music to a set of consumers, our monopoly assumption appears reasonable.

The label's cost structure consists of fixed costs (recording and promotional costs) and variable costs (managing, manufacturing, and distributing costs), and the label is faced with a

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[9] Because the equations for copying demand are not integral to this paper they are not presented here, but it is noted that the partial derivatives for the copy demand function are signed opposite the corresponding partials for the CD demand function. See Michel (2003), pp. 54-57.

[10] See the consumer profiles on the Recording Industry Association of America's website (www.riaa.org).

given copy technology. Instead of purchasing music as CDs supplied by the firm, a fraction of the market may copy. In this section of the paper, the artist's negotiated share of album profits is taken exogenously. In section II, the artist-label bargaining agreement will be endogenized.

E. The Firm's Choice of *p*

The demand function (3) is now used to derive the firm's profit maximizing price for CDs. The label observes the demand for CDs, y^{CD}, and chooses the price of CDs so as to maximize the profit expression

(4) $\pi = (1-\mu)(py^{CD}(p)) - cy^{CD}(p) - F$,

where μ is the *artist's* negotiated share of album profits (taken exogenously), p is the price of the CD, c is the variable cost per CD (manufacturing, managing and distribution expenses), and F is the fixed cost (promotional and recording expenses). Substituting equation (3) into (4) and maximizing with respect to price p results in the following solution for the optimal price[11]

(5) $$p^*(\mu; q, t) = \frac{1}{3}\left[q + t + \frac{2c}{1-\mu}\right].$$

The comparative statics on the optimal price equation (5) show that p^* responds positively to changes in μ, i.e., the profit maximizing label will raise the price of the CD as the artist's negotiated share of profits increases. By (5), the price p^* also responds positively to increases in the transaction costs of copying, t, the quality difference between the CD and the copy, q, and to the firm's marginal cost, c.

Substituting the optimal CD price, p^*, and the corresponding consumer demand, $y(p^*)$, in the label's profit expression, we obtain the firm's profit as a function of the artist's profit share:

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[11] A second price solution (ignored here) that solves the first order condition yields the profit minimizing price.

(6) $\pi(\mu; q, t, c, F) = \left(\dfrac{2k^3}{qt(\mu - 1)^2} \right) - F$,

where $k = p^*(\mu)(1-\mu) - c$, $\partial\pi / \partial\mu < 0$, $\partial^2\pi / \partial\mu^2 > 0$, and $p^*(\mu)$ is defined in (5). (See Appendix A for the derivatives.) Accordingly, profit is a decreasing and convex function of the artist's profit share. When the fixed cost F is zero, it can be readily shown that $\pi(\mu) > 0$ as μ approaches zero and $\pi(\mu) < 0$ as μ approaches one. As the fixed cost increases, profit uniformly declines for all μ; we assume that F is sufficiently small for profit to be positive for an interval of values $\mu \in [0, \mu^u]$, where the upper limit for the artist's share, μ^u , solves $\pi(\mu^u) = 0$.

II. Endogenous Artist-Label Bargaining

A. Overview of the Bargaining and Applicability of the Nash Bargaining Solution

Having derived an expression for the optimized profit, we now apply the Nash cooperative bargaining model (see Nash (1950) and Muthoo (1999)) to analyze the profit-sharing arrangement between the music producing firm and the creative artist. Binmore (1994) argues that when the actual bargaining environment approximates a non-cooperative game (such as the Rubinstein *alternating offers game*), use of the weighted Nash bargaining solution is justified as a "shortcut" to the non-cooperative solution.[12] Since the actual bargaining between record labels and artists can be regarded as an alternating offers game (the label makes an initial offer, the artist through her attorneys makes a counteroffer, and so on), applying the Nash bargaining solution to the artist-label arrangement appears to pass this test.

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[12] Binmore (1994) demonstrates that, to fully justify using the weighted Nash solution, a bargaining situation's characteristics should be checked against several axioms – the independence of utility calibration, independence of irrelevant alternatives, and Pareto efficiency axioms. For a detailed description of the justification for applying the Nash solution to the artist-label arrangement, see Michel (2003), pp. 65 - 72.

For both major and independent labels, the actual profit-sharing arrangement between the firm and the artist is typically quite standard. While the exact percentage of the artist's album royalty rate is negotiable, most new artists receive (gross) between 10% and 12% of the retail price of the album, while proven artists can receive as much as 17% to 25%. Alternatively, the record label will double the artist's royalty percentage on the wholesale price of the album (which is roughly half of the retail list price). The net royalty rate the artist receives, however, can be significantly smaller than the negotiated gross rate.

In either case, the typical recording contract is designed so that nearly all of the label's fixed and variable costs (called recoupable expenses) are deducted from the artist's royalties. For example, recording expenses are usually allocated to artists in the form of an advance and then fully recouped from the artist's gross royalties before the artist is paid. Therefore, the bargaining arrangement is really about sharing profits, not revenues.

By the time a label makes an offer to an artist, the label is reasonably satisfied that the artist's potential is sufficient to make a profit. As a result, the typical artist-label contract is on an exclusive basis for a given number of albums, with the label holding an option for several additional albums. The artist, however, does not have the option to choose against recording those additional albums. While there are exceptions, most artists and labels settle on fairly similar contracts and do not renege.

As alluded to earlier, artists enter contract discussions with relatively little bargaining power. Not only are there many more aspiring artists than well-established labels, but the significant investment needed for large-scale distribution and promotion (reflected in the fixed cost F) has created the opportunity for labels to provide intermediary services to artists. One of the interesting paradoxes of digital downloading on the Internet is that the technology both threatens to eliminate this distributional advantage held by the labels and to make selling music less profitable for artists. In other words, artists can inexpensively make digital files available on the Internet without the help of a record label, but the absolute payoff from selling a single-song digital file is typically much lower than the amount currently earned by selling a full-length CD.

In what follows, we first obtain the simple profit sharing solution that applies when the firm and the artist treat the available surplus, π, as fixed (independent of the artist's share, μ). We then expand the analysis to account for the variability of profit as a function of μ. In both scenarios, the qualitative implications for the artist's share, CD prices, and CD demand are the same. However, in the variable profit case, a closed form solution is only possible when specific assumptions are made regarding the artist's preferences (in particular, her degree of risk aversion).

B. Bargaining Over Fixed Surplus

Assume then that a given (positive) surplus, $\hat{\pi}$, is to be partitioned between the firm and the artist.[13] The set of possible sharing agreements equals $M = \{\mu : 0 \le \mu \le 1\}$, where μ indicates the profit share obtained by the artist. The utility functions of the label and the artist are taken to be $U_L(\mu) = (1-\mu)\hat{\pi}$ and $U_A(\mu) = (\mu\hat{\pi})^\gamma$ $(0 < \gamma < 1)$, respectively. Accordingly, the firm is considered risk neutral but the artist is risk averse as reflected by the parameter γ. As the artist becomes less risk averse, γ approaches one. The artist's disagreement point ($d_A \ge 0$) represents her payoff if she does not sign with the label, and the label's disagreement point ($d_L \ge 0$) represents the label's profit from not signing the artist. It is natural to set $d_L = 0$. We also

[13] For the bargaining portion of the model, all derivations and comparative statics not stated in the main text can be found in Michel (2003), Ch. 5.

set $d_A = 0$ in this section and present the implications of a nonzero disagreement point for the artist (d_A) in Appendix B.

Given the utility functions and disagreement points of the players, the Nash bargaining solution of the artist-label negotiation (when the surplus is fixed) is the unique $\hat{\mu}$ that solves the maximization problem,

$$(7)\quad \max_{\mu \in M} \left(U_A(\mu)\right)^{\alpha} \left(U_L(\mu)\right)^{1-\alpha} = \max_{\mu \in M} \mu^{\gamma\alpha} (1-\mu)^{1-\alpha}.$$

In (7), the nonnegative parameter $\alpha (\leq 1)$ is used to represent the relative bargaining powers of the artist and the label, respectively. As described above, due to the high cost of album production and distribution, most artists currently enter contract negotiations with little relative bargaining power (their α is small). This is especially so in the case of a new ("unknown") artist; such an artist is unlikely to possess significant personal financial resources, and is most likely only one of many prospective new artists that the label is considering for a contract. After a few successful CD releases, however, an artist's bargaining position significantly improves and thus increases the likelihood she will bargain for a higher profit share (as the major industry stars do). From the point of view of all artists, however, secure digital downloading represents a likely improvement in relative bargaining power because the technology drastically reduces the costs of independent production and distribution of music.

Problem (7) yields the following expression for the profit share of the artist:

$$(8)\quad \hat{\mu}^*(\alpha, \gamma) = \frac{\alpha\gamma}{1-\alpha(1-\gamma)}.$$

Equation (8) shows that the artist's profit share depends on her level of risk aversion and her relative bargaining power. When γ equals one (the artist is risk neutral), $\hat{\mu}^*$ is equal to α and thus entirely reflects the artist's relative bargaining power. On the other hand, when the relative bargaining powers of both players are equal ($\alpha = 1/2$), equation (8) gives

$$(9)\ \mu^* = \frac{\gamma}{\gamma + 1},$$

whereby the artist's share only depends on her risk aversion. More generally, by (8), the artist's optimal share is positively related to the artist's bargaining power and negatively related to her level of risk aversion.

Substituting the artist's profit share in (8) into equation (5) we obtain the profit maximizing CD price as a function of the exogenous parameters of the model:

$$(10)\ \ p^*(q,t,c;\alpha,\gamma) = \frac{1}{3}\left[q + t + 2c\left[\frac{1-\alpha(1-\gamma)}{1-\alpha}\right]\right].$$

According to (10), the bargaining power and risk aversion parameters affect the CD price through the multiplier $(1-\alpha(1-\gamma)/1-\alpha)$ on the marginal cost c on the right-hand side of (10). As this multiplier is increasing in both α and γ, the greater the artist's bargaining power, the higher the firm will set the CD price. Similarly, as the artist becomes less risk averse (γ increases) and extracts a larger share of album sales, the label chooses a higher price. There is some evidence supporting these predictions. In particular, albums of well-established artists (who typically obtain higher royalty rates than new artists) tend to sell for higher prices than those of lesser-known artists.

Differentiation of (10) further suggests that each parameter (α and γ) magnifies the effect of the other on the CD price, i.e., we obtain

$$(11)\qquad \frac{\partial p^*}{\partial \alpha} = \frac{2c}{3}\frac{\gamma}{(1-\alpha)^2} > 0,\ \frac{\partial p^*}{\partial \gamma} = \frac{2c}{3}\frac{\alpha(1-\alpha)}{(1-\alpha)^2} > 0.$$

According to (11), the effect of the artist's bargaining power on the firm's pricing is magnified by the artist's level of risk aversion: as the artist becomes less risk averse (γ increases) the magnitude of the price derivative with respect to α increases (and vice versa). Similarly, the effect of the artist's risk aversion on the CD price is magnified by the artist's bargaining power. These findings appear to be backed by actual industry experience. Artists willing (and able) to build a fan base (thus increasing their α) while holding out for a better contract (demonstrating a high γ) tend to sign more lucrative deals.

Substituting the price solution (10) into the consumer demand function (3) we obtain the corresponding quantity of music sales,

(12) $$y^{CD}(q,t,c;\alpha,\gamma) = \frac{1}{2qt}\left(\frac{2}{3}\left[q+t-c\left(\frac{1-\alpha(1-\gamma)}{1-\alpha}\right)\right]\right)^2.$$

According to (12), changes in the artist's relative bargaining power and risk aversion will filter through music pricing into changes in CD sales. For example, industry stars (less risk averse artists) bargain for a larger share of album sales and labels charge higher prices for these CDs. This higher price, in turn, leads to a decrease in the quantity of CDs demanded. As in the case of the pricing equation (10), the effects of the artist's bargaining power and risk aversion are felt through changes in the multiplier $(1-\alpha(1-\gamma)/1-\alpha)$ for the firm's marginal cost.

C. Bargaining Over Variable Profit

In this section, we consider the general bargaining problem that takes into account the dependence of the surplus $\pi(\mu)$ (defined in (6)) on the artist's profit share. The set of possible sharing agreements now equals $M = \{\mu : 0 \le \mu \le 1,\ \pi(\mu) \ge 0\}$ and the utility functions of the label and the artist are $U_L(\mu) = (1-\mu)\pi(\mu)$ and $U_A(\mu) = (\mu\pi(\mu))^{\gamma}$, respectively. Of these, the payoff of the firm, $U_L(\mu)$, is decreasing for all μ in M. The artist's utility $U_A(\mu)$, on the other hand, is increasing on the open interval $(0, \overline{\mu})$, attains its maximum at $\overline{\mu}$, and is decreasing on the open interval $(\overline{\mu}, \mu^u)$, where $\pi(\mu^u) = 0$. The value $\overline{\mu}$ is defined by the equation

$$(13) \qquad \frac{\partial(\mu\pi(\mu))^{\gamma}}{\partial\mu} = 0 \Leftrightarrow p^*(\overline{\mu})[1-2\overline{\mu}] - c - Fqt(1-\overline{\mu})^2 = 0,$$

and, if we set $F = 0$, $\overline{\mu}$ also satisfies

$$(14) \qquad \overline{\mu} = \frac{1}{2}\frac{p^*(\overline{\mu}) - c}{p^*(\overline{\mu})},$$

where $p^*(\mu)$ is defined in (5). Accordingly, the set of possible utilities available through bargaining is $\Omega = \{(u^A, u^L) : u^A = U^A(\mu), u^L = U^L(\mu), \mu \in (0, \overline{\mu})\}$. Equation (14) implies that the artist's profit share is always less than one half of the pricing mark-up per CD.[14]

We maintain the assumption that the firm earns zero payoff if bargaining fails, i.e., $d_L = 0$, and set the artist's disagreement utility at $d_A = 0$ as well.[15] Then, the Nash bargaining solution is defined as the share of the artist, μ^*, that solves the maximization problem

$$(15) \qquad \max_{\mu \in (0, \overline{\mu})} \left((\mu\pi(\mu))^{\gamma}\right)^{\alpha} \left((1-\mu)\pi(\mu)\right)^{1-\alpha}.$$

Differentiation of the logarithm of the Nash product (15) yields the first order condition,

$$(16) \frac{\alpha\gamma}{\mu^*} - \frac{1-\alpha}{(1-\mu^*)} + (1-\alpha(1-\gamma))\frac{\pi'(\mu^*)}{\pi(\mu^*)} = 0.$$

---

[14] When the fixed cost F is positive, the upper limit of the artist's share, $\overline{\mu}$, defined in (13) is less than one half of the pricing mark-up.

[15] The implications of a positive d_A are discussed in Appendix B.

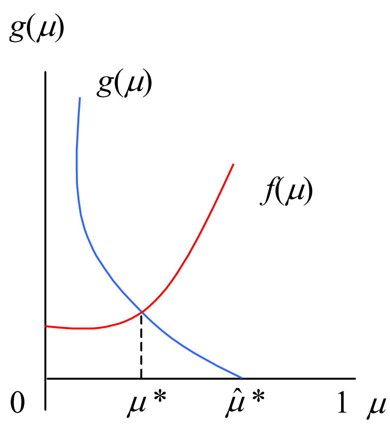
The first two terms on the left-hand side of (16) comprise the first order condition that characterizes the solution to the fixed surplus bargaining problem (7). The last term on the left-hand side of (16) reflects the impact of the artist's share on the available profit. As $\pi'(\mu)$ is negative, equation (16) implies that $\mu^* < \hat{\mu}^*$, where $\hat{\mu}^*$ solves (7). The artist thus yields some profit share when the endogeneity of the available surplus is taken into account (demanding a share higher than μ^* only increases the price of the CD and, therefore, results in fewer CDs sold).

Substituting in (16) the expressions for the profit and its derivative, we obtain the equation

$$(17) \quad g(\mu^*) - f(\mu^*) = 0,\ g(\mu) \equiv \frac{\alpha\gamma}{\mu} - \frac{1-\alpha}{(1-\mu)},\ f(\mu) \equiv \frac{2[1-\alpha(1-\gamma)]k^2 p^*(\mu)}{2k^3 - Fqt(1-\mu)^2},$$

where $k = p^*(\mu)(1-\mu) - c$, and $p^*(\mu)$ is defined in (5). Figure 2 illustrates the solution to (17).

Figure 2, Bargaining Solutions



Of the two functions of μ defined in (17), $g(\mu)$ is downward sloping and $f(\mu)$ is upward sloping. The solution to the bargaining problem (15) is obtained at the intersection of g and f. As the equation $g(\mu) = 0$ yields the solution to the fixed surplus bargaining problem (7), Figure 2 graphically demonstrates the reduction in the artist's profit share when the dependence of profit on μ is taken into account. Examining how curves $g(\mu)$ and $f(\mu)$ respond to changes in parameter values provides insight into effects that determine the solution μ^*.

First, since g is increasing in α while f is decreasing, an increase in the artist's bargaining power (α) shifts both curves g and f to the right, thus increasing the artist's share, μ^*. When the artist becomes less risk averse (γ increases), however, curve g shifts right but f shifts left, whereby the total effect on the artist's profit share cannot be signed without more detailed knowledge of the parameter values. This contrasts with our earlier conclusion that, in the case of fixed surplus, the artist will definitely demand a larger share of the profit as her risk aversion declines. Function $f(\mu)$ is decreasing in $(q + t)$ and increasing in c. Thus, as the difference in CD and copy quality (q) and copy transaction costs (t) decrease, curve f in Figure 2 shifts left thereby decreasing the artist's profit share. An increase in the marginal cost of production, c, as well as an increase in the fixed costs (F) also shift curve f left and thus reduce μ^*.

III. Summary: Effect of Digital Age on Music Industry

The impact of new Internet technologies on creative artists and the record labels that serve as intermediaries between artists and consumers manifests itself in two closely related phenomena: the ability of an increasing number of consumers to obtain close substitutes of marketed music through illicit copying, and the increase in efficiency that such technologies offer in music production and its legitimate (secure) distribution. The long-term effect of these technologies on the profit of the industry and the payoff to artists remains uncertain. Based on our simple model, however, the following conclusions can be drawn.

First, Internet technology has greatly lowered the transaction costs of illegal music copying *and* increased the quality of the copies, suggesting music sales will suffer. The introduction of ever-simpler file swapping programs (such as Napster, Morpheus etc.) has allowed even the less technically adept to join in the anonymous exchange of music. As the copies are digital as well, it is harder to see an advantage in buying from legitimate sources, especially if the quality of separate songs on one CD varies greatly. In the above model, the increased substitutability between the CD and its copy and the reduced transaction costs of copying correspond to a decrease in the parameters q and t, respectively.

The first row of Table 1 shows the effect of this change on the artist's negotiated profit share, the profit, and the incomes of the artist and the firm (the symbol +/- means that the entry cannot be signed without further information regarding the parameter values).[16] For artists, the effect of a reduction in either q or t is entirely negative: not only is the artist's income ($\mu\pi$) smaller, but the profit share the artist is able to collect (μ) is smaller as well. Although the impact on the record producing firm's profit (π) cannot be signed without additional model parameter details, because ($\mu\pi$) is positively related to a change in q and t, respectively, the label's income ($(1-\mu)(\pi)$) must be negatively related to changes in q and t. In other words, for a given level of profit, the artist's income is predicted to absorb the impact of the additional copying that corresponds to the lower q and t.

[16]The partial derivatives for Table 1, discussed in Appendix C, are evaluated at $F = 0$ (i.e., zero fixed costs).

Table 1, Summary of Effect of Digital Age On Music Industry

	μ	π	$\mu\pi$
q,t	+	+/-	+
F	-	+/-	-
c	-	+/-	-
α	+	-	+
d_A	+	-	+

NOTE: The derivatives with respect to q, the quality difference between the copy and original, and t, the copy transaction costs, both additive parameters, are identical. The remaining symbols are defined as follows: F and c represent the label's fixed cost and variable cost per unit, respectively, α and d_A represent the artist's bargaining power and disagreement utility, respectively, μ is the artist's profit share, and π is the label's profit. The symbol +/- indicates that the derivative cannot be signed without additional information on parameter values.

Next, provided that music can be sold from a secure digital platform (one that minimizes Internet copying), there are efficiency gains from the less costly production and distribution of music. Specifically, one digital music file could serve as a master copy for all consumers, thus drastically lowering both variable and fixed costs (F). As shown in Table 1 (rows two and three), the corresponding reduction in c and F improves the artist's profit share (μ) and income ($\mu\pi$). While the effect on the firm's profit level (π) cannot be signed without additional model parameter details, the firm's income from album sales ($(1-\mu)(\pi)$) is positively related to the change in both variable and fixed costs. For a given level of profit, the model predicts that the income gains from these lower costs will be captured by the artist (entirely plausible given that the label routinely passes these costs on to the artist).

In the last two rows of Table 1, the impact of a change in the artist's bargaining power and disagreement utility, respectively, on μ, π, *and*, $\mu\pi$ is definitively signed. The digital age increases the artist's bargaining power (α) and disagreement utility (d_A) because self-financing production and distribution becomes a credible option with the new Internet technologies. Correspondingly, the model predicts that an increase in both α and d_A leads to an increase in the artist's share (μ), a decrease in the firm's profit (π), and an increase in the artist's income ($\mu\pi$). While the model only captures these static changes on the artist-label relationship, it contributes to the literature by beginning to study this asymmetric relationship in an industry context.

IV. Empirical Test

A. Overview

The model presented above contains several testable implications that have not yet been explored in the literature. To begin, the price and demand equations ((10) and (12)) can be estimated to test the impact of artists' bargaining power and risk aversion on CD pricing and demand. However, reasonable instruments for these parameters are not readily available. For example, music downloads from legitimate downloading websites and/or sales volume from early in artists' careers (prior to signing with a major label) could proxy artists' bargaining power, but these data are difficult to collect. Similarly, acquiring a data set of actual CD sale prices is problematic because actual retail CD prices deviate widely from the manufacturer's list price (even more so in recent years).

Given these data constraints, we test another key implication of the model, namely that some consumers who use file-sharing services would not have purchased substantial amounts of music in the first place. The model predicts that more consumers will enter the market through copying as the transaction cost of copying falls and the relative copy quality rises (corresponding to a downward shift of the CC line in Figure 1). Internet file sharing induced a dramatic reduction in copy transaction cost and improvement in copy quality, so it is likely that some consumers who have used file-sharing services (at least initially) would not have purchased substantial amounts of music to begin with.

Relatively few researchers have studied the impact of file sharing on compact disc (CD) sales. Felix Oberholzer and Koleman Strumpf (2004) have matched U.S. record sales data to file-sharing data from a peer-to-peer (P2P) network over a seventeen week period in 2002 and find that the impact of downloads on album sales is statistically indistinguishable from zero.[17] Stan Liebowitz (2004) has examined the impact of file sharing using aggregate U.S. data and estimates that file sharing may have decreased album sales by as much as 30 percent. Alejandro Zentner (2003) has found that cross-country aggregate data support a 20 percent reduction in CD sales from file sharing, but his micro-data tests support a much smaller negative impact (7 percent). In the present study, we use micro-level expenditure data from the Bureau of Labor Statistics' (BLS) Consumer Expenditure Survey (CEX), and we cannot reject the hypothesis that some file sharing was undertaken by consumers previously not in the market. Still, the CEX micro data do indicate file sharing decreased CD sales in the U.S. approximately 4 percent between 1999 and 2001.

B. Data and Methodology

The CEX is used by the BLS to compute the Consumer Price Index, and data is collected in both *interview* and *diary* format. The diary method (consumers keep a log) primarily collects detailed information on consumer staples, such as food. We use the CEX interview files, where

[17] As explained in Oberholzer and Strumpf (2004), the bulk of file sharing takes place on P2P networks.

up to 95 percent of total household expenditures are reported. We create four separate calendar year samples from 1998 through 2001.[18] The first sample year was chosen to reflect the initiation of the first file-sharing service, Napster, in 1999. After 2001, however, the number of for-pay downloading services (which are not captured in the CEX) started to burgeon. Given the time period of observed data, the focus of our test is on the near-term impact of file sharing on CD sales.

During the sample period, the weighted sum of music purchases in the CEX fluctuates between $3.5 billion and $3.8 billion, representing about 30 percent of aggregate U.S. CD sales.[19] The CEX files can be used to create nationally representative calendar year estimates (at the household level) of mean CD expenditures and mean income. Table 2 presents the mean CD expenditures of the following consumer groups (with non-missing CD expenditures): *all* consumers in the CEX for the sample period, all consumers that own a computer at the time of the survey, and those that do not own a computer at the time of the survey. Table 2 also provides confidence intervals on the year-to-year changes in the annual CD expenditure means for each consumer group (household level income, and other summary statistics, are presented later).

As Table 2 indicates, CD expenditures for all three groups followed a downward trend from 1998 to 2001. In 1999, the year of the Napster launch, and in 2000, both years in which aggregate CD sales increased (see Table 3), only the average *computer-owning* consumer spent significantly less (at the five percent level) on CDs than in the prior year. Incidentally, 2001 is the only year (of the four) for which the direction of the change in aggregate U.S. CD sales

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[18] The unit of observation in the CEX is a "consumer unit," a measure analogous to a household. In this paper, we interchangeably use the terms *consumers* and *households* to refer to consumer units.
[19] Weighted statistics calculated using the CEX are representative of the U.S. population. All statistics calculated in this section employ the appropriate weights (see Appendix D for more on the weighting issue).

matched the direction of the change in both computer-owning and non-computer-owning consumers' mean CD expenditures.[20]

Table 2, Mean CD Expenditures (2001 $)

	1998	1999	98-99	2000	99-00	2001	00-01
Panel A - All Consumers							
Mean CD Expenditures	$48.57	$45.62	-	$44.53	-	$40.61	*b*
No. of Obs. (expenditure > 0)	4,921	6,032	-	5,932	-	5,857	-
Panel B - Computer Owning Consumers							
Mean CD Expenditures	$78.30	$67.69	*b*	$61.81	*b*	$56.60	*b*
No. of Obs. (expenditure > 0)	2,870	3,776	-	4,061	-	4,378	-
Panel C - Non Computer Owning Consumers							
Mean CD Expenditures	$28.37	$28.08	-	$27.01	-	$20.31	*b*
No. of Obs. (expenditure > 0)	2,003	2,189	-	1,797	-	1,391	-

All statistics use the required full-sample and replicate weights supplied with the Consumer Expenditure Survey data.
* *a* and *b* denote statistically significant changes at the 10 and 5 percent levels of signficance, respectively

Table 3, Music Industry Sales (2001 $)
(in millions)

Year:	1998	1999	2000	2001
CDs	$12,252	$13,475	$13,565	$12,909
net units shipped	*847*	*939*	*943*	*882*
Total Retail Units	$13,056	$13,719	$13,041	$12,389
net units shipped	*1,124*	*1,161*	*1,079*	*969*

Source: Recording Industry Association of America

The CEX data can be used to directly test for the effects of demographic characteristics on consumer expenditures. We exploit this feature of the data to identify clusters of possible

[20] All nominal figures are converted to 2001 dollars using the Urban Consumer Price Index (CPI-U) for all items less food and energy.

file-sharing activity (in the CEX data households are asked to report whether they own a computer, a necessary tool for using file-sharing services).[21] In particular, we test for the presence of a significant change in the relationship between computer ownership and household expenditures on music during the sample period. If such a change is present in the data, we attribute a causal relationship to file-sharing. For example, if computer owning consumers increased their use of file-sharing services and increased (decreased) their purchases of CDs, we would expect to see a positive (negative) change in the relationship between computer ownership and CD purchases.

The difference-in-differences estimator, designed to compare control and treatment groups before and after a particular event (see Wooldridge (2003)), allows us to conduct our test. The event that we isolate is the initiation of the first file-sharing service in 1999. The estimator compares the difference in expenditures of a control group (consumers that do not own a computer) and a treatment group (consumers that do own a computer) before and after the event. The test is run on data from the years 1998 *and* 2001, so the estimator represents the difference in expenditures due to file-sharing activity.[22] If file sharing between 1999 and 2001 was largely performed by consumers who previously purchased significant amounts of music, then we would expect the estimator to be negative and statistically significant. In the absence of such a finding, we cannot reject the hypothesis that some file sharing was undertaken by consumers formerly not in the market for music.

The test is performed by estimating the following equation:

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[21] Internet usage may be a better predictor of file-sharing activity, but the CEX does not capture Internet usage prior to 2001.

[22] The CEX data cannot be used to measure annual expenditure changes for the *same* consumers over time, so an underlying assumption is that computer owners in 1998 were not systematically different from computer owners in 2001. This issue will be addressed further below.

$$(18)\ lnCDexp = \hat{\beta}_1 + \hat{\beta}_2 lny + \hat{\beta}_3 COMP + \hat{\beta}_4 X' + \hat{\beta}_5 Y01 + \hat{\beta}_6 CMPINT\ .$$

In (18), the natural logarithm of each consumer's real CD expenditures serves as the dependent variable ($lnCDexp$). The variables of interest are *COMP*, *Y01*, and *CMPINT*. The *Y01* variable is a year dummy, set to one for expenditures made in the year 2001, and the coefficient on *CMPINT* is the difference-in-differences estimator, whereby the year dummy (*Y01*) is multiplied by each consumer's *COMP* dummy (set to one for consumers owning a computer).

To control for preferences, the model contains a vector (*X*) of control variables including family size and age. The CEX family size variable is reclassified so that six or more people represent the largest family size, and the age variable is grouped into four categories: under 31, between 31 and 55, between 56 and 65, and over 65 (for married households, the age of the spouses are averaged). Because the CEX definition of before tax income was changed in 2001, the natural logarithm of wage and salary income is used as the independent variable controlling for income (*ln y*). An alternative specification, using the age of the household's children, yields nearly identical results to those presented here (see Michel (2003), Appendix I), and additional preference variables such as race and region of residence do not materially impact the results presented below.[23]

C. Findings

Table 4 gives the most important results. According to Table 4, the estimate of the difference-in-differences estimator (*CMPINT*) is statistically insignificant, even at the 10 percent level of significance. Therefore, we cannot reject the hypothesis that some file sharing (prior to 2002) was undertaken by consumers formerly not in the market for music. Still, the negative

[23] The main test results from model (18) employ all appropriate CEX weights (see Appendix D). However, running model (18) on the non-weighted data does not materially change the main results presented below.

value of the *CMPINT* estimate (-0.041) indicates that the relationship between computer ownership and CD purchases weakened from 1998 to 2001, despite the fact that aggregate U.S. CD sales were about 5 percent higher in 2001 versus 1998 (in 2001 dollars). Because the model regresses the natural logarithm of CD expenditures, this estimate suggests that file sharing decreased CD sales by about 4 percent, though the estimate is statistically insignificant.

Table 4, Difference in Differences, Natural Log of Real CD Expenditures (2001$)

No. of Observations		Overall Fit	
Unweighted:	9,690	F Value:	72.172
		Prob > F:	0.0000
		R^2:	0.0794

Independent Variable	b	SE	p value
Intercept	1.7733	0.1411	0.0000
lny	0.2091	0.0138	0.0000
COMP	0.1142	0.0311	0.0070
Family Size	-0.0392	0.0085	0.0000
Age	0.0817	0.0195	0.0010
Y01	-0.0446	0.0319	0.1696
CMPINT	-0.0408	0.0310	0.1944

All statistics use the required full-sample and replicate weights supplied with the Consumer Expenditure Survey data.

One mitigating factor is that computer owners in 1998 and 2001 are not necessarily two homogenous groups. Computer owners in 2001, for example, could have purchased computers specifically to download music, thus biasing downward the difference-in-differences estimator in (18). Ideally, panel data (with the same computer owning consumers included for all four years) would be used to control for this possibility. Alternatively, because such a panel cannot be constructed from the CEX data, "synthetic" cohorts can be compiled by including in the sample only those consumers with similar demographic characteristics in each time period. Experimentation with synthetic cohorts, based on income, age, family type and family size, respectively, produced results similar to Table 4, although the sample sizes were much smaller (the summary statistics (Table 5) show that household average income, age, and family size are fairly uniform for the four years studied).

Table 5 demonstrates that the raw number of computer owning consumers in the CEX increased from 7,733 in 1998 to 14,106 in 2001, a finding that suggests consumers may have purchased computers specifically for file-sharing purposes. If this were the case, the difference-in-differences estimator would be biased downward. Nevertheless, we cannot reject the hypothesis that some file sharing was performed by consumers formerly not in the market because the estimator is statistically insignificant. Regardless, our results do not have unambiguous implications for the long-term viability of the music industry in an environment where digital downloads from record labels and P2P sharing services coexist as nearly perfect substitutes.

Table 5, Consumer Demographics

	1998	1999	98-99	2000	99-00	2001	00-01
Panel A - All Consumers							
Annual Income	\$35,296	\$36,255	-	\$36,485	-	\$38,360	*b*
Reference Person Age	41.21	41.59	-	41.48	-	41.94	-
Family Size	2.70	2.79	-	2.83	-	2.82	-
No. of Obs.	16,167	20,471	-	20,341	-	21,907	-
Panel B - Computer Owning Consumers							
Annual Income	\$53,995	\$54,374	-	\$52,059	*b*	\$52,617	-
Reference Person Age	41.05	42.06	-	41.74	-	42.25	-
Family Size	2.86	2.95	-	2.96	-	2.92	-
No. of Obs.	7,733	10,775	-	11,890	-	14,106	-
Panel C - Non Computer Owning Consumers							
Annual Income	\$22,837	\$21,952	-	\$20,856	*a*	\$20,172	-
Reference Person Age	41.74	40.99	-	41.09	-	41.21	-
Family Size	2.50	2.54	-	2.57	-	2.55	-
No. of Obs.	8,277	9,406	-	8,114	-	7,369	-

All statistics use the required full-sample and replicate weights supplied with the Consumer Expenditure Survey data.

* *a* and *b* denote statistically significant changes at the 10 and 5 percent levels of signficance, respectively

V. Conclusions and Ideas for Future Research

Our theoretical model suggests that, given the dramatic increase in copy quality and the reduction in the transaction costs of copying, some of the increased copying of music on the Internet in recent years may have been undertaken by consumers who previously did not participate in the music market. Our micro-level data on music purchases does not reject this hypothesis. Still, theory suggests that demand for CDs should decline when file sharing takes place. Our test results suggest that file sharing may have reduced album sales by approximately 4 percent between 1999 and 2001. While this number is rather small, it cannot be used to predict the *long-term* viability of the music industry in an environment where record labels (or artists) compete directly with free file-sharing services.

A key innovation of our theoretical model is that the interactions of firms, consumers, and third party creators of intellectual property (artists) are considered. The model predicts that actions by artists such as building a relatively large fan base and selling many albums as independents should result in a higher profit share for artists. While a more direct test of this hypothesis is desirable, artists' ability to build a solid fan-base and sell albums as independents has long been used by major labels as a predictor of artistic success. By improving artists' ability to increase their fan base and sell their own music, the Internet and digital downloading could strengthen artists' bargaining position and thus allow them to rely less on labels for distribution. However, it is not entirely clear that the artists (or the labels) would have a larger absolute payoff if digital downloading were the dominant form of distribution, and the future role of the record label could change because of these new technologies.

Irrespective of the role of the record label, the model provides a key implication for copyright law in such a market. Since the degree of substitutability between originals and copies would be quite high, and since the other factors of demand would equalize for both copies and originals, consumers would be choosing between near perfect substitutes – one with a positive price and one at no cost. In this scenario, it is difficult to see how a viable market for digital downloads could exist with unchecked Internet file sharing. One way to ensure a viable market for music would be to selectively enforce copyrights, using the law to prevent large-scale sharing on the Internet, a strategy which appears to have been undertaken by major labels.

As for future research, little theoretical work has been done to jointly examine the relationships between the artists, labels, and consumers, and adding to this theory would greatly benefit any future empirical work. In terms of the present model, possible extensions include: (1) making the artist's bargaining power and the total market demand jointly dependent; (2) modeling the taste and ability parameters (θ and x) as bivariate normal with a positive correlation (such that high valuation consumers also exhibit higher technical ability); and (3) directly accounting for uncertainty (with regard to consumer demand for CDs) in the bargaining process. Alternatively, instead of using the Nash bargaining framework, incentive contract theory could be applied to the artist-label relationship. This relationship could perhaps be modeled in terms of investing in a long-lived asset as well.

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Appendix A – First and Second Derivative of Firm's Profit Function

In Section I-E, we presented equation (6), the firm's profit as a function of the artist's profit share, μ, where $k = p^*(\mu)(1-\mu) - c$, $\partial\pi / \partial\mu < 0$, and $\partial^2\pi / \partial\mu^2 > 0$. The first and second derivatives of (6) with respect to μ are as follows:

(B1) $$\frac{\partial\pi(\mu)}{\partial\mu} = -\frac{2k^2 p}{qt(1-\mu)^2} < 0$$

(B2) $$\frac{\partial^2\pi}{\partial\mu^2} = \frac{4ck}{3qt(1-\mu)^4} > 0 .$$

Appendix B - Bargaining when $d_A > 0$

In this appendix, we show that the artist's profit share is positively related to her disagreement utility. In other words, as the artist improves her outside options, such as her ability to distribute albums on her own, she bargains for a higher profit share. When the bargaining surplus is taken to be fixed, the Nash bargaining problem (7) is replaced by the problem

(B1) $$= \max_{\mu \in M} \left((\mu\hat{\pi})^{\gamma} - d_A^{\gamma}\right)^{\alpha} \left((1-\mu)\right)^{1-\alpha},$$

for which the first order condition requires

(B2) $$= \frac{\alpha\gamma}{\mu - \dfrac{d_A^{\gamma}}{\mu^{\gamma-1}\hat{\pi}^{\gamma}}} - \frac{1-\alpha}{1-\gamma} = 0 .$$

In (B1), we have defined the disagreement point as the payoff d_A for which the artist's utility equals d_A^{γ}; this convention is adopted for notational convenience only. When $d_A = 0$, problem (B1) and equation (B2) characterize the solution to the fixed bargaining problem (7).

Differentiation of (B2) with respect to μ and $\bar{d}_A \equiv d_A / \bar{\pi}$ yields

$$\text{(B3)}\quad \frac{\partial \mu}{\partial \bar{d}_A} = -\frac{(1-\alpha)\gamma \bar{d}_A^{\gamma-1}}{\gamma[\alpha(1-\gamma)-1]\mu^{\gamma-1} + \alpha\gamma(\gamma-1)\mu^{\gamma-2}} > 0\,,$$

whereby the artist's profit share responds positively to an increase in the artist's disagreement payoff. As a special case, when $\gamma = 1$, derivative (B3) equals $(1-\alpha)$.

When the profit is considered a function of μ and $d_A > 0$, the Nash bargaining problem (15) becomes

$$\text{(B4)}\quad \max_{\mu \in (0,\bar{\mu})} \left((\mu\pi(\mu))^{\gamma} - d_A^{\gamma}\right)^{\alpha} \left((1-\mu)\pi(\mu)\right)^{1-\alpha}.$$

The first order condition for (B4) is

$$\text{(B5)}\quad \frac{\alpha\gamma[\pi + \mu\pi']}{\mu\pi - \dfrac{d_A^{\gamma}}{\mu^{\gamma-1}\pi^{\gamma-1}}} - \frac{1-\alpha}{1-\mu} + (1-\alpha)\frac{\pi'(\mu)}{\pi(\mu)} = 0\,.$$

When $d_A = 0$, (B5) coincides with (16). As d_A becomes positive, however, the first (positive) term in (B5) increases (compared to condition (16)); thus, the μ solution to problem (B4) is larger than the solution to (16).

Appendix C – Partial Derivatives for Table 1

This appendix provides the partial derivatives used for Table 1 that were not already listed in another appendix to this paper or in Michel (2003). The notation for the partial derivatives underlying Table 1 are as follows.

	μ	π	μπ
q,t	$\frac{\partial\mu}{\partial q}$ (+)	$\frac{\partial\pi}{\partial q}+\frac{\partial\pi}{\partial\mu}\frac{\partial\mu}{\partial q}$ (+) (+/-)	$\frac{\partial\mu}{\partial q}\left[\pi+\mu\frac{\partial\pi}{\partial\mu}\right]+\mu\frac{\partial\pi}{\partial q}$ (+) (+) (+)
F	$\frac{\partial\mu}{\partial F}$ (-)	$\frac{\partial\pi}{\partial F}+\frac{\partial\pi}{\partial\mu}\frac{\partial\mu}{\partial F}$ (-) (+/-)	$\frac{\partial\mu}{\partial F}\left[\pi+\mu\frac{\partial\pi}{\partial\mu}\right]+\mu\frac{\partial\pi}{\partial F}$ (-) (+) (-)
c	$\frac{\partial\mu}{\partial c}$ (-)	$\frac{\partial\pi}{\partial c}+\frac{\partial\pi}{\partial\mu}\frac{\partial\mu}{\partial c}$ (-) (+/-)	$\frac{\partial\mu}{\partial c}\left[\pi+\mu\frac{\partial\pi}{\partial\mu}\right]+\mu\frac{\partial\pi}{\partial c}$ (-) (+) (-)
α	$\frac{\partial\mu}{\partial\alpha}$ (+)	$\frac{\partial\pi}{\partial\mu}\frac{\partial\mu}{\partial\alpha}$ (-)	$\frac{\partial\mu}{\partial\alpha}\left[\pi+\mu\frac{\partial\pi}{\partial\mu}\right]$ (-) (+)
d_A	$\frac{\partial\mu}{\partial\bar{d}_A}$ (+)	$\frac{\partial\pi}{\partial\mu}\frac{\partial\mu}{\partial d_A}$ (-)	$\frac{\partial\mu}{\partial d_A}\left[\pi+\mu\frac{\partial\pi}{\partial\mu}\right]$ (+) (+)

The symbol (+/-) indicates that the expression cannot be signed without additional information on parameter values. Each partial derivative of profit (π) is evaluated at $F = 0$ (i.e., zero fixed costs) because these partials cannot otherwise be signed without additional information on parameter values. The expression for $\frac{\partial\mu}{\partial\bar{d}_A}$ is listed in Appendix B of this paper, and the partials $\frac{\partial\pi}{\partial q}$, $\frac{\partial\pi}{\partial\mu}$, $\frac{\partial\pi}{\partial F}$ and $\frac{\partial\pi}{\partial c}$ are listed in Appendix E of Michel (2003). The remaining partial derivatives for Table 1 are as follows.

$$\text{(C1)}\quad \frac{\partial\mu}{\partial q}=-\frac{F_q}{F_\mu}=\frac{(1-\alpha(1-\gamma))\frac{c}{3k^2}}{-\alpha\frac{\gamma}{\mu^2}-\frac{(1-\alpha)}{(1-\mu)}+\frac{2c^2-3p^{*2}(1-\mu)^2}{3(1-\mu)^2(p^*(1-\mu)-c)^2}}>0$$

(C2) $$\frac{\partial\mu}{\partial F} = -\frac{F_F}{F_\mu} = \frac{\dfrac{\pi'(\mu^*)}{\pi(\mu^*)}}{-\alpha\dfrac{\gamma}{\mu^2} - \dfrac{(1-\alpha)}{(1-\mu)} + \dfrac{2c^2 - 3p^{*2}(1-\mu)^2}{3(1-\mu)^2(p^*(1-\mu)-c)^2}} < 0$$

(C3) $$\frac{\partial\mu}{\partial c} = -\frac{F_c}{F_\mu} = \frac{\left(\dfrac{2[p^*(1-\mu)-c]}{3(1-\mu)} - (p^*)\right)\left(\dfrac{1}{[p^*(1-\mu)-c]^2}\right)}{-\alpha\dfrac{\gamma}{\mu^2} - \dfrac{(1-\alpha)}{(1-\mu)} + \dfrac{2c^2 - 3p^{*2}(1-\mu)^2}{3(1-\mu)^2(p^*(1-\mu)-c)^2}} < 0$$

(C4) $$\frac{\partial\mu}{\partial\alpha} = -\frac{F_\alpha}{F_\mu} = -\frac{\dfrac{\gamma}{\mu} + \dfrac{1}{(1-\mu)} + (\gamma-1)\dfrac{\pi'(\mu^*)}{\pi(\mu^*)}}{-\alpha\dfrac{\gamma}{\mu^2} - \dfrac{(1-\alpha)}{(1-\mu)} + \dfrac{2c^2 - 3p^{*2}(1-\mu)^2}{3(1-\mu)^2(p^*(1-\mu)-c)^2}} > 0$$

Expressions (C1) through (C4) are calculated by applying the implicit function theorem to the first order condition (16), derived when the label and the artist bargain over a variable profit. For (C1), we have $-\frac{F_q}{F_\mu} = -\frac{(1-\alpha(1-\gamma))^* \dfrac{\partial\left(\dfrac{\pi'(\mu^*)}{\pi(\mu^*)}\right)}{\partial q}}{F_\mu}$, where the ratio of the derivative of profit to profit (i.e., $\frac{\pi'(\mu^*)}{\pi(\mu^*)}$) is equivalent to –$p^*/k$, with $k = p^*(\mu)(1-\mu) - c$. (See Michel (2003), Appendix E) As such, the derivative of this ratio with respect to q in the numerator (F_q) of (C1) simplifies to the expression $\frac{c}{3k^2} > 0$. Next, for the denominator in (C1) (as well as in

(C2) (C3) and (C4)) we have $F_\mu = -\alpha \frac{\gamma}{\mu^2} - \frac{(1-\alpha)}{(1-\mu)} + \frac{\partial\left(\frac{-p^*}{k}\right)}{\partial \mu}$ < 0, an expression that

simplifies to $-\alpha \frac{\gamma}{\mu^2} - \frac{(1-\alpha)}{(1-\mu)} + \frac{2c^2 - 3p^{*2}(1-\mu)^2}{3(1-\mu)^2(p^*(1-\mu)-c)^2}$.

That F_μ is negative depends on the sign of the third term in this expression, and the negativity of this third term can be seen with the following derivation.

$$\frac{2c^2 - 3p^{*2}(1-\mu)^2}{3(1-\mu)^2(p^*(1-\mu)-c)^2} = \frac{3\left[\frac{2}{3}c^2 - p^{*2}(1-\mu)^2 + \frac{c^2}{3} - \frac{c^2}{3}\right]}{3(1-\mu)^2(p^*(1-\mu)-c)^2} = \frac{3\left[(c^2 - p^{*2}(1-\mu)^2) - \frac{c^2}{3}\right]}{3(1-\mu)^2(p^*(1-\mu)-c)^2}$$

$$= \frac{\left[(c - p^*(1-\mu))(c + p^*(1-\mu) - \frac{c^2}{3}\right]}{(1-\mu)^2(p^*(1-\mu)-c)^2} = \frac{-(p^*(1-\mu)-c)(c+p^*(1-\mu)}{(1-\mu)^2(p^*(1-\mu)-c)^2} - \frac{c^2}{3(1-\mu)^2(p^*(1-\mu)-c)^2}$$

$$= \frac{-(c+p^*(1-\mu)}{(1-\mu)^2(p^*(1-\mu)-c)} - \frac{c^2}{3(1-\mu)^2(p^*(1-\mu)-c)^2} < 0$$

Because the F_μ expression is the denominator in (C2), (C3), and (C4) the signs for these expressions can be discerned from their respective numerators. For the numerator in (C2), we have $F_F = (1-\alpha(1-\gamma)) * \frac{\partial\left(\frac{\pi'(\mu^*)}{\pi(\mu^*)}\right)}{\partial F} = \frac{-\pi'(\mu^*)(-1)}{\pi(\mu^*)} = \frac{\pi'(\mu^*)}{\pi(\mu^*)}$ < 0, for the numerator in (C3) we have $\left(\frac{2[p^*(1-\mu)-c]}{3(1-\mu)} - (p^*)\right)\left(\frac{1}{[p^*(1-\mu)-c]^2}\right)$ < 0, and for the numerator in (C4) we have

$F_\alpha = \frac{\gamma}{\mu} + \frac{1}{(1-\mu)} + (\gamma - 1)\frac{\pi'(\mu^*)}{\pi(\mu^*)} > 0$.

Finally, for the multiplier used in the third column of Table 1, we have the following expression.

(C5) $\left[\pi + \mu \frac{\partial \pi}{\partial \mu}\right] > 0.$

That (C5) is positive can be seen by using the terms $\pi = \frac{2k^3}{qt(\mu - 1)}$ and $\frac{\partial \pi}{\partial \mu} = \frac{-2k^2}{qt(1-\mu)^2}$.

Adding these terms results in the expression $\frac{2k^2}{qt(1-\mu)^2}(k - \mu p^*)$, which is positive if

$k - \mu p^* > 0$. Because k is equal to the marginal return to the firm for selling a CD, i.e., $k = p^*(1-\mu) - c$), the inequality ($k - \mu p^* > 0$) requires that the firm's marginal return per CD is larger than the artist's when we take into account the marginal cost c. Based on industry experience, we hold that $k - \mu p^* > 0$.

Appendix D– The Consumer Expenditure Survey

The Consumer Expenditure Survey (CEX) is used by the Bureau of Labor Statistics to compute the Consumer Price Index. The public-use CEX files are the only source of micro-level U.S. consumer expenditure data for a broad variety of goods. Music purchases in the CEX include expenditures on "compact discs, tapes, needles, and records not from a club." In this paper, for all statistics using income data, only households coded as "complete income reporters" are used, a designation that indicates at least one major income earner for the household was interviewed. The CEX sample methodology is known as a stratified random sample (or a complex sample), whereby the U.S. population is divided into strata and then random samples are drawn from each strata.

To control for survey design characteristics, we use the CEX-supplied full-sample and replicate weights. The full-sample weights are used in weighted least squares regressions to correct for heteroscedasticity and to ensure that estimates are representative of the U.S. population. The replicate weights are employed to ensure that estimators are unbiased and test statistics are valid because variances within strata tend to be more homogenous than those found in a simple random sample. Brogan (1998) and Landis, Lepkowski, Eklund, and Stehouwer (1982) have shown that ignoring the weighting and sample design schemes of complex survey data can lead to biased and inefficient estimators, as well as invalid statistical inferences (see also Sharon L. Lohr (1999)). For the summary statistics on Tables 2 and 5, because both positive and negative mean expenditure and income changes are present, and since a standard software package cannot be used to compute the significance tests, two-tailed tests are constructed for all changes rather than individual one-tailed tests.