# Should the Music Industry Sue Its Own Customers? Impacts of Music Piracy and Policy Suggestions

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**Abstract**

Two beliefs about music piracy prevail in the music industry. First, music piracy hurts music record sales. Second, the only copyright regime that can help the music industry is one that will eradicate music piracy. To test the two beliefs, I construct a unique survey data set, estimate the demand for music and iPods and show three things. First, music piracy does hurt record sales. Second, music piracy contributes 20% to iPod sales. Finally, counterfactuals experiments show that while a regime without music piracy benefits music producers at the expense of students and Apple, another regime with legal online music and iPod royalty benefits most students and music producers at the expense of Apple.

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# 1 Introduction

The belief that music piracy hurts record sales prevails in the music industry.[1] In 1999, record sales started to decline after a steady growth for more than a decade. In the very same year, Napster, the first ever Peer-to-Peer (P2P) software used by people to pirate music, started to operate. Music industry representatives, including the Recording Industry Association of America (RIAA) and the International Federation of the Phonographic Industry (IFPI), believe and argue that this is not a coincidence. At the same time, some economists combine data of illegal downloading from different sources with data on album sales and find that music piracy hurts record sales.[2] Oberholzer-Gee and Strumpf (2007) disagree, however. They argue that music piracy "allows users to learn about music they would not otherwise be exposed to" and thus may boost record sales. They construct a unique data set using weekly volumes of illegal downloads and show that the effect of music piracy on record sales " is not statistically distinguishable from zero. The economic effect of the point estimate is also small." These contradicting findings cast doubt on the belief. Whether music piracy hurts record sales is still an open empirical question.

In this paper I answer this question with a different approach by constructing a unique survey data set (Section 4). My results contrast with what Oberholzer-Gee and Strumpf (2007) claim and support this belief in the music industry (Section 5).

This first belief that music piracy hurts record sales leads to a second in the music industry: The only copyright regime that can help the music industry is one that will eradicate music piracy. The music industry claims that not only does the eradication of music piracy help the industry, it also benefits society. IFPI claims on its web site that "copyright has underpinned an extraordinary modern economic success story... The dramatic growth of the artistic, cultural and other creative industries... would have been impossible without the strong levels of copyright protection." However, some economists do not agree that eradicating music piracy necessarily benefits society, nor is it the only regime that can help the music industry. Nordhaus (1969) argues that there is a trade-off for enforcing copyrights (or eradicating music piracy):

[1] I use music piracy and illegal downloading interchangeably in this paper.

[2] See Blackburn (2004), Liebowitz (2006), Peitz and Waelbroeck (2004), Rob and Waldfogel (2006) and Zentner (2006).

Weak copyrights lead to under-provision. Strong copyrights create monopoly distortions. Kremer (1998) proposes a regime in which the government buys copyrights of music records (to provide incentives to create music) and legalizes music piracy (to minimize monopoly distortions). Boldrin and Levine (2008) propose a regime that abolishes the current copyright system and legalizes music piracy. They argue that the revenue generated between first legal release and first pirated release provides enough incentives for music producers to create music. Netanel (2003) and Fisher (2004) also propose a regime that legalizes music piracy, with a government-financed fund to compensate music producers according to download rates of their records. The government then finances the fund by collecting royalties from producers whose products benefit from the legalization of music piracy. Proposals of copyright regime abound. Yet, no one has done any convincing empirical research that supports one particular regime. The validity of the second belief about music piracy still requires serious empirical research.

To the best of my knowledge, this is the first paper that quantitatively tests the validity of the second belief by evaluating the impacts of different copyright regimes. In this paper, in addition to the Current Regime which mimics the current copyright system, I also evaluate the impact of two other regimes (Section 3). The first of these is the No Music Piracy Regime in which the government eradicates music piracy. The second of these is the Free Music-Royalty Regime proposed by Netanel (2003) and Fisher (2004), with Apple (a dominant brand of MP3 players) paying the royalties. Although music piracy hurts record sales, it boosts sales of MP3 players. The sales of iPod, which is the dominant brand in the MP3 players market, arguably benefit the most from music piracy. Sabbagh (2008) reports that "[T]eenagers and students have an average of more than 800 illegally copied songs each on their digital music players," with a high proportion of those digital music players being iPods. Apple has experienced an exponential growth in the sales and revenue of iPods since their introduction in 2001. Revenue from iPods grew from $344 million in 2003 to $7.6 billion in 2006, according to revenue data from Apple Inc. If increased profits from the boosted sales of iPods exceed the loss from declining record sales, it is possible to legalize music piracy, set up a royalty system mentioned above, and make everyone better off. The implementation of the Free Music-Royalty Regime brings about two effects on society: On the one hand, if royalties provide enough incentive for music producers to create music, this eliminates the wedge between price and marginal cost and creates surplus

gain in the music market. On the other hand, the royalty burden placed on Apple creates a distortion and surplus loss in the iPod market. Whether the surplus gain in the music market outweighs the surplus loss in the iPod market is an empirical question. In this paper I try to give an answer. Results of counterfactuals (Section 7) indicate that while the No Music Piracy Regime benefits music producers at the expense of students and Apple, the Free Music-Royalty Regime benefits most students and music producers at the expense of Apple. The total surplus also increases in the Free Music-Royalty Regime. In other words, under the Free Music-Royalty Regime, the surplus gain in the music market outweighs the surplus loss in the iPod market.

I construct a unique conjoint survey data set (Section 4) from 884 undergraduates at the University of Minnesota for my empirical analysis. In the survey, students answer two main types of questions. First, they report their demographic information and their recent consumption of both music and iPods. Second, in the conjoint survey, they make hypothetical choices on music (from both legal and illegal sources) and iPods in twelve hypothetical tasks. Green and Rao (1971) first introduce conjoint survey analysis as a way to elicit demand estimates. Conjoint survey data are also known as stated-preference data, as opposed to revealed-preference data collected from real world observations. There are two main advantages to using conjoint survey data, instead of real market data, in this research. First, this is possibly the only way to create a panel data set on the consumption of legal music, iPods, and music piracy. As I argue before, it is important to know the impact of any copyright regime changes in the music industry on other related products like iPods. This requires a clean panel data set on both the consumption of music (from both legal and illegal sources) and iPods. Second, in this conjoint survey, I can use instruments for illegal downloads that are not available in other works for reasons discussed in Section 4.2.

Several studies argue that conjoint survey data can generate reliable demand estimates.[3] Applications of conjoint survey analysis abound. Hensher and Louviere (1983) forecast the choice of attendance at various types of international expositions. Hensher (1994) reviews the development of using conjoint analysis to estimate transportation choice. Many multinational corporations like Marriott, Procter & Gamble (P&G) and General Motors also use conjoint

[3]Carlsson and Martinsson (2001) and Hensher, Louviere, and Swait (1999) collect both stated-preference data and revealed-preference data of donation choice and freight shipper choice. They show that the hypothesis of parameter equality holds for most parameters across the two data sources.

survey data to estimate demand for new products (Green, Krieger, and Wind (2004) and Orme (2005)).

My empirical analysis consists of three parts. First, I set up a demand system of three types of music: CDs, legally-purchased iTunes songs, and pirated songs from P2P web sites (Section 5). I estimate this system of three simultaneous equations using the three-stage least-squares method. Results suggest that music piracy hurts record sales. Second, I use the estimates from the first part to set up a random-coefficient discrete demand model for iPods (Section 6). I follow Rossi, Allenby, and McCulloch (2005) to set up a hierarchical Bayesian discrete demand model for iPods, with a mixture of normal priors, and then use a hybrid of Gibbs Sampling and Metropolis-Hasting algorithm to implement posterior inference. Estimates indicate that music piracy boosts demand and sales of iPods. Third, I use the estimates from the first and second part to conduct counterfactuals to evaluate the welfare effect of different regimes (Section 7). Results show that the second belief in the music industry is wrong under reasonable music prices: An alternative copyright regime, the Free Music-Royalty Regime, can make music producers and most students better off, at the expense of Apple.

The organization of the article is as follows: Section 2 briefly describes the current situation of growing music piracy and declining record sales. Section 3 summarizes three different copyright regimes that people propose. Section 4 discusses the conjoint survey data set. Sections 5 and 6 set up the demand for music and the demand for iPods, and discuss results of the estimation. Section 7 conducts counterfactual experiments using results from Sections 5 and 6. Section 8 concludes.

# 2 Music Piracy Growing, Record Sales Shrinking

## 2.1 Music Piracy is Growing

P2P technology enhances the speed of pirating music and triggers the growth of music piracy. In 1999, the first P2P software, Napster, began to operate, and the number of music pirates has been growing ever since.

People pirate music on the Internet because the cost of doing so is low. If the cost is even

lower, more people would pirate music. Recent advancement in Internet connection speeds has reduced the time cost of pirating music over the Internet, which has led to the growth in music piracy. The marketing research firm Big Champagne finds that there is an increasing trend of people searching, clicking, and pirating music—the average simultaneous users of P2P software in the U.S. increased from 3.5 million in August 2002 to more than 6 million in October 2006 (figure 1).[4] This growing number of music pirates translates into a huge number of pirated songs. IFPI estimates that "almost 20 billion songs were illegally downloaded in 2005."

## 2.2 Record Sales are Shrinking

Music is important to Americans. The average American enjoys almost an hour of music per day.[5] Before Napster, a major source of this enjoyment was music records. Record sales almost quadrupled between 1990 and 1999. The 1990s were a heyday for the music industry. However, once Napster appeared on the scene in 1999, record sales have declined by $3.6 billion (figure 2).

The music industry believes that music piracy hurts record sales; actions taken by music industry representatives reveal this belief. In 1999, the RIAA sued Napster. Ultimately, this lawsuit led to the shutdown of Napster in 2001. In addition, between 2003 and 2005, the RIAA sued approximately 11,700 individual pirates, despite the reputation cost of suing its own customers.[6]

Various economists create their own data sets on illegal downloads to estimate the effect of music piracy on record sales. Rob and Waldfogel (2006) conduct a survey in universities to collect a panel data set on both illegal downloads and album consumption. Oberholzer-Gee and Strumpf (2007) and Blackburn (2004) collect panel data sets on music piracy by tracking individual illegal downloading behavior on P2P software. They all supplement their data with aggregate record sales data either from the RIAA or from Neilsen Soundscan.

Both Oberholzer-Gee and Strumpf (2007) and Rob and Waldfogel (2006) run a regression in

[4]There was a wave of lawsuits against individual pirates in 2003, which caused the decline in the number of P2P users at that time. This motivates me to put the expected punishment as part of the covariates in the conjoint survey in Section 4.

[5]See Table No.909 "Media Usage and Consumer Spending: 1993 to 2003" in the 2000 U.S. Statistical Abstract.

[6]See AssociatedPress (2005).

this form to see the displacement effect of illegal downloads on album sales:

$$A_{jt} = X_{jt}\beta + \alpha D_{jt} + \epsilon_{jt} \tag{1}$$

where $A_{jt}$ is the sales of album $j$ at time $t$, $D_{jt}$ is the number of illegal downloads, $X_{jt}$ are other covariates. $D_{jt}$ may be endogenous. Popular albums usually attract more downloads. In this case $D_{jt}$ is positively correlated with $\epsilon_{jt}$, and the estimate of $\alpha$ would have an upward bias. They deal with this problem by finding instruments for illegal downloads that are not themselves related to album sales and thus not correlated with $\epsilon_{jt}$. Oberholzer-Gee and Strumpf (2007) use the number of German students on vacation as an instrument for illegal downloads under the premise that high school German students spend more time on pirating music during their holidays. [7] Rob and Waldfogel (2006) use the speed of students' Internet connection as an instrument under the assumption that students do not choose Internet speed based on their music preference.

Rob and Waldfogel (2006) and Blackburn (2004) find that music piracy hurts record sales. Rob and Waldfogel (2006) find that "one (illegally) downloaded album reduces music purchases of roughly one-fifth of an album." Blackburn (2004) estimates in his counterfactuals that "the lawsuits brought by the RIAA have resulted in an increase in album sales of approximately 2.9% during the 23 week period after the lawsuit strategy was publicly announced."

Oberholzer-Gee and Strumpf (2007), however, argue that the effect of music piracy on record sales "is not statistically distinguishable from zero. The economic effect of the point estimate is also small." They argue that there could be other more important factors leading to the decline of record sales. First, there might be a shift in entertainment spending from music records toward recorded movies. Second, people might have replaced their old LPs with CDs in the mid-1990s, which boosted record sales then, but by 1999, which was, coincidentally, the year Napster began to operate, people had finished their replacement process. Third, the emergence of digital (online) music stores, like iTunes, provide an even closer substitute to CDs. Table 1 shows that the number of legal downloads of both single tracks and albums increased by

[7] Liebowitz (2007) points out that Oberholzer-Gee and Strumpf (2007) make a contradictory claim in their quasi-experiment that illegal downloading decreases in the summer because American college students lose their broadband connections during their vacation. Since both countries have both high school and college students, we should not expect school holidays to have any clear theoretical impact on illegal downloading.

more than 50% per year from 2004 to 2006. On top of these other factors, Oberholzer-Gee and Strumpf (2007) argue that music piracy may in fact boost record sales since it allows consumers to learn about music they would not otherwise be exposed to.

These conflicting findings lead to my first question: Does music piracy hurt record sales? And, if so, by how much? I use a different approach to answer the question. Section 4 describes the conjoint survey data set and compares the pros and cons of this data set with data sets used by others.

# 3 Possible Copyright Regimes

Results in Section 5 suggest that music piracy hurts record sales. This has two counteracting effects on society. On the one hand, music piracy minimizes monopoly distortion in the music market since P2P technology reduces the marginal cost of distributing music to virtually zero. In the short run, taking the music supply as given, people are able to pirate and enjoy more music using P2P software like Napster. Society benefits from music piracy. On the other hand, music piracy hurts record sales, reduces income to music producers, and stifles their incentive to create new music. In the long run, music producers create less music, and people have less music to enjoy. Society may suffer from music piracy.

This leads to my second question in this paper: Is there a copyright regime that can both maximize people's enjoyment of music and provide music producers enough incentive to create music?

Proposals of copyright regime abound; I classify them into three copyright regimes.[8]

## 3.1 Current Regime

In the Current Regime, the RIAA uses the No Electronic Theft Act to occasionally file lawsuits against P2P software companies and individual pirates. In the first decade of this century, two of the biggest P2P software companies, Napster and Kazaa, were sued and later forced to shut down. Between September 2003 and June 2005, 11,700 music pirates were sued.[9] This wave of

[8]Section 7 gives a more detailed description of the three regimes.

[9]See AssociatedPress (2005).

lawsuits, however, turned out to be one-shot; after a slight decrease immediately following the rulings, the number of music pirates continued to grow (figure 1).

## 3.2 No Music Piracy Regime

In the No Music Piracy Regime, the government increases the expected punishment of piracy in order to eradicate music piracy. This provides music producers enough income and incentive to create music. Eradicating music piracy is difficult, yet possible if Internet Service Providers co-operates. Currently there are proposals in France and Britain urging Internet Service Providers to voluntarily band together and crack down on pirate subscribers.

## 3.3 Free Music-Royalty Regime

While the music industry loses income from declining record sales, many complements of music, including MP3 players, have experienced growth in sales and revenue in the era of music piracy. Apple, the producer of iPods which is the dominant brand in the MP3 market, is no exception. According to the revenue data from Apple Inc, revenue of iPods grew from $344 million in 2003 to $7.6 billion in 2006 (figure 2).

The Free Music-Royalty Regime replicates the regime proposed by Fisher (2004) and Netanel (2003). In this regime, music piracy is legal, and Apple pays royalties to the music industry for the boosted iPod sales.[10] The implementation of the Free Music-Royalty Regime brings about two effects on society: On the one hand, if royalties provide enough incentive for music producers to create music, this eliminates the wedge between price and marginal cost and creates a surplus gain in the music market. On the other hand, the royalty burden placed on Apple creates a distortion and surplus loss in the iPod market.

All three regimes have advocates. However, to the best of my knowledge, no one has put forth a convincing empirical analysis to evaluate these copyright regimes. My contribution to the literature is twofold. First, I use a unique data set to quantitatively estimate the complementary relationship between music and iPods. Second, I quantitatively evaluate and compare the surpluses felt by different social groups under the three regimes.

[10]Without legalizing music piracy, the Japanese government recently proposed a plan to charge copyright royalties on sales of iPods. See `http://search.japantimes.co.jp/cgi-bin/nb20080507a1.html`.

# 4 Data Collection and Description

In order to test the two beliefs about music piracy, I needed a panel data set on the consumption of music (from both legal and illegal sources) and iPods. I collected survey data from college students. College students have lower income and more exposure to the Internet compared to other age groups; as a result, they tend to download or pirate more music than other age groups (table 2).

## 4.1 Conjoint Survey

I conducted a survey in Fall 2007 and Spring 2008 in seven undergraduate classes, which allowed for approximately 1800 possible responses. Of these, 884 students turned in their surveys.

I focus on one dominant brand of MP3 player—iPod (Apple)—in this survey because Apple dominates the MP3 market (table 3). Sandisk, the closest competitor of Apple, only sells one eighth of what Apple does.[11]

The whole survey consists of three parts. In the first part, students report information about their demographic, Internet access and iPod consumption.

In the second part, students report their recent music consumption from three different sources: CDs, iTunes and P2P web sites. Consumption from these three sources affect the income of music producers: CD revenue is the major source of record sales revenue; iTunes royalties are becoming more important to record companies as table 1 suggests; people pirate music through P2P web sites.

The third part is the conjoint survey. Green and Rao (1971) first introduce conjoint analysis in marketing. I follow the approach of Louviere and Woodworth (1983) to use choice-based conjoint, which integrates conjoint analysis with discrete choice analysis. Questions in conjoint surveys are not descriptive, like "How much would you be willing to pay for an iPod?" Instead, they ask students to make concrete choices, like "Given brand A, B, and C with different attributes and prices, which one would you buy?" Conjoint survey data are also known as "stated-preference" data, as opposed to "revealed-preference" data, which is collected from real

[11] Respondents showed a predominant preference over iPods in a try-run of the survey which included other brands of MP3 players.

market transactions.

There are twelve hypothetical tasks in this conjoint survey. In each task, respondents are given the option of listening to music on an iPod, a computer or a radio (which I treat as an outside choice). Choices differ in the level of each of the six choice-specific covariates:

- Price of an iPod (varies from \$30 to \$650)
- Capacity of an iPod (varies from 1 gigabyte to 8 gigabytes)
- Probability of getting caught pirating music (varies from 0 to 1)
- Fine payment per song if caught pirating music (varies from \$0 to \$10,000)
- Price per song in iTunes (varies from \$0.1 to \$3)
- Price per CD (varies from \$1 to \$30)

There are five to ten levels for each covariate within the pre-specified range.

I follow the three principles proposed by SawtoothSoftware (2008) to draw levels of each covariate. The three principles are

1. **Minimal Overlap**: Each covariate level is shown as few times as possible in a single task.
2. **Level Balance**: Each level of a covariate is shown approximately an equal number of times.
3. **Orthogonality**: Covariate levels are chosen independently of other attribute levels, so that each covariate level's effect on utility may be measured independently of all other effects.

A student finishes two sub-tasks in each of the twelve tasks. In the first sub-task, the student is asked to imagine that he does not have an iPod and then ranks the three choices in the task. Figure 3 shows a sample of the first sub-task.

Before ranking the choices, a student would know roughly his music consumption under each choice. For instance, the students who ranked an iPod as their top choice were also the students who estimated that they would buy or pirate a considerable amount of music. In the second

sub-task, I assign the student with one of two choices—iPod or computer. The assignment may or may not be the student's first choice in the first sub-task. Given the assigned choice and associated music prices, he is asked how he would change his music consumption from the previous month and then estimate his music consumption from the three sources (CD, iTunes and P2P web sites). Figure 4 shows a sample of the second sub-task. I put this second sub-task in the conjoint survey of two of the seven classes. Once the surveys were completed, 270 students had answered this part.

## 4.2 Conjoint Survey Data vs Real Market Data

This section lists the advantages and disadvantages of using conjoint survey compared to using real market transaction data to estimate demand for music and iPods.

People have concerns regarding the validity of conjoint survey data. Some think that real market data is more reliable since it is revealed-preference data. However, ever since Green and Rao (1971) introduced conjoint survey analysis in marketing, it has been widely adopted in the marketing literature to elicit demand estimates. Applications of conjoint survey analysis abound. Hensher and Louviere (1983) use it to forecast the choice of attendance at various types of international expositions. Hensher (1994) reviews the development of using conjoint analysis to estimate transportation choice. Many multinational corporations like Marriott, Procter & Gamble (P&G) and General Motors also use conjoint survey data to estimate demand for their new products (Green, Krieger, and Wind (2004) and Orme (2005)). Several studies argue that conjoint survey data can generate reliable demand estimates. Carlsson and Martinsson (2001) and Hensher, Louviere, and Swait (1999) collect both stated-preference data and revealed-preference data of donation choice and freight shipper choice. They show that the hypothesis of parameter equality holds for most parameters across the two data sources.

There are several advantages to using conjoint survey data, instead of real market data, in this research. First, conjoint survey is possibly the only way to create a panel data set on the consumption of legal music, iPod, and music piracy. Oberholzer-Gee and Strumpf (2007) and Blackburn (2004) gather panel data sets on music piracy by tracking individual illegal downloading behavior on a P2P network. They then combine weekly album sales with their novel data on weekly volumes of downloads to estimate the effect of illegal downloads on album

sales. Rob and Waldfogel (2006) conduct surveys in colleges to create a panel data set on legal music consumption and illegal downloading behavior. They use their data set to estimate the same effect. However, as I argue before, it is important to know the impact of any copyright regime changes in the music industry on other related products like iPods. This requires a clean panel data set on both the consumption of music (both legal and illegal) and iPods. To the best of my knowledge, this paper is the first paper that constructs such a panel data set using conjoint survey.

Second, conjoint survey analysis provides good instruments. As discussed in Section 2, both Oberholzer-Gee and Strumpf (2007) and Rob and Waldfogel (2006) use an instrumental variable approach to deal with endogeneity in (1). In this paper I use expected probability of getting caught and possible fine amounts as the instruments for illegal downloads. Each affects illegal downloads, but neither has a direct effect on legal music consumption.[12] While they can serve as instruments in this paper, they do not work in other cases for two reasons. First, there is a larger variation in expected punishment in this conjoint survey than in the real world. In a conjoint survey, the designer can vary the prices of different choices within a pre-specified range. For instance, I vary the fine payment per song from \$0 to \$10,000 whereas the fine payment per song is usually \$10 to \$50. Basic econometrics tells us that larger variation in independent variables (expected probability of getting caught and possible fine payments) provide more information about its impact on the dependent variable (illegal downloads). The second reason is that the levels of these two covariates are drawn exogenously and independently due to the orthogonality principle described in previous subsection. Thus they do not correlate with $\epsilon_{jt}$ in equation (1) and can serve as instruments for illegal downloads.

## 4.3 Data Description

Completed surveys were returned by 884 students. Most of them were typical college freshmen: They do not have a high income. In fact, around 90% of them have a weekly income less than \$200. Also, they like surfing on the Internet, an average of three or four hours per day.

Table 4 shows that the respondents have a huge interest in listening to music. On average,

[12] I also use the price of an iTunes song, the price of a CD, and the price of an iPod as instruments for their corresponding demands.

each student owns 2508 songs on his computer. They buy music, and they pirate it. According to their answers, 59.8% of them have bought music, and 61% of them have pirated music. Students, on average, buy one CD every other month and four to five songs each month from online music stores like iTunes. However, they pirate even more music—70 songs per month. Among the students who have pirated music recently, they pirate roughly 153 songs per month. Bhattacharjee, Gopal, Lertwachara, and Marsden (2006) track 2056 pirates on Kazaa, another P2P software, in 2003 and find similar numbers (table 5).

More than 70% of the students own an iPod.[13] It is not surprising that students who own more music are more likely to own an iPod. If I define music lovers as students who own more than 1000 songs on their computers and non-music lovers as otherwise, 80% of music lovers own an iPod whereas only 60% of non-music lovers do.

Table 6 shows that in the first sub-task of the conjoint survey, iPods are the most popular choice among the three choices, and computers come second.

Students pick iPods as their first choice almost half of the time. Not only do they show preference for iPods, they also prefer lower prices. Table 7 shows that when prices of iPods or prices of music decrease they tend to choose iPods as their first choice more often.

I put the second sub-task in the conjoint survey in two of the seven classes. Of the approximately 700 students, 270 students completed surveys with second sub-tasks. These 270 students have similar characteristics described above with the rest of the 884 students.

# 5 Music Demand

I use data from the second sub-task in the conjoint survey to estimate the demand for music. There are three dependent variables: CDs, iTunes songs and pirated songs from P2P web sites. Independent variables include prices of music from different sources and demographic variables.

Since my first question is whether music piracy hurts record sales, I must figure out the impact of pirated songs on CD and iTunes song consumption. I express the problem as a simultaneous equations problem. In particular, the simultaneous demands for music for agent $i$

[13] Among the students who own an MP3 player, more than 80% of them own an iPod. This justifies my focus on iPods, instead of MP3 players, in this paper.

in task $t$ is

$$\log Y^*_{itp} = \mathbf{z}'_{itp}\gamma_p + \log(Y^*{}_{its})\phi_{ps} + \log(Y^*{}_{itc})\phi_{pc} + u_{itg} \tag{2}$$

$$\log Y^*_{its} = \mathbf{z}'_{its}\gamma_s + \log(Y^*{}_{itp})\phi_{sp} + \log(Y^*{}_{itc})\phi_{sc} + u_{its} \tag{3}$$

$$\log Y^*_{itc} = \mathbf{z}'_{itc}\gamma_c + \log(Y^*{}_{its})\phi_{cs} + \log(Y^*{}_{itp})\phi_{cp} + u_{itc} \tag{4}$$

where the subscripts $p$, $s$ and $c$ denotes P2P (pirated songs), iTunes songs, and CDs. For $g \in \{p, s, c\}$ $Y^*_g = Y_g + 1$, where $Y_g$ is the consumption of $g$. $\mathbf{z}_g$ a vector of exogenous regressors, including prices, uncorrelated with $u_g$. $u_{itg}$ are i.i.d. over $i$ and $t$, homoskedastic but are correlated across $g$. Table 8 shows all the $\mathbf{z}$.

Every dependent variable has its own instruments. For instance, the probability of getting caught pirating music ($\pi$) instruments for the demand for pirated music from P2P web sites; the price per song in iTunes instruments for the demand for iTunes song; and the price per CD instruments for the demand for CD. I use the three-stage least-square method to estimate this simultaneous equations system. Table 9 shows the results.

Students pirate more music and buy more iTunes songs when they have an iPod. In the last row of table 10, when students cannot own an iPod, compared to the current world in which 72% of them own an iPod, they pirate 22.85% less music from P2P web sites, consume 8.81% fewer songs from iTunes but consume 0.73% more CDs.

The law of demand holds. The demand for music drops when prices increase. But since it is a simultaneous equations system, the coefficients of price do not fully reflect the impact of price changes on all three demands equations. Table 10 reports the percentage change of demand for music when different prices change.

The probability of getting caught and the fine payment are significant components of the price (or punishment) of pirating music. Students pirate less music when punishment is more severe. When the probability of getting caught increase 100% from 0.01% to 0.02%, students pirate 2.83% less music from P2P web sites, consume 0.20% more songs from iTunes and 0.10% more from CDs. When fine punishment per song increases 100% from \$100 to \$200, students pirate 13.76% less music from P2P web sites, consume 1.03% more songs from iTunes and 0.54% more from CDs.

Students buy fewer iTunes songs when iTunes songs are more expensive. When the price per song in iTunes increases 10% from \$0.99 to \$1.09, students buy 8.73% fewer songs from iTunes. They also pirate 3.05% more music from P2P web sites and consume 0.73% more from CDs.

Student buy less CDs when CDs are more expensive. When the CD price increases 10% from \$15 to \$16.5, students buy 2.51% fewer CDs. They also pirate more or less the same amount of music but buy 0.22% more songs from iTunes.

My estimates are consistent with Shiller and Waldfogel (2008), who estimate the demand for iTunes songs using survey-based data collected from 500 students. They find that when the price per iTunes song increases from \$0.99 to \$1.87, demand drops from 7434 to 4351, a 42% decrease. I find similar price effect on demand for iTunes songs using the estimates from table 8. When price per iTunes song increases from \$0.99 to \$1.87, demand for iTunes songs drops 49%, which is reasonably close to the 42% in Shiller and Waldfogel (2008). At the same time, I can also find this price effect on the demands for other types of music. Students pirate 25% more music and buy 6% more CDs in this case.

Note that record sales from different sources are substitutes to each other. On the one hand, when students buy 10% more CDs, demand for iTunes songs decreases 0.9%. On the other hand, demand for CDs decreases 0.9% when consumption of iTunes songs increases 10%. The emergence of online music stores like iTunes plays a part in the decline of record sales revenue from CDs.

Finally, music piracy does hurt record sales.[14] When students pirate 10% more music through P2P web sites, they buy 0.7% fewer iTunes songs and 0.4% fewer CDs. This result is both economically and statistically significant contrary to what Oberholzer-Gee and Strumpf (2007) claim. The result corroborates what other economists claim. Using the Rob and Waldfogel (2006) result, people buy 1.3% fewer records (including iTunes songs and CDs) when they pirate 10% more music. Blackburn (2004) suggests a higher number: people buy 1.8% fewer records when they pirate 10% more music.

[14]Table 10 reports the piracy elasticity of sales. Oberholzer-Gee and Strumpf (2007) and Rob and Waldfogel (2006) only report estimates of the displacement effect of illegal downloads (P2P) on album sales. I combine those estimates with their sample statistics on album consumption and illegal downloads to calculate the elasticities.

# 6 A Discrete Choice Demand for iPod

Results in Section 5 suggest that music piracy hurts record sales. Before quantifying the welfare implications of the three copyright regimes, I need to quantify the complementary relationships between music and iPods. This is the purpose of this section.

## 6.1 Estimation with Homogenous Coefficients

In each of the twelve first sub-tasks in the conjoint survey, students rank among the three choices of listening to music: iPod, computer, and radio (which I treat as an outside good). The rankings serve as the students' choices, and are thus the dependent variables in the demand estimation.

Students would know roughly their music consumption before buying an iPod. The average lifetime of an iPod is two years. They buy an iPod if they think they would buy or pirate a considerable amount of music throughout those two years. I thus put the estimated demands for music from the last section into the indirect utility of a choice to account for how music complements the choice.[15] I also include other covariates like prices of the choice and demographic variables in the indirect utility of the choice. The indirect utility of a choice $j$ for student $i$ in task $t$ is

$$U_{ijt} = \beta_0^j + \sum_{l=1}^{L} \beta_{jl} z_{il} + \alpha_1 P_{jt} + \alpha_2 GB_{jt} + \alpha_3 P2\hat{P}_{ijt} + \alpha_4 iT\hat{une}s_{ijt} + \alpha_5 C\hat{D}_{ijt} + \epsilon_{ijt} \qquad (5)$$

where $z_{il}$ is the $l$th demographic variable of student $i$, $P_j$ is the price of choice $j$, and $\epsilon_{ijt}$ is the usual i.i.d. logit error.

Table 12 and 13 show the results from standard mixed logit estimation.

The law of demand holds for the demand for iPods. The indirect utility decreases 0.22 when the price of iPod increases $100. The demand for iPods is inelastic with an own price elasticity at -0.22. The demand for iPods decreases 0.20% when the price of an iPod increases 1% from

[15] I have not corrected the standard errors in the second stage estimation of the discrete demand. In other words, I treat the estimated demands for music as true demands. However, the small standard errors in table 10 and 13 suggests that my conclusion should stay the same regardless of whether I correct the standard errors or not.

$200 to $202. This inelastic demand implies that the marginal cost of an iPod is negative. In the next subsection I introduce random coefficients to overcome this problem.

The most attractive choice is iPod. The iPod dummy coefficient is the highest among the three choices at 0.22, which translates into $97 using the price coefficient. Suppose a student pirates and buys the average of the estimated songs/CDs, has 1000 songs on his computer and the other two choices (computer and radio) are free. This student would prefer an 8-gigabytes iPod to a computer unless the iPod costs more than $390. An iPod is preferred to a radio unless the iPod costs more than $700.

Music complements iPods. Pirating and consuming songs from different sources increases the indirect utility and the dollar value of an iPod. If a student pirates one song per month for two years (the average lifetime of an iPod), he values an iPod $11 more than if he does not pirate at all. In other words, each pirated song is worth a bit less than $0.5. Similarly, one iTunes song per month for two years increases his valuation of an iPod by $40. One iTunes song is worth $1.7, which is slightly higher than the price of an iTunes song. A student's valuation of an iPod increases $121 if he buys one CD per month for two years ($5 per CD). The incremental value of a CD to an iPod is larger than that of a pirated song or an iTunes song since there are multiple songs on a CD. The increment, however, is not proportional. A CD usually has approximately ten songs, but it only increases the value of an iPod roughly five times of a pirated/iTunes song. This corroborates to the general complaint that there are usually only a few "hit" songs on a CD.

Since music and iPods are complements, more expensive music translates into a decrease in iPod demand. A 100% increase in the probability of getting caught from 0.01% to 0.02% decreases iPod demand by 0.04%. A 1% increase in the fine payment decreases iPod demand by 0.02%. If iTunes raises the price of each iTunes song from $0.99 to $1.1, the demand for iPods decreases 0.08%. If record companies raise prices of CDs from $15 to $16.5, students buy 0.10% fewer iPods.

## 6.2 Estimation with Random Coefficients

As Berry, Levinsohn, and Pakes (1995), Nevo (2000), Petrin (2002) and Rossi, Allenby, and McCulloch (2005) argue, random coefficients models generate better estimates of consumer

demands compared to homogenous coefficient models. In this data set, it is natural to think that students have heterogenous coefficients. For instance, an average student may be more responsive to price changes of an iPod than an iPod lover. This translates into a higher price coefficient (in absolute value) for the average student.

I follow Rossi, Allenby, and McCulloch (2005) by using a hierarchical Bayesian model with a mixture of five components of normal priors to estimate the random coefficients. This approach is more flexible than the classical approach since it does not restrict coefficients to come from a normal distribution. Moreover, this approach allows for correlated coefficients without additional computation time. Grouping the set of parameters and covariates other than price as $\beta$ and $x$, the mixture of normals model specifies the distribution of $\phi_i$ and $\beta_i$ across students as follows:

$$
\begin{aligned}
&U_{ijt} = x'_{ijt}\beta_i - \exp(\phi_i)P_{jt} + +\epsilon_{ijt} \\
&[\beta_i; \phi_i] \sim N(\mu_{ind}, \Sigma_{ind}) \\
&ind \sim \text{multinomial}(\gamma)
\end{aligned}
$$

$\gamma$ is a vector giving the mixture probabilities for each of the five components. The complete specification with priors over the mixture probabilities ($\alpha$), the mean ($\bar{\mu}$ and $a_\mu^{-1}$), and covariance matrices ($v$ and $V$) is:

$$
\begin{aligned}
&\gamma \sim Dirichlet(\alpha) \\
&\mu_k|\Sigma_k \sim N(\bar{\mu}, \Sigma_k \times a_\mu^{-1}) \\
&\Sigma_k \sim IW(v, V) \\
&\{\mu_k, \Sigma_k\} \text{ independent}
\end{aligned}
$$

I follow Rossi, Allenby, and McCulloch (2005) to use a hybrid of Gibbs sampling and Metropolis-Hasting method to implement posterior inference for this model. I use a hybrid Metropolis method that uses customized Metropolis candidate density to draw $[\beta_i, \phi_i]$ for each student. Condition on $[\beta_i, \phi_i]$, I use an unconstrained Gibbs sampler to draw $\mu_k$ and $\Sigma_k$.[16]

[16] One needs to impose constraints on the Gibbs sampler to fix an identification problem called "label switching" if inference is desired for the mixture component parameters. This is not a problem here since I am interested in estimating individual student parameters and their distribution across students only. An unconstrained Gibbs

Table 14 reports the log marginal density for alternative model specifications. The posterior probability of the model is monotone in the log marginal density; thus, higher log marginal density means better fit. Note also that log-marginal density includes an automatic penalty for adding additional parameters (Rossi, Allenby, and McCulloch (2005)). Heterogeneity leads to substantial improvement in fit. In addition to that, a more flexible distribution of parameters fits the data better. Estimates from the five-component mixture model yield a higher log marginal density than that from the one-component model.

Table 15 shows the means and standard errors of the coefficients. Table 16 shows the elasticities estimates.

The law of demand still holds for the demand for iPods. The middle left sub-figure of figure 5 shows the density distribution of the price coefficient, the density of the five-component mixture model has a fatter tail than the density of one-component model. The indirect utility decreases on average 2.12 (0.49 in the one component case) when the price of an iPod increases \$100.

The middle right and the third rows of figure 5 show the density distribution of the P2P coefficient, the iTunes coefficient and the CD coefficient, respectively. Again, the density of five components model has a fatter tail. On average, each pirated song is worth \$0.69 (\$0.95 in the one component case), each iTunes songs is worth \$1.14 (\$2.05), and each CD is worth \$2.41 (\$5.67).

Elasticities of demand for iPods are higher with more flexible demand estimates. The own price elasticity becomes more elastic from -0.202 in the homogenous case, to -0.309 in the one-component model, and to -2.373 in the five-component model. The demand for iPods decreases 2.373% in the five-component model when the price of an iPod increases 1% from \$200 to \$202. The more reasonable own price elasticity in the five-component model comes from the fact that the model allows for more spread-out price coefficient with its higher flexibility. The demand for iPods is also more elastic in response to expected punishment when I estimate the demand more flexibly.

I use the own price elasticity from the five-component model, and the "inverse elasticity

sampler is enough to ensure identification. See Rossi, Allenby, and McCulloch (2005) for more detail.

rule" of optimal pricing, to back out the marginal cost of an 8-gigabyte iPod:

$$\frac{p-c}{p} = \frac{-1}{\xi} \tag{6}$$

where $p$ is price of an 8-gigabyte iPod, which is \$200, $c$ is the marginal cost, and $\xi$ is the own price elasticity. The resulting marginal cost is \$116. Table 17 shows that the material cost of an 8-gigabyte iPod is \$82.85. This suggests that other parts of the marginal cost of an 8-gigabyte iPod including assembling, marketing and transportation cost are approximately \$33.

# 7 Counterfactual

In this section I proceed to evaluate the impact of switching from the Current Regime to two other regimes, using the demand estimates from Section 5 and 6.[17] A switch of regime affects three social groups: students, Apple (the producer of iPods) and music producers (including musicians and record companies). In this section, I evaluate the changes in students' surplus, Apple's profit from iPods and music producers' profit one by one.[18]

Table 18 describes the three regimes.[19] The Current Regime describes the current music world. I mimic the current copyright system of the government and the RIAA with a low probability of getting caught and a small fine for pirating music. An 8-gigabyte iPod costs \$200. Each iTunes song and each CD costs \$0.99 and \$15, respectively.

The government and the RIAA impose a more severe expected punishment on music piracy in the No Music Piracy Regime. A student would be caught for pirating music for sure, and he has to pay \$10,000 for each song he pirates. Apple charges a lower price at \$183.5 as the demand for iPods decreases.

Online music is free, CDs are cheaper and iPods are more expensive in the Free Music-Royalty Regime. Downloading music online is free and legal in this regime. Each CD costs \$5 to cover the marginal cost of producing it (I vary this from \$1 to \$7, and my main conclusion does not change). Apple has to pay a \$150 royalty to the music producers for each iPod sold.

[17] I use the estimates of demand for iPods from the five-component model in the counterfactual.

[18] See Section 7.4 for summary.

[19] I calculate the optimal price per iPod using equation (6) and the marginal cost calculated in the previous section. The marginal cost in the Free Music-Royalty Regime is the original marginal cost plus the royalty.

Apple charges $335.4 for each iPod sold in this regime.

## 7.1 Students' Surplus

Most students do not like the No Music Piracy Regime. An average student loses $204 when the government switches from the Current Regime to the No Music Piracy Regime.

In contrast, most students love the Free Music-Royalty Regime. An average student gains $506 when the government adopts the Free Music Regime. Even though some students are worse off, as they are more sensitive to higher prices of iPods (from $200 to $335.4), most students find it worthwhile to pay $135.4 more for an iPod for free and legal online music. In other words, the gains from enjoying more music outweighs the losses from the distortion in the iPods market.

## 7.2 Apple's Profit

I recover the marginal cost of each iPod to be $116 in the previous section. I then calculate the optimal prices and the corresponding marketing share of iPod under in different regimes.

Table 19 shows the predicted market shares of iPod in the three regimes.

The predicted market share of iPod in the Current Regime is 67.77%, whereas 72% of students in the data set actually own an iPod as shown in table 4. Note that this actual market share of iPod (72%) is not a moment in the estimation. Thus, the fact that the two numbers are reasonably close may suggest that the conjoint survey data set is reliable and the specification in the demand estimation is correct.

The predicted market shares of iPod drop from 67.77% to 52.73% when the government adopts the No Music Piracy regime to eradicate music piracy. To put it differently, music piracy contributes approximately 22% to iPod sales. Apple's profit from the sale of iPods decreases $19/student on average in this regime.

Predicted market shares of iPods decreases from 67.77% to 62.91% when the government switches to the Free Music-Royalty Regime. Even online music is free and the price per CD decreases; the higher price of an iPod due to the $150 royalty burden keeps the demand for iPod from increasing. Apple loses $13.3/student on average in this regime when marginal cost increases by $150.

## 7.3 Music Producers' Profits

I take the supply of music as constant in this exercise since I cannot back out the fixed cost of creating music from my demand estimates. In other words, I consider the profit of those music producers who have created and will not create music like Air Supply and Beatles. People may have concerns over this assumption as they are interested in seeing whether a switch from the Current Regime to the Free Music-Royalty Regime would stifle the music producers' incentive to create music. As I will show later, however, music producers' profits increase in the Free Music-Royalty Regime. The incentive to create is not stifled in the Free Music-Royalty Regime.

I make several assumptions about the profit margins of music producers. First, the marginal cost of each iTunes song is zero; all revenue goes to the music producers as profit.

Second, I make some assumptions about the profit margin of each CD.[20] Figure 6 describes the revenue stream in the music industry. Three main parties gain profit from selling a CD. First, a writer (and a publisher whom he works with to publish his song) receives mechanical royalties of \$0.09 for each song in a CD that is sold. They thus receive \$0.9 for each CD sold. Second, after deducting 25% of the retail price per CD as "packaging cost", a recording artist gets 8%-25% of the deducted retail price per CD as her part of mechanical royalties. If the retail price of Britney Spears's latest CD is \$15, and her mechanical royalty rate is 15%, she would get $\$15 \times 0.75 \times 0.15 = \$1.7$ for each CD sold. Third, I assume record companies earn 7% off the retail price of each CD sold judging from similar operating margins at Warner, the only publicly traded record company. In table 20, I add up the profit margins of the three parties as the combined profit margin of music producers. Note that music producers do not earn anything directly from selling CDs in the Free Music-Royalty Regime as I assume they are selling at marginal cost.

From the Current Regime to the No Music Piracy regime, music producers' profits increase on average \$144/student (\$43 from iTunes and \$101 from CDs) in a two-year period (the life of an iPod).

Without record sales revenue from iTunes and CDs, music producers' sole source of income in the Free Music-Royalty Regime is the \$150/iPod royalties from Apple. It turns out that these royalties are enough to compensate for the loss of record sales revenue. Music producers' profits

[20] I assume there are ten songs on each CD.

increase $42/student in a two-year period. The change of the channel of income keeps the music producers as motivated as they currently are, if not more motivated, to create music in the Free Music-Royalty Regime.

### 7.4 Total Welfare Changes

On average, there is a loss of $79/student if the government switches from the Current Regime to the No Music Piracy Regime. On the other hand, even though switching to the Free Music-Royalty Regime does not benefit every student, there is, on average, a gain of $534/student. While the No Music Piracy Regime benefits music producers at the expense of all students and Apple, the Free Music-Royalty Regime benefits most students and music producers at the expense of Apple. Note in the Free Music-Royalty Regime, the per-student profit change for Apple and music producers combined is positive ($-\$13.26 + \$41.71 = \$28.45$).

## 8 Conclusion

Two beliefs about music piracy prevail in the music industry. First, music piracy hurts music record sales. Second, the only copyright regime that can help the music industry is one that will eradicate music piracy. I test these two prevailing beliefs using a unique conjoint survey data set and find that the first belief is right while the second is wrong. Estimates from the three-stage least-square estimation indicate that music piracy does indeed hurt record sales. This corroborates the first belief of the music industry but is contrary to what Oberholzer-Gee and Strumpf (2007) claim. However, a copyright regime that eradicates music piracy is not the only regime that can help the music industry. In order to support my claim, I first use a Bayesian approach to estimate the demand for iPods and show that music piracy contributes approximately 22% to iPod sales. Then I use the demand estimates to conduct counterfactuals. In the counterfactuals, I evaluate and compare the impact of switching from the Current Regime to two other copyright regimes on three groups: students, Apple and music producers. Results indicate that while the No Music Piracy Regime benefits music producers at the expense of students and Apple, the Free Music-Royalty Regime benefits most students and music producers at the expense of Apple.

In addition to iPods, many other products are also complements of music and would thus benefit in the Free Music-Royalty Regime. Examples include other brands of MP3 players, Internet Providers and live music performances. While I only focus on iPods in this paper, my approach can easily be extended to examine the complementary relationships between music and these other products. This extension can make possible the evaluation of the impacts of different copyright regimes on different products.

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Table 1: US Legal Digital Music Market Growing (millions)

| | 2004 | 2005 | 2006 |
|---|---|---|---|
| Broadband lines | 34 | 43 | 57 |
| Single tracks downloaded | 143 | 353 | 582 |
| Album downloads | 6 | 16 | 33 |
| Mobile subscriptions | 163 | 174 | 194 |

Sources: IFPI "Digital Music Report" 2006 and 2007.

Table 2: Percentage of Adult Population Answering YES to "Do you ever download music files on your computer so you can play them at any time you want?"

| | Aug-Sep 2001 | Oct 2002 | June 2003 | Nov 2003 | May-June 2004 | Feb 2005 |
|---|---|---|---|---|---|---|
| Overall | 15 | 19 | 19 | 9 | 13 | 13 |
| 18-29 | 36 | 41 | 43 | 23 | 31 | 32 |
| 30-49 | 16 | 21 | 20 | 9 | 11 | 13 |
| 50-64 | 6 | 8 | 8 | 4 | 6 | 7 |
| 65+ | 2 | 3 | 1 | 2 | 2 | 1 |
| Men | 19 | 22 | 23 | 12 | 17 | 14 |
| Women | 13 | 16 | 15 | 7 | 9 | 12 |

Source: Pew Internet Project

Table 3: Apple Dominates the MP3 Market

| Brand | Unit Share |
|---|---|
| Apple | 72.7% |
| Sandisk | 8.9% |
| Microsoft | 3.2% |
| Creative Labs | 2.9% |
| Samsung | 2.0% |

Source: NPD Group

Table 4: Summary Statistics of Data

| | Mean (s.d.) | Min | Max |
|---|---|---|---|
| Age | 18.94 (1.87) | 13 | 45 |
| Own an MP3 player | 0.86 (0.35) | 0 | 1 |
| Own an iPod | 0.72 (0.45) | 0 | 1 |
| Songs on the computer | 2508 (4773) | 0 | 75000 |
| CD bought last month | 0.58 (1.61) | 0 | 30 |
| iTunes songs bought last month | 4.53 (14.30) | 0 | 250 |
| Free songs downloaded last month | 69.77 (277.90) | 0 | 4000 |

N=844

Table 5: Songs Pirated/Month by Pirates

| | Mean | Min | Max | N |
|---|---|---|---|---|
| Battacharjee et al | 216 | 1 | 3901 | 2056 |
| Leung | 153 | 1 | 4000 | 884 |

Table 6: Summary Statistics of Conjoint Survey

| Choice | First Choice (%) | Second Choice (%) |
|---|---|---|
| iPod | 46.11% | 28.50% |
| Computer | 36.63% | 37.23% |
| Radio | 17.27% | 34.28% |

N=10608

Table 7: iPod as First Choice Under Extreme Attributes' Levels

| Attribute | Lowest level | Highest level |
|---|---|---|
| iPod price | 56.75% | 42.21% |
| Price per song in iTunes | 74.22% | 42.37% |
| Price per CD | 66.88% | 39.66% |
| Probability of getting caught | 85% | 23.89% |
| Fine per song | 85% | 39.22% |
| GB | 53.04% | 53.51% |

N=10608

Table 8: Exogenous Regressors in the Music Demand

| | |
|---|---|
| $\pi^* = \pi + 0.001$ | probability of getting caught |
| $f^* = f + 1$ | fine per song when caught |
| $P_s^*$ | price per iTunes song |
| $P_c^*$ | price per CD |
| $iPod$ | indicator for iPod |
| $h^* = h + 1$ | hours spent on internet per day |
| $Antivirus$ | indicator for having antivirus software |
| $P2Pfd$ | indicator for having piracy friend |
| $Dorm$ | indicator for living in dorm |
| $Income$ | level of income |
| $Prob$ | perceived probability of getting caught in real world |
| $MusInt$ | level of music interest |
| $P2P^*$ | illegal songs downloaded last month |
| $iTunes^*$ | iTunes songs purchased last month |
| $CD^*$ | CD purchased last month |

Table 9: Music Demand/Month (std. err.)

| | $\log(P2P+1)$ Demand/Month | $\log(iTunes+1)$ Demand/Month | $\log(CD+1)$ Demand/Month |
|---|---|---|---|
| Constant | 0.27 (0.19) | 2.21 (0.07) | 0.93 (0.04) |
| $\log Y_p^*$ | | -0.07 (0.01) | -0.04(0.01) |
| $\log Y_s^*$ | -0.33 (0.03) | | -0.09 (0.01) |
| $\log Y_c^*$ | -0.02 (0.10) | -0.09 (0.06) | |
| $iPod$ | 0.37 (0.06) | 0.14 (0.03) | |
| $\log \pi^*$ | -0.32 (0.01) | | |
| $\log f^*$ | -0.21 (0.01) | | |
| $\log P_s^*$ | | -1.82 (0.04) | |
| $\log P_c^*$ | | | -0.28 (0.01) |
| $Antivirus$ | 0.29 (0.12) | | |
| $\log h^*$ | -0.20 (0.07) | | |
| $P2Pfd$ | 0.06 (0.03) | | |
| $Dorm$ | 0.11 (0.06) | | |
| $Income$ | 0.05 (0.03) | | |
| $Prob$ | 0.05 (0.01) | | |
| $MusInt$ | | 0.02 (0.02) | 0.02 (0.01) |
| $MusInstr$ | | | -0.004 (0.015) |
| $\log P2P^*$ | 0.35 (0.01) | | |
| $\log iTunes^*$ | | 0.23 (0.01) | |
| $\log CD^*$ | | | 0.25 (0.01) |

N=3240

Table 10: Percentage Change of Demand for Music When Price Changes

| | $y_{P2P}$ | $y_{iTunes}$ | $y_{CD}$ |
|---|---|---|---|
| $\pi(0.0001 \rightarrow 0.0002)$ | -2.83% | 0.20% | 0.10% |
| f ($100 $\rightarrow$ 200) | -13.76% | 1.03% | 0.54% |
| $P_s(0.99 \rightarrow 1.09)$ | 3.05% | -8.73% | 0.72% |
| $P_c(15 \rightarrow 16.5)$ | -0.01% | 0.22% | -2.51% |
| To a "no-iPod" world | -20.21% | -7.77% | 1.80% |

Table 11: Piracy Elasticity of Sales (%)

| | |
|---|---|
| Oberholzer-Gee and Strumpf | -0.00001 |
| Rob and Waldfogel | -0.13 |
| Blackburn | -0.18 |
| Leung (CD sales) | -0.04 |
| Leung (iTunes sales) | -0.07 |

Table 12: Discrete Choice Demand Estimation (std. err.)

| Coef. | Homogenous Coef. |
|---|---|
| Dummy | |
| iPod | 0.215 (0.060) |
| 0.001*Songs on PC*1{iPod} | 0.146 (0.014) |
| Computer | -0.215 (0.044) |
| 0.001*Songs on PC*1{Computer} | 0.156 (0.014) |
| Product Attributes | |
| $P_j$ ($100) | -0.223 (0.012) |
| $GB$ | 0.056 (0.008) |
| $\hat{P2P}_{ij}$ | 0.024 (0.001) |
| $\hat{iTunes}_{ij}$ | 0.090 (0.004) |
| $\hat{CD}_{ij}$ | 0.270 (0.034) |

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Table 13: Elasticities of iPod with Homogenous Coef.

| | |
|---|---|
| $P_{iPod}$ | -0.202 |
| $P_{iTunes}$ | -0.008 |
| $P_{cd}$ | -0.010 |
| $\pi$ | -0.0004 |
| $f$ | -0.023 |

Table 14: Heterogeneity Improves Fit

| | Log Marginal Density |
|---|---|
| Homogenous Coef. | -15786.634 |
| 1 Component | -11870.235 |
| 5 Components | -10960.389 |

Table 15: Discrete Choice Demand Estimation (std. err.)

| Coef. | | 1 Component | 5 Components |
|---|---|---|---|
| Dummy | | | |
| iPod | Mean | 1.534 (0.208) | 1.660 (0.230) |
| | Std. dev. | 10.316 (1.360) | |
| 0.001*Songs on PC*1{iPod} | Mean | 0.614 (0.124) | 0.141 (0.219) |
| | Std. dev. | 0.263 (0.131) | |
| Computer | Mean | 0.968 (0.176) | 0.853 (0.054) |
| | Std. dev. | 8.435 (1.005) | |
| 0.001*Songs on PC*1{Computer} | Mean | 0.636 (0.110) | 0.943 (0.064) |
| | Std. dev. | 0.239 (0.096) | |
| Product Attributes | | | |
| $P_j$ ($100) | Mean | -0.492 (0.032) | -2.118 (0.467) |
| | Std. dev. | 0.229 (0.039) | |
| $GB$ | Mean | 0.137 (0.011) | 0.395 (0.036) |
| | Std. dev. | 0.039 (0.006) | |
| $P2P_{ij}$ | Mean | 0.112 (0.003) | 0.353 (0.011) |
| | Std. dev. | 0.011 (0.001) | |
| $iTunes_{ij}$ | Mean | 0.242 (0.009) | 0.581 (0.027) |
| | Std. dev. | 0.040 (0.006) | |
| $CD_{ij}$ | Mean | 0.670 (0.124) | 1.224 (0.097) |
| | Std. dev. | 0.533 (0.153) | |

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Table 16: Higher Elasticities of iPod with More Flexible Estimation

| | Homogenous Coef. | 1 Component | 5 Components |
|---|---|---|---|
| $P_{iPod}$ | -0.202 | -0.309 | -2.373 |
| $P_{iTunes}$ | -0.008 | -0.0006 | -0.0009 |
| $P_{cd}$ | -0.010 | -0.0003 | -0.0002 |
| $\pi$ | -0.0004 | -0.0007 | -0.0012 |
| $f$ | -0.018 | -0.041 | -0.073 |

Table 17: Direct Materials Cost Estimate of The New iPod Nano

| Component | 4GB | 8GB |
|---|---|---|
| Flash memory | $24.00 | $48.00 |
| Display | $10.60 | $10.60 |
| Microprocessor | $8.60 | $8.60 |
| Electro mechanicals | $2.44 | $2.44 |
| SDRAM | $2.72 | $2.72 |
| Mechanicals | $2.33 | $2.33 |
| Misc. components | $2.25 | $2.25 |
| Battery | $1.40 | $1.40 |
| Power management IC | $1.38 | $1.38 |
| Video driver | $0.85 | $0.85 |
| CODEC | $0.90 | $0.90 |
| Touch wheel controller | $0.65 | $0.65 |
| Buck regulators | $0.15 | $0.15 |
| Utility flash memory | $0.59 | $0.59 |
| Subtotal | $58.85 | $82.85 |

Source: iSuppli, September 2007

Table 18: Product Attributes in All Regimes

| Product attributes | Current Regime | No Music Piracy Regime | Free Music-Royalty Regime |
|---|---|---|---|
| Royalty per iPod | \$0 | \$0 | \$150 |
| Price per iPod | \$200 | \$183.5 | \$335.4 |
| Price per iTune song | \$0.99 | \$0.99 | \$0 |
| Price per CD | \$15 | \$15 | \$5 |
| $\pi$ (in %) | 0.01 | 100 | 0 |
| Fine per song | \$30 | \$10,000 | \$0 |

Table 19: Predicted Market Shares of iPod in Different Regimes (in %)

| | |
|---|---|
| Current Regime | 67.77 |
| No Music Piracy Regime | 52.73 |
| Free Music-Royalty Regime | 62.91 |

Table 20: Breakdowns of CD Profit Margins

| | Current Regime ($P_{cd} = \$15$) | No Music Piracy Regime ($P_{cd} = \$15$) | Free Music-Royalty Regime ($P_{cd} = \$0$) |
|---|---|---|---|
| Writer/publisher | \$0.90 | \$0.90 | \$0 |
| Recording artist | \$1.70 | \$1.70 | \$0 |
| Recording company | \$1.05 | \$1.05 | \$0 |
| Total | \$4.05 | \$4.05 | \$0 |

Table 21: Changes of Welfare (Per Student)

| Current Regime to | No Music Piracy Regime | Free Music-Royalty Regime |
|---|---|---|
| $\triangle$ Students' Surplus | -\$204.38 | \$505.58 |
| $\triangle$ Apple's profit | -\$19.00 | -\$13.26 |
| $\triangle$ Music producers' profit | \$144.47 | \$41.71 |
| $\triangle$ Total Surplus | -\$78.91 | \$534.03 |

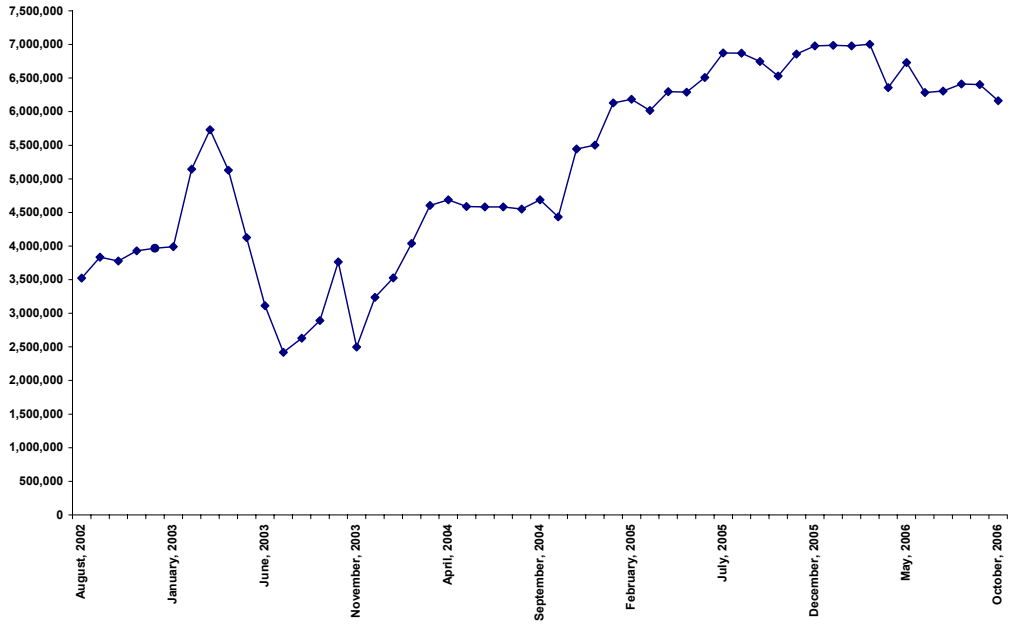



Figure 1:
Big Champagne: Avg Simultaneous P2P Users in the U.S. Has Been Growing

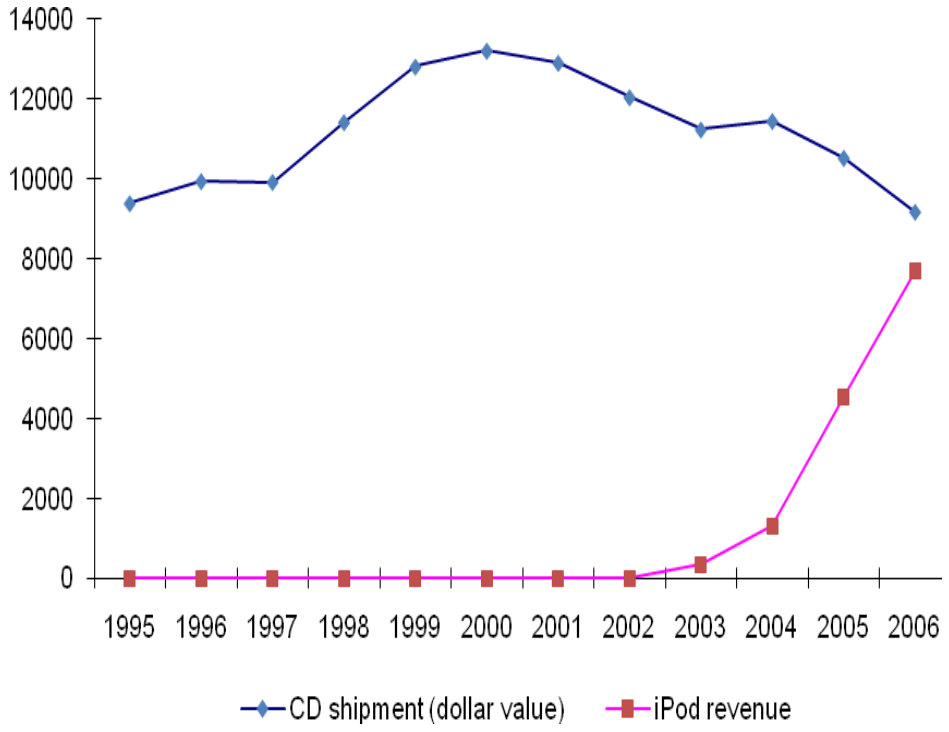



Figure 2:
RIAA and Apple Inc.: CDs Revenue Decreasing, iPods Revenue Growing in the U.S. ($millions)

When you listen to music,
Your first choice is: _____ Second choice is: _____

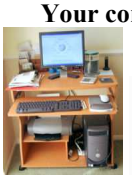
| Option 1 | Option 2 | Option 3 |
|---|---|---|
| **iPod nano**  **$US200, 4GB** | **Your computer**   | **Radio**  |
| Free P2P downloading **illegal**. Fine: **$US200/song** downloaded that month<br>Chance of getting caught per month: **1 in 2000 songs** | Free P2P downloading **illegal**. Fine: **$US50/song** downloaded that month<br>Chance of getting caught per month: **1 in 100,000 songs** | |
| iTunes: **$ US 0.3/song**<br>CD**: $5 each** | iTunes: **$ US 3/song**<br>CD**: $10 each** | Free music |

Figure 3:
A Sample of the First Sub-Task

Suppose you had an iPod  last month and prices of music from different sources were as follows:

| P2P downloading | Illegal | Fine: $200/song | Prob. Of getting caught: 1 in 2000 songs |
|---|---|---|---|
| iTunes | $0.3/song | | |
| CDs | $5/CD | | |

What would be your music consumption from the 3 sources?

P2P downloading : _____ songs
iTunes : _____songs
CDs : _____CDs

Figure 4:
A Sample of the Second Sub-Task

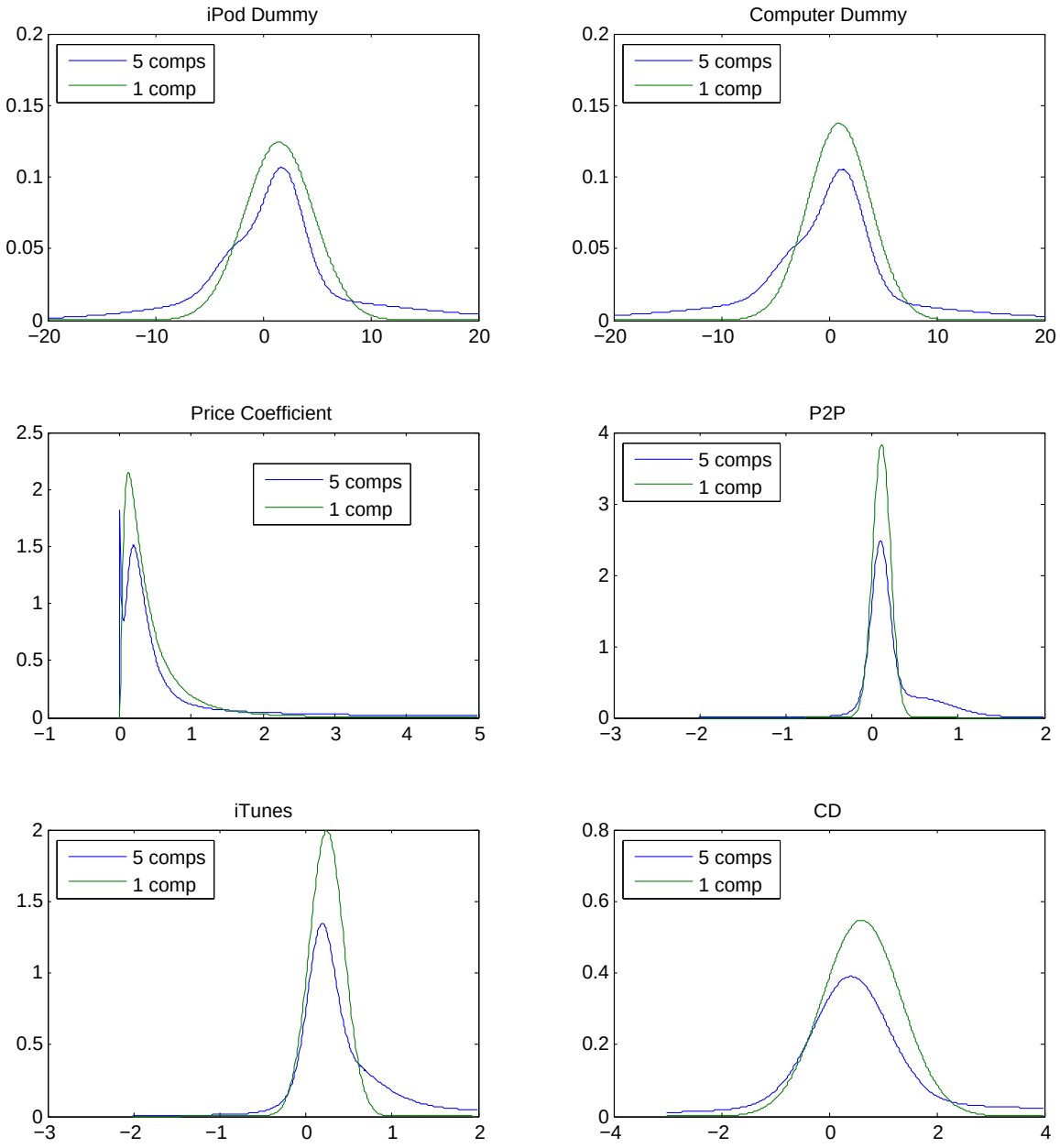



Figure 5:
Density of Random Coefficients

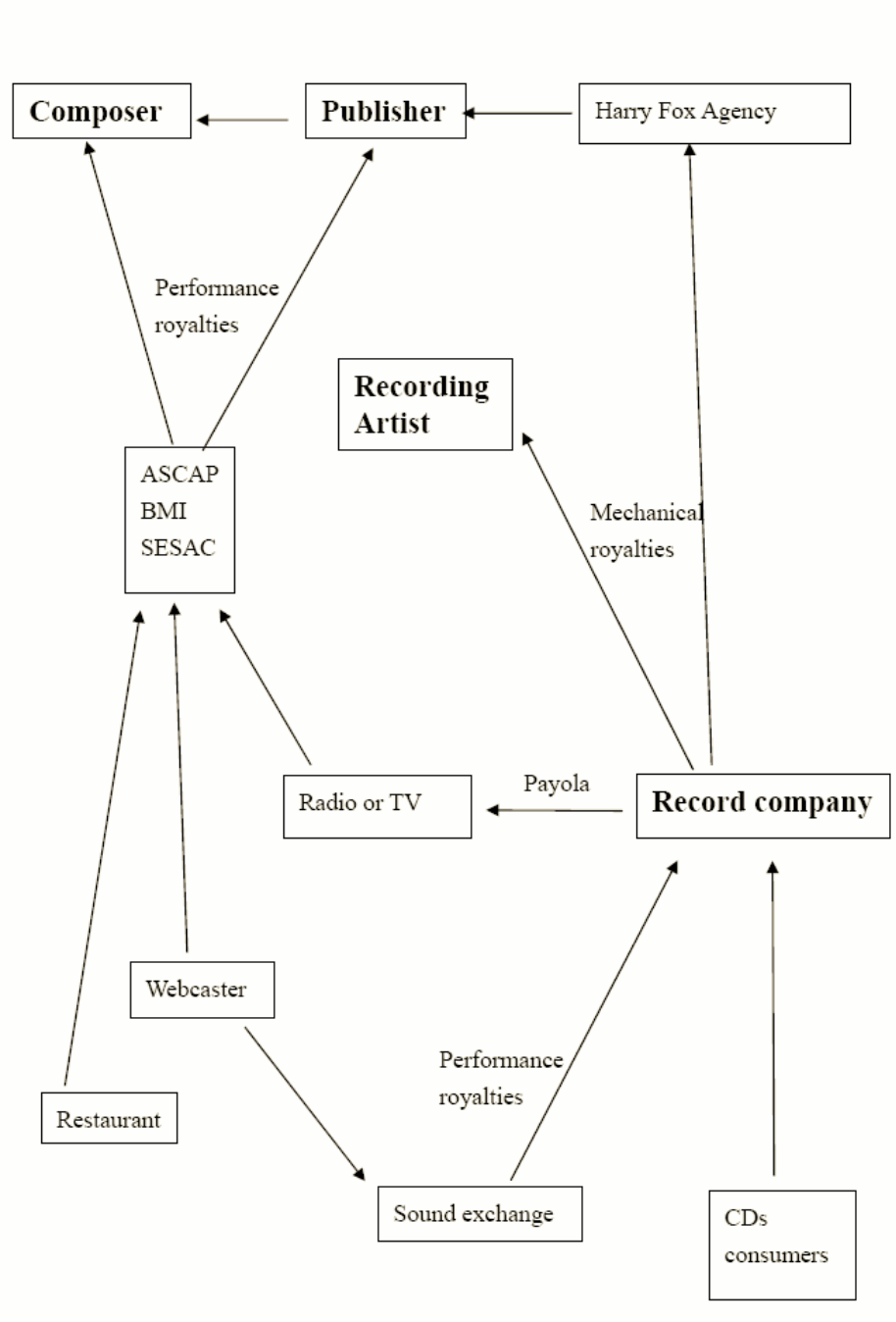



Figure 6:
Fisher (2004): Revenue Stream in the Music Industry