Essays on the Economics of Intellectual Property

A Thesis Submitted to the Faculty of the Graduate School of the

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by

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to Mei Lan for her love...

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Abstract

This dissertation evaluates the effectiveness of different polices on intellectual property when piracy is growing.

The first chapter deals with music piracy. 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. This chapter finds that the first belief is right while the second is wrong; as the music industry overlooks the complementary effect of music piracy on products such MP3 players. I construct a unique data set from 883 undergraduate students, 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, I conduct counterfactuals to evaluate the welfare effect of different copyright regimes. While a regime that eradicates music piracy benefits music producers at the expense of students and Apple, another regime in which Apple pays royalties to music producers for legalizing music piracy benefits most students and music producers at the expense of Apple.

The second chapter deals with software piracy. Chinese and Hong Kong governments enforce intellectual property rights by eradicating street piracy. This chapter shows that this policy is ineffective due to the emergence of Internet piracy. To support the claim, I construct a unique data set from 222 college students in Hong Kong to demonstrate two things. First, I estimate a random-coefficient discrete choice demand system for Microsoft Office from legal and different illegal sources. Estimates obtained from a Bayesian approach, with a mixture of normal prior, indicates a strong substitution pattern between street and Internet piracy. Second, I conduct counterfactuals in which counterfeit Microsoft Office DVD is not available. Results are threefold. First, only 31% of students who bought counterfeit DVD would choose to buy a legal copy, while approximately 50% of them would switch to download on the Internet. Second, the decrease in consumer surplus ($43/student) outweighs the

increase in Microsoft's profit ($6/student). Third, Business Software Alliance (BSA) overestimates the revenue loss due to piracy by up to six times since it ignores the substitution pattern between street and Internet piracy.

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Chapter 1

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

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.

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

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 1.3). My results contrast with what Oberholzer-Gee and Strumpf (2007) claim and support this belief in the music industry (Section 1.4).

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): Weak copyrights lead to under-provision. Strong copyrights create monopoly distor-

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

tions. 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 1.2). 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 1.6) 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 1.3) 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 1.3.2.

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 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 1.4). I estimate this system of three simultaneous equations using the three-stage least-squares method. Results suggest that music piracy hurts

[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.

record sales. Second, I use the estimates from the first part to set up a random-coefficient discrete demand model for iPods (Section 1.5). 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 1.6). 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 1.1 briefly describes the current situation of growing music piracy and declining record sales. Section 1.2 summarizes three different copyright regimes that people propose. Section 1.3 discusses the conjoint survey data set. Sections 1.4 and 1.5 set up the demand for music and the demand for iPods, and discuss results of the estimation. Section 1.6 conducts counterfactual experiments using results from Sections 1.4 and 1.5. Section 1.7 concludes.

1.1 Music Piracy Growing, Record Sales Shrinking

1.1.1 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.

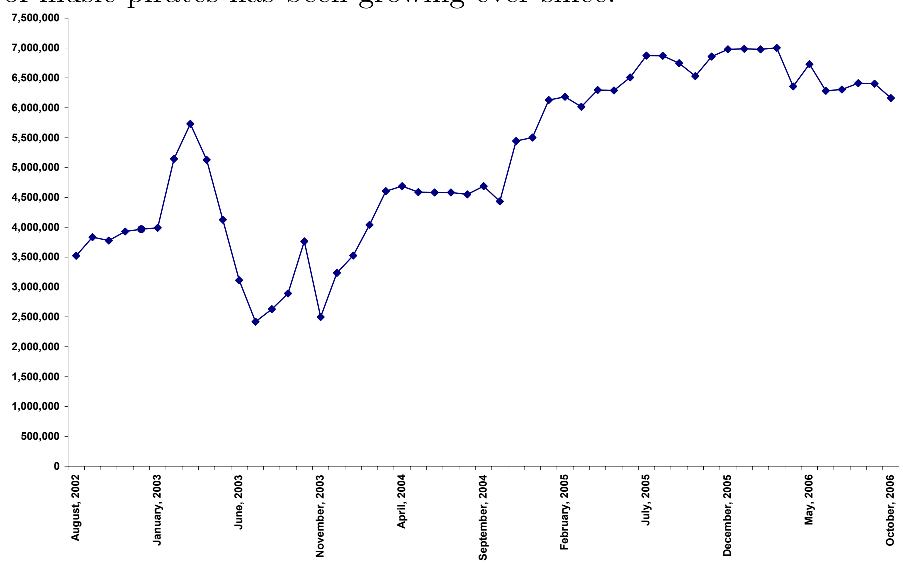

Figure 1.1: Big Champagne: Avg Simultaneous P2P Users in the U.S. Growing

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 1.1).[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."

1.1.2 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 1.2).

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

[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 1.3.

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

[6] See AssociatedPress (2005).

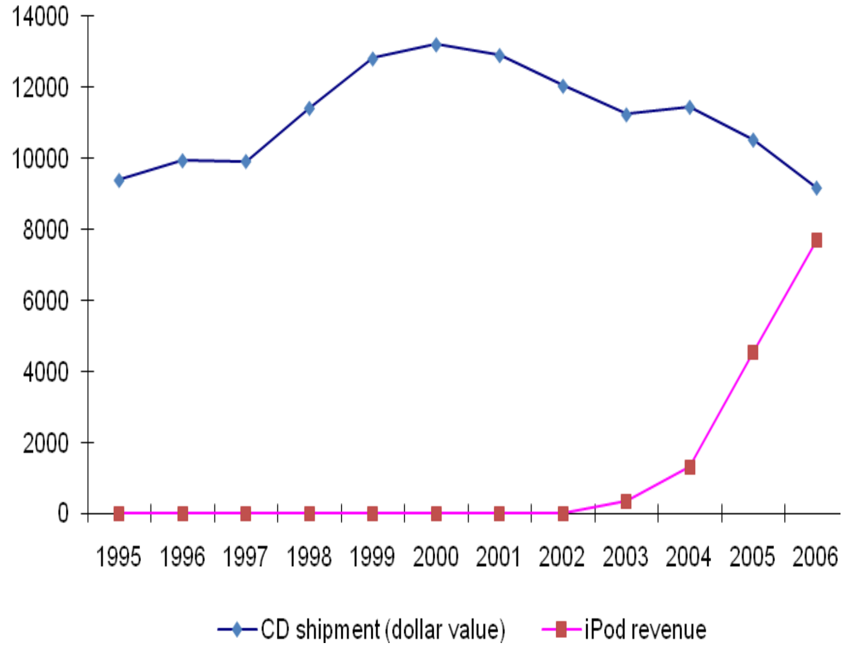

Figure 1.2: RIAA and Apple Inc.: CDs Revenue Decreasing, iPods Revenue Growing in the U.S. ($millions)

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

$$A_{jt} = X_{jt}\beta + \alpha D_{jt} + \epsilon_{jt} \tag{1.1.1}$$

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 ϵ_{jt}, and the estimate of α would have an upward bias. They deal with this problem by finding instruments

Table 1.1: US Legal Digital Music Market Growing (M)

	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.

for illegal downloads that are not themselves related to album sales and thus not correlated with ϵ_{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

[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.

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 1.1 shows that the number of legal downloads of both single tracks and albums increased by 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 1.3 describes the conjoint survey data set and compares the pros and cons of this data set with data sets used by others.

1.2 Possible Copyright Regimes

Results in Section 1.4 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]

1.2.1 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 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 1.1).

1.2.2 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 cooperates. Currently there are proposals in France and Britain urging Internet Service Providers to voluntarily band together

[8]Section 1.6 gives a more detailed description of the three regimes.
[9]See AssociatedPress (2005).

and crack down on pirate subscribers.

1.2.3 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 1.2).

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`.

Table 1.2: 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

1.3 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 1.2).

1.3.1 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 1.3). 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 infor-

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

Table 1.3: 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

mation 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 1.1 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 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 1.3 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

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 Chance of getting caught per month: **1 in 2000 songs**	Free P2P downloading **illegal**. Fine: **$US50/song** downloaded that month Chance of getting caught per month: **1 in 100,000 songs**	
iTunes: **$ US 0.3/song** CD: **$5 each**	iTunes: **$ US 3/song** CD: **$10 each**	Free music

Figure 1.3: 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 1.4: A Sample of the Second Sub-Task

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 1.4 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.

1.3.2 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 1.1, both Oberholzer-Gee and Strumpf (2007) and Rob and Waldfogel (2006) use an instrumental variable approach to deal with endogeneity in (1.1.1). 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 ϵ_{jt} in equation (1.1.1) and can serve as instruments for illegal downloads.

1.3.3 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 1.4 shows that the respondents have a huge interest in listening to music. On average, 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

[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.

Table 1.4: Music-iPod Data Description

	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 1.5: Songs Pirated Per Month by Pirates

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

Table 1.6: Summary Statistics of iPod Conjoint Survey

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

N=10608

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 1.5).

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.

[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.

Table 1.7: 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 1.6 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 1.7 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.

1.4 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

Table 1.8: 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

the problem as a simultaneous equations problem. In particular, the simultaneous demands for music for agent i in task t is

$$\log Y^*_{itp} = \mathbf{z}'_{itp}\gamma_p + \log({Y^*}_{its})\phi_{ps} + \log({Y^*}_{itc})\phi_{pc} + u_{itg} \tag{1.4.1}$$

$$\log Y^*_{its} = \mathbf{z}'_{its}\gamma_s + \log({Y^*}_{itp})\phi_{sp} + \log({Y^*}_{itc})\phi_{sc} + u_{its} \tag{1.4.2}$$

$$\log Y^*_{itc} = \mathbf{z}'_{itc}\gamma_c + \log({Y^*}_{its})\phi_{cs} + \log({Y^*}_{itp})\phi_{cp} + u_{itc} \tag{1.4.3}$$

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 1.8 shows all the $\mathbf{z}$.

Every dependent variable has its own instruments. For instance, the probability of getting caught pirating music (π) 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

Table 1.9: Music Demand Per 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

least-square method to estimate this simultaneous equations system. Table 1.9 shows the results.

Students pirate more music and buy more iTunes songs when they have an iPod. In the last row of table 1.10, 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 1.10 reports the percentage change of demand for music when different prices change.

The probability of getting caught and the fine payment are significant components

Table 1.10: 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 → 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%

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 1.8. When price per iTunes song increases from \$0.99 to \$1.87, demand for iTunes songs drops 49%, which is reasonably close to the

Table 1.11: 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

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 1.11 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.

1.5 A Discrete Choice Demand for iPod

Results in Section 1.4 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.

1.5.1 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

$$U_{ijt} = \beta_0^j + \sum_{l=1}^{L} \beta_{jl} z_{il} + \alpha_1 P_{jt} + \alpha_2 GB_{jt} + \alpha_3 P2\hat{P}_{ijt} + \alpha_4 iTu\hat{n}es_{ijt} + \alpha_5 C\hat{D}_{ijt} + \epsilon_{ijt} \quad (1.5.1)$$

[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 1.9 and 1.13 suggests that my conclusion should stay the same regardless of whether I correct the standard errors or not.

Table 1.12: Mixed Logit Estimation of iPod Demand with Homogenous Coefficients (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)

N=10608

Table 1.13: Elasticities of iPod with Homogenous Coefficients

P_{iPod}	-0.202
P_{iTunes}	-0.008
P_{cd}	-0.010
π	-0.0004
f	-0.023

where z_{il} is the lth demographic variable of student i, P_j is the price of choice j, and ϵ_{ijt} is the usual i.i.d. logit error.

Table 1.12 and 1.16 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 $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.

1.5.2 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 β and x, the mixture of normals model specifies the distribution of ϕ_i and β_i across students as follows:

$$U_{ijt} = x'_{ijt}\beta_i - \exp(\phi_i)P_{jt} + +\epsilon_{ijt}$$

$$[\beta_i; \phi_i] \sim N(\mu_{ind}, \Sigma_{ind})$$

$$ind \sim \text{multinomial}(\gamma)$$

γ is a vector giving the mixture probabilities for each of the five components. The complete specification with priors over the mixture probabilities (α), the mean ($\bar{\mu}$

Table 1.14: Heterogeneity Improves Fit

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

and a_μ^{-1}), and covariance matrices (v and V) is:

$$\gamma \sim Dirichlet(\alpha)$$

$$\mu_k|\Sigma_k \sim N(\bar{\mu}, \Sigma_k \times a_\mu^{-1})$$

$$\Sigma_k \sim IW(v, V)$$

$$\{\mu_k, \Sigma_k\} \text{ independent}$$

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 μ_k and Σ_k.[16]

Table 1.14 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

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

Table 1.15: Mixed Logit Estimation of iPod Demand with Random Coefficients (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)	

N=10608

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 1.15 shows the means and standard errors of the coefficients. Table 1.16 shows the elasticities estimates.

The law of demand still holds for the demand for iPods. The middle left sub-figure of figure 1.5 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 1.5 show the density distribution of

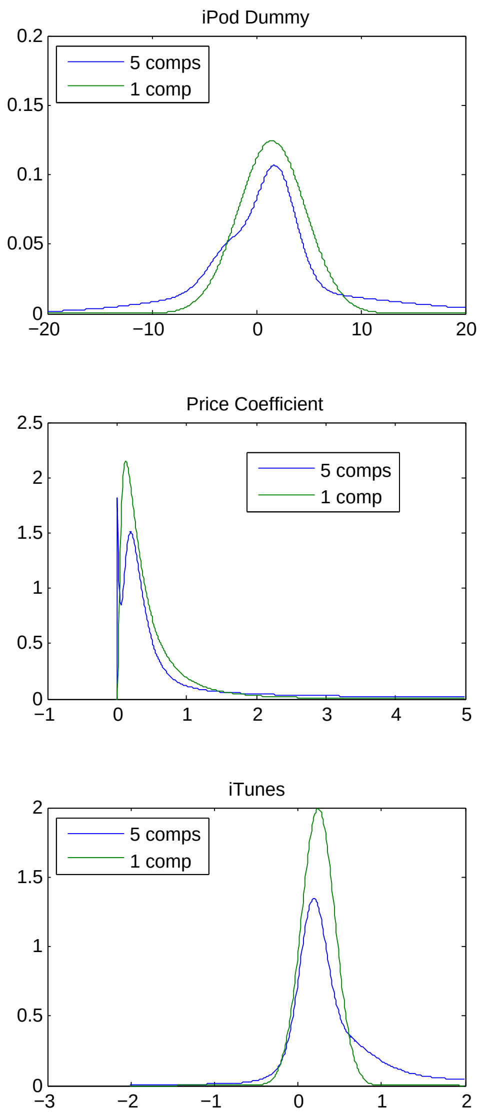

Figure 1.5: Density of Random Coefficients

Table 1.16: 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
π	-0.0004	-0.0007	-0.0012
f	-0.018	-0.041	-0.073

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

$$\frac{p-c}{p} = \frac{-1}{\xi} \tag{1.5.2}$$

where p is price of an 8-gigabyte iPod, which is \$200, c is the marginal cost, and ξ is the own price elasticity. The resulting marginal cost is \$116. Table 1.17 shows that the material cost of an 8-gigabyte iPod is \$82.85. This suggests that other

Table 1.17: 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

parts of the marginal cost of an 8-gigabyte iPod including assembling, marketing and transportation cost are approximately $33.

1.6 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 1.4 and 1.5.[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 1.18 describes the three regimes.[19] The Current Regime describes the cur-

[17] I use the estimates of demand for iPods from the five-component model in the counterfactual.
[18] See Section 1.6.4 for summary.
[19] I calculate the optimal price per iPod using equation (1.5.2) and the marginal cost calculated in the previous section. The marginal cost in the Free Music-Royalty Regime is the original marginal

Table 1.18: 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
π (in %)	0.01	100	0
Fine per song	\$30	\$10,000	\$0

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

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cost plus the royalty.

Table 1.19: Predicted Market Shares of iPod in Different Regimes (%)

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

1.6.1 Students' Surplus

Most students do not like the No Music Piracy Regime. An average student loses $354 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 $319 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.

1.6.2 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 1.19 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 1.4. 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 $14/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.

1.6.3 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.

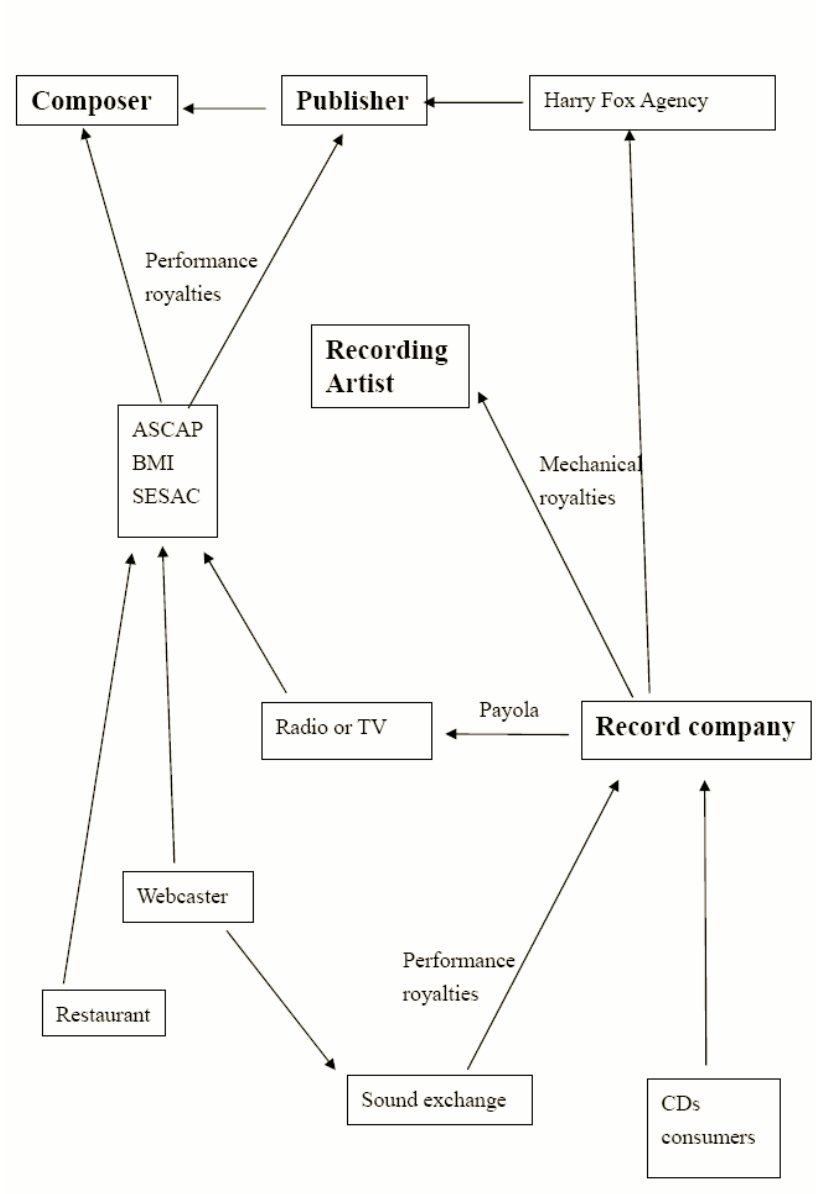

Figure 1.6: Fisher: Revenue Stream in the Music Industry

Table 1.20: 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

Second, I make some assumptions about the profit margin of each CD.[20] Figure 1.6 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 1.20, 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 \$33/student (\$19 from iTunes and \$14 from CDs) in a two-year period (the life of an iPod).

Without record sales revenue from iTunes and CDs, music producers' sole source

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

Table 1.21: Total Welfare Increases in Free Music-Royalty Regime (Per Student)

Current Regime to	No Music Piracy Regime	Free Music-Royalty Regime
△ Students' Surplus	-$354.18	$318.9
△ Apple's profit	-$13.79	-$13.26
△ Music producers' profit	$32.64	$32.41
△ Total Surplus	-$335.33	$338.01

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 increase $32.4/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.

1.6.4 Total Welfare Changes

As shown in table 1.21, on average, there is a loss of $335/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 $338/student. While the No Music Piracy Regime benefits music producers at the expense of all students and Apple, the Free Music-Royalty Regime benefits most students and music producers at the expense of Apple. Note in the Free Music-Royalty Regime, the per-student profit change for Apple and music producers combined is positive ($-\$13.26 + \$32.41 = \$19.15$).

Figure 1.7 shows the changes in surplus for different social groups when royalty varies. Students, on average, are better off in the Free Music-Royalty Regime. But the surplus gain decreases when royalty increases. Apple gains in the Free Music-

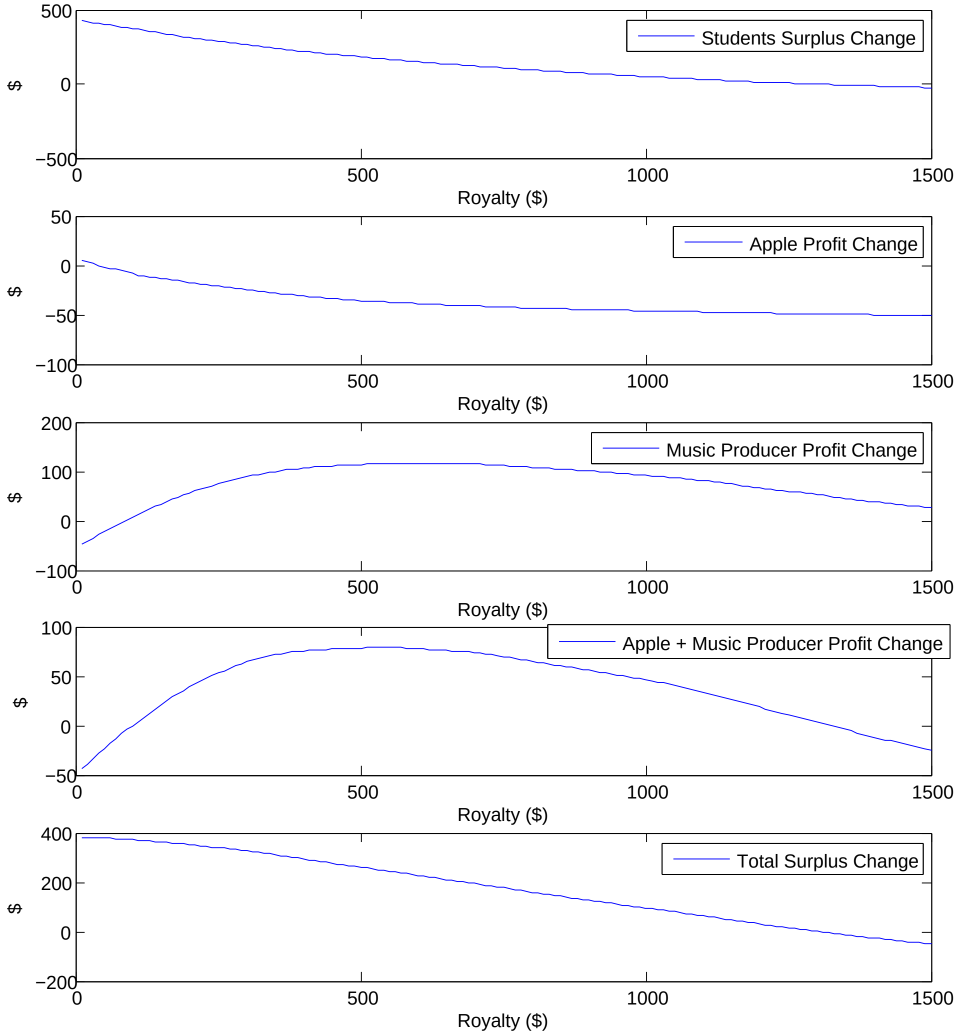

Figure 1.7: Surplus Changes For the Three Groups When Royalty Changes in the Free Music-Royalty Regime

Royalty Regime when royalty burden is small (below $40). Music producers gain in the Free Music-Royalty Regime only with a high royalty (above $90). Thus there does not exist a royalty level such that both Apple and music producers are better off. Combined profit of Apple and music producers increases under certain royalty levels, like $150 in the counterfactual.

1.7 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.

Chapter 2

Intellectual Property Enforcement in the Internet Era Evidence from Microsoft Office in Hong Kong

2.1 Introduction

Innovation induces economic growths. Yet the economics profession has not reached a consensus on whether intellectual property rights (IPR) can foster innovation. On the one hand, as Nordhaus (1969) points out, IPR provides commercial incentives to innovate. Chen and Puttitanun (2005) uses a panel data consisting of

64 developing countries and shows that IPR has a positive impact on innovations. Hu and Png (2009) finds that a stronger IPR had a larger positive impact on more patent-intensive industries in over 72 countries between 1981 and 2000. But on the other hand, as Boldrin and Levine (2008) argues with examples, IPR can increase the monopoly power of copyright/patent owner and thus increase the cost of other innovations. Qian (2007) shows that national IPR does not stimulate domestic innovation on pharmaceutical products in the 26 countries in the study.

One key factor ignored in the discussion is the effectiveness of the IPR enforcement. In particular, we would expect the higher cost of IPR enforcement, the less net benefit from stronger IPR. The cost of enforcement changes with IPR infringement technology.[1] Since the late 1990s, emergence of Internet has given people one more option to obtain counterfeit copyrighted goods in addition to street hawkers. Governments and copyright owners file lawsuits against suppliers and individual pirates, both on the street and on the Internet, to enforce IPR. But the enforcement cost is higher on the Internet. While governments have achieved successes in curbing street piracy , they have setbacks on the Internet.(Section 2.3)

The emergence of Internet also lowers the effectiveness of any effort that reduces street piracy, since people can substitutes a counterfeit software DVD obtained from a street hawker with an illegally downloaded software file from the Internet. In the extreme case in which street and Internet piracy are perfect substitutes, any effort that reduces street piracy would not be effective in protecting IPR at all. Thus, from the point of view of policy makers, it is important to know the substitutability between street and Internet piracy, and hence the effectiveness of eradicating street

[1] I use IPR infringement and piracy interchangeably in this paper.

piracy.

As the importance of software innovation grows in the era of digitization, more software applications are under the protection of copyrights or patents.[2] And software application has a high piracy rate, both on the street and on the Internet. According to Business Software Alliance (BSA), software piracy rate was 38% worldwide and more than 60% in most developing regions. While ignoring the substitutability between street and Internet piracy, BSA estimates that the revenue loss due to piracy was approximately $47 billion.

To the best of my knowledge, this is the first paper to separately estimate demands for copyrighted products legal and different illegal sources. This is essential to quantify the substitutability between piracy on the street and on the Internet. For my empirical analysis, I construct a unique conjoint survey data set (Section 2.4) on Microsoft Office (henceforth Office), one of the most successful and also heavily pirated software application, from 222 college students in Hong Kong. In the survey, students answer two types of questions. First, they report information on their demographics and consumption of copyrighted goods like Microsoft Office and anti-virus software. Second, in the conjoint survey, they make hypothetical choices on Office (from legal source, street piracy or Internet piracy) in ten 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

[2]According to Bessen and Hunt (2007), almost 15% of patents issued in the US were software patents in 2002, compared to 1.1% in 1976.

of Office from legal and various illegal sources. As I argue before, it is important to know the substitutability between street and Internet piracy, and hence the real impact of different copyright policies. This requires demand estimates for Office from different sources. Second, conjoint survey can create good instruments for demand estimation for reasons discussed in Section 2.4.2.

Several studies argue that conjoint survey data can generate reliable demand estimates.[3] Applications of conjoint survey analysis abound. Leung (2009) uses a similar approach to estimate the complementarity between music and iPod, and evaluate various copyright policies. 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 survey data to estimate demand for new products (Green, Krieger, and Wind (2004) and Orme (2005)).

My empirical analysis consists of two parts. First, I set up a random-coefficient discrete demand model for Office (Section 2.5). I follow Rossi, Allenby, and McCulloch (2005) to set up a hierarchical Bayesian discrete demand model for Office from different sources, with a mixture of normal priors, and then use a hybrid of Gibbs Sampling and Metropolis-Hasting algorithm to implement posterior inference. Second, I use the estimates to conduct counterfactuals to evaluate the effectiveness of various policies including one that completely eradicate street piracy (Section 2.6). Results are threefold. First, only 31% of students who bought street pirated Office

[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.

would choose to buy a legal copy, while approximately 50% of them would switch to download on the Internet. Second, the decrease in consumer surplus ($43/student) outweighs the increase in Microsoft's profit ($6/student). Third, BSA overestimates the revenue loss due to piracy by up to 600% since it ignores the substitution pattern between street and Internet piracy.

The organization of the article is as follows: Section 2.2 briefly describes the current situation of software piracy. Section 2.3 summarizes the international cooperation on IPR enforcement. Section 2.4 discusses the conjoint survey data set. Section 2.5 set up the demand for Microsoft Office, and discuss results of the estimation. Section 2.6 conducts counterfactual experiments using results from Section 2.5. Section 2.7 concludes.

2.2 Software Piracy Across the Globe

Improvement in technology has been a major driving force for growths. Starting from 1980s, with the widespread of computers, innovation and development of softwares has been an important factor for technological improvement.

Software, like music and movies which are also under the protection of copyright laws, has one common property in production: High fixed cost and low marginal cost. This property creates a problem for software producers—software piracy. According to Business Software Alliance, the industry representative of the software industry, "35% of the software installed in 2006 on personal computers (PCs) worldwide in 2006 was obtained illegally, amounting to nearly $40 billion in global losses due to software piracy."

Table 2.1: Software Piracy Rates in Selected Regions (%)

	2003	2004	2005	2006	2007
United States	22	21	21	21	20
Canada	35	36	33	34	33
European Union	37	35	36	36	35
Middle East & Africa	56	58	57	60	60
Latin America	63	66	68	66	65
Asia-Pacific	53	53	54	55	59
China	92	90	86	82	82
Hong Kong	52	52	54	53	51

Source: Business Software Alliance

2.2.1 Software Piracy and the Emergence of Internet

Software piracy rates vary across countries. Table 2.1 shows that software piracy rates are higher in developing regions, like Asia. In particular, China's software piracy rate is one of the highest in the world (above 80% between 2003-2007). Hong Kong also has a relatively high software piracy rate among developed regions (above 50% between 2003 and 2007).

In the 1990s and early 2000s, sale of counterfeit software CDs was the main form of software piracy. However, the emergence of Internet has changed the way some people pirate software. According to the World Bank's World Development Indicator, the Internet penetration rate increases worldwide from 7% in 2000 to 23% in 2007. Also, the number increases at a faster rate in many developing countries like China. The Internet penetration rate increases from 2% to 16% in China from 2000 to 2007, whereas the corresponding numbers in the US are 44% and 73%.

Both easier access and the increase in Internet speed contribute to the widespread of Internet piracy. One common technology people use to pirate digital copyrighted goods is Peer-to-Peer (P2P) software. According to Big Champagne, a marketing research firm specializing in Internet products, the simultaneous P2P users has been increasing worldwide (figure 2.1). At any moment in October 2006, there were about 9 million people in the world using P2P software to share files, a significant portion of them being software files.

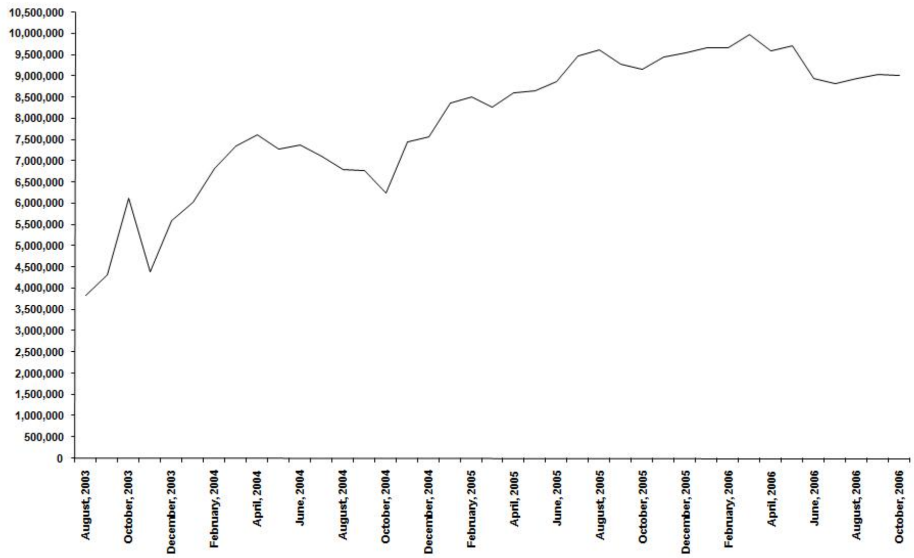

Figure 2.1: Big Champagne: Average Simultaneous P2P Users Worldwide

2.2.2 Revenue Loss Due to Piracy

According to BSA, the industry's loss to software piracy in China is also among the highest despite its low income level. Table 2.2 shows that economic loss due to software piracy in China was the second highest in the whole world, behind the United States, at more than $6,000 million in 2007.

These numbers on revenue loss are, however, higher than it actually is. As I argue in Section 2.6.6, BSA's calculation ignores the substitution between street and Internet piracy and assumes one less pirated Office translates into one more legitimate

Table 2.2: Countries with $1,000 Million or More in Piracy Loss ($M)

Country	2007 ($M)
United States	8,040
China	6,664
Russia	4,123
France	2,601
India	2,025
Germany	1,937
United Kingdom	1,837
Japan	1,791
Italy	1,779
Brazil	1,617
Canada	1,071

Source: Business Software Alliance

sale . This can inflate the estimates on revenue loss since people can switch to download from the Internet even when they cannot buy counterfeit DVD from street hawkers.

2.3 International Cooperation and Enforcement of IP

International cooperation on IPR protection can be traced back to the United International Bureaux for the Protection of Intellectual Property (BIRPI). Established in 1893, it is the first international treaty on IPR protection. Its successor, the World Intellectual Property Organization (WIPO), was created in 1970 and became a specialized agency of United Nations (UN) in 1974. Frustrated by the limited expansions of IPR treaties in WIPO, the United States and other developed countries negotiated the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) at the end of the Uruguay Round of the General Agreement on Tariffs and Trade

Table 2.3: Seizure of Counterfeit Products in China (M)

	2001	2002	2004	2005	2006	2007
Book	12	20	19	19	18	11
Music/Movie Records	37	27	39	66	48	52
Software	4	6	6	8	4	3

Source: State Intellectual Property Office of China
The 2003 report does not show the relevant data.

Table 2.4: Street Piracy Declining in Hong Kong

	2003	2004	2005	2006	2007	2008
Optical Disc Seizure (M)						
Quantity	6.2	7.3	3.8	3.0	4.3	2.2
Value	135.3	157.8	89.2	72.4	99.1	52.3
Shops Engage in Piracy						
Quantity	105	70	50	45	30	25

Source: Hong Kong Customs and Excise Department

(GATT) in 1994. TRIPS imports most of the provisions on copyright, trademark and patent from conventions that WIPO administers, but has a more powerful enforcement mechanism through the dispute settlement mechanism of the World Trade Organization (WTO) which administers TRIPS.

Hong Kong and China have been members of the WTO and hence TRIPS since 1995 and 2001. Both have implemented laws required by TRIPS to protect copyright owners. Table 2.3 shows that the Chinese government have been active in enforcing IPR by seizing counterfeit products. Even though most of the seizure are music or movie records, the Chinese government still seizes millions of copies of counterfeit software every year.

Table 2.4 shows the IPR enforcement in Hong Kong. Street piracy in Hong Kong has declined in the past six years: Hong Kong Customs and Excise Department estimates that the number of shops that engage in piracy decreased from 105 in 2003 to 25 in 2008. The seizure of counterfeit products also declined through the years.

While enforcement of IPR on the street has achieved some success in places like China and Hong Kong, the same is not true on the Internet. The RIAA has recently stopped its strategy to sue online music pirates because of the public-relations disaster it created.[4] Recently, arguing that Internet access is a fundamental human right, French lawmakers rejected an anti-piracy plan which would empower the government to sever pirates' Internet connection.[5] Even though the founders of Pirate Bay, one of the worlds biggest file-sharing sites, were found guilty of breaching copyright law in Sweden, the web site can still operate since its server is located beyond the reach of Swedish or European Union law enforcers.[6]

The situation is similar in China and in Hong Kong. Both governments have put effort to enforcement on the Internet. The Chinese government closed down about 600 web sites that provided illegal source of copyrighted goods between 2005 and 2007. The Hong Kong Intellectual Property Department set up two 7-man Anti-Internet Piracy Teams to monitor Internet piracy in Hong Kong. These efforts yield limited success at best. Despite the fact that a Hong Kong citizen was convicted for illegal distribution of copyrighted works using P2P software in 2005, the only such case so far in Hong Kong, it is still relatively easy to download an illegal copy of Microsoft Office in some popular web sites in Hong Kong. Also, as I argue in Section 2.6, the effect of successful enforcement on the Internet might still be small.

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[4] See Wall Street Journal at http://online.wsj.com/article/SB122966038836021137.html.

[5] See New York Times April 13th, 2009 at http://www.nytimes.com/2009/04/13/technology/internet/13iht-piracy13.html?_r=1&scp=1&sq=french%20government,%20peer%20to%20peer&st=cse.

[6] See The Economist April 17th, 2009 at http://www.economist.com/business/displayStory.cfm?story_id=13518830&source=features_box2

2.4 Data Collection and Description

In order to estimate the substitutability between street pirated goods and Internet pirated goods, I need a panel data set on the consumption choices of legal, street pirated and internet pirated goods. However, like other illegal activities, data with such feature is hard to come by. This leads me to collect conjoint survey data from college students, the main culprits of all kinds of piracy, in Hong Kong. To the best of my knowledge, this paper is the first to collect such data.

2.4.1 Conjoint Survey

I conducted the survey in Fall 2008 and Spring 2009 in five undergraduate classes in the Open University of Hong Kong (OUHK) and the Chinese University of Hong Kong (CUHK), which allowed for potentially 300 students. Of these, 222 students turned in their surveys.

I focus on one particular software product in this survey—Microsoft Office (Office), which is one of the most popular desktop applications and is also heavily pirated throughout the world.

The whole survey consists of two parts. In the first part, students report their demographic information and consumption behavior of other copyrighted goods like Microsoft Windows and Movies.

The second 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. Respondents make choices in hypothetical situation with hypothetically set prices and other product attributes for different products. Conjoint survey data is also known as “stated-preference” data, as opposed to “revealed-preference” data, which is collected from real market transactions.

First choice: ☐1 ☐2 ☐3 ☐4 Second choice: ☐1 ☐2 ☐3 ☐4

Option 1:	Option 2:	Option 3:	Option 4
Buy a legal copy of Office CD	**Buy a pirated** copy of Office CD	**Download a pirated** copy of Office on the internet	Do not buy and use Office
$300	**$5**	$0 **30 mins** of search and download time	
Auto update	**No** update	**No** update	

Figure 2.2: A Sample of the Software Conjoint Survey

At the beginning of the conjoint survey, I describe the package of the Microsoft Office which includes four products:

- Microsoft Word 2007
- Microsoft Excel 2007
- Microsoft PowerPoint 2007
- Microsoft FrontPage 2007

There are ten hypothetical tasks in this conjoint survey. Figure 2.2 shows a sample of a conjoint task. In each task, respondents can choose from one of the four options to obtain the Microsoft Office package described above: 1. To buy a legal copy of Office CD; 2. To buy a street pirated copy of Office CD; 3. To download a pirated copy of Office on the Internet; 4. Not to use Office. Choices differ in the level of each of the three choice-specific covariates:

- Price (HKG$50 to HKG$2000)
- Search and download time (5 minutes to 5 days)
- Availability of update

The prices of street pirated Office, legal Office and student version of legal Office are approximately at HKG$50, HKG$1170 and HKG$500. The search and download time of Office on the Internet varies from 30 minutes to ten hours depending on the availability of BT seeds. Microsoft provides regular update, mostly security updates, for most of its products including Office. Anecdotal evidence suggests that it is easy to find relevant updates on the Internet for illegal version of Office.

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

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.

2.4.2 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. Leung (2009) uses a similar approach to estimate the complementarity between music and iPod, and evaluate various copyright policies. 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 a copyrighted goods from legal and various illegal sources. For music records, 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) conducts 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. They do not, however, estimate demand for piracy from different sources. This is important for policy analysis since a policy to seize all counterfeit Office may shift people from street piracy to internet piracy and thus may not boost legal sales. 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. There can be two problems using price data from real market data. First, price is endogenously determined. As Berry, Levinsohn, and Pakes (1995) and Nevo (2000) illustrate, prices can be a function of the unobserved product characteristic and be correlated with the unobserved product heterogeneity. This will lead to bias of the price estimate. Second, price variation for Office is small. Conjoint survey analysis can avoid these problems. First, prices, as one of the product attributes, are drawn exogenously and indepen-

Table 2.5: Software Data Description

	Mean (s.d.)	Min	Max
Age	21.4 (4.3)	17	50
Have used BitTorrent recently	0.67	0	1
Hours spent on internet per day	4.13 (3.23)	0	24
Use legal Windows	0.71	0	1

N=222

dently using the orthogonality principle described in previous subsection. Second, as the designer of the survey, I can vary the prices of Office within a pre-specified range which can be substantially larger than that in the real market data.

2.4.3 Data Description

Of the potential 300 students from the five undergraduate classes, 222 of them turned in their surveys. Table 2.5 shows some of the characteristics of the students. Most students from CUHK are below the age of 21, while some part-time students from OUHK are older with age above 30. The average age is 21. More than 60% of them have family income less than HK$20,000 ($2,500) per month.

Most students have exposure with the Internet technology. On average, they spend about 4 hours per day on Internet. Also, 67% of the students have used BitTorrent, a P2P software, to share digital files recently. As expected, younger students from CUHK have more exposure new Internet technology: 70% of CUHK students have used BitTorrent recently compared to 60% of OUHK students.

Most students have experience with piracy, be it purchase of counterfeit copyrighted products or illegal downloads on the Internet. Table 2.5 shows that almost 30% of the students are using illegal copy of Microsoft Windows. The proportion is lower than that of other copyrighted goods since most Microsoft Windows are pre-

Table 2.6: Sources of Copyrighted Goods

	Legal	Counterfeit CD	Illegal Download
Anti-Virus Software	29%	6%	65%
Microsoft Office	38%	23%	39%

N=222

installed in a new computer. Approximately 60% and 70% of them are using illegal copies of anti-virus software and Microsoft Office. Of those, more than half of them obtained the copy from the Internet.

2.5 A Discrete Choice Demand for Microsoft Office

An accurate evaluation of a government's copyright policy requires a thorough understanding of the demand for copyrighted products, both from legal and illegal sources. I estimate the demand for Microsoft Office from different sources using the conjoint survey data in this section. In each task in the conjoint survey, student can choose either to buy a legal copy of Office, to buy an illegal copy of Office CD, to download an illegal copy of Office on the Internet, or not to obtain and use Office. The indirect utility of a choice j for student i in task t is

$$U_{ijt} = \beta_{ij} + \sum_{l=1}^{L} \beta_{jl} z_{il} + \phi_1 P_{jt} + \phi_2 DT_{jt} + \phi_3 Update_{jt} + \epsilon_{ijt} \qquad (2.5.1)$$

where z_{il} is the lth demographic variable of student i, P_j is the price of choice j, DT_j is the search and download time for j, $Update_j$ is the availability of update of j and ϵ_{ijt} is the usual i.i.d. logit error.

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, and thus better own and cross price elasticities, compared to homogenous coefficient models. In this paper, I follow Rossi, Allenby, and McCulloch (2005) to use a hierarchical Bayesian model with a mixture of three 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, it allows for correlated coefficients without additional computation time. The demand model can be expressed as follows:

$$
\begin{aligned}
&U_{ijt} = \beta_{ij} + \sum_{l=1}^{L} \beta_{jl} z_{il} + \phi_1 P_{jt} + \phi_2 DT_{jt} + \phi_3 Update_{jt} + \epsilon_{ijt} \\
&\beta_{ij} \sim N(\mu_{ind}, \Sigma_{ind}) \\
&ind \sim \text{multinomial}(\gamma)
\end{aligned}
$$

γ is a vector giving the mixture probabilities for each of the five components. The complete specification with priors over the mixture probabilities (α), the mean ($\bar{\mu}$ and a_μ^{-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

Table 2.7: Mixed Logit Estimation of Demand for Office (std. err.)

Coefficient		Homo. Coef.	1 Comp.	3 Comp.
Interactions with Legal Office Dummy				
Dummy	Mean	2.90 (0.23)	4.99 (0.58)	3.87 (0.76)
	Std. Dev.		15.10 (3.90)	
BitTorrent		-0.71 (0.22)	-1.57 (0.55)	-0.59 (0.45)
Internet Hours		-0.08 (0.03)	-0.22 (0.08)	-0.16 (0.07)
Interactions with Street Pirated Office Dummy				
Dummy	Mean	1.73 (0.22)	4.90 (0.57)	3.84 (0.68)
	Std. Dev.		5.37 (1.50)	
BitTorrent		-0.27 (0.22)	-0.45 (0.38)	-0.37 (0.46)
Internet Hours		-0.04 (0.03)	-0.17 (0.06)	-0.13 (0.06)
Interactions with Internet Pirated Office Dummy				
Dummy	Mean	1.98 (0.20)	5.04 (0.57)	3.98 (0.73)
	Std. Dev.		9.38 (2.13)	
BitTorrent		0.25 (0.21)	0.38 (0.47)	0.76 (0.51)
Internet Hours		-0.01 (0.02)	-0.15 (0.07)	-0.11 (0.07)
Product Attributes				
Price ($100)		-0.32 (0.02)	-0.61 (0.05)	-0.74 (0.04)
Download Time (day)		-0.22 (0.03)	-0.36 (0.04)	-0.40 (0.04)
Auto Update		0.43 (0.06)	0.66 (0.08)	0.72 (0.07)

N=2220

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 β_{ij} for each student. Condition on β_{ij}, I use an unconstrained Gibbs sampler to draw μ_k and Σ_k.[7]

Table 2.7 shows the estimates from mixed logit with homogenous coefficients and random coefficients (with one and three components of mixture).

The estimates show, as would be expected, that more exposure with Internet and P2P technology translates into a higher tendency to Internet piracy. In particular, having used with BitTorrent recently and more exposure to Internet increases the

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

Table 2.8: Price Elasticities of Microsoft Office

	Homo. Coef.	1 Comp.	3 Comp.
Price of Legal Office			
Legal Office Share	-1.26	-1.21	-1.31
Street Pirated Office Share	0.30	0.14	0.15
Internet Pirated Office Share	0.27	0.12	0.12
Price of Street Pirated Office			
Legal Office Share	0.04	0.05	0.05
Street Pirated Office Share	-0.12	-0.07	-0.10
Internet Pirated Office Share	0.04	0.04	0.05
Download Time of Internet Pirated Office			
Legal Office Share	0.05	0.04	0.04
Street Pirated Office Share	0.06	0.03	0.04
Internet Pirated Office Share	-0.05	-0.03	-0.04

demand for Internet pirated Office. If all students in the sample have used BT recently, demand for Internet pirated Office would increase 6.72% while demand for legal Office and demand for street pirated Office would drop 9.6% and 7.3%. Also, if all students spend 10% more time on Internet, demand for legal Office and demand for street pirated Office would drop 0.6% and 0.3% respectively, and demand for downloading Office would increase 0.02%.

Table 2.8 shows the elasticities implied by the coefficients, which illustrates how prices and download time affects the demand for Office.

A legal copy of Office is sold at HKG$500 ($60) to students in Hong Kong. Under this price, the own price elasticity for legal Office is at approximately -1.3, which implies that the marginal cost for one copy of Office is approximately HKG$120 ($15) using the inverse elasticity rule. The high mark-up can be due to the fact that the fixed cost, in the form of R&D expenditure, is high for software like Office.

The demands for Office from illegal sources (both from street piracy and Internet piracy) are less sensitive to price changes of legal Office in the random coefficient cases. This implies reducing price for legal Office cannot shift as much demand from

Table 2.9: Microsoft Office Market in Hong Kong

Price for Legal Office	HKG$500
Price for Street Pirated Office	HKG$50
Download Time of Internet Pirated Office	0.5 day

Exchange Rate: HKG$7.8/$

piracy to legal Office as implied by the homogenous case.

The elasticities of demand with respect to download time is small (less than 0.1%). Since people can do other things (like surfing on YouTube) while downloading Office through BT, the time cost of downloading is low and thus the demand is not responsive to download time.

2.6 Counterfactual

With the demand estimates of Office from different sources, I can proceed to evaluate different copyright policies. In this section, I evaluate three different policies that either government or Microsoft, the copyright owner, can pursue to reduce piracy and boost the demand for legal Office.

The counterfactuals are based on the market situation described in table 2.9. The official version of Microsoft Office specified in the survey costs approximately HKG$1170 ($150), but students can usually get a student discount through universities at HKG$500 ($64).[8] The prices of counterfeit Office on the street vary, and are at HKG$50 ($6.4) on average. The results do not change significantly if I vary the price from HKG$30 to HKG$100. The download time of illegal copy of Office depends on the Internet connection speed and the popularity of the BT seed that one downloads the Office file with.

[8]I recalculate the optimal price for legal Office under each policy.

Table 2.10: Change in Purchase Probability When Illegal Update Not Available

	Homo. Coef.	1 Comp.	3 Comp.
Legal Office	4.16%	2.00%	2.82%
Street Pirated Office	-2.01%	-1.26%	-1.70%
Internet Pirated Office	-4.16%	-1.49%	-2.10%

2.6.1 Policy I: No Update for Illegal Office

Microsoft only provides updates to legally registered products in order to encourage legal purchase. However, anecdotal evidence suggests that acquiring updates for illegal Office does not take much time and effort on the Internet. This reduces the appeal to buy legal Office. While it may be difficult, it is not entirely impossible to make update be available only to legal Office.

Table 2.10 shows that only 2.8% of the students would switch to buy legal Office when update is exclusive to legal Office. Note that demand increase less in more flexible demand settings, which suggests legal and illegal Office are less of a substitute when we do not fully account for unobserved heterogeneity in preferences.

2.6.2 Policy II: Crack Down BitTorrent Seeds

Internet piracy is growing as suggested in Section 2.2. Governments and corresponding associations have been filing lawsuits against individual pirates and file-sharing sites like Pirate Bay to reduce the supply of files on the Internet. Despite the high monetary cost and public relations damage it costs, Bhattacharjee, Gopal, Lertwachara, and Marsden (2006) shows legal threats can reduce availability of files on P2P networks. This would translate into longer download time (DT) of Internet pirated Office.

Table 2.11 shows the change in purchase probability when DT increases four times

Table 2.11: Change in Purchase Probability When DT Increases Four Times

	Homo. Coef.	1 Comp.	3 Comp.
Legal Office	1.96%	0.83%	1.27%
Street Pirated Office	4.86%	3.96%	4.32%
Internet Pirated Office	-7.76%	-5.09%	-5.98%

from half a day to two days. Fewer students would switch to buy legal Office since most students substitute Internet pirated Office with street pirated Office. Note again that with more flexible demand estimates, the increase in demand is smaller. Only 1.27% of the students would switch to buy legal Office under this policy.

2.6.3 Policy III: No Street Piracy

As pointed out in Section 2.3, governments in China and Hong Kong spend most effort to reduce street piracy. This can become less effective with more widespread Internet piracy because of the substitutability between street and Internet piracy.

In this subsection, I evaluate the effectiveness of the copyright policy that reduce street piracy. In particular, I remove the option of obtaining counterfeit Office on the street as if the Hong Kong government can completely get rid of street piracy. This copyright policy is effective if most of the demand for street pirated Office goes to legal Office.

Table 2.12 shows the result of the counterfactuals. When the government eliminates the option of obtaining counterfeit Office on the street, most of the demand (more than 70%) goes to Internet piracy. Note that fewer students would swap street pirated Office with Internet pirated Office in the more flexible demand setting (from 78% to 74%). Overall, even if the government can completely eliminate street piracy, only 15% of the demand for street pirated Office would go to legal Office.

Table 2.12: Substitution Patterns for Street Pirates (with street pirated Office unavailable)

% Substituting to:	Homo. Coef.	1 Comp.	3 Comp.
Legal Office	15%	13%	15%
Internet Pirated Office	78%	79%	74%
Outside Option	7%	8%	11%

Table 2.13: Substitution Patterns for Street Pirates (when all three policies are enforced)

% Substituting to:	Homo. Coef.	1 Comp.	3 Comp.
Legal Office	47%	25%	31%
Internet Pirated Office	27%	58%	47%
Outside Option	26%	17%	22%

2.6.4 All Three Policies Together

I also consider the case when all three policies are enforced. Table 2.13 shows the results. Since Internet and street pirated Office are closer substitutes in more flexible demand setting, more students swap street pirated Office for Internet pirated Office in the more flexible setting (from 27% to 47%), while the number of students swapping to legal Office decreases from 47% to 31%. But overall, more students would swap to buy legal Office from street pirated Office.

2.6.5 Welfare

While most policies are not as effective as governments or Microsoft would hope in boosting demand for legal Office, these policies still have negative impacts on consumer welfare because they reduce the availability of options. Table 2.14 shows that loss in consumer surplus always outweighs the gains in producer surplus under all three policies.[9]

[9] I use estimates from 3-components mixture model to calculate the numbers in tables 14 and 15.

Table 2.14: Welfare (Per Student) Decreases Under All Three Policies

Welfare △ under	△ in CS	△ in PS
Policy I	-$11	$1
Policy II	-$5	$0.4
Policy III	-$26	$3
Policy I + II + III	-$43	$6

Students have low demand elasticities with respect to download time, thus reducing the supply of update (policy I) and files (policy II) on the Internet has a relatively small welfare impact on students. On average, each student loses $11 and $5 under these two policies. And Microsoft gain less than $1 per student under these two policies.

Completely eliminating street piracy has a bigger welfare impact. While a legal Office costs $64, a student, on average, loses $26 when street pirated Office is not available (policy III) or $43 when all three policies are enforced. The additional gains for Microsoft are only $3 and $6 under these two scenarios.

2.6.6 Revenue Loss From Piracy—BSA VS Leung

Governments and industry representatives always cite BSA for business software losses due to piracy. For instance, the 2007 report of the US Trade Representative writes: "According to industry (BSA) estimates, Singapore's piracy rate averaged five percent for music and twelve percent for movies. Business software losses were estimated at nearly $86 million in 2005."[10] These revenue loss numbers by BSA are, however, inflated. BSA counts each pirated software as a loss sale and calculates

[10] US Trade Representative, 2007 report on Singapore, http://www.ustr.gov/assets/Document_Library/Reports_Publications/2007/2007_NTE_Report/asset_upload_file129_10979.pdf.

Table 2.15: BSA Overestimates Piracy Loss (Per Student)

Loss in profit due to	Leung's Calculation	BSA's Calculation
Street Piracy	$3	$19
Internet Piracy	$5	$29
Street + Internet Piracy	$23	$48

losses as follows:

$$\$\text{ Losses} = \#\text{ Pirated Software Units} \times \text{Average System Price} \tag{2.6.1}$$

Obviously, one less pirated Office does not translate into one more legitimate sale. As I show in previous subsections, most of the demand for street pirated Office would swap to Internet pirated Office when street piracy is not available. Even when both street and Internet piracy are not available, there can still be various reasons not to buy legal Office. First, students may already have access to legal Office at universities; second, there are free and legal substitutes like Google Docs provided by Google.

Table 2.15 shows the loss in profit due to piracy using BSA and my calculation.[11] BSA overestimates the piracy loss due to either street or Internet piracy by approximately six times since it ignores the high substitution between street and Internet piracy. Even when there is no piracy, Microsoft's profit would only increase by half as much as BSA would suggest.

[11] I use marginal profit (price - marginal cost), instead of price, in equation (2.6.1) to calculate loss in profit.

2.7 Conclusion

The net welfare effect of enforcing IPR depends on the cost and effectiveness of doing so. This paper argues that a copyright policy to eradicate street piracy can be ineffective due to the emergence of Internet piracy. Even if people cannot buy counterfeit software DVDs street hawkers, they can substitute it with downloading the software on the Internet. The effectiveness of such policy is an empirical question. To answer the question, I construct a unique conjoint survey data set from 222 college students in Hong Kong, estimate the demand for Microsoft Office from legal and different illegal sources, and then use the estimate to conduct counterfactuals. The results from the counterfactuals are threefold. First, the policy to eradicate only street piracy is ineffective, with only approximately 30% of the demand for street pirated Office shifting to legal Office. Second, the decrease in consumer surplus ($43/student) outweighs the increase in Microsoft's profit ($6/student) under such policy. Third, Business Software Alliance (BSA) overestimates the revenue loss due to piracy by up to six times since it ignores the substitution pattern between street and Internet piracy. With Internet piracy growing and seemingly impossible to stop, the net benefit of maintaining the current IPR system would decrease further.

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