

Does File Sharing Crowd Out Copyrighted Goods? Evidence from the Music Recording Industry

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Abstract

This paper examines the extent to which Internet file sharing crowds out purchases of both physical and digital music. The existing evidence on the effect of file sharing on music sales has been mixed and focused mainly on the period 1999-2001. Using a representative survey for 2004-2006, I find that, in contrast to the previous studies, illegal downloads and legal music purchases are positively correlated across individuals. Since the correlation could reflect an unobserved taste for music purchases, I instrument for the propensity to download illegally with the interaction of measures of ethical behavior and comfort with computer technology. Using this identification strategy with both a standard probit estimation and a semiparametric rank correlation based estimation, I find legal music purchases and illegal music downloads are complements. (JEL C14, C21, C25, L82, L86, O34)

Keywords: Music Sales; File Sharing; Bivariate Probit; Semiparametric Estimation

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1 Introduction

Technological innovations and the proliferation of Internet services over the last twenty years have gradually and profoundly changed the way people purchase goods and services, including the newspaper and entertainment goods. Many economic studies investigate whether new goods substitute or complement the existing copyrighted products. For example, Sterling and Kittross (2001) survey research on whether radio broadcasting displaced or complemented record sales since the 1920s. Gentzkow (2007) investigates whether online newspapers crowd out or complement traditional newspapers. This paper will examine the extent to which illegal downloads substitute or complement legal music purchases.

In the late 1990s, innovations in audio-compressing technologies made the MP3 the dominant format of music. The palm-sized MP3 players soon replaced more bulky appliances, including portable CD players. Shortly thereafter, peer-to-peer (P2P) applications and the rapid growth of Internet use made online music sharing possible and popular. In 2001 and 2003, Apple computer first introduced iPod and opened iTunes Music Store (iTMS), respectively. By 2007, Apple had cumulatively sold more than one billion iPod units worldwide (see Figure 1). Rather than the traditional way of purchasing “albums” of music, the inception of online music stores, such as iTMS, enabled consumers to purchase a “single”¹ for less than \$1 a song. The newly introduced digital albums and digital singles not only made music less costly to distribute but also more accessible for consumers to purchase. Prior to the inception of online music stores, one of the major reasons for consumers to download music illegally was the impossibility of separately purchasing individual songs from an album. A consumer may be unwilling to pay an album’s full price if she only enjoys one or two songs on the entire album. Hence the availability and accessibility of digital singles brought substantial hopes to revive the music industry.

¹Online music stores include but are not limited to iTunes, Walmart, Best Buy and Amazon. Each store has its own pricing model. For example, iTunes sells digital singles for \$0.99 per digital download, and Walmart offers \$0.88 per digital download.

The Recording Industry Association of America (RIAA) continues to claim that digital sharing technologies have negatively impacted the music industry. RIAA has reported a substantial and persistent decline in overall music sales since 2000 (see Figure 2). RIAA has attributed these dramatic changes directly to illegal downloads, and thus promotes anti-piracy efforts² to protect the ability of the recording industry to invest in new bands and better music.

The existing literature identifies two competing factors that may explain the net impact of illegal downloads on music sales: the substitution effect and the learning (or penetration) effect. The substitution effect causes consumers to switch from legal purchases to illegal downloads, which are cheaper. On the other hand, the learning effect stimulates music sales, as the spread of a musician's work through illegal downloads may in turn enhance the musician's reputation and popularity, thereby stimulating music sales. For example, an individual might not be willing to spend much on songs of an artist with whom she is not already familiar. However, she may make purchases in the future if she listens to some of the songs and finds them enjoyable. Ultimately, a combination of these two effects determines the net impact of file sharing on music purchases. If the substitution effect dominates the learning effect, illegal downloads crowd out record sales. If the learning effect dominates, illegal downloads complement music sales and enhance the probability of buying music. Using individual-level data sets containing both legal and illegal music downloads, this paper examines the net impact of illegal downloads on purchases of both physical music and digital music in North America during 2004-2006.

The existing evidence on the effect of file sharing on music purchases is mixed. Zentner (2006) finds that peer-to-peer applications reduce the probability of buying music by 30 percent. Similarly, Hong (2007) shows that file sharing explains 20 percent of the total reduction in music sales. In contrast, Oberholzer-Gee and Strumpf (2007) conclude that illegal downloads have an effect on sales that is statistically indistinguishable from zero.

²In one case, a court has imposed a \$222,000 penalty on someone who shared 24 songs, which is equivalent to over \$9,000 a song (Levy 2007).

These studies, however, focus on the relationship between file sharing and recorded music during the Napster period (1999-2001), and thus exclude the effect of file sharing on online digital music sales.

It is essential to include purchases of digital music in addressing the impact of file sharing on music sales. According to the International Federation of the Phonographic Industry (IFPI), global online music sales nearly doubled in 2006 and digital sales became 10% of total revenue in the music industry. The booming demand for music on the Internet and mobile phones have significantly mitigated, though not completely offset, the decline in sales of physical formats, which fell by 6.7% in retail values in 2005 (IFPI).

Using a representative survey for 2004-2006, I find that illegal downloads and legal music purchases are positively correlated across individuals. Single-equation estimates suggest that for the typical consumer, using file-sharing applications increases the probability of purchasing music by twenty-five percentage points in 2004, by nineteen percentage points in 2005, and by fifteen percentage points in 2006. Since this correlation could reflect an unobserved taste for music, I instrument for the propensity to download illegally with the interaction of measures of ethical behavior and comfort with computer technology. Using both a standard probit estimation and a semiparametric rank correlation based estimation, I find that the penetration effect dominates the substitution effect, and file sharing complements music purchases.

In contrast to the previous studies, this paper finds that legal music purchases and illegal music downloads are complements. In particular, Oberholzer-Gee and Strumpf (2007) examine whether the number of illegal album downloads has an effect on album sales, and find no relationship between file sharing and music sales. While Oberholzer-Gee et al. focus on the intensity of the effect of illegal downloads on legal music purchases, I exploit a representative consumer mail survey to examine whether file-sharers are more likely to participate in buying either digital or physical music. Since digital music sales grow substantially each year and become a significant fraction of the industry revenue, it is possible that file-sharers only spend a few dollars on digital music and non-file-sharers spend much more on music. In

this case, we may still observe either a negative or an insignificant effect of illegal downloads on music purchases from an expenditure approach yet a positive effect from the probability approach.

The paper is organized as follows: Section 2 provides an overview of the existing literature. Section 3 describes the data. Section 4 describes the econometric approach and identification. Section 5 presents the estimation results. Finally, section 6 concludes.

2 Historical Background and Literature Review

Shortly after its introduction in June 1999, Napster became the dominant peer-to-peer (P2P) file-sharing service until early 2001. After Napster was shut down by the courts in July 2001, other P2P applications soon replaced the services provided by Napster and surpassed Napster in popularity³. The downturn of music sales in the late 1990s appears to coincide with the introduction of Napster. However, the theoretical studies on sharing of information goods (Besen and Kirby 1989; Takeyama 1994; Bakos, Brynjolfsson and Lichtman 1999) suggest ambiguous predictions for the effects of file sharing on the sale of copyrighted goods.

The existing evidence on file sharing and record sales has been mixed and focused mostly on the period 1999-2001. Blackburn (2004) finds that file sharing has a negative impact on music sales and that the RIAA's strategy of initiating legal suits against individuals who made the illegal copies of music available has both reduced file-sharing activities and increased record sales. Rob and Waldfogel (2006) conduct their own survey and conclude that illegal downloads displaces music sales among a sample of 412 U.S. college students in 2003. Oberholzer-Gee and Strumpf (2007) instrument for illegal downloads using album-level data on sales and file-sharing activities in 2002 and conclude that downloads do not have an effect on music sales that is statistically distinguishable from zero. Using a survival

³As of April 2007, BioTorrent has a community of over 135 million users for file sharing, and Emule has been downloaded 303,921,894 times.

analysis, Bhattacharjee et al. (2007) conclude that illegal downloads have a negative impact on low rank albums yet it has no effect on the survival of top-selling albums. Hong (2007) attempts to construct the counterfactual estimates of record sales in the absence of file sharing by combining the Consumer Expenditure Survey (CEX) from 1996-2002 and the UCLA Internet Survey (UCLAIS) from 2000-2002. He uses a difference-in-difference (DD) approach and a nonparametric difference-in-difference matching (DDM) method to produce the results that suggest file sharing explains 20% of the decline in total sales⁴.

Results of international studies on file sharing and music purchases are also mixed. Using measures of Internet use and access to broadband as instruments, Zentner (2006) reports that downloads may explain a 30% reduction in the probability of buying music for a typical European consumer. Tanaka (2004) shows that file sharing has had very limited influence on music purchases in Japan. Anderson and Frenz (2007) employ survey data from 2,100 Canadian respondents and find a strong positive relationship between P2P file-sharing and CD purchases.

To measure the possible sale displacement effect of illegal downloads, the dataset needs to contain information on both music purchases and unpaid music downloads for each sample. Blackburn (2004) uses a product-level dataset, which is not able to distinguish between the sales decline among file-sharing users and the decline among non-users. Instead, micro-level data are needed to quantify the effect of file sharing on music sales. Rob and Waldfogel (2006) conduct their own survey and collect data on albums either purchased or free downloaded by a small group of college students in the United States. Unfortunately, their sample only comprises 412 college students across four campuses, and therefore it is not nationally representative.

A related issue, which has not been explored substantially by previous studies, is the impact of illegal downloads on attendance at live performances. Krueger (2005) suggests that file sharing causes a decline in complementarities between live concerts and record

⁴The nonparametric difference-in-difference matching (DDM) method was developed by Heckman, Ichimura, and Todd (1997, 1998).

sales, and hypothesizes that the decline in record sales drives concert ticket prices to rise. Mortimer and Sorensen (2005) show that after the introduction of file-sharing applications, the profitability of live performances increases. While Mortimer et al. focus on the intensity of the impact of illegal downloads on live performances, it would be interesting to examine whether file-sharing participants are more likely to attend live performances.

3 Data Set

This paper will use North America (U.S. and Canada) consumer mail surveys by Forrester Research taken between January 2004 and January 2006. Forrester is a market research company specializing in the information economy. The fieldwork was conducted annually by the NACTAS (North American Consumer Technology Adoption Study) group. Each year samples of survey recipients are randomly drawn from the NFO panel. While the sampling methodology remains proprietary, it is meant to ensure a representative sample in the U.S. and Canada. The survey contains over 90 questions each year about a spectrum of topics that relate to technology adoption. Though the majority of questions and answer choices stays the same from one year to the next, there are several minor changes between the 2004 survey and 2005 survey. In 2005, the survey includes additional questions, such as participation of church activities. Analogous U.S. data from Forrester have been used extensively in the economic literature related to the Internet (Goolsbee 2000, 2001; Goolsbee and Brown 2002; Goolsbee and Klenow 2002); analogous European data from Forrester have also been used to examine the effect of file sharing on music purchases (Zentner 2006).

The survey each year includes more than 60,000 U.S. and Canadian households. The survey respondents include all age groups between 18 and 99. The NACTAS survey is especially useful for this study because it contains a rich set of economic and demographic variables as well as detailed data on hours spent on TV, Internet, and radio. In addition to detailed demographics, the dataset contains discrete $\{0, 1\}$ variables indicating purchases of music both online and offline, illegal music downloads, type of Internet access, and ownership of portable

MP3 players. In the event of purchasing music online, the data contain information on the frequency of purchases (daily, a few times per week, or a few times per month). Importantly for this paper, the data also include information on whether the respondent has received any parking ticket within the last twelve months prior to the 2005 interview⁵. The data also contain detailed information on technology adoption, including whether one publishes a webpage, writes audio CDs, participates in online auctions, uses instant messaging, reads computer magazines, how often one searches for free (or discounted) goods and services, technology attitude, and purchases of software, books, DVDs, and videogames. In addition, the data include measures of ethical behavior and comfort with computer technology.

Table 1 presents summary statistics. From 2004 to 2006, the percentage of people who bought music within three months prior to responding to the survey decreases from 26.66% to 17.36%. There is a slight increase in the percentage of people who regularly download music illegally (from 8.85% in 2004 to 7.90% in 2006). Across the overall sample population, the probability of music purchases (including digital music) for people who regularly download music illegally is much higher than the probability of music purchases for people who do not regularly download illegal music. Such a pattern is consistent across all three years of study, and the difference is particularly drastic among people who do not own portable MP3 players.

4 Empirical Strategy

To examine whether illegal downloads crowd out or complement legal music purchases, section 4.1 shows correlation between illegal downloads and legal purchases and section 4.2 discusses the potential omitted variable bias. To establish causality, section 4.3 presents instruments for the propensity to download illegally.

⁵The data includes detailed information on the type of parking tickets (from federal, state, or local government) that one received within the last twelve months.

4.1 Correlation

To investigate the effect of file sharing on the probability of music purchases, I first examine the individual's decision to purchase music by estimating a standard probit model. Let the indicator variable $Music_i = 1$ if individual i buys music, and $Music_i = 0$ otherwise. Suppose the latent variable $Music_i^*$ follows:

$$Music_i^* = X_i\beta + \alpha P2P_i + \varepsilon_i, \quad (1)$$

$$Music_i = 1[Music_i^* > 0], \quad (2)$$

where $Music_i^*$ is the net benefit an individual receives from buying music, X_i is a vector of individual characteristics, $P2P_i$ is a dummy variable $\{0, 1\}$ indicating that individual i uses peer-to-peer applications (from BitTorrent, KaZaA, etc.), and ε_i is a normally distributed random error with zero mean and unit variance. The vector of observed individual characteristics X_i that correlate with the decision of buying music includes age, log of income, gender, education level, size of household, high-speed Internet access, hours spent listening to the radio, hours spent watching TV, ownership of portable MP3 players (including iPod, Rio, and iRiver), ownership of surround-sound stereo with four or more speakers, and purchases of books, software, DVD, and videogames. Individuals will only buy music if the expected net benefits of purchasing are positive, and thus the probability that an individual purchases music is

$$\Pr(Music_i = 1) = \Pr(x_i\beta + \alpha P2P_i + \varepsilon_i > 0) = \Phi(X_i\beta + \alpha P2P_i), \quad (3)$$

where $\Phi(\cdot)$ is the evaluation of the standard normal cdf.

To examine the effect of illegal downloads on music purchases, the parameter of interest α is estimated using maximum likelihood estimations. If the coefficient α is positive (negative), unauthorized music downloads and legal music purchases are positively (negatively) correlated. If α is statistically indistinguishable from zero, file sharing and music purchases are not significantly correlated. Since the correlation could reflect an unobserved heterogeneity, I instrument for the propensity to download illegally with measures of ethical behavior and comfort with computer technology.

4.2 Omitted Taste for Music

The probit model presented in equations (1) and (2) treats the decision of buying music as exogenous. If the file-sharing ($P2P$) variable and the error term in equation (1) are correlated, the single-equation probit estimates will be biased and inconsistent. Since a bivariate probit model allows for correlated disturbances across equations and simultaneous estimation of two probit equations, its estimates tend to be consistent and more efficient than separate maximum likelihood estimation of single-equation models. Evan and Schwab (1995) employ the maximum likelihood estimation to study the effect of attending a Catholic high school on the probability of graduating from high school and entering college, and they also test for selectivity bias by estimating the bivariate probit models.

Following the latent variable model in equation (1), suppose that the net benefits of file sharing $P2P_i^*$ can be written as

$$P2P_i^* = Z_i\gamma + \nu_i, \quad (4)$$

$$P2P_i = 1[P2P_i^* > 0], \quad (5)$$

where Z_i is a vector of observables and ν_i is a random error. An individual will use file-sharing applications if the net benefits are positive. To allow for the possibility that the unobserved determinants of an individual's taste for music purchases and the unobserved determinants of the individual's decision to use peer-to-peer applications are correlated, we assume that ε_i and ν_i are distributed bivariate normal, with $E[\varepsilon_i] = E[\nu_i] = 0$, $Var[\varepsilon_i] = Var[\nu_i] = 1$ and $Cov[\varepsilon_i, \nu_i] = Corr[\varepsilon_i, \nu_i] = \rho$. Since both of the dependent variables in equations (4) and (5) are binary, there are four possible events ($Music_i = 0$ or 1 and $P2P_i = 0$ or 1) and thus the corresponding likelihood function is a bivariate probit.

The coefficient ρ is the correlation coefficient between the residuals of each of two probit models. If ρ is positive, the estimated effect of treatment from single-equation estimation will generally be biased away from zero. If ρ is negative, the estimated effect will be biased towards zero. In general, the two probit equations should be estimated simultaneously if ρ is significantly different from zero. If ρ is statistically indistinguishable from zero, single-

equation estimates are subject to selection bias and two separate probits should be estimated.

4.3 Identification

The additional regressors in equation (4) not included in equation (1) are analogous to the role of instrumental variables in a standard linear model. The main instruments for illegal music downloads are measures of ethical behavior, such as participation of religious activities and violations of traffic laws. Other instruments include measures of comfort with computer technology, such as attitudes toward technology, participation in online auctions, and establishment of one's own webpage.

The most important instruments that I considered are active participations of religious activities (*CHURCH*) and violations of traffic laws (*TICKET*) within the last twelve months. It can be argued that individuals who have violated traffic laws are less concerned about being prosecuted and are also more likely to violate other laws, including intellectual property laws. Supporting this intuition, I find a positive correlation between file sharing and whether one recently received parking tickets. Willingness to violate laws, however, should not be relevant to the decision of making music purchases. On the other hand, active participants of religious activities are expected to be less likely to violate intellectual property rights since they are encouraged by the religious community to maintain high moral standards. Not surprisingly, I find a negative correlation between illegal downloads and church attendance.

Other instruments measure one's comfort with technology, including whether one frequently uses a CD writer (*CD_WRITER*), publishes a webpage (*WEBPAGE*) or participates in online auction (*AUCTION*); hours spent online (*INTERNET*); one's attitude towards technology (*TECHNOLOGY_ATTITUDE*). While using a CD writer does not tend to influence one's decision of making music purchases, frequent users of CD writers are more likely to download illegally since CD writers are conveniently used to copy existing compact discs and to quickly backup and transfer files. To participate in file sharing, one needs to have advanced computer skills and eagerness to learn new technology. For individ-

uals who are able to publish their own webpage or to participate in online auction, there are no technology barriers that may prevent them from downloading unauthorized files once they decide to do so. The instrument, *TECHNOLOGY_ATTITUDE*, also measures how comfortable an individual is to adapt new technology. The hours spent online and *P2P* are positively correlated because one needs to spend more time online searching for available unauthorized copies of the songs and albums.

For religious or driving behaviors to serve as legitimate instruments for the propensity to download illegally, they should significantly affect individual file-sharing decisions but have no direct impact on music purchases. There are two main reasons why file-sharers may have higher probabilities of making music purchases, controlling for demographics and other purchasing behaviors. First, illegal downloads and music purchases are indeed complements. Second, an unobserved characteristic induces illegal downloads also directly affect the decision of making music purchases. For example, an 80-year-old religious man may not download illegally because he has extreme difficulties acquiring advanced computer skills. At the same time, he does not buy music because he enjoys his old collection of music and not interested in constantly updating his collection. To distinguish the two possibilities, I consider two additional instruments by interacting church participation variable with individual-specific characteristics. In particular, I instrument for the propensity to download illegally with the interaction of church participation (*CHURCH*) and whether one is over sixty-years-old (*YOUNG*), and the interaction of church participation (*CHURCH*) and measures of computer literacy (*COMPUTER_LIT*)⁶.

⁶A dummy variable equals to unity if one frequently uses instant messenger (MSN, AIM, Yahoo, etc.), publishes a webpage, or participates in online auction.

5 Estimation Results

5.1 Baseline Result

To examine the effect of illegal downloads on legal music purchases, the coefficient α in equation (1) is the parameter of interest. Maximum likelihood estimates of music purchases are performed and the marginal effects $\partial \Pr(Y_i = 1)/\partial x_i$ during 2004-2006 are reported in columns 1-3 of Table 2, respectively. The results in Table 2 show that file-sharers have a higher probability of making music purchases. In 2004, our reference individual's probability of buying music is twenty-five percentage points higher if she regularly uses peer-to-peer applications. In 2005 and 2006, the probabilities of making music purchases for file-sharers are nineteen percentage points and fifteen percentage points higher, respectively.

To determine whether illegal downloads crowd out or complement legal music purchases, I calculate the mean and the standard error of the probability of buying music given that the individual regularly downloads music for free and the probability of buying music given that the individual does not regularly download free music. The conditional probabilities are summarized in Table 3, and the trend is illustrated in Figure 3. During the period 2004-2006, the probability that a file-sharer buys music substantially exceeds the probability for non-file-sharers, which suggests that illegal downloads complement legal music purchases.

5.2 Bivariate Probit Estimates

The finding of a positive coefficient α in equation (1) suggests a positive correlation between illegal downloads and legal music purchases. Since the correlation could reflect an unobserved taste for music, the sign of α does not imply causality. To establish causality, I instrument for the propensity to download illegally, first with separate measures of ethical behavior and comfort with technology, and then with an interaction of the two.

The maximum likelihood estimates of the bivariate probit models during 2004-2006 are

summarized in Tables 4. The marginal effects and the standard errors are reported, and the correlation (ρ) of error terms in equations (1) and (4) are presented in brackets. In 2004, the estimates of the effect of illegal downloads on legal music purchases using instruments range from 0.1365 to 0.3782. In 2005, the estimates fall to between 0.0610 and 0.1694. In 2006, the estimates fall to between 0.0810 and 0.1848.

Using measures of comfort with computer technology (*TECHNOLOGY_ATTITUDE*) as an instrument, the effect of illegal downloads on legal music purchases ranges between 0.0911 and 0.3215 during 2004-2006. To determine the extent to which file sharing crowds out or complements purchases of either physical or digital music, I compare the conditional probabilities $\Pr(Music = 1|P2P = 1, X, Z)$ and $\Pr(Music = 1|P2P = 0, X, Z)$. The probability of making legal music purchases among illegal-downloaders greatly exceeds the probability of legal music purchases among non-illegal downloaders. The detailed results are presented in Table 5, and the trend is depicted in Figure 4. To analyze the causal effect of file sharing on music purchases, I compute the difference in conditional expectations, $E(Music|P2P = 1) - E(Music|P2P = 0)$. If the sample mean of the treatment group is less (greater) than the sample mean of the control group, illegal downloads have a negative (positive) impact on legal music purchases. If the difference in conditional expectations is approximately zero, file sharing has no effect on music purchases. Since the *Music* variable is binary ($music_1 = 0$ and $music_2 = 1$), the conditional expectations can be simplified as

$$E(Music|P2P = 1) = \sum_{i=1}^2 music_i \Pr(Music = music_i|P2P = 1) = \Pr(Music = 1|P2P = 1), \quad (6)$$

and similarly

$$E(Music|P2P = 0) = \Pr(Music = 1|P2P = 0). \quad (7)$$

In 2004, the difference in conditional expectations is 0.2042. In 2005 and 2006, the sample mean of the treatment group exceeds the sample mean of the control group by 0.1530 and 0.1628, respectively. Hence it is evident that file sharing has a positive and significant effect on music purchases, and the penetration effect dominates the substitution effect.

Using measures of ethical behavior (*CHURCH*) as an instrument, I also find a positive effect of illegal downloads on legal music purchases. There are two explanations for this finding. First, illegal downloads and legal music purchases are complements. Second, an unobserved characteristic induces illegal downloads also directly affect the decision of making music purchases. I consider two additional instruments by interacting the church participation variable with individual-specific characteristics. Using the interaction of church participation and whether one is young, the estimates of the probability of buying music are 0.1227 in 2005, with a standard error of 0.0174 (see Table 6), and 0.0818 in 2006, with a standard error of 0.0134 (see Table 7). Using the interaction of church participation and computer literacy, the estimates are 0.0666 in 2005, with a standard error of 0.0155, and 0.0462 in 2006, with a standard error of 0.0115. The IV estimates based on the interaction of computer skills and church participation are similar to the IV estimates based on church participation alone, reinforcing the conclusion that illegal downloads and music purchases are indeed complements.

5.3 Instrument Validity

The two conditions that an instrumental variable must satisfy to be a valid instrument are instrument relevance and instrument exogeneity. The instrument relevance condition can be satisfied if the coefficient γ in equation (6) is statistically distinguishable from zero. To be a valid instrument, the instrumental variable needs to be a critical determinant of illegal downloading but should not be correlated with the error term. To show the instrument is not a key determinant of music purchasing, I perform a hypothesis test of $H_o : \delta = 0$ in the following probit regression:

$$Music_i = 1[X_i\beta + \alpha P2P_i + z_{1i}\delta + \varepsilon_i > 0]. \quad (8)$$

I use a standard t test on the instrumental variable z_1 in equation (8) if there is one instrument. If two or more instruments are in equation (8), a F test is performed.

Based on these tests, participation in church activities (*CHURCH*) is a determinant of

the decision to download unauthorized files. Furthermore, participation in religious events and downloading unauthorized files negatively correlates. In a probit model that explains the probability an individual will download illegally in 2005, the coefficient of *CHURCH* has an estimate of -0.4094 with a standard error of 0.0022. The negative correlation is statistically significant since the t-statistic is 185.52, which greatly exceeds the critical value. In an OLS model where *P2P* is regressed on *CHURCH*, the R^2 is 0.0575. This suggests participating in religious events influences significantly the decision of whether to download files illegally. To show *CHURCH* is not a determinant of music purchasing, I conduct a t test of $H_0 : \delta = 0$ in equation (8). The t statistic of δ is 1.34 in 2005 and thus the null hypothesis cannot be rejected. Hence participating in religious activities does not correlate with the decision of making music purchases.

The correlation coefficient ρ measures the correlation between the disturbances in the equations (1) and (4). If the coefficient ρ is statistically distinguishable from zero, the two probit equations should be estimated simultaneously. If ρ is not statistically different from zero, two separate probits need to be estimated. Using *CHURCH* as an instrument, the estimate of ρ is 0.1931 with a standard error of 0.0214. The t statistic for the test of the hypothesis that ρ equals zero is 9.02, and thus the null hypothesis can be rejected. Since ρ is positive and statistically significant, the estimates from single-equation estimation will generally be biased away from zero and the two probit equations should be estimated simultaneously.

Since *P2P* is the only endogenous regressor in equation (1), the regression coefficients are exactly identified if there is one instrumental variable. If there are two or more instruments, the system is overidentified. Publishing a webpage and participating in online auctions also correlate with file sharing. In a probit model that explains the probability of using *P2P* applications in 2005, the coefficient of *WEBPAGE* is 0.8062 with a standard error of 0.0309 and the coefficient of *AUCTION* is 0.6512 with a standard error of 0.0210. The t statistics are 26.08 and 30.99, respectively. Thus publishing a webpage and participating in online auctions are relevant to the decision of illegal downloads. To show *WEBPAGE* and

AUCTION are not determinants of music purchases, a standard F test of $H_o : \delta_{webpage} = \delta_{auction} = 0$ is conducted in the probit regression in equation (8). The F statistic is 0.33 in 2005 and thus the null hypothesis cannot be rejected. Hence, publishing a webpage and participating in online auctions are not relevant to the decision of music purchases. Since the number of instruments is greater than the number of endogenous variable, the model is overidentified and the overidentifying restrictions are tested.

5.4 Music Expenditure

In a standard probit model, I find illegal downloads and legal music purchases are positively correlated. To establish causality, I instrument for file-sharing participation with measures of ethical behavior and comfort with computer technology. To determine the extent to which file sharing crowds out or complements music purchases, I compare the conditional probabilities $\Pr(Music = 1|P2P = 1, X, Z)$ and $\Pr(Music = 1|P2P = 0, X, Z)$. Though it is evident that the probability of buying music for file-sharers substantially exceeds the probability of buying music for non-file-sharers, it is possible that file-sharers who make music purchases only spend a few dollars on digital singles and non-file-sharers who buy music spend significantly more.

Consider a group of five people who constantly download unauthorized files, and the other group of five who never download illegally. In an extreme example, four out of five file-sharers constantly listen to unauthorized MP3 and then decide to spend a dollar buying a digital single for the song they enjoy the most. On the other hand, only one non-file-sharer out of five spends ten dollars buying a physical album. In this case, although the conditional probability $\Pr(Music = 1|P2P = 1, X, Z) = 0.80$ is substantially larger than $\Pr(Music = 1|P2P = 0, X, Z) = 0.20$, the four file-sharers spend (\$4 in total) significantly less than the non-file-sharer (\$10) in terms of dollars. Hence both the intensity and the participation approach are important to study the effect of illegal downloads and legal music purchases.

5.5 Robustness Tests

In the probit models in Equations (1), (2), (4) and (5), the error term is assumed to follow a normal distribution. To relax the parametric assumptions on the error disturbances, I employ semiparametric estimation and the testing methodology proposed by Abrevaya, Hausman and Khan (2007). The testing procedure consists of three steps. First, the coefficient vector γ in equation (4) is estimated by either parametric or semiparametric \sqrt{n} -consistent estimators. I use a probit estimator to estimate γ . Secondly, the coefficients of exogenous variables (β_0) are estimated by a kernel-weighted rank-based estimator. Lastly, Abrevaya et al. suggest a kernel-weighted version of the *tau* statistic of Kendall (1938) to test for the statistical significance of the causal effect.

In the second stage, the coefficients β_0 are estimated with $\hat{\beta} = \arg \max_{\beta \in B} Q(\beta)$. The objective function resembles the rank correlation between $Music_i$ and $X_i\beta$:

$$Q(\beta) = \frac{1}{n(n-1)} \sum_{j=1}^n \sum_{i \neq j} 1[P2P_i = P2P_j] k_h(Z_i\hat{\gamma} - Z_j\hat{\gamma}) 1[Music_i > Music_j] 1[X_i\beta > X_j\beta], \quad (9)$$

where $k_h(u) \equiv h^{-1}k(u/h)$ for a kernel function $k(\cdot)$ and a bandwidth h that shrinks to zero as n gets large. For simplicity, I choose the uniform kernel to estimate $\hat{\beta}$. The basis of the kernel-weighted rank-based estimator is formed by:

$$\Pr(Music_i \geq Music_j | X_i, X_j, P2P_i = P2P_j, Z_i\gamma = Z_j\gamma) \geq \Pr(Music_i \leq Music_j | X_i, X_j, P2P_i = P2P_j, Z_i\gamma = Z_j\gamma) \text{ whenever } X_i\beta_0 \geq X_j\beta_0, \quad (10)$$

because F is monotonically increasing in $X_i\beta_0$. For the pair of observations with $P2P_i = P2P_j$ and $Z_i\hat{\gamma}$ close to $Z_j\hat{\gamma}$, there is a high correlation between the ranking of the $Music_i$ and the rankings of the $X_i\beta$ when $\beta = \beta_0$.

To determine whether the endogenous variable ($P2P$) has an effect on music purchasing, a kernel-weighted version of Kendall's *tau* statistic (τ) is calculated using the estimated coefficients of exogenous variables ($\hat{\beta}$) by maximizing the rank-based objective function in

equation (9) and the estimated coefficients of instrumental variables ($\hat{\gamma}$) from the first stage:

$$\hat{\tau} \equiv \frac{\sum_{i \neq j} k_h(X_i \hat{\beta} - X_j \hat{\beta}) \text{sgn}(Music_i - Music_j) \text{sgn}(Z_i \hat{\gamma} - Z_j \hat{\gamma})}{\sum_{i \neq j} k_h(X_i \hat{\beta} - X_j \hat{\beta})}, \quad (11)$$

where $\text{sgn}(\omega) = 1(\omega > 0) - 1(\omega < 0)$. To test for the presence of a treatment effect, a two-sided t-test of $H_0 : \tau = 0$ is conducted. The intuition behind the testing statistic in equation (11) is that for a given $X\beta_0$, the sign of the rank correlation between *Music* and $Z\gamma$ depends on the presence of a treatment effect.

Using *TECHNOLOGY_ATTITUDE* as an instrument, the $\hat{\tau}$ is 0.2757 in 2004. Since it is complicated to compute the asymptotic variances, Abrevaya et al. recommend the use of bootstrap methods to compute the asymptotic variances. In 2004, the asymptotic standard error of $\hat{\tau}$ is 0.0078. To test for the effect of file-sharing on music purchasing, a two-sided t-test of $H_0 : \tau = 0$ is performed with the alternative hypothesis of $H_1 : \tau \neq 0$. The t-statistic is 35.35, hence file sharing has a strong positive effect on music purchases. In 2005, the $\hat{\tau}$ is 0.1010 and the asymptotic standard error of $\hat{\tau}$ is 0.0070. The resulting t-statistic is 14.43, which suggests positive treatment effect. In 2006, the $\hat{\tau}$ is 0.0734, the asymptotic standard error of $\hat{\tau}$ is 0.0060, and the resulting t-statistic is 12.23. This reinforces the results of the simultaneous probit estimations: a positive and statistically significant effect on music purchases. The results are summarized in Table 8.

6 Conclusion

This paper investigates the effect of file sharing on music purchases, in particular whether file sharing crowds out or complements music sales. There are two opposing theories that determine whether file sharing has a positive or a negative effect on music purchases. The substitution effect suggests that illegal downloads crowds out music purchases. On the other hand, the penetration effect suggests that people who download music illegally are exposed to more music, inducing more music purchases.

In contrast to the previous studies, I find file sharing has a positive and statistically significant effect on music purchases, thus legal music purchases and illegal music downloads are complements. Oberholzer-Gee and Strumpf (2007) investigate whether the number of illegal album downloads has an effect on album sales, and find no relationship between file sharing and music sales. While Oberholzer-Gee et al. examine the intensity of the effect of illegal downloads on legal music purchases, I focus on the difference in participation rate of illegal downloaders and non-illegal downloaders on purchases of either digital or physical music. A plausible explanation to reconcile the distinct results from the expenditure approach and the participation approach is that more illegal downloaders buy music yet spend significantly less than non-illegal downloaders, as explained in section 5.4. More specifically, illegal downloaders may only spend a few dollars buying digital singles instead of buying the more costly physical albums.

An interesting related issue is the impact of illegal downloads on attendance of live performances, and the intimate relationship among illegal downloads, legal music purchases and attendance of live performances. Krueger suggests that illegal downloads cause a decline in complementarities between live performances and music sales. While Mortimer et al. focus on the effect of illegal downloads on the revenue and the profitability of live performances, it would be interesting to examine whether illegal downloaders are more likely to attend live performances in future studies.

Lastly, consider a situation in which the digital music is made free to the general public. We would expect that many people would download without paying a cent, and thus it would not be profitable to the artists and to the music industry. Interestingly, in October 2007, the musical group Radiohead allowed their fans to set their own price (from nothing to £100) for its recent album, "In Rainbows." During the first 29 days of the release, comScore's study showed that 38 percent of global downloaders of the album paid for the album, with an average expenditure of \$6.00 for each paid download and an average expenditure of \$2.26 per all downloads. The U.S. consumers paid substantially more (\$8.05 per paid download and \$3.23 per all downloads) than the rest of the world (\$4.64 per paid download and \$1.68

per all downloads). The difference may result from the possible higher disposable income in the United States. In this experiment, more than one-third of the consumers are willing to pay for an album that may be legally downloaded for free.

Since the introduction of Napster, the music industry and other industries selling copyrighted goods have been threatened by the popularity of digital sharing technologies. The steady decline in overall music sales in recent years worries artists, producers, and policy-makers. To help the industry, it is important to understand not only whether file-sharers spend more on music but also whether they are more likely to buy music. While the existing evidence suggests a negative or an insignificant effect of illegal downloads on the intensity of music purchases, I find a positive effect of illegal downloads on the participation of music purchases during 2004-2006. From the natural experiment of Radiohead, it is evident that consumers are willing to spend a few dollars on songs that they enjoy, even in the situation when free downloads are available. With stimulating marketing strategies, such as the introduction of digital singles, it is possible that the file-sharers who make music purchases now will spend more on both music and live performances.

7 Appendix

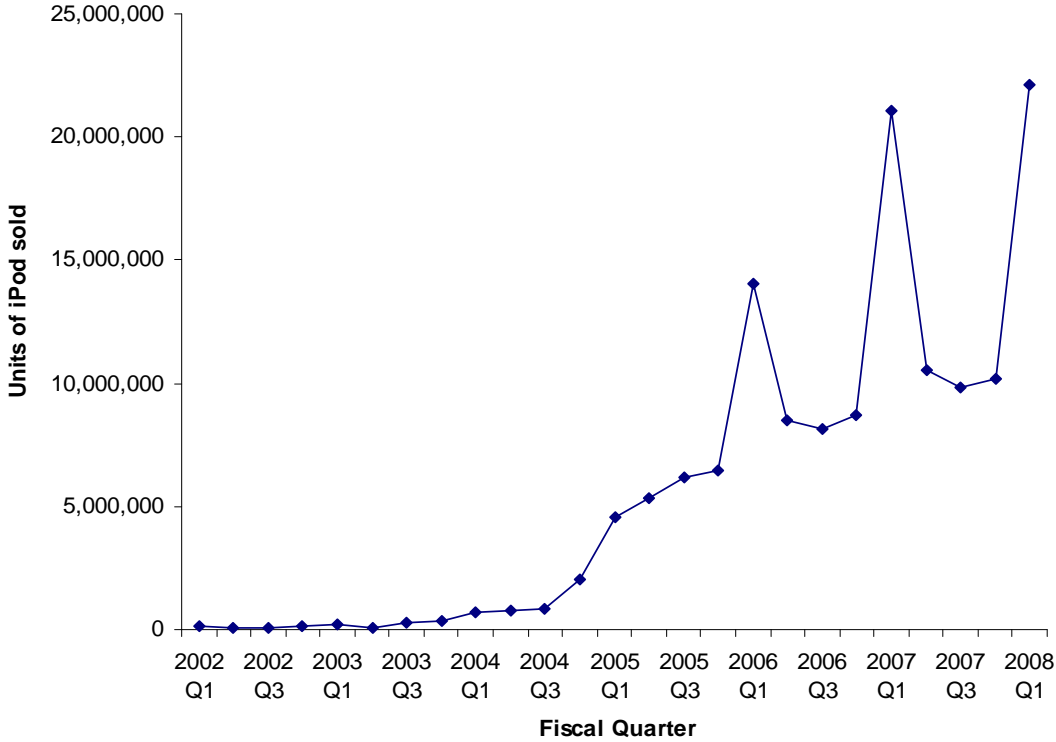


Figure 1. Units of iPod Sold vs. Fiscal Quarters

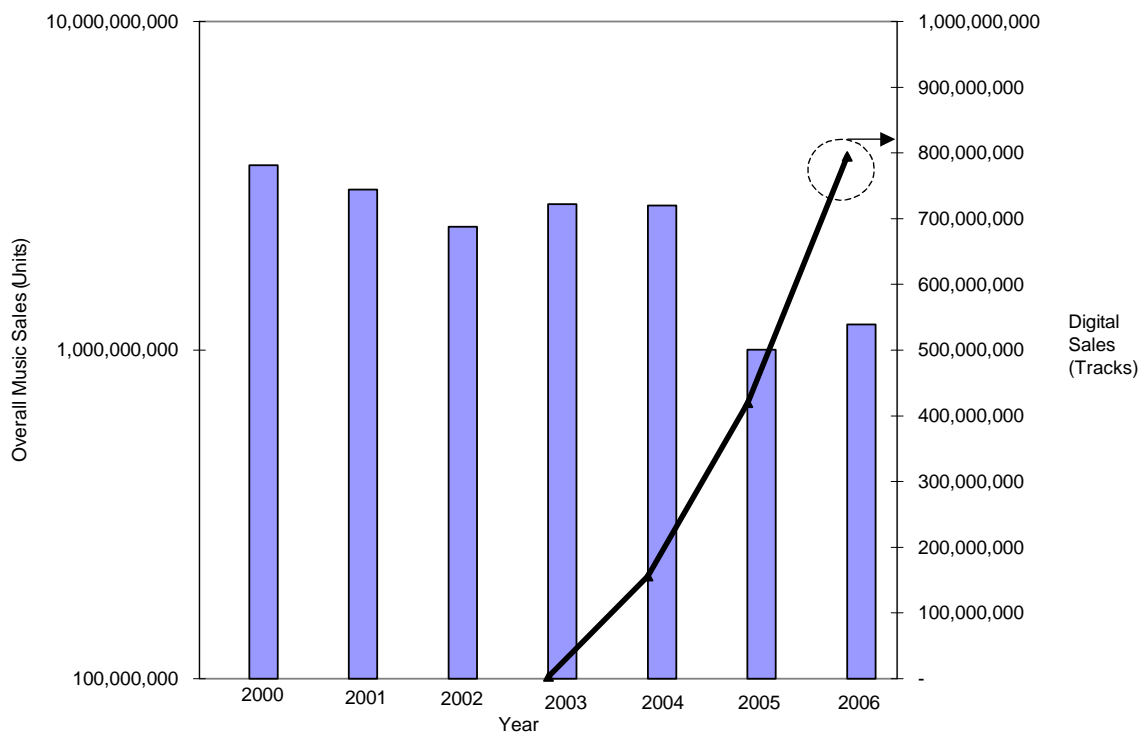


Figure 2. Global Overall Music Sales/Digital Sales vs. Year

Table 1
Descriptive Statistics

Statistics	2004	2005	2006
Overall Population:	60010	68664	66707
High Speed Internet Users	42.82%	65.73%	70.90%
People who own portable MP3 players	4.54%	9.80%	18.85%
People who regularly download music for free	8.85%	7.23%	7.90%
People who bought music within the last 3 months	26.66%	21.80%	17.36%
People who bought music within the last 3 months given that they regularly download music illegally	61.49%	63.72%	49.22%
People who bought music within the last 3 months given that they do not regularly download illegal music	24.75%	19.26%	10.67%
Own portable MP3 players:			
People who regularly download music for free	28.41%	17.30%	17.41%
People who bought music within the last 3 months	54.70%	41.62%	31.45%
People who bought music within the last 3 months given that they regularly download music illegally	76.92%	72.29%	55.77%
People who bought music within the last 3 months given that they do not regularly download illegal music	50.09%	36.53%	27.54%
Do not own portable MP3 players:			
People who regularly download music for free	7.92%	6.14%	5.69%
People who bought music within the last 3 months	25.32%	19.64%	8.69%
People who bought music within the last 3 months given that they regularly download music illegally	58.76%	60.94%	44.17%
People who bought music within the last 3 months given that they do not regularly download illegal music	23.70%	17.57%	7.15%

Table 2
Probit Estimates of Music Purchase Models (Marginal Effects)

Independent variable	2004	2005	2006
<i>P2P</i>	0.2495** (0.0094)	0.1933** (0.0108)	0.1539** (0.0082)
<i>AGE</i>	-0.0065** (0.0002)	-0.0030** (0.0002)	-0.0017** (0.0001)
<i>FEMALE</i>	0.0246** (0.0043)	0.0089* (0.0039)	0.0037 (0.0026)
<i>LOG OF INCOME</i>	0.0550** (0.0031)	0.0182** (0.0028)	0.0081** (0.0020)
<i>EDUCATION</i>	0.0118** (0.0009)	0.0025** (0.0009)	0.0022** (0.0006)
<i>HOUSEHOLD SIZE</i>	0.0091** (0.0019)	-0.0015 (0.0017)	-0.0027* (0.0012)
<i>MP3</i>	0.0401** (0.0107)	0.0470** (0.0071)	0.0865** (0.0044)
<i>BROADBAND</i>	0.0862** (0.0054)	0.0276** (0.0044)	0.0418** (0.0032)
<i>OWN HI-FI STEREO</i>	0.0247** (0.0048)	0.0084* (0.0042)	0.0077** (0.0028)
<i>HOURS ON RADIO</i>	0.0023** (0.0002)	0.0014** (0.0002)	0.0006** (0.0001)
<i>HOURS ON TV</i>	0.0009** (0.0002)	0.0006** (0.0002)	0.0001 (0.0001)
<i>SOFTWARE PURCHASE</i>	0.0576** (0.0069)	0.0290** (0.0053)	0.0634** (0.0067)
<i>BOOK PURCHASE</i>	0.1640** (0.0070)	0.2277** (0.0058)	0.0777** (0.0042)
<i>DVD PURCHASE</i>	0.1470** (0.0083)	0.2912** (0.0063)	0.1418** (0.0056)
<i>VIDEOGAME PURCHASE</i>	0.0399** (0.0100)	0.0833** (0.0070)	0.0300** (0.0051)
Rseudo R2	0.2502	0.4071	0.3185
Sample Size	60010	68664	65254

*Significant at the 5 percent level.

**Significant at the 1 percent level.

Table 3
Summary of Conditional Probabilities (Univariate Probit)

	2004	2005	2006
$\text{Prob}(\text{Music}=1 P2P=1)$	0.4439 (0.2434)	0.4024 (0.2952)	0.2478 (0.2251)
$\text{Prob}(\text{Music}=1 P2P=0)$	0.2436 (0.2089)	0.2487 (0.2715)	0.1122 (0.1553)

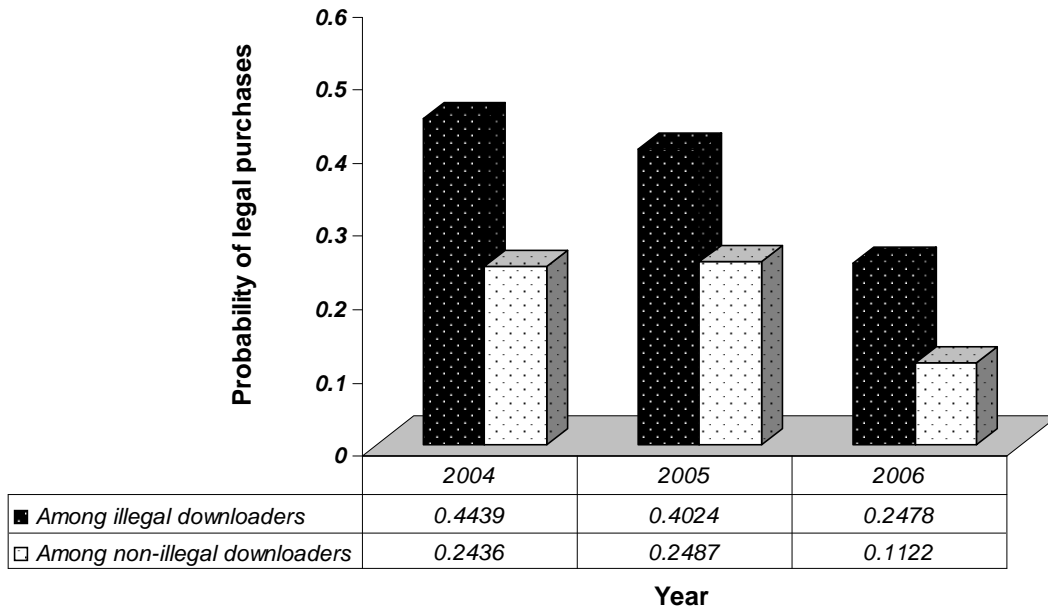


Figure 3. Conditional probability of legal music purchase

Table 4
Maximum Likelihood Estimates of *Music Purchase* Using Instruments

Instruments	2004	2005	2006
(1) <i>TECHNOLOGY ATTITUDE</i>	0.3215** (0.0224) [-0.0678]**	0.0939** (0.0168) [0.1777]**	0.0911** (0.0137) [0.1538]**
(2) <i>PUBLISH A WEBPAGE, BID IN ONLINE AUCTION</i>	0.2206** (0.0249) [0.0405]	0.0755** (0.0158) [0.1928]**	0.1511** (0.0173) [0.0054]
(3) <i>CD WRITER</i>	0.3782** (0.0203) [-0.1902]**	0.1694** (0.0177) [0.0352]	0.1848** (0.0150) [-0.0592]**
(4) <i>HIGH SPEED INTERNET</i>	0.1365** (0.0221) [0.1605]**	0.0610** (0.0142) [0.2160]**	0.0954** (0.0139) [0.1432]**
(5) <i>BID IN ONLINE AUCTION, TECHNOLOGY ATTITUDE, PUBLISH A WEBPAGE</i>	0.2486** (0.0241) [0.0039]	0.0835** (0.0162) [0.1802]**	0.1560** (0.0173) [-0.0022]
(6) <i>CHURCH</i>		0.0841** (0.0164) [0.1931]**	0.0810** (0.0133) [0.1754]**
(7) <i>PARKING TICKET</i>		0.0975** (0.0171) [0.1701]**	0.0936** (0.0139) [0.1470]**

Note: Standard errors of the marginal effect are in parenthesis, and rho is in brackets.

*Significant at the 5 percent level.

**Significant at the 1 percent level.

Table 5
 Summary of Conditional Probabilities
 Using *TECHNOLOGY_ATTITUDE* as an instrument

	2004	2005	2006
Prob(<i>Music</i> =1 <i>P2P</i> =1)	0.4978 (0.2361)	0.2714 (0.2920)	0.1920 (0.2056)
Prob(<i>Music</i> =1 <i>P2P</i> =0)	0.2394 (0.2008)	0.2068 (0.2631)	0.1176 (0.1621)

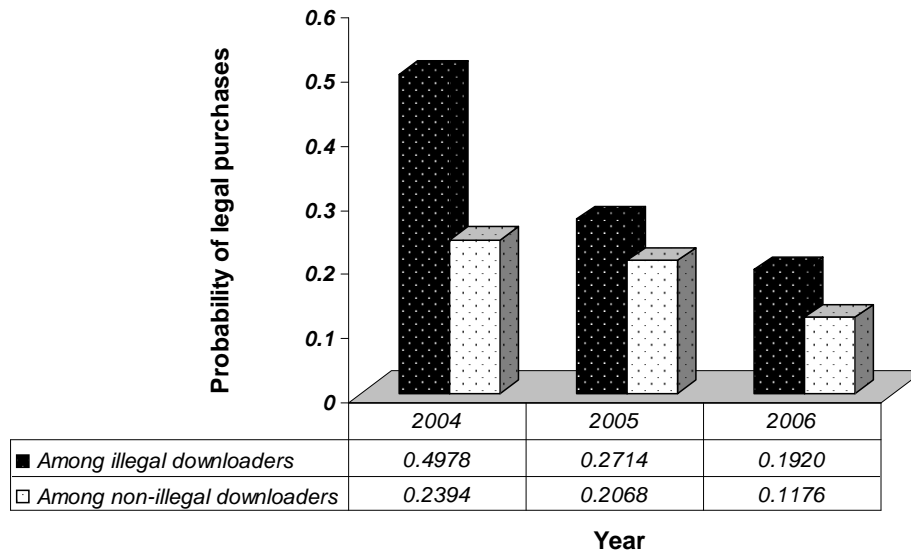


Figure 4. Conditional Probability of legal music purchase (using *TECHNOLOGY_ATTITUDE* as an instrument)

Table 6
2005 Instrumental Variables Estimates: P2P and Music Purchases

	Model 1	Model 2		Model 3		Model 4	
	Music Purchases	1st stage Instrument	2nd stage IV estimate	1st stage Instrument	2nd stage IV estimate	1st stage Instrument	2nd stage IV estimate
<i>P2P</i>	0.1933** (0.0108)		0.0841** (0.0164)		0.1227** (0.0174)		0.0666** (0.0155)
<i>CHURCH</i>		-0.0054** (0.0023)		0.0055 (0.0054)	-0.0035 (0.0044)	0.0003 (0.0033)	-0.0005 (0.0043)
<i>CHURCH x YOUNG</i>				-0.0150** (0.0050)			
<i>YOUNG</i>				0.0531** (0.0024)	0.0942** (0.0039)		
<i>CHURCH x COMPUTER LIT</i>						-0.0086** (0.0039)	
<i>COMPUTER LIT</i>						0.0739** (0.0035)	0.0416** (0.0045)

*Significant at the 5 percent level.

**Significant at the 1 percent level.

Table 7
2006 Instrumental Variables Estimates: P2P and Music Purchases

	Model 1	Model 2		Model 3		Model 4	
	Music Purchases	1st stage Instrument	2nd stage IV estimate	1st stage Instrument	2nd stage IV estimate	1st stage Instrument	2nd stage IV estimate
<i>P2P</i>	0.1539** (0.0082)		0.0810** (0.0133)		0.0818** (0.0134)		0.0462** (0.0115)
<i>CHURCH</i>		-0.0085** (0.0025)		0.0028 (0.0054)	-0.0048 (0.0030)	-0.0006 (0.0036)	-0.0051 (0.0030)
<i>CHURCH x YOUNG</i>				-0.0167** (0.0051)			
<i>YOUNG</i>				0.0448** (0.0027)	0.0172** (0.0043)		
<i>CHURCH x COMPUTER LIT</i>						-0.0110** (0.0041)	
<i>COMPUTER LIT</i>						0.0820** (0.0036)	0.0615** (0.0035)

*Significant at the 5 percent level.

**Significant at the 1 percent level.

Table 8
Testing for the Presence of a Treatment Effect
Using *TECHNOLOGY_ATTITUDE* as an instrument

Year	tau-hat	standard error
2004	0.2757	0.0078
2005	0.1010	0.0070
2006	0.0734	0.0060

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