DIGITAL PIRACY: AN ASSESSMENT OF CONSUMER PIRACY RISK AND OPTIMAL SUPPLY CHAIN COORDINATION STRATEGIES

by

Bong-Keun Jeong

A dissertation submitted to the faculty of
The University of North Carolina at Charlotte
in partial fulfillment of the requirements
for the degree of Doctor of Philosophy in
Information Technology

Charlotte

2010

Approved by:

____
Dr. Moutaz Khouja

____
Dr. Ram L. Kumar

____
Dr. SungJune Park

____
Dr. Kexin Zhao

____
Dr. Robert Roundtree

ABSTRACT

BONG-KEUN JEONG. An assessment of consumer piracy risk and optimal supply chain coordination strategies. (Under the direction of DR. MOUTAZ KHOUJA)

Digital piracy and the emergence of new distribution channels have changed the dynamics of supply chain coordination and created many interesting problems. There has been increased attention to understanding the phenomenon of consumer piracy behavior and its impact on supply chain profitability. The purpose of this dissertation is to better understand the impact of digital piracy on online music channel and optimal supply chain strategies which achieve high levels of coordination. A multi-method approach including survey, mathematical modeling, and simulation are used to a) analyze the impact of piracy on digital music channel coordination under different contract arrangements, b) develop theoretical and operational basis for conceptualizing a measurement model of consumer piracy risk, c) examine the effectiveness of piracy control strategies used to dissuade consumers from illegal music downloads. Findings from this dissertation contribute to the literature on digital piracy, consumer piracy behavior, online channel distribution, and supply chain coordination, and provide several important managerial implications.

ACKNOWLEDGMENTS

I would like to express the deepest gratitude to my mentors for their directions and insights. First, I would like to thank my dissertation chair, Dr. Moutaz Khouja for his support and guidance. His instructive comments and evaluations at every stage of the dissertation process helped me to complete the projects on schedule and substantially to improve the quality of work. Also, I would like to thank all my dissertation committee members, respectively, Dr. Ram Kumar, Dr. SungJune Park, Dr. Kexin Zhao, and Dr. Robert Roundtree for their insights, support, and guidance.

I also would like to thank my family and friends for their love and support. I would never have been able to survive this long journey without their help. Very special thanks to HJ for our friendship, love, and happy memories. Finally, this dissertation is dedicated to the memory of my beloved brother in heaven. May his soul rest in peace.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

The ability to digitize information goods such as software, music and movies and the growing accessibility of the Internet has created unique opportunities and threats for the digital good industries. Recent advances in digital and file compression technologies have transformed the way digital products are created and distributed. For example, in the music industry, online distribution channels have proliferated in recent years. Songs can be transmitted via the Internet in digitized form so that consumers can conveniently choose to download a single song, an entire album, or a customized bundle from websites such as iTunes and Rhapsody. While current online music sales account for only 15% of total sales (IFPI 2008), online sales are increasing rapidly.

At the same time, the prevalence of unauthorized copying and dissemination has been a serious threat in the digital experience goods industries. In the music industry, for example, the rapid developments of compression and file-sharing technologies as well as the decreasing cost of copying mediums have provided consumers with greater access to free music than ever before. A report from the Recording Industry Association of America (RIAA) shows that unit sales of CD albums declined by 27.5% from 2005 to 2007 while digital album unit sales increased by 212.5%. Similarly, unit sales of single song CDs declined by 7.1% while digital single song unit sales increased by 121% (RIAA 2008). Although numerous piracy control strategies have been implemented, it is likely that piracy will remain a serious problem in the future.

Digital piracy and the emergence of new distribution channels have changed the dynamics of supply chain coordination and created some interesting problems. There has been increased attention to understanding the phenomenon of consumer piracy behavior and its impact on supply chain profitability. As can be seen in Figure 1, research in this area has focused on several topics such as pricing decision, artist royalty, contract, government subsidiary, piracy control strategy, and more.

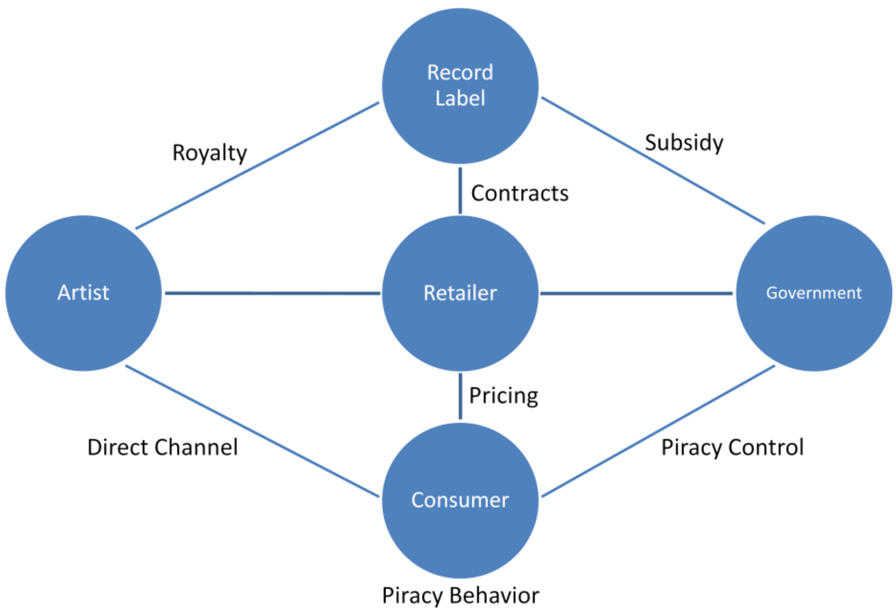


Figure 1: Research streams in the area of digital piracy

The purpose of this dissertation is to better understand the impact of digital piracy on online music channel and optimal supply chain strategies which achieve high levels of coordination. Using multiple approaches including survey, mathematical modeling, and simulation, this dissertation is organized as follows: In chapter 2, we develop a game-theoretic model to analyze the impact of piracy on digital music channel coordination under different contract arrangements. To better understand the implications of piracy on digital music sales, we define two types of consumer piracy risk cost: 1) linear piracy cost and 2) fixed piracy cost. In the linear cost case, we assume that a consumer's piracy risk cost increases linearly as the number of songs pirated increases. In the fixed cost case, the risk cost a consumer attaches to piracy is independent of the number of songs pirated. The piracy act may involve a single song or a full album, but once the consumer violates the law, a fixed risk cost is assigned to the act.

We also analyze two contract types between a record label and an online retailer: 1) fixed fee contract and 2) per song contract. In the fixed fee contract, the record label charges the retailer a fixed fee for an entire album of songs regardless of the number of times songs are downloaded from the retailer's website. In the per song contract, which is the most common contract type in the music industry, the record label charges the retailer a certain wholesale price for each song downloaded. For each case, we identify an optimal Stackelberg equilibrium and analyze how different piracy risk costs and contract types affect supply chain pricing, record label and retailer's profits, and supply chain coordination.

In chapter 3, we develop a theoretical and operational basis for conceptualizing a measurement model of consumer piracy risk using an empirical survey. Previous research in this area has focused on the influence of social, economic, and behavioral factors on the intention to pirate digital products. Although many theoretical models have been proposed to understand consumers' ethical decision-making process in the context of piracy, there have been little research undertaken to formally assess risks involved in consumer piracy behavior. Few studies have examined how the risks may affect consumer piracy decision, but, no attempts have yet been made to identify components of consumer piracy risk when they illegally download contents, and to what extent different risk components contribute to an overall piracy risk.

To address these shortcomings, we identify fundamental determinants of consumer piracy risk and empirically test the relative importance of risk dimensions in the context of illegal music downloads. In addition to examining the components of consumer piracy risk, we also explore how consumers assess their piracy risk with respect to the amount of content they pirate. For instance, if a consumer perceives a high probability of prosecution, she is more likely to perceive higher risk as the number of songs she pirates increases. On the other hand, some consumers may be conscious about their image, or they may have a desire to be identified with certain social group. In such a case, the pirating behavior can be perceived as being unethical regardless of how many songs they pirate. Many piracy acts may involve pirating more than one song, but it is unclear whether consumer piracy risk is increasing in the content pirated or fixed. Therefore, we investigate the relationship between the amount of content pirated and each dimension of piracy risk as well as the overall risk. This empirical study would help us to better understand consumers' piracy risk assessment and to enable us to develop more realistic analytical and simulation models.

Chapter 4 provides an alternative methodology to evaluate a relationship among players in the digital supply chain. In particular, we analyze the effectiveness of piracy control strategies used to dissuade consumers from illegal music downloads. Record labels, often working with the government, have employed a number of anti-piracy strategies to protect intellectual property and increase the demand for legitimate products. However, the overall effectiveness of the music industry's efforts to curtail online piracy is still questionable. Also, understanding the effectiveness of piracy control strategies on consumer behavior is a complex problem which is difficult to analyze. If the relationships in the model are simple enough, it is possible to use the mathematical modeling techniques to obtain insights into the problem. However, many real-world problems are too complex to allow realistic models to be evaluated analytically (Law and Kelton 2000).

We use an agent-based modeling (ABM) approach to analyze the effectiveness of various piracy control strategies. The use of ABM enables us to analyze agents' behavior, motives, and interactions and examine their consequences in terms of aggregate system behavior. Based on the literature review, we identify four strategies to combat digital piracy: low-price, educational, legal, and value-added service strategy. Using the agent-based modeling approach, we 1) provide an alternative methodology for analyzing the piracy control strategies, 2) find good piracy control strategies in a market where some piracy is unavoidable, and 3) investigate the impact of piracy on consumers, retailers, record labels, and artists.

Finally, chapter 5 concludes with an overview of dissertation, summary of findings and contribution, and future work.

CHAPTER 2: THE IMPACT OF PIRACY AND SUPPLY CHAIN CONTRACTS ON DIGITAL MUSIC CHANNEL COORDINATION

2.1 INTRODUCTION

Advances in the Internet and file compression technologies have transformed the way digital products, such as software, movies, and music, are created and distributed. For example, in the music industry, online distribution channels have proliferated in recent years. Songs can be transmitted via the Internet in digitized form so that consumers can conveniently choose to download a single song, an entire album, or a customized bundle from websites such as iTunes and Rhapsody. While current online music sales account for only 15% of total sales (IFPI 2008), online sales are increasing rapidly. A report from the Recording Industry Association of America (RIAA) shows that unit sales of CD albums declined by 27.5% from 2005 to 2007 while digital album unit sales increased by 212.5%. Similarly, unit sales of single song CDs declined by 7.1% while digital single song unit sales increased by 121% (RIAA 2008).

As online distribution channels become more popular, there is an increasing need to re-examine contracts and coordination issues in digital music supply chains. For instance, an important question we should ask is how do existing business models, pricing schemes, and licensing structures need to be adjusted in order to reflect the changes caused by moving from brick-and-mortar retailing to online digital sales. Traditional coordination strategies in physical product supply chains such as buy-back and return policies may not be applicable due to the unique characteristics of digital experience goods (Chellappa and Shivendu 2005). Marginal production cost, packaging cost, and a portion of distribution cost can be eliminated by selling these products through an online digital channel. Furthermore, digital products do not require inventory, which eliminates the risk of obsolescence and perishability (Shapiro and Varian 1999). However, digital products are vulnerable to piracy.

The prevalence of unauthorized copying and dissemination has been a serious threat in the digital experience goods industries. In the music industry, rapid development of compression and file-sharing technologies as well as decreasing cost of copying mediums have provided consumers with greater access to free music than ever before. Although technological preventive controls using software and hardware have been implemented, they have often had limited success, and imposed unfair restrictions on what legitimate consumers can do with the songs they have bought (Stone 2009). Also, despite the clear articulation of digital copyright law and legal as well as educational deterrence efforts, piracy still exists due to the high cost of increasing consumers' awareness and of enforcing the law. Thus, it is likely that piracy will remain as a serious problem well into the future.

In this paper, we develop a model to analyze the impact of piracy on digital music supply chain profitability under different contract arrangements between record labels and online retailers. We focus on profit maximization for newly released music albums. A number of studies have examined how perceived risk affects consumer decision and behavior (Gopal and Sanders 1997, Peace, et al. 2003). These studies have identified various aspect of risk, such as financial, performance, social, and prosecution risk, involved in ethical decision making (Tan 2002). However, it is unclear how consumers assess their piracy risk cost with respect to the amount of content they pirate. For example, if a consumer perceives a high probability of prosecution, she is more likely to perceive higher risk as the number of songs she pirates increases. On the other hand, some consumers may be conscious about their image, or they may have a desire to be identified with certain social group. In such a case, pirating behavior can be perceived as being unethical regardless of how many songs a consumer pirates. To better understand the implications of piracy on digital music sales, we first define two types of consumer piracy risk cost: 1) linear piracy cost and 2) fixed piracy cost. In the linear cost case, we assume that a consumer's piracy risk cost increases linearly as the number of songs pirated increases. In the fixed cost case, the risk cost a consumer attaches to piracy is independent of the number of songs pirated. The piracy act may involve a single song or a full album, but once the consumer violates the law, a fixed risk cost is assigned to the act.

In addition to different types of piracy risk cost, we also examine contractual arrangements between a record label and an online retailer. We consider two contract types: 1) fixed fee contract and 2) per song contract. In the fixed fee contract, the record label charges the retailer a fixed fee for an entire album of songs regardless of the number of times songs are downloaded from the retailer's website. In the per song contract, which is the most common contract type in the music industry, the record label charges the retailer a certain wholesale price for each song downloaded. For each case, we identify an optimal Stackelberg equilibrium and analyze how different piracy risk costs and contract types affect supply chain pricing, record label and retailer's profits, and supply chain coordination. Analytical results show that:

- The amount of supply chain profit loss due to piracy depends on the type of piracy risk cost of consumers as well as the contract type between the record label and the retailer
- Changes in consumers' piracy risk cost not only alter total supply chain profit but also change the distribution of the profit between the record label and the online retailer
- Piracy has larger negative impact on the profitability of music albums containing a large number of popular songs
- The fixed fee full transfer contract will always fully coordinate the supply chain, and
- The profitability of the fixed fee contract further increases as online market size increases, consumer piracy risk cost increases, and marginal cost decreases

The rest of this paper is organized as follows. Section 2.2 presents relevant literature in the area of piracy and supply chain coordination. Section 2.3 provides an overview of the model in which we describe consumer purchase behavior, consumers' piracy risk costs, and contract types between the record label and the online retailer. Section 2.4 derives the optimal prices and supply chain profits in the presence of different piracy risk costs as well as under different contract types. Section 2.5 presents a number of findings and demonstrates the robustness of our results using a numerical experiment. Section 2.6 contains managerial implications, conclusions, and directions for future research.

2.2 LITERATURE REVIEW

We review relevant literature in two research streams. First, we discuss the impact of piracy on digital experience goods, including approaches to modeling consumer piracy behavior. Then, we briefly review the literature on supply chain coordination strategies.

A large body of research has explored the impact of piracy on digital experience goods industries, especially in the software industry. Hong (Hong 2007) analyzed data on Internet growth and consumer expenditure on entertainment, which included expenditure on recorded music. Based on 1996-2002 data, the author found that Internet growth had a significant negative effect on recorded music sales, which the author in part contributed to the negative effect in the form of file sharing. However, other studies have shown that the negative impact of piracy on the legitimate demand is considerably smaller than industry estimates (Hui and Png 2003), and tolerating some piracy might even be beneficial when it creates positive network externality, that is, the potential legitimate purchase might increase as more people pirate and experience a product (Conner and Rumelt 1991, Givon, et al. 1995, Nascimento and Vanhonacker 1988, Takeyama 1994).

To better understand the impact of digital piracy, a careful analysis of consumer piracy behavior is needed. Previous studies incorporated various economic and behavioral factors such as penalties and ethical propensities that influence consumers' piracy tendency. Chen and Png (Chen and Png 1999) developed a model that incorporates a penalty for copyright violation set by the government. In the model, consumers are segmented into ethical and unethical groups. While ethical consumers can choose either buying a legitimate product or not using it, unethical consumers maximize their net benefits by choosing among buying the legitimate product, not using it, and pirating. In the case of pirating the product, consumers will be detected with certain probability and must pay a penalty cost. The results show that changes in pricing and monitoring rates have qualitatively different effects on consumers and that from a social welfare perspective, reductions in price are better than increases in monitoring. Similar market segmentation was used by Khouja and Park (Khouja and Park 2007) in a model that considered a heterogeneous consumer market with three segments: ethical, indifferent, and pirating with each having a different affinity to piracy. While the indifferent segment has the penalty for the wrongness of piracy (moral cost) as well as the penalty cost, the pirating segment only incurs the penalty cost. The model focuses on retailer's pricing policies of digital experience goods under piracy. The results indicate that the explicit incorporation of different consumer segments will cause the retailer to charge lower prices and, therefore, lead to higher legal product diffusion. The authors also show that the royalty system does not solve the double marginalization problem and is suboptimal from a supply chain perspective.

Chellappa and Shivendu (Chellappa and Shivendu 2005) developed a model for motion picture DVDs. The authors analyzed the implications of maintaining different technology standards in DVD players on the global pricing and piracy. The model considers two distinct types of piracy: 1) global where consumers obtain illegal copies for a region other than their own and 2) regional where consumers pirate products meant for their own region. Consumers differ among regions with some regions having consumers with higher marginal willingness to pay for the product (Region A) compared to other regions with lower consumer income (Region B). The authors assume that the moral cost as well as the penalty cost in Region A is greater than Region B due to greater intellectual property right protection efforts. The results indicate that when piracy is prevalent, losses from global piracy can be higher than when there is only regional piracy. Thus, maintaining separate technology standards is critical to minimize the loss. Sundararajan (Sundararjan 2004) analyzed the optimal pricing and technological protection levels for a monopolist using price discrimination among consumers. The author shows that the optimal pricing schedule can be characterized as a combination of a zero-piracy pricing schedule and a piracy-indifferent pricing schedule. In the absence of price discrimination, an optimal protection level is at the technologically maximum level, while it is always at a lower level in the case when a seller can price discriminate.

An interesting finding by Gopal and Sanders (Gopal and Sanders 1997) is that deterrent controls that employ educational and legal campaigns to dissuade pirates provide more profits to the publisher than preventive controls that use technology to make piracy costly and difficult. Also, deterrent controls are shown to be superior with respect to a social welfare. Bhattacharjee et al. (Bhattacharjee, et al. 2006b) modeled a consumer search process and retailer strategies in the presence of online piracy. In their study, different pricing options, including per unit, subscription, and mixed pricing, and different licensing structures, including lump sum, percentage, and per download payment, were considered. The result indicates that the mixed pricing strategy dominates the other two options, and the lump sum and percentage revenue are the better licensing structures than the per download cost structure. However, reactions of other important players in the chain such as the manufacture were not considered. Chen and Png (Chen and Png 2003) extended their earlier model (Chen and Png 1999) to include a tax on copying media and equipment and a government subsidy for legitimate purchases in addition to the penalty for copying. They focused on effective government actions that protect social welfare by incorporating different government policies against piracy, producer's business strategies, and users' choices. The results indicate that taxing the copying media is superior to imposing a penalty for piracy, and that subsidizing legitimate purchases is the optimal government policy from social welfare perspective.

In sum, consumer ethical attitude and perceived risk have been widely used in the literature as a key factor to model consumer piracy behavior. However, prior studies (Bhattacharjee, et al. 2006b, Chen and Png 1999, Chen and Png 2003, Gopal and Sanders 1997, Khouja and Park 2007, Sundararjan 2004) mainly dealt with the piracy of a single product (e.g. a consumer incurs a certain penalty cost if they are caught pirating a song), and did not examine what happens if piracy risk cost increases as the amount of content pirated increases. Since many piracy acts may involve pirating more than one product, it is questionable whether piracy risk cost increases linearly in content pirated. The implications of the risk cost structures where more than one song is pirated in a single act may have profound impact on profitability. To better understand the effect of piracy, we compare the fixed piracy risk cost case with the linearly increasing case. Given the large volume of music files available online and the option to pirate multiple songs in each piracy session, our approach can provide new insight into the impact of piracy on the digital music market.

The Internet has brought renewed research interest in supply chain management. Much of this research has focused on physical products supply chains. A good deal of this research has found that the Internet has increased the power of manufacturers due to making it possible for them to bypass retailers and sell directly to consumers (Chiang, et al. 2003, Tsay and Agrawal 2004). In these e-commerce models, the physical product is unchanged but the manufacturer ships it directly to the consumer. While the Internet has given increased power to the manufacturers of physical products, it has had an opposite effect in experience goods industries. In the music industry, for example, the power once held by the record labels is undergoing a profound shift due to advances in the technology needed to produce and distribute experience goods. As described by Clemons et al (Clemons, et al. 2002), the forces which made "stars" in the industry captive to record labels in spite of receiving only 10-15% of unit price in royalties are weakening.

Table 1: Sales figures for the music industry

	2004	2005	2006	2007	% change (05-06)	% change (06-07)	% change (05-07)	% change (04-07)
Album downloaded (millions of units)	4.6	13.6	27.6	42.5	103%	54%	213%	824%
Album downloaded (millions of dollars)	45.5	135.7	275.9	424.9	103%	54%	213%	834%
Single downloaded (millions of units)	139.4	366.9	586.4	809.9	60%	38%	121%	481%
Single downloaded (millions of dollars)	138.0	363.3	580.6	801.8	60%	38%	121%	481%

Table 1 (continued)

CD sales (millions of units)	767.0	705.4	619.7	511.1	-12%	-18%	-28%	-33%
CD sales (millions of dollars)	11446	10520	9372	7452	-11%	-20%	-29%	-35%
CD Single (millions of units)	3.1	2.8	1.7	2.6	-39%	53%	-7%	-16%
CD Single (millions of dollars)	15.0	10.9	7.7	12.2	-29%	58%	12%	-19%

Digital experience goods and recorded music in particular may be distributed through one of several channels. Premkumar (Premkumar 2003) outlined six distribution strategies in the music industry, record label-retailer-customer, record label-customer, record label-intermediary-customer, artist-customer, artist-intermediary-customer, and audio-on-demand. While the traditional supply chain configuration of record label-retailer-customer (RLRC) channel remains the most common way of distributing music, the record label-intermediary-customer (RLIC) channel is gaining in popularity. In this channel, consumers buy songs in digital format from an intermediary such as iTunes or Rhapsody who pay the record label for the songs. Table 1 shows that the number of singles sold digitally on the Internet using the RLIC channel exceeds the number sold on the RLRC channel (RIAA 2008). Also, the average growth/decline rates over 2005-2007 show that sales of CD albums on the RLIC channel will well exceed the sales on the RLRC channel by 2012.

Supply chain coordination for physical products, including experience goods, have been extensively studied in the area of operations management and economics. Cachon and Lariviere (Cachon and Lariviere 2005) showed that revenue-sharing arrangements coordinate the supply chain in the video rental industry and maximize overall supply chain profit. They compared revenue sharing with buy-back, quantity-flexibility, price discount, and sales rebate contracts. The authors found that revenue sharing is superior in its ability to coordinate many types of supply chains. Revenue sharing encourages retailers to have higher order quantities which tend to increase the overall revenue of the whole supply chain. Chellappa and Shivendu (Chellappa and Shivendu 2003b, Chellappa and Shivendu 2007) examined the impact of piracy on digital products supply chains under different contracts. They found that, in the absence of piracy, both manufactures and retailers are indifferent between payment policies (a fixed one-time payment vs. a per-copy payment) since their profits are the same. However, in the presence of piracy, due to high fixed infrastructure cost, zero marginal cost, and uncertainty in market size, retailers prefer fixed-fee contract where they pay one time licensing fee. They also demonstrated that the piracy and the prices are lower in the fixe-fee contract regime.

Chellappa and Shivendu (Chellappa and Shivendu 2003b, Chellappa and Shivendu 2007) studies are the first to examine digital supply chain coordination under piracy; however, our study is different in several ways. First, the studies were limited to homogenous consumer segment in their taste and risk cost. Their focus was on purchasing/pirating a single product, consequently, the studies did not consider the relationship between consumers' piracy risk and the amount of content pirated. As we mentioned earlier, piracy may involve pirating more than one song in a single piracy session, but it is not clear how consumers assess their piracy risk with respect to the amount of content they pirate. It is important to understand how consumer piracy risk changes with respect to the amount of content since it will influence their purchase/piracy behavior. In this regard, we consider two different types of consumer piracy risk costs; linear risk cost and fixed risk cost. Second, they assume that the quality of digital product would increase as the number of features increases. However, prior studies show that consumers perceive compressed music quality as almost the same or very good compared to legitimate CD quality (Bhattacharjee, et al. 2003). Therefore, we assume consumers view a pirated copy as a perfect substitute for a legitimate copy and thus get the same utility from the pirated copy.

In sum, we focus on two contract arrangements between the record label and the online retailer: a fixed fee contract and a per song (wholesale price) contract currently used in the music industry. In addition, we incorporate heterogeneity in the consumers' behaviors with regard to valuation for products and piracy risk cost. A comparison of different contract types and their interaction with different piracy risk costs can provide better insights into digital music supply chain coordination strategies and their implications. Table 2 provides the main aspects of models most closely related to our framework.

Table 2: Selected literature in the area of piracy and supply chain coordination

	Players in supply chain					Consumer piracy behavior	
Research Study	Consumer	Retailer	Manufacturer	Creator	Government	Homogeneous	Heterogeneous
Gopal and Sanders (1997)	x		x			x	
Hui and Png (2003)	x		x			x	
Chen and Png (2003)	x		x		x		x

Table 2 (continued)

Sundararajan (2004)	x	x				x	
Chellappa and Shivendu (2003, 2005, 2007)	x	x	x			x	
Bhattacharjee et al. (2006)	x	x				x	
Khouja and Park (2007)	x	x		x			x
Khouja and Wang (2010)	x	x	x	x		x	
Our Study	x	x	x				x

2.3 A DIGITAL MUSIC SUPPLY CHAIN MODEL

We first examine consumers' purchase behavior. We assume that, for a newly released album, a consumer's valuation for songs is a non-decreasing concave function in the number of songs purchased, indicating that the marginal valuation is diminishing in the number of songs purchased from the album. This is a reasonable assumption because consumers can buy their favorite songs first when using online stores. Consumer *i*'s valuation for μ songs is given by:

$$V_i = \begin{cases} y_i \mu^{\kappa}, & \text{if} \mu < \mu_0 \\ V_{0i} = y_i \mu_0^{\kappa}, & \text{if} \mu \geq \mu_0 \end{cases} \tag{1}$$

where

i = 1, 2, … , M , a consumer index,

y = a random variable satisfying $\alpha_1 \leq y \leq \beta_1$ and $\alpha_1, \beta_1 \geq 0$. y has a known probability density function, pdf, $f_Y(y)$ and cumulative density function, cdf, $F_Y(y)$,

y_i = random variable y associated with consumer i ,

κ = a constant satisfying $0 \leq \kappa \leq 1$, and

μ_0 = the number of songs at which a consumer's marginal valuation becomes zero.

y_i is a parameter indicating the scale of the utility function and κ is a constant describing the shape of the utility function. The consumer valuation function above implies that consumers have different valuations for songs and these valuations diminish at the same rate. Assume, F_i has a finite mean and an inverse F_i^{-1}. Define $\overline{F}_i(\cdot) = 1 - F_i(\cdot)$. In our model, consumers are uniformly distributed with respect to y. The number of songs that a consumer purchases must satisfy $\mu \leq \mu_0$ since the marginal utility becomes zero beyond μ_0. We assume that μ_0 is same for all consumers to maintain analytical tractability while allowing different consumers to prefer different songs. For any given price per song, consumers will purchase the number of songs that maximize their net gains. Figure 2 shows different consumer valuation functions with respect to κ and y. In practice, a consumer buys an integer number of songs, but the use of a continuous μ allows us to better analyze the problem.

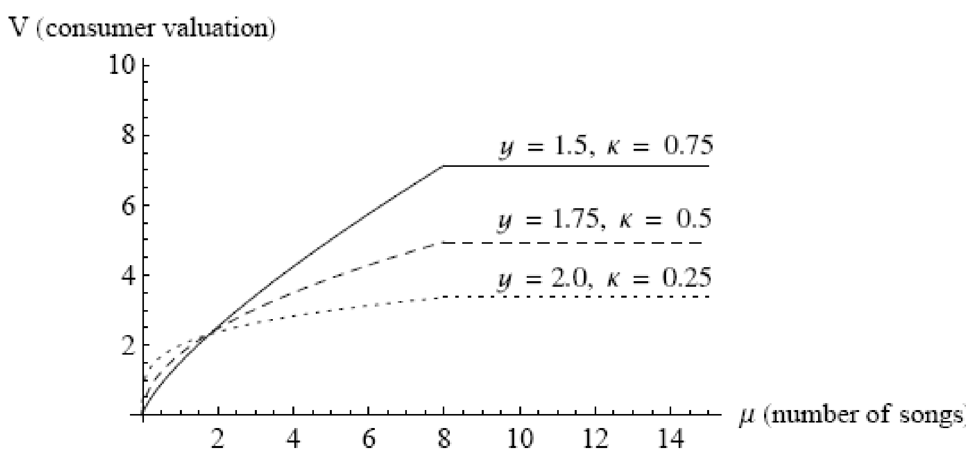


Figure 2: Consumer's valuation for songs in an album, $\mu_0 = 8$

Proposition 1 *The optimal number of songs consumer i purchases is*

$$\mu_i^* = \left(\frac{\kappa y_i}{p}\right)^{\frac{1}{1-\kappa}} \ or \ \ p = \frac{\lambda}{2}\kappa \mu_i^{*k-1} \tag{2}$$

Proof. See Appendix 1

The left hand side of equation (2) is the consumer's marginal cost of purchasing an extra song, while the right hand side is the marginal valuation that an average consumer gains from purchasing one additional song. The consumer will purchase the number of songs where the marginal cost is equal to the marginal valuation. The optimal expected number of songs a consumer buys is:

$$\mu^* = \int_{\alpha_1}^{\beta_1} \left(\frac{\kappa y}{p}\right)^{\frac{1}{1-\kappa}} \frac{1}{\beta_1 - \alpha_1} dy = \frac{(\kappa-1)\left(\frac{\kappa}{p}\right)^{\frac{1}{1-\kappa}}\left(\beta_1^{\frac{2-\kappa}{1-\kappa}} - \alpha_1^{\frac{2-\kappa}{1-\kappa}}\right)}{(\kappa-2)(\beta_1 - \alpha_1)}$$

Let $\lambda = (\frac{2(\kappa-1)\left(\beta_1^{\frac{\kappa-2}{\kappa-1}} - \alpha_1^{\frac{\kappa-2}{\kappa-1}}\right)}{(\kappa-2)\kappa(\beta_1-\alpha_1)})^{1-\kappa}$, the optimal expected number of songs a consumer buys becomes (given that the upper limit is μ_0)

$$\mu^* = min((\frac{\lambda\kappa}{2p})^{\frac{1}{1-\kappa}}, \mu_0) \tag{3}$$

2.3.1 Impact of Piracy on Consumer Purchase Behavior

Consumers can obtain a song by purchasing a legitimate copy or by pirating it. While consumers can get songs for free (or at a negligible cost) if they pirate, they are subject to piracy costs caused by potential penalties for violating copyright if they are caught, and a search cost to identify and download pirated copies. In this paper, we consider two different types of piracy risk costs: linear cost and fixed cost, which we will explain in detail in the following subsections. We use $\overline{G}$ to represent the probability that a consumer will purchase a legitimate copy. $\overline{G}$ is determined by comparing the net gain from purchasing legitimate songs and pirating them. For the no piracy case, $\overline{G}^N = 1$ because, according to our utility function, all consumers will purchase some quantity of songs in the absence of piracy, albeit the quantity purchased may be very small. Table 3 explains the notations used in this paper.

Table 3: Notation

$(p, w, \mu, \Pi)^j_{q,s}$
p : retail price, w : wholesale price, μ : number of songs, Π : profit
j : piracy risk cost (N = no piracy, L = linear piracy cost, F = fixed piracy cost)
q : type of contract (PS = per song contract, FC = fixed fee contract, FF = fixed fee contract with full transfer, FP = fixed fee contract with partial transfer)
s : player (CC = centralized chain, RE = retailer, RL = record label, TC = total chain)

2.3.1.1 Linear Piracy Risk Cost

In the linear piracy risk cost case, the risk cost consumer i attaches to piracy increases linearly in the number of songs pirated. Prior studies suggest that consumers perceive compressed music quality as almost the same or very good compared to legitimate CD quality (Bhattacharjee, et al. 2003). Therefore, we assume consumers view a pirated copy as a perfect substitute for a legitimate copy and thus get the same utility from the pirated copy. In this scenario, consumer i will purchase μ songs if the gain from purchasing them is larger than the gain from pirating, i.e.,

$$y_i \mu^\kappa - \mu p \geq y_i \mu^\kappa - \mu z_i^L$$

For analytical convenience, we assume that consumer i 's piracy risk cost, z_i^L , is uniformly distributed between α_2 and β_2. Then, the probability that consumer i will purchase a legitimate product is

$$\overline{G}^L = max(\int_{\alpha_1}^{\beta_1}(1-\int_{\alpha_2}^{p}\frac{1}{\beta_2-\alpha_2}dt)\frac{1}{\beta_1-\alpha_1}dy,0) = max(\frac{\beta_2-p}{\gamma},0) \quad (4)$$

where $\gamma = \beta_2 - \alpha_2$

We expect the price (p) to be greater than the lower bound on the piracy cost (α_2). However, in the case of $p \le \alpha_2$, the above equation becomes

$$\overline{G}^L = min(max(\frac{\beta_2-p}{\gamma},0),1) \quad (5)$$

2.3.1.2 Fixed Piracy Risk Cost

In the fixed piracy risk cost case, the risk cost consumer i attaches to piracy is independent of the number of songs pirated. In other words, once a consumer violates copyright law, she perceives the penalty to be z_i^F , which is also uniformly distributed between α_2 and β_2. The piracy act may be pirating a single song or a full album, but the risk cost is only associated with the act. The rational for this case lies in the expectation that the largest piracy risk cost occurs in pirating the first song and the marginal cost of pirating more songs diminishes very quickly after that. The extreme case occurs when the whole piracy risk cost is perceived by the consumer to occur in pirating the first song.

In this case, the risk cost of pirating μ_0 songs is the same as pirating just one song. Therefore, if consumer i chooses to pirate, she will maximizes her gain by illegally downloading all μ_0 songs, at which the consumer's marginal valuation for songs becomes zero. Therefore, consumer i compares the net gain from purchasing any number of songs to the net gain from pirating μ_0 songs, and purchases if

$$y_i \mu^{\kappa} - \mu p \geq y_i \mu_0^{\kappa} - z_i^F$$

The probability that consumer i will purchase μ songs is

$$\overline{G}^F = max(\int_{\alpha_1}^{\beta_1}(1 - \int_{\alpha_2}^{y(\mu_0^{\kappa} - \mu^{\kappa}) + \mu p} \frac{1}{\beta_2 - \alpha_2} dt) \frac{1}{\beta_1 - \alpha_1} dy, 0)$$

which gives,

$$\overline{G}^F = max(\frac{2(\beta_2 - \mu p) + \psi(\mu^{\kappa} - \mu_0^{\kappa})}{2\gamma}, 0) \qquad (6)$$

where $\psi = \alpha_1 + \beta_1$

If $p \leq \frac{2\alpha_2 + \psi(\mu^{\kappa} - \mu_0^{\kappa})}{2\mu}$ then, the equation (6) becomes

$$\overline{G}^F = min(max(\frac{2(\beta_2 - \mu p) + \psi(\mu^{\kappa} - \mu_0^{\kappa})}{2\gamma}, 0), 1) \qquad (7)$$

2.3.2 Contract between the Record Label and the Online Retailer

In this subsection, we explore different types of contracts between the record label and the online retailer. We consider two common contract schemes: a per song contract (PS) and a fixed fee contract (FC).

2.3.2.1 Per Song Contract

Under the per song contract, the retailer will pay a wholesale price to the record label each time a song is downloaded. The record label acts as a Stackelberg leader in the chain, as the record label chooses the wholesale price before the online retailer sets the retail price. The retailer takes the wholesale price as predetermined and maximizes the retail profit. The record label anticipates this retail response and maximizes its profit subject to the retail pricing decision. The record label charges a wholesale price per song sold of w and incurs a marginal cost, c_l. The royalty per song paid to the artist is the major component of the marginal cost incurred by the record label. Also, c_r is the online retailer's marginal cost, which is mainly made up by the cost of bandwidth. If the total consumer market size is M , the retailer's profit in the per song contract is

$$\Pi_{PS,RE} = M(p - c_r - w)\mu\overline{G} \tag{8}$$

The record label's profit is

$$\Pi_{PS,RL} = M(w - c_l)\mu\overline{G} \tag{9}$$

If the record label and the retailer are vertically integrated (centralized chain), the profit of the chain is

$$\Pi_{PS,CC} = M(p - c_t)\mu\overline{G} \tag{10}$$

where $c_t = c_r + c_l$.

2.3.2.2 Fixed Fee Contract

In the fixed fee contract, the record label charges a lump sum fee for an entire collection/album of songs regardless of the number of times songs are downloaded from the retailer's website. Depending on who is responsible for the royalty paid to artists, two different sub-structures can be examined. The record label may transfer the royalty cost responsibility to the retailer so that the retailer bears the royalty cost. This case is refereed to as *fixed fee full transfer* (FF). The profits of the record label and the online retailer in FF are:

$$\Pi_{FF,RE} = M(p - c_t)\mu\overline{G} - FF \tag{11}$$

$$\Pi_{FF,RL} = FF \tag{12}$$

Another possible contract is for the retailer to pay the record label a larger fee and the record label keeps the responsibility for paying the royalty. This case is refereed to as *fixed fee partial transfer* (FP). The profits of the record label and the online retailer in FP are:

$$\Pi_{FP,RE} = M(p - c_r)\mu\overline{G} - FP \tag{13}$$

$$\Pi_{FP,RL} = FP - Mc_l\mu\overline{G} \tag{14}$$

We refer to $\Delta\Pi$ as the *fixed fee advantage*, which is determined by:

$$\Delta\Pi = \Pi_{FC,TC} - \Pi_{PS,TC} \tag{15}$$

If $\Delta\Pi$ is positive, the FF/FP contract is better than the PS contract from the supply chain perspective. The record label and the retailer have to bargain over partitioning of the supply chain profit surplus and the actual value of FF/FP will be determined by the bargaining process. Many factors, such as the relative bargaining power between the retailer and the record label and the risk of breakdown (Muthoo 1999) will affect FF. For example, in the simplest bargaining situation (i.e., one shot game between two equally powerful firms), the Nash bargaining solution, FF, will satisfy the following condition:

$$\Pi_{FF/FP,RE} - \Pi_{PS,RE} = \Pi_{FF/FP,RL} - \Pi_{PS,RL} = \frac{\Delta\Pi_{FF/FP,TC}}{2} \tag{16}$$

which implies an equal division of additional profits. In this paper, we do not discuss how FF/FP is determined in detail since our focus is how the contract structures and piracy affect channel coordination.

2.4 COMPARISON OF DIFFERENT SCENARIOS

Based on different piracy risk costs and contract arrangements, we evaluate the scenarios shown in Table 4. Each scenario is compared with the benchmark case in which the supply chain is centrally coordinated. Closed-form expressions can't be obtained for the general case where κ is any value from the interval (0, 1). Therefore, we focus on the case of $\kappa = 1/2$, for which closed-form expressions can be derived. This enables us to provide insights into the problem. We examine the results under different values of κ numerically in the Analysis section. Also, for $\beta_2 < c_t$, no consumers buy a legitimate product for any profitable price. Therefore, to avoid trivial cases, we assume $\beta_2 \geq c_t$.

Table 4: Different scenarios

		No Piracy	Linear Cost	Fixed Cost
Centralized Chain		S1	S2	S3
Per Song Contract		S4	S5	S6
Fixed Fee Contract	Full Transfer	S7	S8	S9
	Partial Transfer	S10	S11	S12

2.4.1 Centralized Supply Chain

The decision maker chooses the price which maximizes the total profit of the integrated supply chain. Although this supply chain configuration is not common in the music industry, it provides the maximum profit for the supply chain, and is used as the benchmark to which other contracts are compared.

Proposition 2 *The optimal prices for a centralized supply chain are:*

S1. No piracy:

$$p_{CC}^{N*} = max(2c_t, \frac{\lambda}{2}\kappa\mu_0^{\kappa-1}) \tag{17}$$

S2. Linear piracy cost:

$$p_{CC}^{L*} = max(\frac{2c_t\beta_2}{c_t+\beta_2}, \frac{\lambda}{2}\kappa\mu_0^{\kappa-1}) \tag{18}$$

S3. Fixed piracy cost:

$$p_{CC}^{F*} = max(\frac{\lambda^2 - 2\psi\lambda + 8\eta c_t + \zeta_t}{8\eta}, \frac{\lambda}{2}\kappa\mu_0^{\kappa-1}) \tag{19}$$

where $\eta = 2\beta_2 - \lambda\sqrt{\mu_0}$ and $\zeta_t = \sqrt{\lambda^2(\lambda-2\psi)^2 + 8\eta c_t\left(8\eta c_t - \lambda(\lambda-2\psi)\right)}$

Proof. See Appendix 1

Proposition 2 shows that if $\mu^* < \mu_0$, the centralized supply chain responds to piracy under the linear piracy cost by decreasing the price by $p_{CC}^{N*} - p_{CC}^{L*} = \frac{2c_t^2}{c_t+\beta_2}$. This implies that piracy has a little effect on the optimal price when piracy risk cost is high. More interestingly, for products with low marginal cost, the supply chain can lower the price considerably to encourage legitimate sales and discourage piracy while still being profitable.

For fixed piracy cost, the optimal price when $\mu^* < \mu_0$ depends on μ_0. This is because consumers will pirate all μ_0 songs when they pirate and therefore they compare the net gain of any purchase of $\mu^* < \mu_0$ songs to the net gain from pirating μ_0 songs. The analysis indicates that piracy reduces the optimal price in the fixed cost case as well. This is intuitive since firms need to lower price to keep consumers from pirating Stone2009. However, the amount of price decline in the fixed piracy cost case may be less or more than the decrease in the linear case depending on problem parameters. For example, for $\beta_2 = 6$, $\lambda = 3$, and $\mu_0 = 2$, $p_{CC}^{F*} < p_{CC}^{L*}$ for $c_t < 0.428$. If

$\mu_0 = 5$, then $p_{CC}^{F*} < p_{CC}^{L*}$ for $c_t < 0.508$. Therefore, when the marginal cost is small, the decrease in the optimal price for the fixed piracy cost case is larger than in the linear case. Table 5 summarizes results for the centralized chain optimum.

Table 5: Summary of centralized chain optimums, $\mu^* < \mu_0$

Centralized Chain		
No Piracy	p_{CC}^{N*}	$2c_t$
	μ_{CC}^{N*}	$(\frac{\lambda}{8c_t})^2$
	Π_{CC}^{N*}	$\frac{M\lambda^2}{64c_t}$
Linear Piracy Cost	p_{CC}^{L*}	$\frac{2c_t\beta_2}{c_t+\beta_2}$
	μ_{CC}^{L*}	$(\frac{\lambda(c_t+\beta_2)}{8c_t\beta_2})^2$
	Π_{CC}^{L*}	$\frac{M\lambda^2(c_t-\beta_2)^2}{64c_t\gamma\beta_2}$
Fixed Piracy Cost	p_{CC}^{F*}	$\frac{\lambda^2-2\lambda\varphi+\zeta_t+8\eta c_t}{8\eta}$
	μ_{CC}^{F*}	$\frac{4\eta^2\lambda^2}{\left(\lambda(\lambda-2\varphi)+8\eta c_t+\zeta_t\right)^2}$
	Π_{CC}^{F*}	$\frac{M\eta^2\lambda^2\left(\lambda(\lambda-2\varphi)+\zeta_t\right)\left(8\eta c_t+\zeta_t\right)}{4\gamma\left(\lambda(\lambda-2\varphi)+8\eta c_t+\zeta_t\right)^3}$

2.4.2 Decentralized Supply Chain with Per Song Contract

In a decentralized chain with per song contract, the retailer pays the record label a wholesale price for each song sold. The record label pays a portion of this wholesale price to the artists in royalty. This is the most common contract arrangement between record labels and retailers (Bockstedt, et al. 2006). The retailer's margin per song is quite small since the wholesale price averages about \$ 0.70 (Chen and Png 2003).

Proposition 3 *Under the per song contract, the optimal retail and wholesale prices for a decentralized supply chain are:*

S4. No piracy:

$$p_{PS}^{N*} = max(2(w+c_r), \frac{\lambda}{2}\kappa\mu_0^{\kappa-1}) \tag{20}$$

$$w_{PS}^{N*} = 2c_l + c_r \text{ [1]} \tag{21}$$

S5. Linear piracy cost:

$$p_{PS}^{L*} = max(\frac{2\beta_2(w+c_r)}{w+c_r+\beta_2}, \frac{\lambda}{2}\kappa\mu_0^{\kappa-1}) \tag{22}$$

$$w_{PS}^{L*} = \frac{\beta_2^2}{\varphi} - \frac{\varphi}{3} - c_{\mathrm{r}} \tag{23}$$

where $\varphi = (3\theta)^{\frac{1}{3}}$ and $\theta = -9c_t\beta_2^2 + \sqrt{81c_t^2\beta_2^4 + 3\beta_2^6}$

S6. Fixed piracy cost: [2]

$$p_{PS}^{F*} = max(\frac{\lambda^2 - 2\psi\lambda + 8\eta\rho + \frac{1}{2}\sqrt{4\left(\lambda^2 - 2\lambda\psi + 8\eta\rho\right)^2 - 96\eta\lambda\rho(\lambda - 2\psi)}}{8\eta}, \frac{\lambda}{2}\kappa\mu_0^{\kappa-1}) \tag{24}$$

where $\rho = w + c_r$

Proof. See Appendix 1

Table 6 summarizes the results for the decentralized chain with per song contract. An interesting result from Table 6 is that $\frac{\Pi_{PS,RE}^{N*}}{\Pi_{PS,RL}^{N*}} = 2$ in the no piracy case which implies that the retailer makes twice as much profit as the record label. This is the opposite of the classic supply chain profit distribution under a Stackelberg

[1] w^* is obtained under the condition $\mu^* < \mu_0$

[2] we're unable to obtain the closed-form solution for w in the fixed piracy cost case

equilibrium and linear demand where the manufacturer makes twice as much profit as the retailer (Chiang, et al. 2003). Another noteworthy finding is that changes in the piracy risk cost, β_2, not only change total supply chain profit but also change the distribution of profit between the retailer and the record label. As β_2 increases (through increasing efforts to combat piracy), total supply chain profit will increase. However, the retailer gets a larger share of the surplus profit leaving the record label a smaller share. We will provide more insights about the relationship between the profit distribution and the piracy risk cost in the Analysis section.

Table 6 : Summary of decentralized supply chain optimums with per song contract

Decentralized Chain with Per Song Contract		
No Piracy	p_{PS}^{N*}	$2(w+c_r)$
	μ_{PS}^{N*}	$(\frac{\lambda}{8(w+c_r)})^2$
	w_{PS}^{N*}	$2c_l + c_r$
	$\Pi_{PS,RE}^{N*}$	$\frac{M\lambda^2}{128c_t}$
	$\Pi_{PS,RL}^{N*}$	$\frac{M\lambda^2}{256c_t}$
	$\Pi_{PS,TC}^{N*}$	$\frac{3M\lambda^2}{256c_t}$
Linear Piracy Cost	p_{PS}^{L*}	$\frac{2(w+c_r)\beta_2}{w+c_r\beta_2}$
	μ_{PS}^{L*}	$(\frac{\lambda(w+c_r+\beta_2)}{8(w+c_r)\beta_2})^2$
	w_{PS}^{L*}	$\frac{\beta_2^2}{\varphi}-\frac{\varphi}{3}-c_r$
	$\Pi_{PS,RE}^{L*}$	$\frac{M\lambda^2\left(\varphi^2+3\beta_2\varphi-3\beta_2^2\right)^2}{-192\gamma\beta_2\left(\varphi^3-3\varphi\beta_2^2\right)}$
	$\Pi_{PS,RL}^{L*}$	$\frac{M\lambda^2\left(\varphi^2+3c_t\varphi-3\beta_2^2\right)\left(\varphi^4-15\beta_2^2\varphi^2+9\beta_2^4\right)}{192\varphi\beta_2\gamma\left(\varphi^2-3\beta_2^2\right)^2}$
	$\Pi_{PS,TC}^{L*}$	$\frac{M\lambda^2\left(\varphi^2+3(\varphi-\beta_2)\beta_2\right)\left(2\beta_2\left(\varphi^2-3\beta_2^2\right)+c_t\left(3\beta_2(\varphi+\beta_2)-\varphi^2\right)\right)}{-64\gamma\beta_2\left(\varphi^2-3\beta_2^2\right)^2}$

Table 6 (continued)

Fixed Piracy Cost	p_{PS}^{F*}	$\dfrac{\lambda^2 - 2\psi\lambda + 8\eta\rho + \frac{1}{2}\sqrt{4\left(\lambda^2 - 2\psi\lambda + 8\eta\rho\right)^2 - 96\eta\lambda\rho(\lambda - 2\psi)}}{8\eta}$
	μ_{PS}^{F*}	$\dfrac{4\eta^2\lambda^2}{\left(\lambda^2 - 2\psi\lambda + 8\eta\rho + \frac{1}{2}\sqrt{4\left(\lambda^2 - 2\psi\lambda + 8\eta\rho\right)^2 - 96\eta\lambda\rho(\lambda - 2\psi)}\right)^2}$
	w_{PS}^{F*}	No closed form solution
	$\Pi_{PS,RE}^{F*}$	$\dfrac{M\eta^2\lambda^2(8\eta\rho + \tau)\left(\lambda^2 - 2\psi\lambda + \tau\right)}{4\gamma\left(\lambda^2 - 2\psi\lambda + 8\eta\rho + \tau\right)^3}$
	$\Pi_{PS,RL}^{F*}$	No closed form solution
	$\Pi_{PS,TC}^{F*}$	No closed form solution

where $\tau = \sqrt{\lambda^4 - 4\psi\lambda^3 + 4\left(\psi^2 - 2\eta\rho\right)\lambda^2 + 16\eta\rho\psi\lambda + 64\eta^2\rho^2}$

2.4.3 Decentralized Supply Chain with Fixed Fee Contract

If a fixed fee contract is used in the decentralized chain, the retailer pays the record label a fixed fee in exchange for being able to sell songs from a record label's album/collection to the public. Depending on who is responsible for the royalty payment to artists, two fixed fee contract types, full transfer and partial transfer, can be considered.

2.4.3.1 Fixed Fee Full Transfer Contract

Proposition 4 *The optimal retail prices for a decentralized supply chain with fixed fee full transfer contract are:*

S7. No piracy:

$$p_{FF}^{N*} = max(2c_t, \frac{\lambda}{2}\kappa\mu_0^{\kappa-1}) \tag{25}$$

S8. Linear piracy cost:

$$p_{FF}^{L*} = max(\frac{2\beta_2 c_t}{c_t + \beta_2}, \frac{\lambda}{2}\kappa\mu_0^{\kappa-1}) \tag{26}$$

S9. Fixed piracy cost:

$$p_{FF}^{F*} = max(\frac{\lambda^2 - 2\lambda\psi + 8\eta c_t + \zeta_t}{8\eta}, \frac{\lambda}{2}\kappa\mu_0^{\kappa-1}) \tag{27}$$

Proof. See Appendix 1

Proposition 4 shows that the optimal retail price under the FF contract is the same as the optimal retail price of the fully coordinated chain. Consequently, the total supply chain profit under the FF contract is the same as the profit in the centrally coordinated supply chain. In the no piracy case, the range of lump sum payment that yields the same or greater profits for the decentralized record label and retailer than under the per song contract is:

$$\frac{M\lambda^2}{256c_t} \le \text{FF} \le \frac{M\lambda^2}{128c_t} \tag{28}$$

Since $\frac{M\lambda^2}{128c_t} - \frac{M\lambda^2}{256c_t} = \frac{M\lambda^2}{128c_t} > 0$, there exists a fixed fee payment under which both parties are better off. Table 7 summarizes results in the fixed fee full transfer contract.

Table 7: Summary of fixed fee full transfer contract optimums, $\mu^* < \mu_0$

Fixed Fee Full Transfer Contract		
No Piracy	p_{FF}^{N*}	$2c_t$
	μ_{FF}^{N*}	$(\frac{\lambda}{8c_t})^2$
	$\Pi_{FF,RE}^{N*}$	$\frac{M\lambda^2}{64c_t} - FF$
	$\Pi_{FF,RL}^{N*}$	FF
	$\Pi_{FF,TC}^{N*}$	$\frac{M\lambda^2}{64c_t}$

Table 7 (continued)

Linear Piracy Cost	p_{FF}^{L*}	$\frac{2c_t\beta_2}{c_t+\beta_2}$
	μ_{FF}^{L*}	$(\frac{\lambda(c_t+\beta_2)}{8c_t\beta_2})^2$
	$\Pi_{FF,RE}^{L*}$	$\frac{M\lambda^2(c_t-\beta_2)^2}{64c_t\gamma\beta_2}-FF$
	$\Pi_{FF,RL}^{L*}$	FF
	$\Pi_{FF,TC}^{L*}$	$\frac{M\lambda^2(c_t-\beta_2)^2}{64c_t\gamma\beta_2}$
Fixed Piracy Cost	p_{FF}^{F*}	$\frac{\lambda^2-2\psi\lambda+8\eta c_t+\zeta_t}{8\eta}$
	μ_{FF}^{F*}	$\frac{4\eta^2\lambda^2}{\left(\lambda^2-2\psi\lambda+8\eta c_t+\zeta_t\right)^2}$
	$\Pi_{FF,RE}^{F*}$	$\frac{M\eta^2\lambda^2\left(\lambda(\lambda-2\psi)+\zeta_t\right)\left(8\eta c_t+\zeta_t\right)}{4\gamma\left(\lambda(\lambda-2\psi)+8\eta c_t+\zeta_t\right)^3}-\mathrm{FF}$
	$\Pi_{FF,RL}^{F*}$	FF
	$\Pi_{FF,TC}^{F*}$	$\frac{M\eta^2\lambda^2\left(\lambda(\lambda-2\psi)+\zeta_t\right)\left(8\eta c_t+\zeta_t\right)}{4\gamma\left(\lambda(\lambda-2\psi)+8\eta c_t+\zeta_t\right)^3}$

2.4.3.2 Fixed Fee Partial Transfer Contract

Proposition 5 *The optimal retail prices for a decentralized supply chain with fixed fee partial transfer contract are:*

S10. No piracy:

$$p_{FP}^{N*} = max(2c_r, \frac{\lambda}{2}\kappa\mu_0^{\kappa-1}) \tag{29}$$

S11. Linear piracy cost:

$$p_{FP}^{L*} = max(\frac{2\beta_2 c_r}{c_r+\beta_2}, \frac{\lambda}{2}\kappa\mu_0^{\kappa-1}) \tag{30}$$

S12. Fixed piracy cost:

$$p_{FP}^{F*} = max(\frac{\lambda^2 - 2\lambda\psi + 8\eta c_r + \zeta_r}{8\eta}, \frac{\lambda}{2}\kappa\mu_0^{\kappa-1}) \tag{31}$$

where $\zeta_r = \sqrt{\lambda^2(\lambda-2\psi)^2 + 8\eta c_r\left(8\eta c_r - \lambda(\lambda-2\psi)\right)}$

Proof. See Appendix 1

Note that the optimal prices for this contract are independent of the marginal cost of the record label. For the fixed fee partial transfer contract, the fee that yields the same or greater supply chain profit than the per song contract in the no piracy case is:

$$\frac{M\lambda^2}{128}(\frac{2c_l}{c_r^2} + \frac{1}{2c_t}) \le \text{FP} \le \frac{M\lambda^2}{128}(\frac{2}{c_r} - \frac{1}{c_t}) \tag{32}$$

Equation (32) implies that if $0 < c_l < \frac{1}{2}c_r$ then there is a fixed fee under which the fixed fee partial transfer contract can leave both the retailer and the record label better off than in the per song contract. Since there is no wholesale price under this contract, and the retailer is not responsible for the royalty, the fixed fee partial transfer contract is better than the per song contract when the royalty (the major component of c_l) is small relative to c_r. In this case, the retailer charges higher price due to the large c_r and sells less songs which reduces the royalty cost paid by the record label.

Given p^* and μ^* for each scenario, we can show that total supply chain profit under fixed fee full transfer contract is always greater than the total supply chain profit in both per song and fixed fixed fee partial transfer contracts. Table 8 summarizes the results for the fixed fee partial transfer contract.

Table 8: Summary of fixed fee partial transfer contract optimums, $\mu^{*} < \mu_0$

Fixed Fee Partial Transfer Contract		
No Piracy	p_{FP}^{N*}	$2c_r$
	μ_{FP}^{N*}	$(\frac{\lambda}{8c_r})^2$
	$\Pi_{FP,RE}^{N*}$	$\frac{M\lambda^2}{64c_r} - FP$
	$\Pi_{FP,RL}^{N*}$	$FP - \frac{M\lambda^2 c_l}{64c_r^2}$
	$\Pi_{FP,TC}^{N*}$	$\frac{M\lambda^2}{64c_r}(1 - \frac{c_l}{c_r})$
Linear Piracy Cost	p_{FP}^{L*}	$\frac{2c_r\beta_2}{c_r + \beta_2}$
	μ_{FP}^{L*}	$(\frac{\lambda(c_r + \beta_2)}{8c_r\beta_2})^2$
	$\Pi_{FP,RE}^{L*}$	$\frac{M\lambda^2(c_r - \beta_2)^2}{64c_r\gamma\beta_2} - FP$
	$\Pi_{FP,RL}^{L*}$	$\frac{Mc_l\left(c_r^2 - \beta_2^2\right)\lambda^2}{64c_r^2\gamma\beta_2} + FP$
	$\Pi_{FP,TC}^{L*}$	$(\frac{M\lambda^2}{64c_r\gamma\beta_2})((c_r - \beta_2)^2 - \frac{c_l(c_r^2 - \beta_2^2)}{c_r})$
Fixed Piracy Cost	p_{FP}^{F*}	$\frac{\lambda^2 - 2\psi\lambda + 8\eta c_r + \zeta_r}{8\eta}$
	μ_{FP}^{F*}	$\frac{4\eta^2\lambda^2}{\left(\lambda^2 - 2\psi\lambda + 8\eta c_r + \zeta_r\right)^2}$
	$\Pi_{FP,RE}^{F*}$	$\frac{M\eta^2\lambda^2\left(\lambda(\lambda - 2\psi) + \zeta_r\right)\left(8\eta c_r + \zeta_r\right)}{4\gamma\left(\lambda(\lambda - 2\psi) + 8\eta c_r + \zeta_r\right)^3} - \mathrm{FP}$
	$\Pi_{FP,RL}^{F*}$	$\mathrm{FP} - \frac{2M\eta^3\lambda^2 c_l\left(8\eta c_r + \zeta_r\right)}{\gamma\left(\lambda(\lambda - 2\psi) + 8\eta c_r + \zeta_r\right)^3}$
	$\Pi_{FP,TC}^{F*}$	$\frac{M\eta^2\lambda^2\left(\lambda(\lambda - 2\psi) - 8\eta c_l + \zeta_r\right)\left(8\eta c_r + \zeta_r\right)}{4\gamma\left(\lambda(\lambda - 2\psi) + 8\eta c_r + \zeta_r\right)^3}$

2.5 ANALYSIS

There are a number of interesting results related to managing a digital music channel under piracy. We begin by discussing the impact of piracy on supply chain profits as well as profits distribution between the online retailer and the record label.

2.5.1 Piracy Implication

Finding 1 *Piracy will reduce the total profit of the supply chain. The decrease in supply chain profits depends on the type of piracy risk cost of consumers.*

In the no piracy case, the probability of purchase, if the net gain is positive, is $\overline{G}^N = 1$ which is always greater than or euqal to the linear piracy cost probability of purchase $\overline{G}^L$ and the fixed piracy cost probability of purchase $\overline{G}^F$. Thus, the following condition is satisfied:

$$M(p^{L*\text{or}F*} - c_t)\mu\overline{G}^{L\text{or}F} \leq M(p^{L*\text{or}F*} - c_t)\mu\overline{G}^N$$

Also, for any p, the following condition is satisfied as well.

$$M(p^{L*\text{or}F*} - c_t)\mu\overline{G}^N < M(p^{N*} - c_t)\mu\overline{G}^N$$

The above two inequalities yield

$$M(p^{L*\text{or}F*} - c_t)\mu\overline{G}^{L\text{or}F} \leq M(p^{L*\text{or}F*} - c_t)\mu\overline{G}^N < M(p^{N*} - c_t)\mu\overline{G}^N$$

Therefore, piracy will reduce the profit of the supply chain.

An interesting result is that the magnitude of supply chain profit loss is related to the type of piracy risk costs. As shown in Figure 3, when the upper limit on piracy cost, β_2, is relatively small, the total chain profit under the linear piracy cost is greater than the profit under the fixed piracy cost. However, as β_2 increases, the total chain profit under the fixed piracy cost becomes larger than the linear case. This result indicates that, if consumers' piracy risk costs are low, the supply chain suffers more from the fixed piracy cost.

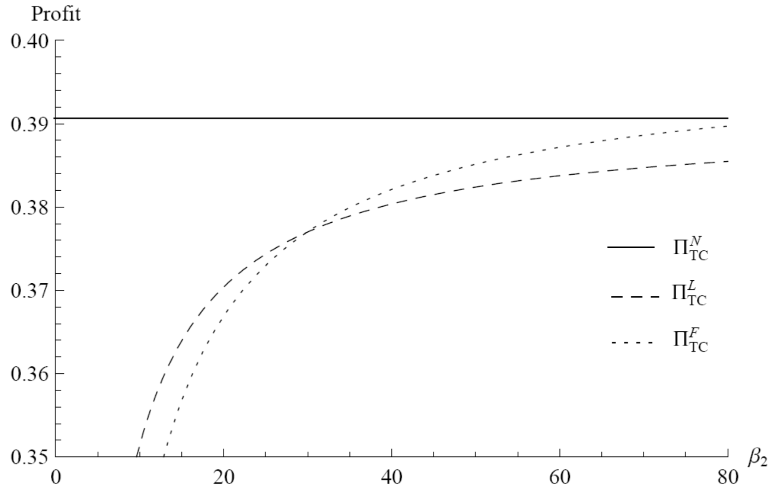


Figure 3: Total chain profits vs. piracy cost for the per song contract ($c_r = 0.15$, $c_l = 0.25$, α_1, $\alpha_2 = 0$, $\beta_1 = 1$, $\mu_0 = 10$, $M = 10$)

In addition to β_2, profits also depend on β_1 and μ_0. Figure 4 shows that when β_1 is large, i.e. high valuation for songs, and/or μ_0 is large which is the case for popular artists, total supply chain profit is greater in the linear piracy cost case. In other words, popular artists suffer more from piracy when consumers have fixed piracy cost. In the case of no piracy and linear piracy, μ_0 does not affect total chain profit because consumers buy only the songs which maximize their net gain. However, when the piracy cost is fixed, consumers pirate all μ_0 songs where their marginal valuation for songs become zero. Popular artists usually have higher μ_0, which, in turn, makes pirating even more attractive for consumers. Another interesting result is the shape of total chain profit vs. β_1 in the fixed piracy cost. Unlike the other two cases, the total chain profit under the fixed piracy cost increases for a range of β_1 and then start decreasing. A closer examination shows that although consumers' valuation for songs increases, the price stays relatively constant in the fixed piracy cost case. Hence, consumers who decide to purchase songs would purchase more songs and the total chain profit increases. However, as β_1 increases further, piracy becomes more preferable by consumers which reduces the pricing power of the retailer and decreases total chain profit.

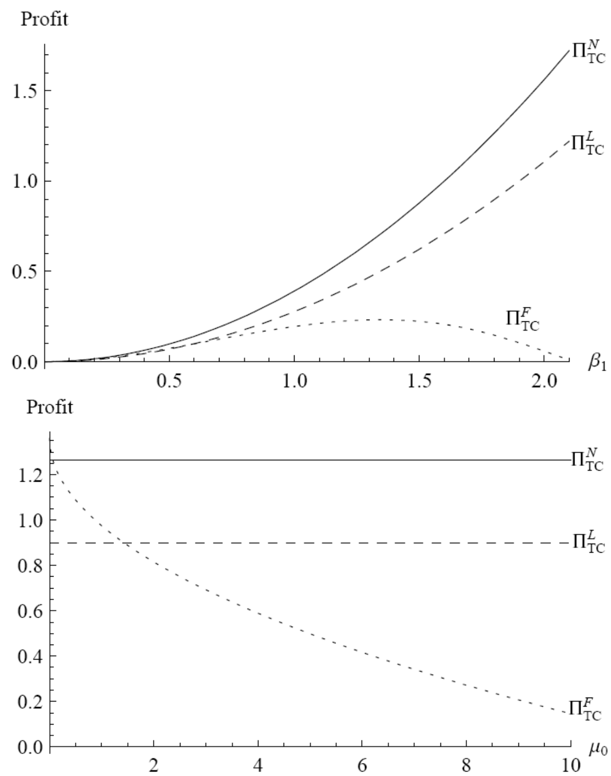
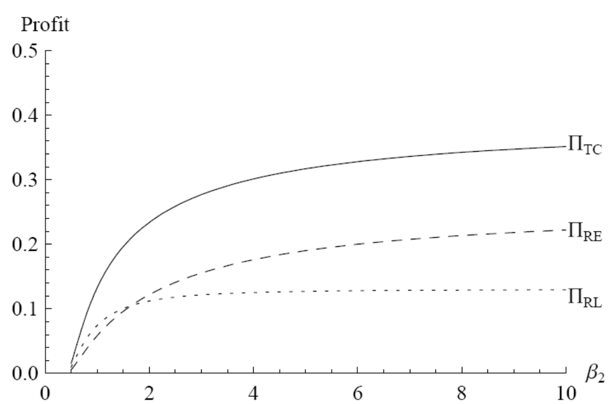


Figure 4: Total chain profits vs. β_1 and μ_0 ($c_r = 0.15$, $c_l = 0.25$, α_1, $\alpha_2 = 0$, $\beta_1 = 1$, $\beta_2 = 3$, $\mu_0 = 10$, $M = 10$)

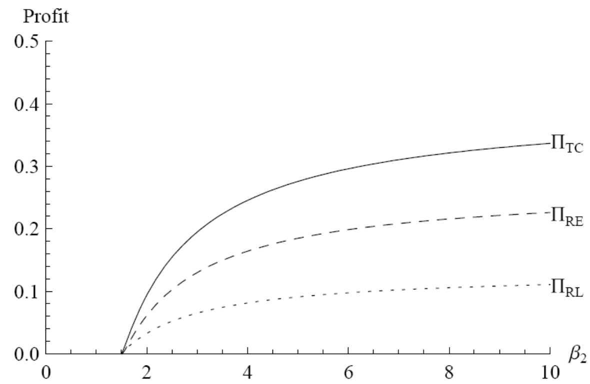
Finding 2 *Changes in the piracy risk cost not only change total supply chain profit but also change the distribution of the profit between the retailer and the record label.*

Figure 5 shows that as β_2 increases, total supply chain profit increases. Total chain profit is a concave increasing function of β_2 indicating that the positive marginal impact of β_2 is decreasing. This is because the probability of purchasing a legitimate product becomes close to 1 for high β_2, thus most consumers will buy a legitimate product rather than pirate. However, Figure 4 shows that the profit of the retailer increases more than the profit of the record label.

Let $\hat{\beta}_2$ be the value of β_2 at which $\Pi_{PS,RE}^{L*} = \Pi_{PS,RL}^{L*}$, i.e. each party gets 50% of the chain's profits. For values of β_2 satisfying $\beta_2 < \hat{\beta}_2$, the record label gets more than 50% of the supply chain profit. Suppose $f(\beta_2)$ is a convex increasing function denoting the amount of investment in deterrent and preventive piracy controls needed to increase piracy risk cost (i.e. increase to β_2). If $\beta_2 < \hat{\beta}_2$ then, Figure 6 shows that it is more profitable for the record label to invest in combating piracy since the label keeps a large share of the profit. However, as β_2 increases, it becomes less profitable for the record label to invest in combating piracy since $f(\beta_2)$ is convex and the record label's share of the supply chain profit decreases. If $\beta_2 \geq \hat{\beta}_2$, the retailer keeps a larger share of the profits leaving the record label with a smaller share which may make the record label's investment in combating piracy suboptimal.

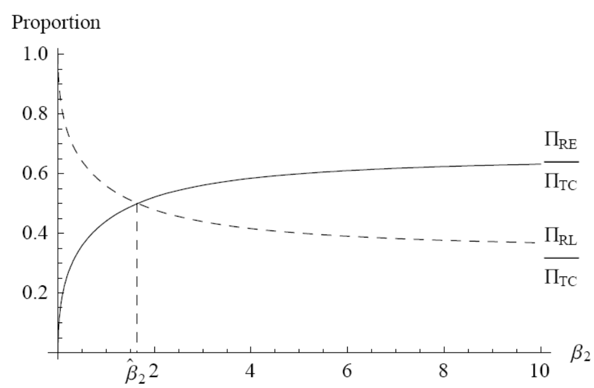


(a) Linear Piracy Risk Cost

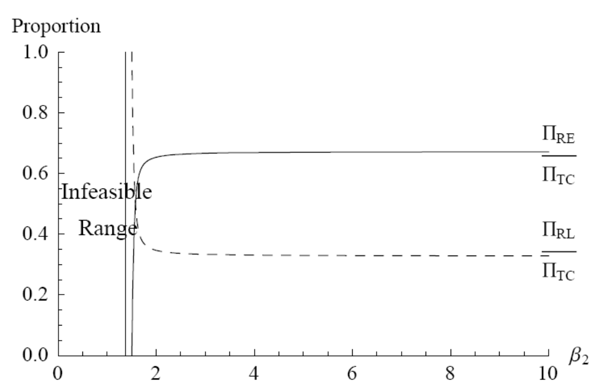


(b) Fixed Piracy Risk Cost

Figure 5: Profits vs. piracy cost under linear and fixed risk cost for the per song contract ($c_r = 0.15$, $c_l = 0.25$, α_1, $\alpha_2 = 0$, $\beta_1 = 1$, $\mu_0 = 10$, $M = 10$)



(a) Linear Piracy Risk Cost



(b) Fixed Piracy Risk Cost

Figure 6: Profit distribution vs. piracy cost for the per song contract ($c_r = 0.15$, $c_l = 0.25$, α_1, $\alpha_2 = 0$, $\beta_1 = 1$, $\mu_0 = 10$, $M = 10$)

Finding 3 *In the fixed piracy risk cost case, supply chain profit decreases in* μ_0*, the number of songs where the consumer's marginal valuation becomes zero.*

In the case of fixed piracy cost, μ_0 has a significant impact on supply chain profits. As shown in Figure 7, total chain profit under all contracts decreases as μ_0 increases, which is counter-intuitive. This is due to the fact that consumers in this case will pirate all μ_0 songs when they pirate, thus large μ_0 makes net gain from pirating larger and the supply chain less profitable. If everything is held constant except for μ_0 and β_2, then setting $\Pi^{F*}_{PS,TC}$ equal to zero gives the curve in Figure 8. This figure shows that as β_2 increases, more consumers buy rather than pirate, thus the total chain's profit increases. On the other hand, since consumers pirate all μ_0 songs when they pirate, the profitable region shrinks as μ_0 increases.

The distribution of the profit between the retailer and the record label in the fixed piracy cost case follows a similar pattern to the linear piracy cost (refer to Figure 6.b). However, the decreasing rate of the record label profit share is steeper indicating that the record label share of the profit can be significantly reduced even with a small increase in β_2. Given the impact of different piracy risk costs, the next question is which contract type is the best from a total supply chain perspective. The following subsection answers this question.

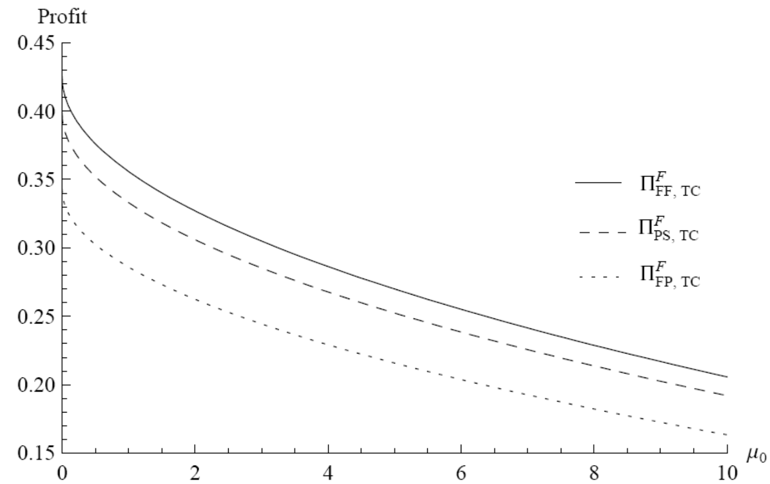


Figure 7: Profits vs. μ_0 under fixed piracy risk cost (c_r = 0.35, c_l = 0.15, α_1 , α_2 = 0, β_1 = 1, β_2 = 3, M = 10)

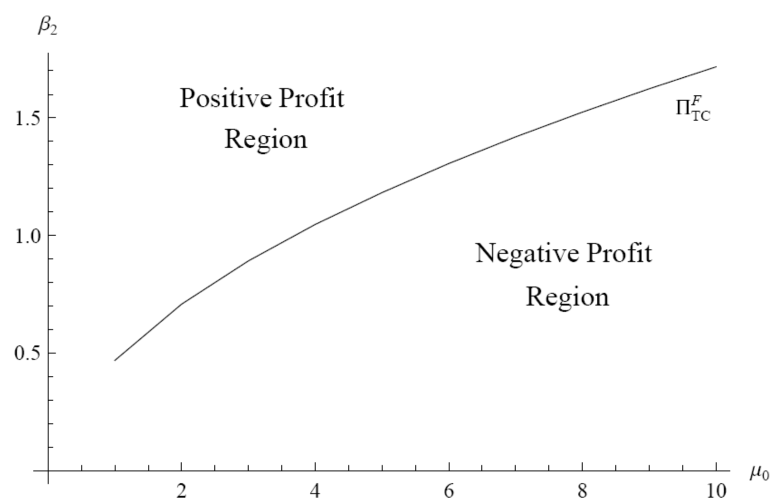


Figure 8: Profitable values of β_2 and μ_0 under fixed piracy risk cost (c_r = 0.15, c_l = 0.25, α_1 , α_2 = 0, β_1 = 1, M = 10)

2.5.2 Implication of Contract Structure

Finding 4 *For any* $\kappa \in (0,1)$ *, fixed fee full transfer contract will always fully coordinate the supply chain.*

In a fully coordinated supply chain, the optimal retail price (p^*) satisfies the following conditions:

$$\frac{d\Pi_{CC}}{dp} = \frac{dM(p-c_t)\mu_{CC}\overline{G}}{dp} = 0$$

$$\frac{d^2\Pi_{CC}}{dp^2} = \frac{d^2M(p-c_t)\mu_{CC}\overline{G}}{dp^2} < 0$$

And the profit of centralized supply chain is:

$$\Pi^*_{CC} = M(p^*_{CC} - c_t)\mu^*_{CC}\overline{G}$$

If the retailer and record label adopts the fixed fee full transfer contract, the optimal retail price (i.e., p^*_{FF}) satisfies the following condition:

$$\frac{d\Pi_{FF,RE}}{dp_{FF}} = \frac{dM(p-c_t)\mu_{FF}\overline{G}}{dp_{FF}} = 0$$

$$\frac{d^2\Pi_{CC}}{dp^2_{FF}} = \frac{d^2M(p-c_t)\mu_{FF}\overline{G}}{dp^2_{FF}} < 0$$

And, the total supply chain profit is:

$$\Pi^*_{FF,TC} = M(p^*_{FF} - c_t)\mu^*_{FF}\overline{G}$$

Therefore, $p^*_{CC} = p^*_{FF}$, and $\Pi^*_{CC} = \Pi^*_{FF,TC}$ and the fixed fee full transfer contract coordinates the chain.

We numerically examine the fixed fee advantage where the total supply chain is better off relative to the per song contract for two fixed fee structures and the two piracy risk costs. If this advantage is positive, we assume the record label and the retailer can find a satisfactory division of the profit surplus.

Finding 5 *Fixed fee contract (both FF and FP) becomes more profitable as*

1) The upper limit on the piracy risk cost, β_2 *, increases,*

2) The market size, M *, increases, and*

3) The marginal costs, c_r *and* c_l *, decrease.*

Figure 9 shows that as β_2 and M increase, the fixed fee full transfer advantage increases most in both the linear and fixed piracy cost cases. Given the increasing trend of digital music sales and continuous efforts to combat piracy, this result indicates that the fixed fee full transfer is the most preferable type of contract.

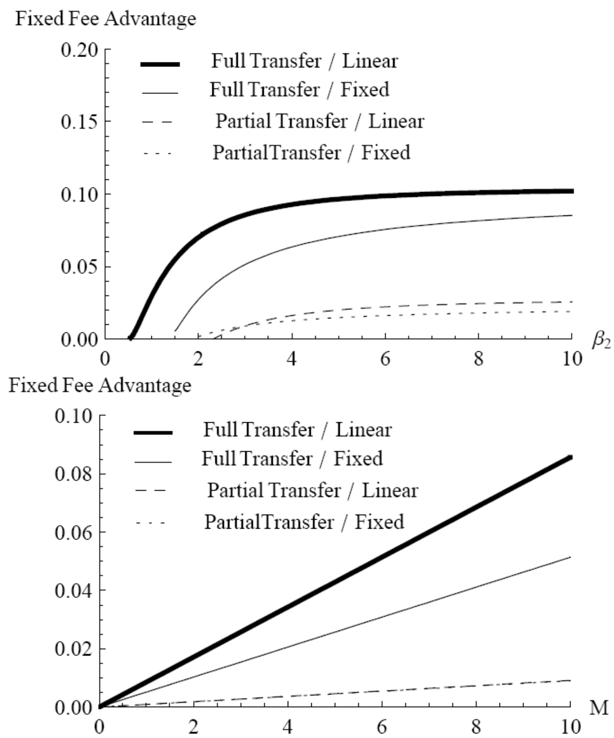


Figure 9: Fixed fee advantage vs. β_2 and M (c_r = 0.35, c_l = 0.15, α_1, α_2 = 0, β_1 = 1, μ_0 = 10)

Figure 10 shows that, as c_r and c_l increase, the fixed fee advantage decreases in both the linear and fixed piracy cost cases. The royalty paid to artists is the major component of c_l, and therefore it is likely that the record label's marginal cost wouldn't change drastically in the future. On the other hand, major components of c_r such as the bandwidth cost can be reduced gradually as technology advances. The fixed fee full transfer contract is significantly better than the per song contract as the retailer's marginal costs decrease.

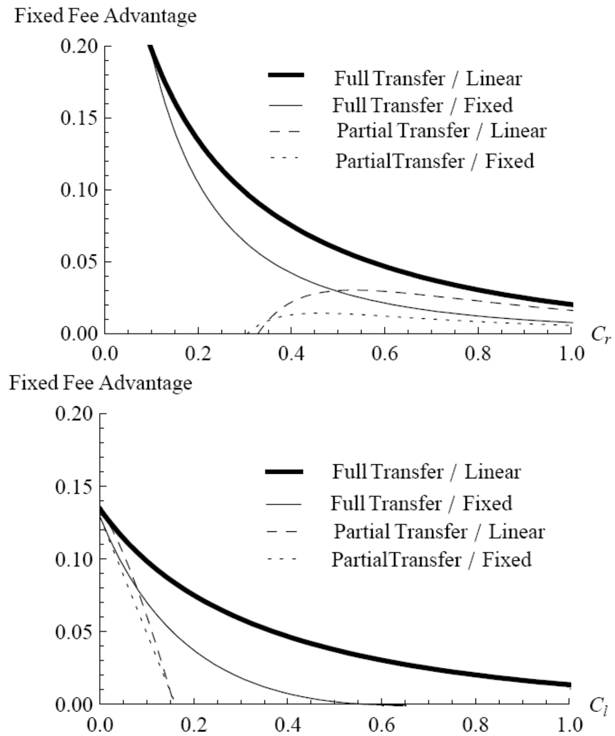


Figure 10: Fixed fee advantage vs. c_r and c_l (β_1 = 1, β_2 = 3, μ_0 = 10, M = 10, α_1, α_2 = 0)

An interesting finding is the shape of fixed fee advantage vs. c_r in the fixed fee partial transfer case. As shown in Figure 10, the fixed fee advantage becomes positive and increasing for a range of c_r and then decreases. We suspect that this is due to the unique characteristics of fixed fee partial transfer contract as well as the non-linear demand. Unlike full transfer, the online retailer in the partial transfer contract only takes c_r into account in her pricing decision. Therefore, at low values of c_r, the retailer sets the price at a low value to maximize her profit, and large number of songs is sold. The royalty cost paid by the record label is large enough to wipe out the record label's profit and therefore there is no feasible FP contract for low values of c_r. As c_r increases, the retailer raises the price causing a sales decline large enough to reduce the royalty cost which makes the FP contract feasible. As c_r increases further, the fixed fee advantage starts decreasing due to decline in the retailer's profit.

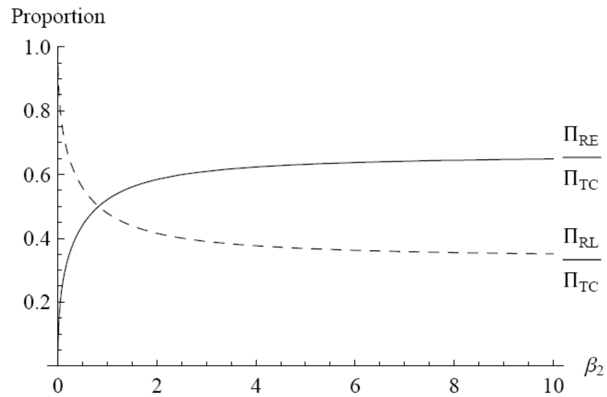
2.5.3 Numerical Experiment on Different Shapes of the Utility Function

To verify the robustness of our results with respect to the value of κ and to examine the effects of different parameters, we conducted an experiment with different parameter settings for κ, c_r, c_l, β_1, and, μ_0. The problems were solved for both linear and fixed piracy cost, and each parameter was set at three levels resulting in $3\times3\times3\times3\times3\times2 = 486$ cases as shown in Table 9.

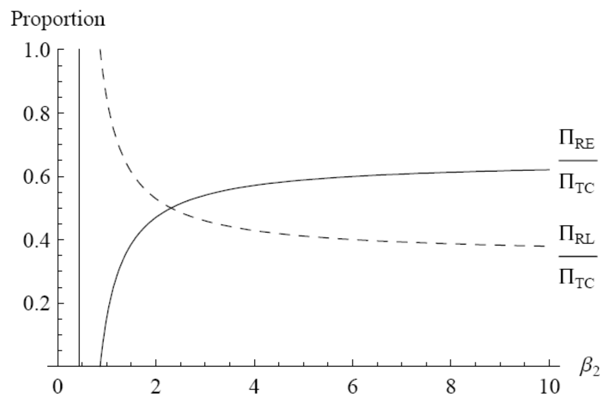
Table 9: Different parameter settings

κ	c_r	c_l	β_1	μ_0	Piracy cost
0.2	0.1	0.1	1	1	Linear
0.5	0.25	0.25	3	5	Fixed
0.8	0.4	0.4	5	10	

The results indicate that the shape of the profit distribution between the record label and the retailer holds for all parameter setting in the linear piracy cost case. For the few cases where $\mu^* = \mu_0$ (Figure 11.b), the same pattern for profit distribution also holds. Again, as β_2 increases, the retailer keeps a larger share of profits leaving the record label with smaller share. Similarly, our analysis shows that the previous pattern of the distribution of profits holds in the fixed piracy cost case.



(a) $\mu^* \leq \mu_0$, Linear Piracy Risk Cost



(b) $\mu^* = \mu_0$, Linear Piracy Risk Cost

Figure 11: Profit distribution vs. piracy cost under the per song contract

2.6 DISCUSSION AND CONCLUSION

We developed a model for analyzing the impact of piracy and supply chain contracts on the performance of supply chains for one type of digital experience good - music. In our model, the product is transmitted digitally through a pure online channel. The consumer's risk cost of piracy is divided into two cases: 1) linear risk cost and 2) fixed risk cost, based on whether the risk cost a consumer attaches to piracy depends on the amount of content pirated or not. We also examine two different contract types that record labels and online retailers may enter into, a fixed fee contract and a per song contract. We derive a variety of implications for the different cases and demonstrated the robustness of our results using a numerical experiment.

From the perspective of a manager, understanding consumers' risk cost with respect to music piracy is critical since it has many implications for pricing and piracy control strategies. For example, consistent with the finding in (Khouja and Park 2007), we show that the optimal price in the presence of piracy is always lower than or equal to the price assuming no piracy. This suggests that it is optimal for record labels and online retailers to price products with full consideration of piracy. In addition, we demonstrate that the magnitude of supply chain profit loss is related to the type of piracy risk cost. Assuming that consumers' propensity toward piracy is currently low, changing consumers' perception of piracy risk cost toward the linear case (e.g. charging a penalty based on the amount of songs pirated) can provide more profits to the chain. Also, retailers should pursue different strategies depending on the popularity of artists/songs. When the fixed piracy risk cost is dominant, popular songs and/or artists suffer more from piracy. Hence, different pricing policies through subscription, quantity discount, and bundling can be an effective strategy for popular artists since they encourage legitimate sales while discouraging piracy.

We also find that increasing consumers' piracy risk cost through preventive and deterrent controls does not equally benefit both record labels and retailers under the per song contract. As consumers' piracy risk cost increases through piracy controls, the record label's share of supply chain profit decreases while the retailer's share increases. Interestingly, most evidence suggest that the record labels have lead the effort in combating digital piracy (O'Rourke 2004, Wade 2004), which may be due to the fact that they believe the consumers' risk cost is currently very low and they benefit the most from increasing it. However, record labels should adjust their strategies as the piracy risk cost changes. If consumers' piracy risk cost is beyond certain threshold, it will be better for the record label not to make an investment in piracy control and leave it up to the retailer to do so.

Finally, we show that the fixed fee full transfer contract dominates partial transfer and per song contracts suggesting a need for new licensing models for digital online music sales. This dominance increases when the piracy risk cost and the market size for online music increase, and when marginal costs decrease. Unlike other industries in the digital goods business, such as movie rental chains, which engaged in improving market conditions through contractual innovation (e.g. revenue-sharing (Cachon and Lariviere 2005, Liu and Zhang 2006)), the music industry's response has been limited. Optimal supply chain performance can be achieved if firms coordinate by contracting using fixed fee payments under which the total supply chain's profit improves. The per song contract is currently the most common contract type in the music industry, but we demonstrate the superiority of fixed fee full transfer contract relative to the per song contract.

The proposed model has several limitations. First, the model focuses on the relationship between the record label and online retailer, and does not consider other important players in the chain such as artists and government. Second, while our model considers heterogeneous consumer valuations for songs, we assume that the valuation diminishes at the same rate. Third, our model does not consider different pricing strategies such as subscription pricing, quantity discounts, non-linear pricing, or a mixed per unit and subscription pricing. The above limitations guide us to several areas for future research. In our model, two different types of consumer risk costs are assumed based on the amount of content pirated. Therefore, it would be interesting to empirically explore how consumers actually evaluate the risk cost of piracy. Also, simulation techniques such as an agent-based modeling (ABM) can be promising to relax some of the limiting assumptions that we mentioned. The use of ABM may enable us to analyze agents' (i.e. retailer, record label, and consumers) behavior, motives, and interactions and to examine their consequences in terms of aggregate system behavior. It would also help us to incorporate various coordination strategies such as different pricing schemes and approaches to combat piracy.

CHAPTER 3: CONCEPTUALIZATION AND MEASUREMENT OF CONSUMER PIRACY RISK: THE CASE OF ILLEGAL MUSIC DOWNLOADS

3.1 INTRODUCTION

The prevalence of unauthorized copying and dissemination has been a serious threat in the digital experience goods industries. In the music industry, for example, the rapid developments of compression and file-sharing technologies as well as the decreasing cost of copying mediums have provided consumers with greater access to free music than ever before. A report from the Institute for Policy Innovation (IPI) shows that illegal music file-sharing result in $12.5 billion of economic damage and loss of 71,060 jobs every year in the United States (IFPI 2009).

In response to illegal music downloading, the music industry has employed a number of strategies to combat piracy including innovation, education, and enforcement. Despite various anti-piracy efforts, there is little evidence that these policies have successfully decreased piracy levels (Sinha and Mandel 2008). Technological preventive controls using piracy-prevention software and hardware (e.g. Digital Right Management) have been implemented, however, they have often had limited success, and imposed unfair restrictions on what legitimate consumers can do with the songs they have bought (Stone 2009). Also, even with the clear articulation of digital copyright law and legal as well as educational deterrence efforts, piracy is still prevalent due to the high cost of increasing consumers' awareness and of enforcing the law. Thus, it is likely that piracy will remain a serious problem well into the future.

The significant loss in revenue due to piracy has spurred research on understanding of consumer piracy behaviors. Previous research in this area has focused on the influence of social, economic, and behavioral factors on the intention to engage in piracy. Although several theoretical models have been proposed to explain consumers' ethical decision-making process in the context of piracy, there have been little research undertaken to formally assess various types of risk involved in piracy behavior. A few studies have examined how different risks may affect consumer piracy decisions (Chiou, et al. 2005, Tan 2002), but no attempts have yet been made to identify all aspects of consumer piracy risk when they illegally download content, and to what extent different risk components contribute to an overall piracy risk. There are various aspects of risk involved in consumer piracy behavior. In order to assess the extent and nature of piracy behavior, components of consumer piracy risk should be theoretically and operationally defined. Therefore, an important step to advance our knowledge would be the development of a measure for the construct of consumer piracy risk. Such measure would enable researchers and practitioners to quantify risk, which is one of the most important steps in the risk assessment process (Barki, et al. 1993) as well as provide valuable insights into how to develop effective strategies to deal with digital piracy.

The objective of this study is to develop a theoretical and operational basis for conceptualizing a measurement model of consumer piracy risk. Adapted from Perceived Risk Theory (Bauer 1960, Bauer 1967), we identify components of consumer piracy risk and empirically test their importance in the context of illegal music downloads [3]. In addition to examining the components of consumer piracy risk, we also explore how consumers assess their piracy risk with respect to the amount of content they pirate. For example, if a consumer perceives a high probability of prosecution, she is more likely to perceive higher risk as the number of songs she pirates increases. In contrast, some consumers may be conscious about their image, or they may have a desire to be identified with certain social group. In such a case, the pirating behavior can be perceived as being unethical regardless of how many songs are pirated. Many piracy acts may involve pirating more than one song, but it is unclear whether consumer piracy risk is increasing or fixed with the content pirated. Therefore, we investigate the relationship between the amount of content pirated and each component of piracy risk.

The rest of this paper is organized as follows. Section 3.2 presents relevant theoretical perspectives in the area of consumer ethical decision making processes and piracy behavior. Section 3.3 provides the theoretical foundation of our research model and discusses it in further details. Section 3.4 outlines the research methodology, and Section 3.5 presents the results of data analysis. Finally, Section 3.6 contains managerial implications, conclusions, and directions for future research.

---

[3] While piracy of digital music through physical CDs is also common, we focus on digital piracy where files are shared through peer-to-peer networks. P2P networks have been known as a major distribution channel for unauthorized software and audio files.

3.2 THEORETICAL PERSPECTIVES FOR UNDERSTANDING CONSUMER PIRACY RISK

Understanding consumer piracy behavior has received significant attention in marketing, consumer ethics, and information system literature. Many theoretical models such as the four component model (Moores and Chang 2006), issue-contingent model (Chiou, et al. 2005, Tan 2002), theory of planned behavior (Cronan and Al-Rafee 2008, Peace, et al. 2003), ethical decision-making theory (Thong and Yap 1998), and deterrence theory (Peace, et al. 2003, Wolfe, et al. 2008) have been proposed to explain and predict consumers' intention to engage in digital piracy.

Despite the fact that there is growing body of literature on consumer piracy behavior, there is limited understanding of how to assess consumer piracy risk. Different theories mentioned above are more relevant for assessing the process behind the piracy behavior of individuals rather than evaluating and measuring the uncertainty and/or risk involved in the piracy behavior. To identify and measure different aspects of risk involved in consumers' piracy behavior, a theory that provides a more applicable measurement perspective need to be developed. A further examination of literature within information systems and marketing suggests that the perceived risk theory can be helpful in assessing the multifaceted nature of consumer piracy risk. The measurement of consumer piracy risk based on the perceived risk theory can capture multiple components of risk involved in consumer piracy behavior, and provide insight into the nature of interrelationship among risk components. In this regard, the perceived risk theory is chosen as our theoretical model for conceptualizing consumer piracy risk. Prior to reporting scale development process, we introduce the notion of perceived risk and prior attempts to measure this construct.

The perceived risk has been formally defined as “a combination of uncertainty plus seriousness of outcome involved” (Bauer 1967). In the context of consumer choice, perceived risk is “the expectation of loss associated with purchase and acts as an inhibitor to purchase behavior” (Peter and Ryan 1976). Since the concept was introduced by Bauer, much research has been devoted to measuring risk and building a formal model and developing its components. Perceived risk has been modeled as both a two-dimensional construct (i.e., uncertainty and negative consequences) (Bauer 1960), and a multidimensional construct, including financial, performance, physical, psychological, and social risk (Jacoby and Kaplan 1972). Several other components of perceived risk were added later such as time risk (Roselius 1971) and source credibility risk (McCorkle 1990).

The perceived risk construct has been used extensively in the marketing and consumer behavior literature for wide-ranging topics such as counterfeit brand (Veloutsou and Bian 2008), and mail-order and retail store shopping (Jasper and Ouellette 1994, Spence, et al. 1970). Within the IS literature, the construct has been applied in the area of e-service adoption (Featherman and Pavlou 2003), Internet banking (Littler and Melanthiou 2006), and online shopping (Forsythe and Shi 2003, Garbarino and Strahilevitz 2004, Miazaki and Fernandez 2005). Few studies have examined the impact of perceived risks on consumer piracy behavior. For example, Tan (2002) considered four dimensions of perceived risks including financial, performance, prosecution, and social risk on the intention to purchase pirated software.

The author found that those components are significant in predicting intention to pirate (Tan 2002). Also, Chiou et al. (2005) developed a model of consumer's music piracy intention formation including six constructs influencing the attitude toward music piracy: Singer/band idolization, perceived prosecution risk, perceived magnitude of consequence, perceived social consequence, perceived proximity, and attributive satisfaction. They found that perceived prosecution risk was found to significantly influence attitude toward music piracy (Chiou, et al. 2005). However, these two studies are limited since they incorporated only a few components of consumer piracy risk, and did not examine the extent to which different risk components contribute to an overall piracy risk.

We model consumer piracy risk as a higher-order construct formed by multi-dimensional sub-constructs. The use of multi-dimensional conceptualization provides valuable information about various types of risk involved in consumer piracy behavior and the relative importance of each risk dimension.

3.3 A THEORETICAL DOMAIN OF CONSUMER PIRACY RISK

A review of perceived risk studies reveals that the importance of various perceived risk components varies widely across different situations. In other words, perceived risk appears to be extremely context-dependent (Jacoby and Kaplan 1972). Among several components of perceived risk, performance, financial, social, and prosecution risk have been previously considered in the piracy domain (Tan 2002). In addition to those four components, we also include three other risk components that relevant in the context of illegal music downloads: psychological, time, and privacy risk.

3.3.1 Measures of Consumer Piracy Risk

3.3.1.1 Performance Risk

Performance risk is defined as the risk that pirating activities may create a loss due to malfunctioning and not performing as designed. Consumers face performance risk since the pirated copy may not function as perfectly as a legitimate product or as it was designed. Operational measures related to performance risk are the quality of pirated content and the possibility of content pollution. A recent study by Bhattacharjee et al. (2006) shows that less than 10 percent of music files available on a popular P2P network were considered high or near CD quality. They also conducted a survey to analyze consumer perception of quality of music and found that although the acoustic quality of music files from illegal networks was perceived as “very good”, it was not the same as the quality of audio CDs (Bhattacharjee, et al. 2006b). These results suggest that consumers who download music files from P2P sites may perceive the quality of a pirated product to be inferior to some extent to the quality of legitimate product. Furthermore, polluted or bad copies are widely available on many P2P networks. The music industry has been involved in the dissemination of polluted content on P2P networks by spreading corrupted copies. Using this mechanism, a music company attempts to decrease the popularity of the file and to make it more difficult for users to download a good copy (Benevenuto, et al. 2006). Liang et al. (2005) showed that more than 50% of copies and versions of a popular file that were found by searching the FastTrack network were polluted (Liang, et al. 2005).

3.3.1.2 Financial Risk

Financial risk is defined as the risk that pirating activities will cause a monetary loss. Operational measures related to the financial risk are re-installment of software and data recovery due to viruses and malwares from file-sharing programs. P2P networks have been known to be vulnerable to many security attacks. One study reports that 44% of the 4,778 executable files downloaded through a KaZaA client application contained malicious code like viruses and Trojan horses (Shin, et al. 2006). Yahoo Tech also reports that many MP3 files that are being shared contain a Trojan horse program that has attacked over half a million computers in a week (Null 2008). The fear of computer viruses can influence consumers' decision to engage in digital piracy since viruses can delete or change files, slow down the computer system, and change security settings so that hackers can get an access to the pirating systems anytime. It is difficult to get accurate virus damage statistics, but one can argue that the financial damage caused by virus activities is substantial and is on the rise. For example, computer virus attacks caused global businesses an estimated $55 billion in damages in 2003, according to Trend Micro Inc (Tan 2004).

3.3.1.3 Social Risk

Social risk is defined as the risk that pirating activities will cause a loss of status in one's social group such as family, peers, and colleagues. Social risk is concerned with an individual's perception of other people, and is related to potential loss of status in one's social group as a result of pirating behavior. Subjective norms, also often referred to as peer norms, are the individual's perception of pressures from the social environment. This is the pressure that the individual feels from family, friends, and colleagues (Peace, et al. 2003). Consumers may be conscious of the image they project to their peers, and they may desire to be identified with certain social groups. Prior studies suggest that the possibility of discovering criminal action by friends and family can be perceived as a form of risk, and family disapproval may have a significant impact on deterring the behavior (Wolfe, et al. 2008). In this study, the social risk is operationalized based on loss of respect, negative image, and negative social status.

3.3.1.4 Prosecution Risk

Prosecution risk is defined as the risk that the acquisition of a pirated product would subject the pirates to legal prosecution. A consumer survey by IFPI reports that 50% of respondents stopped or reduced downloading music files from P2P networks due to fear of legal consequences (IFPI 2006). Other studies also showed that prosecution risk is important in influencing consumers' piracy attitude (Chiou, et al. 2005, Tan 2002). Downloading unauthorized music files are infringement on copyright law, and consumers run the risk of civil action by the copyright holders. Under current copyright law, people who violate the law can be held liable for up to $150,000 per violation although most lawsuit targets settle their cases for amounts ranging from $3,000 to $11,000 (EFF 2008). In this study, the prosecution risk is operationalized based on punishment (law-suit or penalty) for the violation of copyright law.

3.3.1.5 Time Risk

Time risk is defined as the risk that pirating activities will cause potential time and effort loss due to technological problems. Operational measures related to time risk are lost time due to the search process and network congestion. Studies have shown that people cut back on the use of P2P networks because they frequently could not find songs that they would like to download (IFPI 2006). The process of obtaining content in P2P network is different from purchasing songs from online stores which provide a unified interface with various value-added services. Users of P2P network must navigate a complex environment to locate content (time spent looking for an illegal copies) and endure varying levels of downloading time due to congestion which diminishes the quality of the process. It also requires additional time to learn how to use different file sharing programs and how to protect their systems from any possible intrusions.

3.3.1.6 Psychological Risk

Psychological risk is defined as the risk that pirating activities will have a negative effect on the consumer's mind such as tension or psychological discomfort. Contemporary deterrence theory suggests that, in addition to punishment certainty and severity, guilt, shame, and embarrassment can also be effective measures to reduce the likelihood of committing criminal acts (Peace, et al. 2003, Wolfe, et al. 2008). When consumers perceive pirating activities as being risky, for any of numerous reasons, this creates a tension or psychological discomfort. The feelings of discomfort or tension may come from various sources. It may arise when a person perceives a situation as an ethical dilemma or possibly when they hear the music industry is launching large number of lawsuits against individuals for copyright infringement. The psychological risk is operationalized based on unwanted anxiety, loss of self-image and concept, and psychological discomfort.

3.3.1.7 Privacy Risk

Privacy risk is defined as the risk that pirating activities will cause a loss of private and confidential information. Privacy risk has been considered in the literature with regard to predicting e-services adoption (Featherman and Pavlou 2003, Lim 2003). The studies show that privacy risk plays a significant role in the adoption intention of e-services. In the context of music piracy, the privacy risk is operationalized as the loss of confidential information due to file-sharing activities.

When consumers are connected to file-sharing programs, they may unintentionally allow others to access confidential files that they did not intend to share such as email messages, medical records, and other personal and financial documents. A recent study by Good and Krekelberg (2003) found that a large number of KaZaa users seem to be unknowingly sharing personal and private files as a result of system misconfiguration, and that some users are indeed taking advantage of this information (Good and Krekelberg 2003). In addition, file-sharing programs may install other software known as spyware on the pirating system. Spyware monitors a user's browsing habits and then sends that information to third parties. A number of popular P2P file sharing programs have been found to install spyware onto users' computers, often without their knowledge (Stafford and Urbaczewski 2004). The user gets advertisements based on the information that the spyware has collected and forwarded to these third parties. Therefore, unintentional sharing of confidential information as well as collecting user activities can severely erode consumers' privacy.

Table 10: Consumer piracy risk dimensions

Dimensions	Description - Definition
Performance risk	The risk that pirating activities will create a loss due to malfunctioning and not performing as designed
Financial risk	The risk that pirating activities will cause a monetary loss due to re-installment of software and data recovery
Time risk	The risk that pirating activities will cause potential time and effort loss due to technological problems
Social risk	The risk that pirating activities will cause a loss of status in one's social group such as family, peers, and colleagues
Psychological risk	The risk that pirating activities will have a negative effect on the consumer's well-being such as tension or psychological discomfort
Privacy risk	The risk that pirating activities will cause a loss of private and confidential information
Prosecution risk	The risk that pirating activities will cause a legal prosecution

To summarize, a number of dimensions components of consumers' overall piracy risk have been identified as illustrated in Table 10. These components are performance, financial, time, social, psychological, privacy, prosecution risk. These seven components will help us understand the multi-faceted nature of consumer piracy risk by capturing the importance of each dimension in the overall piracy risk assessment process. We model the consumer piracy risk construct as a second-order factor with reflective measures for the first-order factors and formative measures for the second order factor. Formative operationalization to model the relationship between the overall piracy risk and its dimensions was used for following reasons. Formative measures are commonly used for constructs considered as composites of specific component variables (Chin 1998). In this study, the overall consumer piracy risk constructs are formed with indicators that reflect different types of risks. Consequently, the direction of causality is from indicator to construct (i.e., formative). Also, positive inter-correlations among risk components are not expected which is the main characteristic in the formative measurement model (Edwards and Bagozzi 2000). For example, downloading illegal songs from file-sharing programs may involve high prosecution risk, but not necessarily high social risk. Lastly, the perceived risk construct has been considered as the second-order formative measurement in prior studies (Kim, et al. 2008, Mitchell 1999, Stone and Gronhaug 1993).

3.3.2 Consumer Piracy Risk and the Relationship with the Amount of Content Pirated

The relationship between perceived piracy risk and the amount of content pirated has critical implications for consumer choice and pricing. We use a simple numerical example to illustrate this concept. Suppose, a consumer is interested in obtaining five songs and the reservation prices for each song in decreasing order are \$1.50, \$1.25, \$1.00, \$0.75 and \$0.50. In the case of linear piracy risk cost, the risk cost a consumer attaches to piracy increases linearly in the number of songs pirated. In this example, the cost is \$1.00 per song. In the fixed piracy risk cost, the risk cost is assigned to the piracy session no matter how many songs are pirated. In this example, the cost is \$2.50 per piracy session. The consumer will purchase legitimate products if the net gain from purchasing them is positive and is greater than the net gain from pirating. If the songs are sold for \$0.99 each, then consumers' decision is shown in Table 11. The example shows that the consumer's decision to either purchase/pirate is different in the two cases depending on the number of songs the consumer is interested in getting. The consumer would purchase legitimate copies up to 5 songs in the linear risk cost case since the net gain from purchasing is larger than the gain from pirating. However, in the case of fixed risk cost, the consumer would pirate when the number of songs is three or more.

Table 11: Numerical example of consumer piracy risk and the number of contents pirated

		Number of Songs				
		1	2	3	4	5
Net Gain (Purchase)		0.51	0.76	0.78	0.54	-0.20
Linear	Net Gain (Pirate)	0.50	0.75	0.75	0.50	-0.25
	Decision	Purchase	Purchase	Purchase	Purchase	Purchase
Fixed	Net Gain (Pirate)	-1.50	0.25	1.25	2.00	2.25
	Decision	Purchase	Purchase	***Pirate***	***Pirate***	***Pirate***

Prior empirical studies have not focused on the relationship between consumers' piracy risk and the amount of content they pirate. Researchers used different measurement terms such as a single unit ("the pirated software") (Limayem, et al. 2004, Tan 2002), multiple units ("pirated music products" or "copies of pirated software") (Moores and Chang 2006), or a general term ("music/software piracy") (Chiou, et al. 2005), and implicitly assumed that the piracy risk is either be fixed or increasing in content.

Piracy may involve pirating more than one song in a single piracy session, but it is not clear how consumers assess their piracy risk with respect to the amount of content they pirate. It is possible that consumers' piracy risk increases in the number of songs pirated, or it could be fixed once a consumer violates copyright law. The rationale for fixed piracy risk in a session is that some consumers may expect that the largest piracy risk cost occurs in pirating the first song and the marginal cost of pirating more songs diminishes very quickly after that. The extreme case occurs when the whole piracy risk is perceived by the consumer in pirating the first song. We examine the relationship between the amount of content pirated and each dimension of consumer piracy risk.

3.3.2.1 Piracy risk components expected to increase with the amount of content pirated

We expect that the prosecution, time, performance, privacy, and financial risk components of piracy risk will increase with the number of content pirated. Since September 2003, the recording industry has filed, settled, or threatened legal actions against at least 30,000 individuals who have used P2P networks. According to the RIAA, most people sued were sharing 1,000 songs or more on the file-swapping networks (EFF 2008). This suggests that the more a consumer shares or downloads files from P2P networks, the higher the probability that she will be sued. Therefore, there might be a positive relationship between the amount of content pirated and the prosecution risk.

In order to download pirated music, consumers should install file-sharing programs and be connected to networks. As the amount of time during which they are connected to the file-sharing networks increases, there is a higher chance that they may unknowingly reveal their private information or allow spyware to be installed on their computers. Therefore, there might be a positive relationship between the amount of content pirated and the privacy risk. Following similar argument, we expect that the more time consumers are connected to P2P networks, the higher the chance that their computers are infected by viruses and malware which in turn causes financial damage. Also, as the number of songs a consumer pirates increases, there is a higher chance that some of the files are polluted or the quality of pirated content is significantly lower than the original one. Therefore, there might be a positive relationship between the amount of content pirated and the financial and performance risk.

For legal online channels, a retailer usually provides a unified interface with effective search tools (e.g. music recommendation system). Compared to legal online sellers who have an incentive to provide better search tools, the process of obtaining content in P2P network usually involves more time to search relevant items and evaluate them. In addition, the amount of time to obtain content also varies depending on network congestion. Given the large volume of songs available, it is likely that consumers' time loss risk will increase as the amount of content pirated increases.

3.3.2.2 Piracy risk components not expected to change with the amount of content pirated

An individual's social and psychological risk is related to her feelings of favorableness or aversion toward performing an action. An individual who believes that the action will lead to negative results will have unfavorable attitude toward the behavior, and the pirating behavior, will be perceived as being unethical once she violates the copyright law independent of the amount of content. Thus, it is unlikely that consumers' social and psychological risk will change with the amount of content pirated.

We also expect that as the amount of content pirated changes, the relative importance of each risk component may change as well. For example, in the case of pirating one song, the social risk may be the most important, but in the case of pirating many songs, the prosecution risk may become more important than the social risk. Due to lack of prior work and theoretical foundation, we also explore whether the relative importance of piracy risk components will change as the amount of content pirated changes.

3.4 RESEARCH METHODOLOGY

3.4.1 Scale Development and Questionnaire Design

The consumer piracy risk construct shown in Figure 12 was tested using data collected from a questionnaire survey. A literature review was conducted to identify past operational measures of the constructs, and a group of questions were compiled to represent each risk component construct (Chiou, et al. 2005, Featherman and Pavlou 2003, Stone and Gronhaug 1993, Tan 2002, Xu, et al. 2005). The wording was then modified to fit our context of illegal music downloads. Two different scenarios were developed: 1) pirating one song from file sharing programs and 2) pirating ten songs. The respondents were asked to indicate their assessment of the magnitude of their perceived risk. Each question was measured on a five-point Likert scale, ranging from (1) strongly agree to (5) strongly disagree.

The questionnaire was tested extensively for validity before the actual survey was administered. As mentioned above, past operational measures were slightly modified to create the items used in the survey. While the use of previously developed constructs and items helps in developing a valid instrument, it does not ensure validity. Iterative review process was undertaken by four IS professionals to maximize content validity and identify ambiguous or poorly worded items. The 25 items were selected for the components of piracy risk, and were included on the survey instrument in a random order. Some items were reversed in order to establish internal consistency and to ensure that participants are consistent in their thinking and responses. The instrument was then pilot-tested to identify problems with the instrument's wording, content, format, and procedures. For this pilot test, surveys were distributed to 54 students in a College of Business in a major university. Pilot respondents completed the survey and provided written comments about length, wording, and instructions. Based on the results of the pilot sample, further minor changes were made to the survey design. The final survey items for each construct are shown in the Table 12.

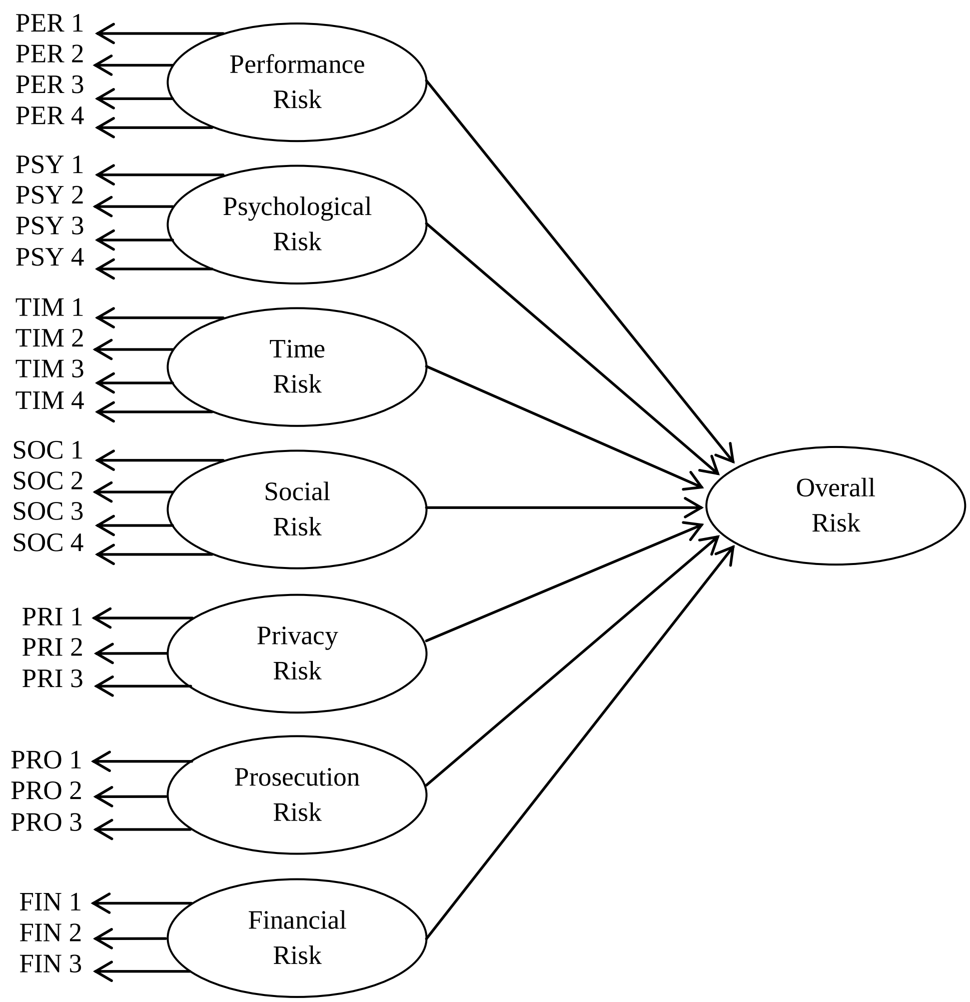


Figure 12: Proposed second-order factor model of consumer piracy risk

There are a number of variables that may influence the results of our survey. For example, studies have discussed the possibility of change in the attitude toward software piracy depending on prior computer experience or past purchase experience of pirated products (Kwong, et al. 2003, Siegfried 2004). Similarly, a high amount of file-sharing knowledge and experience may enable consumers to obtain illegal copies with little effort. In addition, consumer file-sharing experience may also affect the search cost because knowledge reduces the time and effort needed to locate an illegal copy. To deal with this issue, two questions were added at the end of the survey to obtain whether the subject has experience with file-sharing programs and if so, how long they have used file-sharing programs. We also collected other information such as gender and age to control their effects on the result.

Table 12: Scenarios and construct measurement

<table>
<tr><td colspan="2">Scenario 1 (downloading a single song)
While you were driving, you heard a song that you really like on a radio station. You decided to illegally download the song from peer-to-peer networks so that you could listen to it on your MP3 player or computer whenever needed.

Scenario 2 (downloading multiple songs)
Over the last few days, you heard 10 songs that you really like on a radio station. You decided to illegally download all songs from peer-to-peer networks (e.g. KaZaA, BitTorrent, LimeWire) so that you could listen to those on your MP3 player or computer whenever needed</td></tr>
<tr><th>Construct</th><th>Items</th></tr>
<tr><td>Social Risk</td><td>1. Once my family, friends, and colleagues are aware that I have downloaded songs from file-sharing programs, I may lose their respect because they will think that I am unethical. (Tan 2002)
2. Downloading songs from file-sharing programs may negatively affect the way others think of me. (Featherman and Pavlou 2003)
3. Downloading songs from file-sharing programs may lead to a social loss for me because my friends, family, and colleagues will think less of me. (Featherman and Pavlou 2003)
4. Downloading songs from file-sharing programs may cause me to be thought of as being foolish by some people whose opinion I value. (Stone and Gronhaug 1993)</td></tr>
<tr><td>Prosecution Risk</td><td>1. As I download songs, I worry that I will be caught for the infringement of copyright law. (Tan 2002)
2. As I download songs, I worry that I will be punished for the infringement of copyright law. (Chiou, et al. 2005)
3. As I download songs, I worry that I will have to pay a fine for the infringement of copyright law. (Tan 2002)</td></tr>
</table>

Table 12 (continued)

Social Risk	1. Once my family, friends, and colleagues are aware that I have downloaded songs from file-sharing programs, I may lose their respect because they will think that I am unethical. (Tan 2002) 2. Downloading songs from file-sharing programs may negatively affect the way others think of me. (Featherman and Pavlou 2003) 3. Downloading songs from file-sharing programs may lead to a social loss for me because my friends, family, and colleagues will think less of me. (Featherman and Pavlou 2003) 4. Downloading songs from file-sharing programs may cause me to be thought of as being foolish by some people whose opinion I value. (Stone and Gronhaug 1993)
Performance Risk	1. As I download songs from file-sharing programs, I worry that the pirated songs will fail to play. (Tan 2002) 2. As I download songs from file-sharing programs, I worry that the pirated songs will fail to play like the original one. (Tan 2002) 3. As I download songs from file-sharing programs, I worry about whether the pirated songs will play as well as it is supposed to. (Stone and Gronhaug 1993) 4. As I download songs from file-sharing programs, I worry that the pirated songs will not provide the level of quality like a legitimate copy. (Stone and Gronhaug 1993)
Psychological Risk	1. Downloading songs from file-sharing programs makes me feel psychologically uncomfortable. (Stone and Gronhaug 1993) 2. Downloading songs from file-sharing programs gives me a feeling of unwanted anxiety. (Stone and Gronhaug 1993) 3. Downloading songs from file-sharing programs may cause me to experience unnecessary tension. (Stone and Gronhaug 1993) 4. Downloading songs from file-sharing programs may lead to a psychological loss for me because it will not fit in well with my self-image and self-concept. (Featherman and Pavlou 2003)

Table 12 (continued)

Privacy Risk	1. Downloading songs from file-sharing programs cause me a concern that I will lose control over the privacy of my information. (Featherman and Pavlou 2003) 2. Downloading songs from file-sharing programs may lead to a loss of privacy for me because my personal information can be revealed without my knowledge. (Featherman and Pavlou 2003) 3. Downloading songs from file-sharing programs may lead to a loss of privacy for me because a hacker may access my personal information without my knowledge. (Xu, et al. 2005)
Financial Risk	1. As I download songs from file-sharing programs, I worry that the pirated songs will cause damage to my computer due to viruses and malware resulting in a monetary loss (e.g. new hard drive, system re-installment, data recovery). (Tan 2002) 2. Downloading songs from file-sharing programs may lead to a financial loss for me. (Featherman and Pavlou 2003) 3. I may lose money as I use file-sharing programs to download songs. (Featherman and Pavlou 2003)
Time Risk	1. Downloading songs from file-sharing programs may be a waste of time for me because it will take time to set up the required software (e.g. BitTorrent). (Featherman and Pavlou 2003) 2. Downloading songs from file-sharing programs may be inconvenient for me because I will have to waste a lot of time to fix errors. (Featherman and Pavlou 2003) 3. Downloading songs from file-sharing programs worries me that I will have to spend too much time learning how to download files. (Stone and Gronhaug 1993) 4. Downloading songs from file-sharing programs may lead to an inefficient use of my time for searching files, understanding various software packages, and so forth. (Stone and Gronhaug 1993)

3.4.2 Sample

The subjects for the study are undergraduate business students in a major university. Students are considered good subjects for studying piracy since they are most likely to be engaged in pirating activities (Limayem, et al. 2004, Sims, et al. 1996). Also, student subjects have been widely used in previous studies investigating the impact of software/music piracy (Cheng, et al. 1997, Chiou, et al. 2005, Gopal, et al. 2004, Sims, et al. 1996, Sinha and Mandel 2008, Thong and Yap 1998).

Table 13: Demographic information on subjects

		Combined	Single Song	Multiple Songs
Total Number of Subjects		510	252	258
Gender	Male	269	143	126
	Female	241	109	132
Age	10 – 20	131	60	71
	21 – 30	334	171	163
	31 – 40	34	16	18
	Above 40	11	5	6
File Sharing Experience [4]	Yes	417	206	211
	No	60	30	30
File Sharing Experience in Years	Less than 1 year	88	42	46
	1 year – 2 year	68	29	39
	2 year – 3 year	59	30	29
	3 year – 4 year	52	26	26
	More than 4 years	150	84	66

Students enrolled in Management Information Systems courses were asked to fill out the survey. One of the authors introduced the survey, and invited the students to take some time to complete the web-based survey at the end of the class. Java-script code was embedded in a web link to the survey so that participants were assigned to different scenarios randomly. Participation was entirely voluntary, and there was no penalty for non-participation. The subjects were allocated fifteen minutes to complete the questionnaire. Interactions were not allowed, and confidentiality of responses was emphasized again. In addition, the subject did not identify themselves on the

[4] Some participants did not provide the answers on whether and how long they have used file sharing programs. Therefore, the total number of subjects in those two items are different from the total number of subjects participated in the survey.

questionnaires so that they would be truthful in their responses with regard to this sensitive topic. Of 828 subjects, 510 subjects returned fully completed questionnaires, yielding a response rate of 61.6 percents. Table 13 provides descriptive statistics on the demographic profile of subjects. As the table shows, 52.7 percent of the respondents were male, and 91.2 percent of subjects were between the age of 10 and 30 years. Furthermore, 87.4 percent of the respondents have used file sharing programs where 31.4 percent have more than 4 years of file sharing experience.

3.5 DATA ANALYSES AND RESULTS

3.5.1 Exploratory Factor Analysis

Principal Component Analysis with varimax rotation was used to test the initial survey items' loading on the different factors. The criterion used in the analysis was a factor loading greater than 0.5, and Eigen values greater than 1.0 (Tabachnick and Fidell 2007). Most items loaded on their respective theorized constructs, but there were two cross-loading instances. In the first instance, the four items measuring social risk and three items measuring psychological risk were loaded on a single factor. To determine whether they are single or multiple constructs, we examined both the theoretical conceptualization as well as the empirical validation for the constructs of social and psychological risk used in prior IS research (Premkumar, et al. 1994). An independent factor analysis of the items measuring these two constructs showed that they loaded on one factor. Furthermore, previous study has suggested that the psychological risk may be correlated with other risks (Stone and Gronhaug 1993). Therefore, we decided to combine psychological and social risk into a single construct.

We name the new construct as moral-awareness risk, which refers to unfavorable perceptions from one's social group as well as self-reflection.

In the second instance, three items measuring prosecution risk and the two items measuring financial risk were loaded on one factor. Although we could not find any literature supporting the connection between financial and prosecution risk, we suspect that consumers might perceive fines as the main legal penalty from pirating activities. Therefore, both financial and prosecution risks involve monetary loss, and consumers may perceive the two similarly. Nandedkar and Midha examined the perceived risk as four sub-constructs consisting of performance, financial, social, and prosecution risk. However, they dropped financial risk since the items did not load on the factor (Nandedkar and Midha 2009). Finally, we ran the independent factor analysis of the items measuring these two constructs and found that they loaded on one factor. Based on the arguments above, we decided to combine prosecution risk and financial risk into a single construct, and name it as monetary-loss risk, which refers to loss of money due to software re-installment, data recovery, or legal prosecution. The final results of the factor analysis are shown in Table 14.

Table 14: Results of principal component factor analysis [5]

Construct	Item	1	2	3	4	5
Performance Risk	PER1	0.74				
	PER2	0.86				
	PER3	0.85				
	PER4	0.80				

[5] One item in the psychological (PSY4) and financial risk (FIN2) were dropped since the factor loadings were less than 0.5

Table 14 (continued)

Privacy Risk	PRI1		0.84			
	PRI2		0.85			
	PRI3		0.72			
Monetary-Loss Risk	PRO1			0.77		
	PRO2			0.75		
	PRO3			0.78		
	FIN1			0.57		
	FIN3			0.52		
Moral-Awareness Risk	PSY1				0.65	
	PSY2				0.66	
	PSY3				0.50	
	SOC1				0.85	
	SOC2				0.84	
	SOC3				0.78	
	SOC4				0.83	
Time Risk	TIM1					0.61
	TIM2					0.66
	TIM3					0.74
	TIM4					0.76

3.5.2 Confirmatory Factor Analysis

We checked normality, linearity and multi-collinearity using SPSS and LISREL, and found that the dataset violated multivariate normality assumption. Therefore, the research model was tested using partial least square (PLS), a component-based approach well suited for assessing complex predictive models. PLS is recommended when data has the normality problem (Chin 1998, Hsieh, et al. 2008). It is also a preferred technique to analyze formative constructs (Chin 1998). SmartPLS version 2.0 (Ringle, et al. 2005) was used for the analysis.

The assessment of the measurement model includes the estimation of internal consistency for reliability, and tests of convergent and discriminant validity for construct validity. Internal consistency was evaluated by computing AVE (Average Variance Extracted), CR (Composite Reliability), and Cronbach's alpha (Hair, et al.

2005, Keil, et al. 2000). Factor loadings should be at least 0.6 and preferably greater than 0.7 (Bagozzi and Yi 1988, Fornell and Larcker 1981). Additionally, all AVE values of constructs should be higher than 0.5, the suggested minimum. As can be seen from Table 15, all reliability measures were well above the cut-off level, indicating adequate internal consistency.

Table 15: Assessment of internal consistency

Construct	Number of Items	AVE	Composite Reliability	Cronbach's Alpha
Performance	4	0.72	0.91	0.87
Privacy	3	0.77	0.91	0.85
Monetary-Loss	5	0.59	0.88	0.83
Moral-Awareness	7	0.67	0.93	0.92
Time	4	0.63	0.87	0.80

Table 16: Pair-wise correlations: Assessment of discriminant validity

	Performance	Privacy	Monetary-Loss	Moral-Awareness	Time
Performance	0.85				
Privacy	0.40	0.88			
Monetary-Loss	0.29	0.49	0.77		
Moral-Awareness	0.28	0.38	0.59	0.82	
Time	0.41	0.48	0.50	0.60	0.79

Discriminant validity was checked by examining whether the correlations between the variables are lower than the square root of the average variance extracted (Chin 1998, Fornell and Larcker 1981). Table 16 shows that all the squared roots of AVEs on the main diagonal are greater than the pair-wise correlations between constructs on the off diagonal. This indicates discriminant validity among variables. In addition, we provide item cross-loading results in Table 17. Although some cross-loadings are greater than 0.6 (e.g., MA6), the cross-loading difference is higher than the suggested threshold of 0.1 (Gefen and Straub 2005, Hsieh, et al. 2008). As a result, there are no severe cross-loading problems, regarding discriminant validity. Convergent validity is demonstrated when the factor loading of an item on its designated construct is 0.6 or more (Chin, et al. 1997, Kim and Son 2009). As can be seen, all the items meet this requirement. We also conducted the analysis for sub-samples (one song and multiple songs) separately, and found that the results are consistent.

Table 17: Cross-loading: Assessment of convergent and discriminant validity

	Performance	Privacy	Monetary-Loss	Moral-Awareness	Time
PER1	0.79	0.34	0.30	0.23	0.32
PER2	0.86	0.31	0.22	0.21	0.32
PER3	0.88	0.35	0.18	0.21	0.31
PER4	0.86	0.37	0.28	0.28	0.42
PRI1	0.30	0.86	0.36	0.29	0.38
PRI2	0.33	0.87	0.40	0.27	0.36
PRI3	0.42	0.90	0.49	0.42	0.50
ML1	0.27	0.37	0.81	0.50	0.38
ML2	0.20	0.24	0.62	0.28	0.21
ML3	0.30	0.47	0.86	0.48	0.46
ML4	0.12	0.38	0.77	0.48	0.38
ML5	0.22	0.38	0.76	0.50	0.46
MA1	0.20	0.24	0.38	0.80	0.40
MA2	0.19	0.26	0.43	0.82	0.40
MA3	0.26	0.30	0.46	0.85	0.51
MA4	0.16	0.29	0.43	0.85	0.49
MA5	0.29	0.35	0.55	0.81	0.50
MA6	0.26	0.34	0.61	0.75	0.54
MA7	0.21	0.37	0.52	0.83	0.57
TIM1	0.32	0.42	0.42	0.48	0.78
TIM2	0.40	0.41	0.36	0.46	0.79
TIM3	0.19	0.27	0.37	0.50	0.76
TIM4	0.36	0.40	0.42	0.47	0.84

Following confirmation of acceptable properties in the first-order factors, we examined the second-order factor measurement model. The second-order factor (overall piracy risk) is created using the indicators for all the first order factors. This repeated indicator approach, also known as the hierarchical component model, allows the model to be estimated using PLS algorithm (Wetzels, et al. 2009). It also allows examining the path weights of factors forming the higher order construct to examine the relative importance (Chin and Gopal 1995, Chwelos, et al. 2001). The bootstrap re-sampling method (1000 re-samples) was used to determine the significance of the paths between the first-order and the second-order factors.

Table 18: PLS path weight

Combined				
	Path Weight	Standard Error	t-value	Significance
Moral-Awareness – Overall	0.461	0.016	*29.598*	$p < 0.001$
Monetary-Loss – Overall	0.266	0.012	*22.087*	
Time – Overall	0.227	0.008	*27.123*	
Performance – Overall	0.178	0.014	*12.737*	
Privacy – Overall	0.172	0.009	*18.777*	
Single Song				
	Path Weight	Standard Error	t-value	Significance
Moral-Awareness – Overall	0.452	0.017	*26.568*	$p < 0.001$
Monetary-Loss – Overall	0.253	0.014	*17.787*	
Time – Overall	0.226	0.011	*20.820*	
Performance – Overall	0.177	0.018	*10.026*	
Privacy – Overall	0.153	0.011	*14.201*	
Multiple Songs				
	Path Weight	Standard Error	t-value	Significance
Moral-Awareness – Overall	0.471	0.029	*16.509*	$p < 0.001$
Monetary-Loss – Overall	0.284	0.019	*14.719*	
Time – Overall	0.226	0.014	*16.571*	
Privacy – Overall	0.198	0.016	*12.287*	
Performance – Overall	0.176	0.023	*7.503*	

As shown in Table 18, it is found that all five components are significant ($p < 0.001$) in the combined sample, one song, and multiple songs. This indicates that moral-awareness, performance, piracy, monetary-loss, and time risk are significant components constituting the consumer piracy risk. We also found that moral-awareness risk is the most important dimension explaining the overall consumer piracy risk in all three scenarios followed by monetary-loss, time, performance, and prosecution risk.

To explore the relationship between the amount of content pirated and consumer piracy risk, we first compared the weights between sub-constructs and second-order latent construct for one song with the corresponding weight in multiple songs. This statistical comparison was carried out using the following procedure suggested by Chin (Chin 1998, Keil, et al. 2000, Qureshi and Compeau 2009).

$$t = \frac{PW_{multiple} - PW_{one}}{\left(\sqrt{\frac{(N_{one}-1)^2}{(N_{one}+N_{multiple}-2)} \times SE^2{}_{one} + \frac{(N_{multiple}-1)^2}{(N_{one}+N_{multiple}-2)} \times SE^2{}_{multiple}}\right) \times \left(\sqrt{\frac{1}{N_{one}} + \frac{1}{N_{multiple}}}\right)}$$

where

t = t-statistic with $N_{one} + N_{multiple} - 2$ degrees of freedom

N = sample size

SE = standard error of path

PW = path weight

As can be seen in Table 19, we found a significant path weight increase in the privacy risk ($p < .01$) and a marginal increase in the monetary-loss risk ($p < .10$). These results suggest that, as the amount of content pirated increases, the relative importance of privacy and monetary-loss risks increases. In other words, when consumers pirate multiple songs, they put more weight on the loss of confidential information and the monetary loss in their risk evaluation process.

Table 19: Differences in the path weight estimates

	One song	Multiple songs	t-value	Significance
Privacy – Overall	0.153	0.198	*2.347*	$p < 0.01$
Monetary-Loss – Overall	0.253	0.284	*1.292*	$p < 0.10$
Moral-Awareness – Overall	0.452	0.471	*0.567*	*N/S*
Time – Overall	0.226	0.226	*-0.017*	*N/S*
Performance – Overall	0.177	0.176	*-0.061*	*N/S*

Next, we examine the relationship between the amount of content pirated and consumer piracy risk (in terms of magnitude) by comparing the survey responses of the two different scenarios. Latent variable scores (weighted average over the indicators of its components) for each risk component as well as overall risk were obtained in PLS analysis, and used to test whether the means of two groups are statistically different from each other. For two group comparison, both the t-test and the Mann-Whitney test were used, and for multiple groups, Analysis of Variance (ANOVA) and the Kruskal-Wallis test were used. Mann-Whitney and Kruskal-Wallis are non-parametric tests for assessing two or more group differences when the distribution is non-normal and/or the equal variance is not assumed (Gravetter and Wallnau 2004). As seen in Table 20, the means for pirating multiple songs were slightly higher than pirating one song in most cases. However, the differences were not statistically significant for the all risk components. This result indicates that the magnitude of consumers' piracy risk does not change with the amount of content pirated, thus piracy risk cost in a session is fixed (consumers assign the same risk cost regardless of the number of songs pirated).

Table 20: Group differences in two scenarios

Construct	Scenario	Mean	Std. Deviation	t-test		Mann-Whitney	
				t	p	Z	p
Performance	One	2.98	1.02	-0.99	0.49	-0.66	0.51
	Multiple	3.07	0.93				
Privacy	One	3.27	0.93	0.39	0.32	-0.40	0.69
	Multiple	3.23	0.96				
Monetary-Loss	One	2.73	0.92	-0.18	0.70	-0.04	0.97
	Multiple	2.73	0.88				
Moral-Awareness	One	2.06	0.88	-0.99	0.99	-1.35	0.18
	Multiple	2.14	0.82				
Time	One	2.45	0.94	-0.51	0.32	-0.70	0.49
	Multiple	2.49	0.85				
Overall	One	2.53	0.73	-0.69	0.61	-1.19	0.24
	Multiple	2.58	0.64				

We also compare the mean differences in gender, age, file sharing experience (Y/N), and file sharing experience in years. The results show that females tend to perceive significantly higher risk than males, older individuals tend to perceive higher risk than younger individuals, and no (or less) file sharing experience individuals tend to perceive higher risk than more file sharing experience individuals (Table 21 - 24).

Table 21: Group differences in gender

Construct	Gender	Mean	Std. Deviation	t-test		Mann-Whitney	
				T	p	Z	p
Overall	Male	2.47	0.71	*-2.66*	*0.01*	*-3.06*	*0.00*
	Female	2.63	0.64				
Performance	Male	2.91	1.00	*-2.89*	*0.01*	*-2.67*	*0.01*
	Female	3.16	0.92				
Privacy	Male	3.15	0.99	*-2.25*	*0.03*	*-2.25*	*0.02*
	Female	3.34	0.87				
Monetary-Loss	Male	2.63	0.93	*-2.57*	*0.01*	*-2.64*	*0.01*
	Female	2.83	0.85				
Moral-Awareness	Male	2.06	0.88	-0.84	0.40	-1.21	0.23
	Female	2.12	0.81				
Time	Male	2.35	0.85	*-3.02*	*0.00*	*-3.08*	*0.00*
	Female	2.58	0.90				

Table 22: Group differences in file sharing experience (Y/N)

Construct	Sharing Experience	Mean	Std. Deviation	t-test		Mann-Whitney	
				t	p	Z	p
Overall	Yes	2.42	0.63	*-7.04*	*0.00*	*-6.18*	*0.00*
	No	3.04	0.70				
Performance	Yes	2.99	0.99	-0.90	0.37	-0.76	0.45
	No	3.11	0.94				
Privacy	Yes	3.17	0.93	*-2.29*	*0.02*	*-1.96*	*0.05*
	No	3.47	0.92				
Monetary-Loss	Yes	2.62	0.88	*-4.79*	*0.00*	*-4.91*	*0.00*
	No	3.19	0.78				
Moral-Awareness	Yes	1.94	0.74	*-7.68*	*0.00*	*-6.08*	*0.00*
	No	2.76	0.99				
Time	Yes	2.32	0.83	*-6.91*	*0.00*	*-6.37*	*0.00*
	No	3.11	0.85				

Table 23: Group differences in age

Construct	Age	Mean	Std. Deviation	ANOVA		Kruskal-Wallis	
				F	p	χ^2	p
Overall	10-20	2.53	0.60	*5.55*	*0.00*	*12.99*	*0.01*
	21-30	2.51	0.69				
	31-40	2.86	0.77				
	Above 40	3.16	0.72				
Performance	10-20	3.15	0.94	2.27	0.08	5.59	0.13
	21-30	2.97	0.99				
	31-40	2.96	0.89				
	Above 40	3.58	0.68				
Privacy	10-20	3.19	0.86	0.85	0.47	2.69	0.44
	21-30	3.25	0.93				
	31-40	3.38	0.97				
	Above 40	3.60	1.20				
Monetary-Loss	10-20	2.73	0.88	*3.73*	*0.01*	*10.59*	*0.01*
	21-30	2.67	0.89				
	31-40	3.12	0.96				
	Above 40	3.22	0.60				
Moral-Awareness	10-20	2.04	0.72	*6.46*	*0.00*	*12.58*	*0.01*
	21-30	2.05	0.84				
	31-40	2.55	1.04				
	Above 40	2.8	1.19				
Time	10-20	2.44	0.85	*3.47*	*0.02*	*9.07*	*0.03*
	21-30	2.43	0.89				
	31-40	2.76	0.95				
	Above 40	3.15	0.87				

Table 24: Group differences in file sharing experience in years

Construct	Sharing Time (year)	Mean	Std. Deviation	ANOVA		Kruskal-Wallis	
				F	p	χ^2	p
Overall	> 1	2.74	0.61	*10.27*	*0.00*	*41.15*	*0.00*
	1 - 2	2.65	0.59				
	2 - 3	2.40	0.59				
	3 - 4	2.31	0.56				
	< 4	2.28	0.65				
Performance	> 1	3.12	0.90	1.43	0.22	5.16	0.27
	1 - 2	3.07	0.80				
	2 - 3	3.03	0.99				
	3 - 4	3.01	1.07				
	< 4	2.84	1.05				
Monetary-Loss	> 1	2.96	0.81	*8.16*	*0.00*	*31.52*	*0.00*
	1 - 2	2.94	0.89				
	2 - 3	2.57	0.90				
	3 - 4	2.53	0.83				
	< 4	2.39	0.89				
Moral-Awareness	> 1	2.22	0.74	*6.36*	*0.00*	*28.92*	*0.00*
	1 - 2	2.17	0.84				
	2 - 3	1.96	0.65				
	3 - 4	1.78	0.64				
	< 4	1.81	0.76				
Privacy	> 1	3.46	0.89	*3.24*	*0.01*	*12.42*	*0.02*
	1 - 2	3.28	0.99				
	2 - 3	3.05	0.86				
	3 - 4	3.04	0.96				
	< 4	3.08	0.95				
Social	> 1	2.75	0.84	*10.12*	*0.00*	*38.87*	*0.00*
	1 - 2	2.58	0.79				
	2 - 3	2.22	0.71				
	3 - 4	2.18	0.81				
	< 4	2.15	0.83				

3.6 DISCUSSION AND CONCLUSION

This paper contributes to the literature on digital piracy by addressing two main issues. First, drawing upon prior research on perceived risk theory, we extend and support the notion of consumer piracy risk as a multi-dimensional construct formed by performance, time, privacy, moral-awareness, and monetary-loss risk. The multi-dimensional conceptualization we propose offers detailed information about the structure of consumer piracy risk and the relative importance of each risk component. From managerial perspective, understanding different components of consumers' piracy risk is critical since it has many important implications for pricing and piracy control strategies. For example, we found that moral-awareness risk is the most important risk component explaining the overall consumer piracy risk. Based on this finding, educational strategy can be particularly effective in increasing consumer’s moral-awareness risk. Record labels can design and deliver public campaigns that attempt to educate and inform consumers about the risks and the negative social impact of piracy. Through this educational strategy to control piracy, the music industry can encourage consumers to think critically (or increase psychological or social discomfort) about how they acquire music, and motivate consumers’ attitude changes.

Second, many piracy acts may involve pirating more than one song in a session, but it has been unclear whether consumer piracy risk is increasing in the amount of content pirated or fixed. Our findings suggest that although the relative importance of monetary-loss and privacy risks increases with the amount of content pirated, consumers’ overall piracy risk does not change with the amount of content pirated in a session suggesting that consumers’ risk cost is in fact fixed. The implications of fixed piracy risk cost where more than one song is pirated in a single session have profound impact on pricing and profitability of the music industry. One study demonstrated that the magnitude of a digital experience goods supply chain profit loss is related to the type of piracy risk costs (Jeong, et al. 2010b). If consumers' piracy risk cost is fixed and relativly low, the supply chain suffers more from the fixed piracy cost than the linear cost case. As our prior numerical example indicates, the more songs a consumer is interested, the more likely she will pirate under fixed piracy costs. Therefore, when the piracy risk cost is fixed, popular songs and/or artists suffer more from piracy. For popular artists, a more drastic solution to the problem of piracy should be considered such as a subscription model that is less vulnerable to piracy while encouraging legitimate sales.

Our study has several limitations as well as potential avenues for future research. First, the use of undergraduate students is appropriate and convenient for testing our model, but the results may have limited generalizability. Therefore, the external validity of this study needs to be verified by testing the proposed model to other populations. Similarly, different scenarios should be tested to validate the relationship between the amount of content pirated and piracy risk. In this study, we developed two scenarios by choosing “pirating one song vs. ten songs”. However, subjects may not perceive much difference in terms of the numbers that we selected. Also, it would be interesting to examine how and to what extent different anti-piracy strategies (educational campaigns and law-suits) influence different components of piracy risk.

CHAPTER 4: EFFECTIVE PIRACY CONTROL STRATEGIES: AN AGENT-BASED MODELING APPROACH

4.1 INTRODUCTION

The prevalence of unauthorized copying and dissemination has been a serious threat in the music industry. For example, the rapid developments of compression and file-sharing technologies as well as the decreasing cost of copying mediums have provided consumers with greater access to free music than ever before. According to International Federation of the Phonographic Industry (IFPI), more than 40 billion files were illegally shared in 2008, and P2P file sharing accounts for approximately 80 percent of traffic volumes on Internet Service Provider (ISP) networks (IFPI 2009).

In an attempt to protect intellectual property and increase legitimate sales, record companies, often working with the government, have employed numerous anti-piracy strategies including innovation, education, and enforcement. Despite various piracy control efforts, there is little evidence that these policies have successfully decreased piracy levels (Sinha and Mandel 2008). Legal actions initiated by the music industry have been shutting down some of the most well-known file sharing websites such as Napster. However, the traffic volume of P2P sites does not decrease significantly even after the legal threats, and the total number of files shared continue to increase (Bhattacharjee, et al. 2006a). Also, even with the clear articulation of digital copyright law and educational deterrence efforts, piracy is still prevalent due to the high cost of increasing consumers' awareness and of enforcing the law.

The objectives of this paper are to 1) provide an alternative methodology for analyzing the effectiveness of piracy control strategies, 2) find good piracy control and pricing strategies in a market where some piracy is unavoidable, and 3) investigate the impact of different piracy control strategies on consumers, retailers, record labels, and artists. The paper is organized as follows. Section 4.2 presents theoretical background by offering a review of the literature on piracy control strategies, and introduces Agent-Based Modeling (ABM) and its use in problem solving. In Section 4.3, we develop an agent-based model for analyzing the effectiveness of different piracy control strategies. In Section 4.4, we present the results from simulation experiments. Section 4.5 concludes with summary of findings and suggestions for future research.

4.2 THEORETICAL BACKGROUND

4.2.1 Piracy Control Strategies

Piracy can be reduced using preventive or deterrent measures (Gopal and Sanders 1997). Preventive controls refer to the provision of additional benefits to legitimate consumers and/or the use of hardware and software technology to prevent piracy. Prior studies suggest that additional benefits offered are important to encouraging consumers to engage in long-term relationships, and satisfied customers are less likely to pirate (Chiu, et al. 2008a, Chiu, et al. 2008b). In the context of digital piracy, companies can enhance consumers' use of legal products and turn them into loyal customers through lower-price and value-added product strategy such as personalized recommendation and customization. Additional preventive strategies use technology to prevent unauthorized reproduction of digital music files. Examples of protection methods include Digital Right Management (DRM), encryption, and digital watermarks. However, technological preventive controls have often had limited success, and imposed unfair restrictions on what legitimate consumers can do with the songs they have bought. Also, there is little evidence that preventive technology reduces piracy (Sinha and Mandel 2008, Stone 2009).

Deterrent controls refer to the use of education and legal campaigns and sanctions to reduce piracy. Deterrent controls attempt to dissuade users from copying digital products by disseminating litigious information about piracy to the public (Gopal and Sanders 1997). In the music industry, the Recording Industry Association of America (RIAA) coordinates anti-piracy efforts such as educational campaigns and lawsuits against pirates and the operators of P2P networks. Several studies have been conducted to investigate the impact of deterrent controls on piracy in digital good industries. For example, Gopal et al. (2004) demonstrated that the level of music piracy was not significantly affected by a deterrent information message. However, they propose that the results are due to the difficulty of delivering deterrent information through imaginary scenarios such as the one used in their survey (Gopal, et al. 2004). Another interesting finding by Gopal and Sanders (1997) is that deterrent controls that employ educational and legal campaigns provide more profits to the publisher than preventive controls that use technology. Also, deterrent controls are shown to be superior with respect to a social welfare (Gopal and Sanders 1997).

An empirical study on consumer ethics by Levin et al. (2004) showed that illegal downloaders are less likely to believe that their behavior harms the publisher or the artist, which is an indication that the music industry has not been successful in educating consumers on the real economic impact of piracy on the music industry

(Levin, et al. 2004). In a follow up to their 1997 study, Gopal and Sanders (1998) studied individuals' ethical behavior toward piracy. The justice construct, which explains ethical predisposition of individuals toward the legal and justice system, is shown to have a significant impact on the level of piracy regardless of ethical and cultural differences (Gopal and Sanders 1998). Given these findings, we may argue that piracy prevails unless appropriate piracy control strategies are set up to influence consumer behavior. Four generic strategies to combat digital piracy are identified based on the literature: low-price strategy, legal strategy, educational strategy, and value-added service strategy. In the following, we discuss each strategy in further details.

4.2.1.1 Low-price Strategy

Low-price strategy is defined as lowering the price to encourage consumers to buy legal products rather than pirate. Prior studies suggest that price is a primary determinant that influences consumers' purchase and piracy decision. For example, Chiu et al. (2008) show that the low-price strategy has a positive impact on purchase intentions for legitimate online music and software (Chiu, et al. 2008a, Chiu, et al. 2008b). A record label can take advantage of the low production, packaging, inventory, and distribution cost of digital products to decrease price, and thereby reduce consumers' incentive to pirate. If record companies adopt a low-price strategy, consumers have greater motivation to buy legitimate online music rather than pirate it.

4.2.1.2 Legal Strategy

The legal strategy is defined as the actions that music industry takes against pirates and antipiracy regulations or laws by the government. In the past, the RIAA issued threats only to the operators of P2P networks, and have been successful in shutting down some well-known file sharing websites. Recently, the music industry has redirected legal actions and threats toward individual users of P2P networks, and they have filed well-publicized lawsuits in which violators of copyright laws were subject to fines and potential jail time. According to the Wall Street Journal, more than 35,000 people have been sued for illegal music sharing since September 2003 (McBride and Smith 2008).

Legal actions are likely to influence customer intentions to buy legitimate products. The legal prosecution risk resulting from acquiring pirated products is considered a significant factor in predicting intention to pirate (Chiou, et al. 2005, Tan 2002). Also, there is an inverse relationship between the perceived severity of punishment and willingness to buy pirated goods (Albers-Miller, 1999). However, the impact of legal action against pirates tends to be limited. Bhattacharjee et al. (2006) examined how individuals actually responded to legal threats from the recording industry. The authors tracked the file sharing behavior of 2,056 individuals before and after RIAA related legal actions, and found that the majority of substantial sharers as well as non-substantial shares in P2P sites decreased the number of files they shared after the RIAA's legal actions. But, they found an upsurge in the frequency of usage after some time period from the file sharers who continue to use the file-sharing network (Bhattacharjee, et al. 2006a). This result suggests that consumers' response to the music industry's legal threats is temporary and sometime after the legal threats, the level of file sharing and the availability of music files quickly bounce back and remain substantial.

4.2.1.3 Educational Strategy

The educational strategy involves the music industry disseminating information to consumers about the risks involved in illegal music downloads and the damage piracy causes (Chiu, et al. 2008b, Shultz and Saporito 1996). The record companies have designed and delivered public campaigns that attempt to educate and inform consumers that illegal music downloading activities harm recording artists and/or music companies. Through this educational approach, the record companies encourage consumers to think critically about how they acquire music and other forms of intellectual property. If the music industry continues to inform consumers about the risks of illegal music download and the benefits (better service, quality, and guarantees) that legal products can provide with good success, it may motivate consumers' attitude changes about appropriate copying behavior.

4.2.1.4 Value-Added Service Strategy

A value-added service strategy is defined as the provision of added value or extended services to encourage consumers to purchase legal products (Gopal and Sanders 1997). Studies have shown that additional services that online music retailers offer such as personalized recommendation, customization, and reward programs provide great benefits to consumers, and encourage consumers to engage in long-term relationships with music retailers (Chiu, et al. 2008a, Chiu, et al. 2008b). Therefore, the value-added product strategy can enhance purchase intentions for legitimate music.

4.2.2 Agent-Based Modeling (ABM)

Agent-based modeling is a simulation technique. Simulations can be used in situations where 1) not a significant amount of empirical research has been done – it allows the researcher to understand key variables and focus future research effort; 2) it is difficult to collect real-life data on particular phenomena; 3) it is hard to dissociate inter-related or confounding factors from the ones that the researcher is interested in studying (Khouja, et al. 2008). It is true that simulation poses the question of reliability of results since researchers end up generating their own data (based on some theoretical foundations). However, the simulation gives greater control and flexibility in analyzing different situations.

ABM can be applied to a problem by defining a set of agents with related characteristics (attributes), operations (behaviors) and fitness function (performance measuring function). The agents are defined in context of a simulated environment or system and certain overall performance-measuring parameters for the system are identified as well. The entities in the system are modeled as agents whose behavior mimics that of the real entities. Agents act according to their rules/schema. Agents in ABMs can have a high degree of heterogeneity or be very similar depending on the nature of the system being modeled. There can be heterogeneity across the types of agents being modeled (e.g. consumers, firms, nations etc) as well as within each type of agent (e.g. consumers of different types based on their attributes and behaviors). Over time, as a result of repeated actions and interactions of the agents, an aggregate behavior of the system emerges that may not have been originally programmed into the behavior of any of the individual agents (Twomey and Cadman 2002). At times the agents will act independently of each other while on other occasions they may collaborate or compete with each other in pursuit of their individual goals. What is important is that our objective to study systems, usually involving some form of social interaction, is to understand the collective through an investigation of the behavior of individuals. This has now become possible due to increased computing power (Srbljinovic and Skunca 2003).

Several advantages of using ABM have been given in the literature. While these advantages may not be unique to ABM, their combination makes this method attractive. ABM does not require assumptions with regard to the behavior of the system (Twomey and Cadman 2002). Agents also provide a useful approach for modeling entities in many social problems (Bankes 2002). The use of ABM enables us to use the wealth of information about agents' behavior, motives, and interactions to examine the consequences in terms of aggregate system behavior. As mentioned earlier, agents also provide a method for modeling heterogeneity, which is a key characteristic of consumers (Twomey and Cadman 2002). Agents are autonomous entities with limited perception of their environment. They are guided by a few simple rules and act locally. They may or may not have the history of their previous interactions and the ability to learn from them. At times information about past performance is used by agents to determine the type and the degree of improvement in their behavior.

4.3 AGENT-BASED MODELING AND OPTIMAL PIRACY CONTROL

In applying agent-based modeling, one must first identify the agents in the system and their rules. Agents in this problem include online retailers, record labels, artists, consumers, and government. The following assumptions are made:

1. There is only one retailer, record label, and artist.
2. The objective of the retailer, the record label, and the artist is to maximize their profits over the life of the product.

3. The objective of the consumers is to maximize their utility.

4. Consumers have complete information about the current price.

The following notation is used:

t = 1, 2, … , T , a period index,

i = 1, 2, … , N , a consumer index,

$y_{i,t}$ = scale of the utility function associated with consumer i in time period t,

$\kappa_{i,t}$ = shape of the utility function associated with consumer i in time period t,

$\mu_{i,t}$ = number of songs consumer i is interested in obtaining in time period t,

$z_{i,t}$ = risk cost consumer i attaches to piracy in time period t,

p_t = retail price per song in time period t,

$\zeta_{i,t}$ = probability that consumer i is aware of the legal actions in time period t,

n_t = the number of anti-piracy legal actions in time period t,

$q_{i,t}$ = probability that consumer i is exposed to anti-piracy educational campaign in time period t,

m_t = the number of anti-piracy educational-campaigns in time period t,

φ , θ = constants denoting effectiveness of the legal and educational campaigns, $0 \le \varphi \le 1$ and $0 \le \theta \le 1$,

ρ_t = degree of anti-piracy social pressure in time period t,

M = percentage markup from wholesale price,

w_t = wholesale price per song in time period t,

$\overline{\mu}_t$ = total number of songs sold in time period t ($\overline{\mu}_t = \sum_{i=1}^{N} \mu_{it}$),

r = royalty rate for artist,

$I_{\zeta,t} =$ total investment in anti-piracy legal actions in time period t,

$\chi =$ cost of each anti-piracy law-suit,

$I_{q,t} =$ total investment in anti-piracy educational campaigns in time period t,

$\tau =$ cost of each anti-piracy educational campaign,

$\psi =$ value-added effect,

c_{ψ} = cost of implementing value-added service,

c_r = retailer's variable cost per song.

All variables indexed by *t* are dynamic in terms of potentially having a different value each period. For simplicity, we omit the subscript *t* in the following discussion.

4.3.1 Consumer schema

There are *N* consumers and all have complete information about the current selling price. At the beginning of each period, a consumer *i* is interested in obtaining μ_i number of songs. Similar to the study by Khouja and Wang (Khouja and Wang 2010), we assume that the consumer's valuation for songs is a non-decreasing concave function in the number of songs purchased indicating that the marginal valuation is diminishing in the number of songs purchased. This is a realistic assumption because consumers can buy their favorite songs first when using online stores. A consumer *i*'s valuation for μ_i songs is given by:

$$V_i = y_i \mu_i^{\kappa_i}$$

The consumer valuation function above implies that consumers have different valuations for songs and these valuations diminish at a different rate. We assume that y_i and μ_i are normally distributed with known mean and standard deviation, and κ_i is uniformly distributed on the interval [0, 1]. However, the system can deal with any known distribution. Figure 13 illustrates different consumer valuation functions with respect to y and κ.

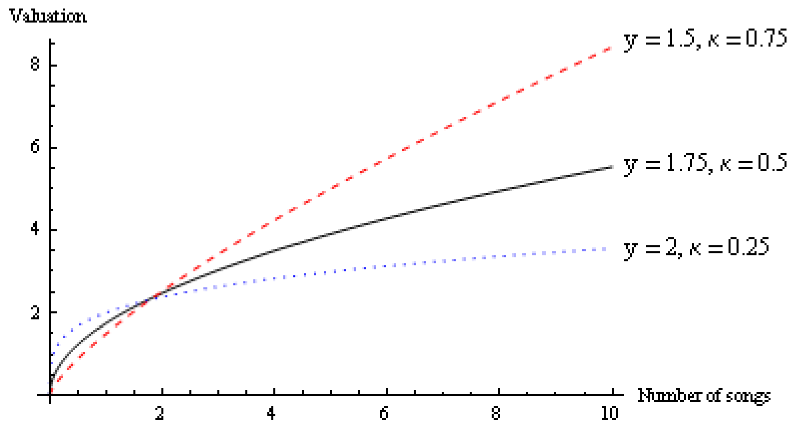


Figure 13: Consumer's valuation for songs

Consumers can obtain songs either by purchasing legitimate copies or by pirating them. While consumers can get songs for free (or at a negligible cost) if they pirate, they are subject to piracy costs caused by potential penalties for violating copyright if they are caught, moral costs of pirating, and search costs to identify and download pirated copies (Bhattacharjee, et al. 2006b, Chellappa and Shivendu 2003a, Chellappa and Shivendu 2005). Therefore, each consumer may purchase some quantity, pirate some quantity, or do nothing depending on which action maximizes her utility. One study has demonstrated that when a consumer pirates a single or multiple songs, the risk cost is only associated with the act. In other words, once a consumer violates copyright law, she perceives the penalty to be fixed (Jeong, et al. 2010a). Therefore, we assume that the risk cost consumer *i* attaches to piracy is a normally distributed random variable, z_i , and independent of the number of songs pirated in a piracy session. Consumers' piracy risk cost is affected by the type of piracy control strategies used. In the following section, we discuss the impact of piracy control strategies on consumer risk assessment process in further details.

4.3.1.1 Legal strategy

Consumers' value/risk assessment process is updated at the end of each period (or beginning of next period) due to the actions implemented by the record label. Each time there is a legal action, consumer *i* has a probability of ζ_i of becoming aware of the law-suit. The probability of awareness depends on the expenditure that music industry spends to make consumers aware of the legal actions. We assume that ζ_i is a non-decreasing concave function in the number of legal action indicating that the marginal awareness is diminishing with the total number of legal actions.

$$\zeta_i = 1 - \frac{1}{e^{n\varphi}}$$

where φ is a constant, satisfying $0 \le \varphi \le 1$, which represents the effectiveness of legal campaigns. To determine if consumer *i* is aware of the legal action, a random variable is drawn from a uniform distribution on [0, 1], and if the number is less than ζ_i, we assume that the consumer is aware of the legal actions, otherwise unaware. Different responses are expected depending on whether consumers are aware/unaware of the law-suits. For consumers who are aware of legal actions, their piracy risk cost, z_i , will increase at a certain rate. A previous study has shown that while the law-suits successfully reduce a number of sharers as well as files shared, P2P traffic volume quickly bounce back after the legal actions (Bhattacharjee, et al. 2006a). Based on this result, we assume that the impact of the legal strategy on consumers' piracy risk costs is temporary (short-lived), thus the risk cost will decrease and eventually go back to the initial level if consumers do not become aware of any new legal actions in the next period.

4.3.1.2 Educational strategy

For educational strategy, consumer *i* has a probability of q_i of becoming aware of the educational campaign. The probability, q_i, also depends on the expenditure that music industry invests in educating consumers, and assumed to be a non-decreasing concave function in the number of educational-campaigns.

$$q_i = 1 - \frac{1}{e^{m\theta}}$$

where θ is a constant, satisfying $0 \le \theta \le 1$, which represents the effectiveness of educational campaigns. Similarly, a random variable is drawn from a uniform distribution on [0, 1] to determine if consumer *i* is aware of the educational campaign, and if the number is less than q_i, we assume that the consumer is aware of the educational campaigns, otherwise unaware. Educational campaign may have less impact in terms of reducing the magnitude of consumer piracy risk. However, unlike the legal strategy, their effect on consumers' piracy risk will not diminish with time. This is a realistic assumption because educational campaigns teach consumers about copyright laws and motivate permanent attitude changes about appropriate copying behavior. Once consumers' attitude toward piracy change, it is likely that this change becomes permanent. Figure 14 highlights the temporal difference of the impact of legal and educational strategy on consumer piracy risk cost.

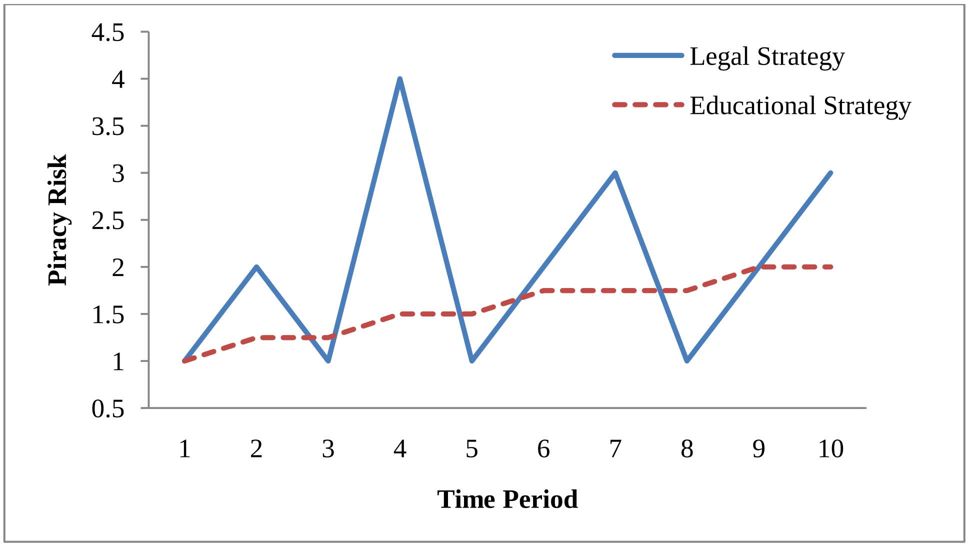


Figure 14: Impact of piracy control strategies on consumers' piracy risk

4.3.1.3 Value-added service and Low-price strategy

Value-added service strategy and low-price strategy encourage consumers to buy legal products and reduce consumers' incentive to pirate. When the value-added service strategy is implemented, we assume that consumers' valuation for purchasing legitimate songs will increase by adjusting ψ (value-added effect) using

$$V_i = \psi \cdot y_i \mu_i^{\kappa_i}$$

We consider three different levels of value-added services; standard (5%), upgrade (10%), and premium (15%). For example, premium value-added services can offer personalized user interface and recommendation, flexibility of use (ability to store and duplicate songs in different systems), and technical support. Costs involved in implementing different levels of value-added services are $c_{\psi b}$ (basic), $c_{\psi u}$ (upgrade), $c_{\psi p}$

(premium), respectively where $c_{\psi b} < c_{\psi u} < c_{\psi p}$. For the low-price strategy, we assume the record label will reduce the current wholesale price (*w*) by a certain percent.

4.3.1.4 Other factor

In addition to the individual's risk cost, we also consider the impact of social (external) pressure on consumers' risk assessment process. Social norm or social pressure has a significant impact on an individual's behavioral intention (d'Astous, et al. 2005). For example, if most consumers (neighbors) purchase songs legally rather than pirate, it will also affect one's purchase/pirate decision. We use ρ to represent the intensity (degree) of social pressure on music piracy which is calculated:

$$\rho = \frac{\text{size of pirating segment (a number of consumers who pirate)}}{\text{a total number of consumers}}$$

If ρ is high (most consumers pirate), more weight is assigned to the net gain from pirating songs so that the degree of social acceptance (consensus) for the practice of music piracy can be reflected in individual risk assessment process.

Based on the discussion of consumer utility function, risk cost assessment, and the effect of piracy control strategies, consumer i will purchase μ songs if the gain from purchasing them is positive and greater than the net gain from pirating, i.e.,

$$(1-\rho)(\psi y_i \mu_i^{\kappa_i} - \mu_i p) \geq \rho(y_i \mu_i^{\kappa_i} - z_i) \text{ and } (1-\rho)(\psi y_i \mu_i^{\kappa_i} - \mu_i p) \geq 0$$

4.3.2 Record label schema

The per song contract is currently the most common contract type in the music industry. Under this contract, a retailer pays the record a wholesale price for each song sold. Studies have shown that the retailer's margin per song is quite small since the wholesale price averages about $ 0.70 (Chen and Png 2003). The record label chooses the wholesale price before the online retailer sets the retail price. The record label charges a wholesale price per song sold of w and incurs a marginal cost. The royalty per song paid to the artist is the major component of the marginal cost incurred by the record label. Also, the record label incurs costs due to investments in law-suits (I_ζ) and educational campaigns (I_q). In this scenario, the record label's profit is

$$\text{Record label's profit} = (w - pr)\overline{\mu} - I_\zeta - I_q - c_\psi$$

where

$I_\zeta = \chi \times n$ and $I_q = \tau \times m$

$p = (1 + M)w$

4.3.3 Other agents' schema

While the retailer and the artists are simple agents in our model, we incorporate these agents to examine how different piracy control strategies also affect on their profitability. The retailer's profit and the artist's royalty are calculated as follows:

$$\text{Retailer's profit} = Mw\overline{\mu} - c_r\,\overline{\mu}$$

$$\text{Artist's royalty} = (1 + M)wr\overline{\mu}$$

The royalty rate is usually negotiated as a percentage of prices before an artist signs a contract. If the artist and the monopolist try to reach a point where both parties agree, the negotiated royalty rate would represent a fair rate based on each party's negotiation power (e.g. the popularity of the artist and the investment needed by the record label). Therefore, creators focus mainly on obtaining the best royalty rate. Studies show that artists are paid royalties usually somewhere between 8% and 25%.

4.4 ANALYSES AND RESULTS

The system was developed using NetLogo 4.1 – a multi-agent programmable modeling environment for simulating natural and social phenomena. Several experiments were conducted to test the system and develop managerial insights. The parameter values used in the simulation are summarized in Table 25, and Appendix C illustrates the flow of the simulation.

Table 25: Parameters for the experiment

Parameter	Value
Market size	1,000 consumers
Valuation for songs ($y_{i,t}$)	N ~ (1, 1), $y_{i,t} \geq 0$
Valuation decrease rate ($\kappa_{i,t}$)	U ~ (0.5, 0.8)
Number of songs ($\mu_{i,t}$)	N ~ (3, 1), $N \geq 0$
Piracy risk costs ($z_{i,t}$)	N ~ (2, 0.5), $z_{i,t} \geq 0$
Retailer's margin (M)	0.15, 0.25, 0.35
Royalty rate (r)	0.10, 0.15, 0.20
Effectiveness of law-suits (φ)	0.2, 0.3, 0.4
Effectiveness of educational campaigns (θ)	0.2, 0.3, 0.4
Cost of implementing value-added service ($c_{\psi b}, c_{\psi u}, c_{\psi p}$)	5, 10, 20
Retailer's marginal cost (c_r)	$0.2
Cost of legal action (χ) [6]	$23
Cost of educational campaign (τ)	$23

For each of the parameter combinations, simulation was run for 50 time periods with 5 repetitions. We identified the best law-suits and educational campaigns investment amount in terms of maximizing profits of the record label. We also identified the profits of the retailer, and artist, and the number of consumers who

[6] A study by Wan (2010) shows that the average net cost of law-suit is approximately $2,300.

purchased, pirated, or neither to compare the effectiveness of different piracy control strategies. We assume that the cost of each anti-piracy legal action (τ) and educational campaign (χ) is same. Simulations were computationally intensive and were run on a Linux-based cluster which had 200 CPU cluster blade servers, Intel Xeon CPUs and gigabit Ethernet interconnections with 2TBs of dedicated network attached storage.

Table 26: Effectiveness of law-suit investments

# of Law-suit	Investment Amount	Label Profit	Retailer Profit	Artist Profit	Total Chain Profit
0	$0	$48.09	$48.91	$6.25	$103.25
1	$23	$25.42	$59.75	$7.63	$92.80
2	$46	$23.34	$91.53	$11.70	$126.56
3	$69	$418.80	$527.59	$67.41	$1,013.80
4	$92	$593.34	$738.99	$94.43	$1,426.76
5	$115	$627.92	$808.06	$103.25	$1,539.23
6	$138	$620.61	$834.52	$106.63	**$1,561.76**
7	$161	$602.38	$849.88	$108.60	$1,560.86
8	$184	$578.95	$859.95	$109.88	$1,548.77
9	$207	$545.32	$859.64	$109.84	$1,514.80
10	$230	$523.23	$871.08	$111.30	$1,505.62

Table 27: Effectiveness of educational campaign investments

# of Education	Investment Amount	Label Profit	Retailer profit	Artist Profit	Total Chain Profit
0	$0	$47.59	$48.39	$6.18	$102.16
1	$23	$489.45	$531.65	$67.93	$1,089.03
2	$46	$616.34	$694.58	$88.75	$1,399.67
3	$69	$625.72	$738.02	$94.30	$1,458.04
4	$92	$625.27	$771.46	$98.58	$1,495.30
5	$115	$612.09	$791.96	$101.19	**$1,505.25**
6	$138	$593.69	$807.14	$103.13	$1,503.97
7	$161	$572.99	$819.99	$104.78	$1,497.76
8	$184	$539.22	$819.54	$104.72	$1,463.47
9	$207	$511.27	$825.02	$105.42	$1,441.70
10	$230	$482.25	$829.41	$105.98	$1,417.65

4.4.1 Impact of Legal and Educational Campaigns on Record Label's Profit

The system can be used to identify a good, possibly optimal, piracy control investment amount for the record label. For example, Tables 26 and 27 show the best law-suit and educational campaigns investment for $r = 0.1$, $M = 0.15$, $\varphi = 0.2$, $\theta = 0.2$. It is best for the record label if they invest in five law-suits which provide a profit of $627.92 in this case. If the record label decides to implement educational strategy instead, three educational campaigns would provide the highest profit which is $625.72. One interesting result is that, from the supply chain perspective, it is optimal to invest in six law-suits or five educational campaigns instead. This indicates if the record label and the retailer coordinate (e.g. partial supports from retailers on label's investment), better supply chain solution can be achieved and there will be a division of profit surplus under which both party can be better-off.

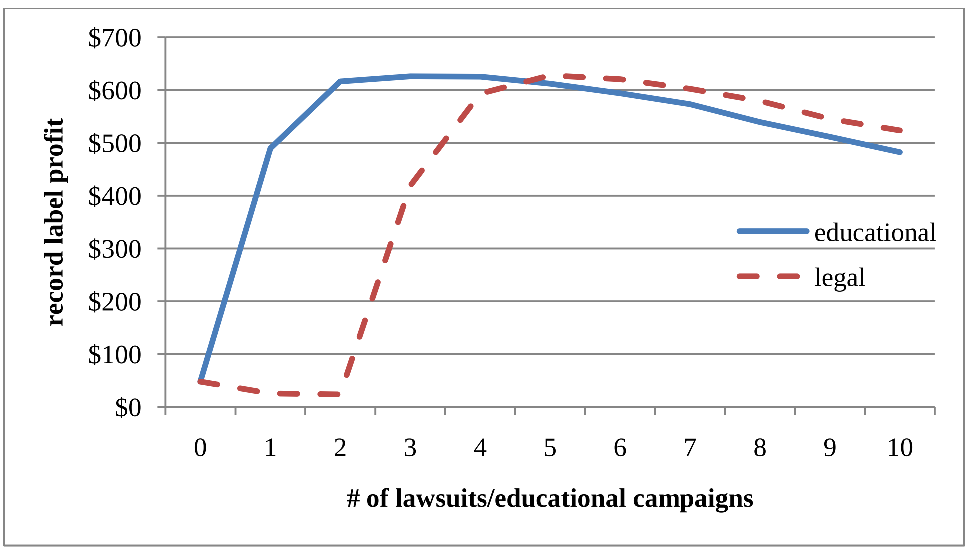
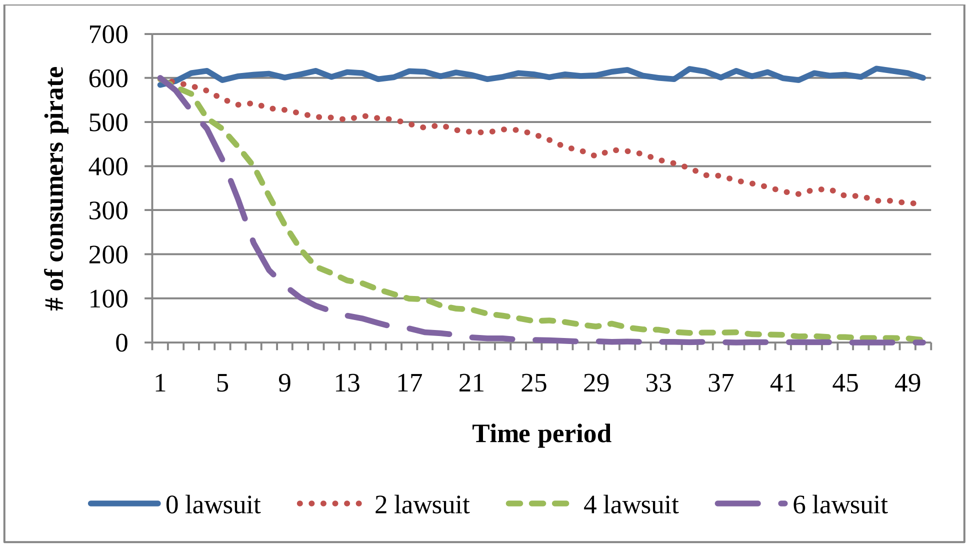


Figure 15: The impact of legal and educational campaigns on record label's profit ($r = 0.1$, $M = 0.15$, $\varphi = 0.2$, $\theta = 0.2$)

Figure 15 shows that as the number of legal and educational campaigns goes beyond five and three, respectively, additional investments in piracy control wouldn't help the record label since the number of consumers in the pirating segment is close to 0 for high number of legal/educational campaigns, thus most consumers will buy a legitimate product rather than pirate (Figure 16a and 16b). Another interesting result is that when the amount of investment in legal and educational campaigns is low, educational campaigns are more effective than law-suits. This is because even if consumers are aware of law-suits, the impact of the legal strategy on consumer's piracy risk costs is temporary so it wouldn't affect consumer choice in the next period. This result suggests that, given limited resources to enforce copyright law, educational campaigns can provide more cost-effective remedies to combat piracy.



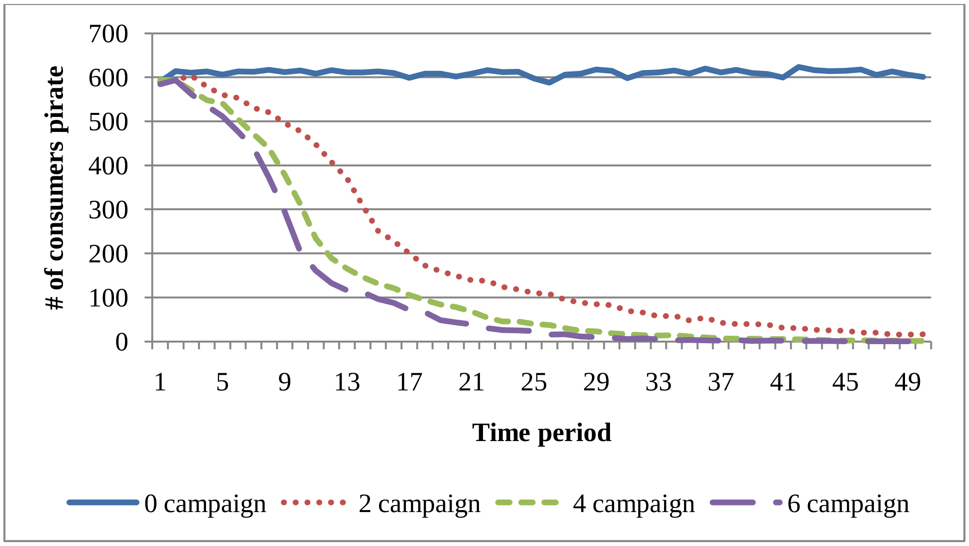


Figure 16: The relationship between the number of law-suits and educational campaigns and consumer piracy behaviors (r = 0.1, M = 0.15, φ = 0.2, θ = 0.2)

We also examine the impact of legal and educational campaign effectiveness (φ and θ) on the record label's profit. As shown in Figure 17, when the effectiveness of legal/educational campaigns is low (0.2), educational campaigns provides more profit for the record label than law-suits. However, when both legal and educational campaigns become more effective, law-suits generate more profit. Based on the findings above, we can conclude that when the amount of investment and the effectiveness of both piracy control strategies are low, educational campaign strategy is better than law-suits. But, as the amount of piracy control investment and the effectiveness of strategies increases, law-suits become more effective.

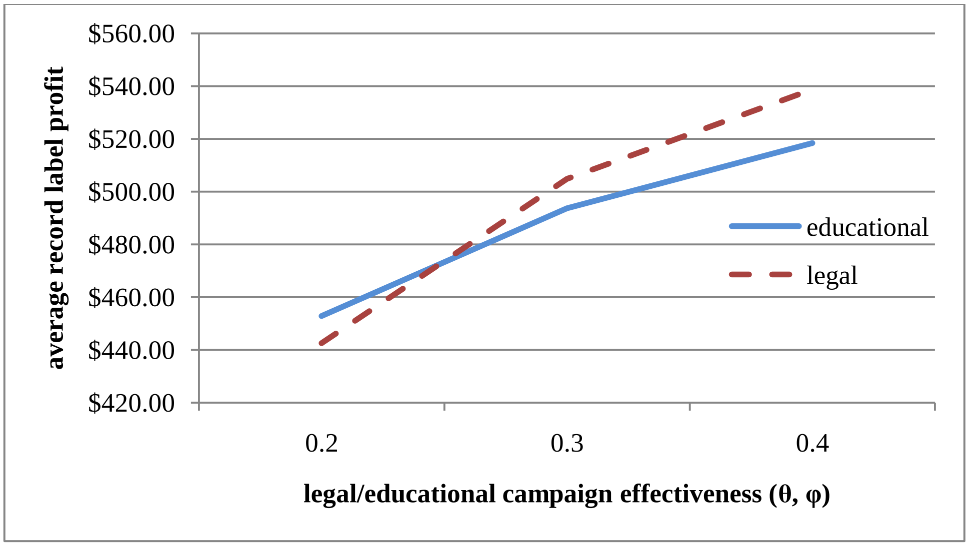


Figure 17: The relationship between effectiveness of legal and educational campaign and record label's profit

4.4.2 Impact of Value-Added Services and Low-Price on Record Label's Profit

Figure 18 shows the record label's profit for value-added services (assuming $c_{\psi} = 0$) and low-price strategy. The record label's profit increases marginally when value-added effect is low, but start increasing rapidly as the value-added effect becomes high. This result suggests that, depending on the utility and consumer risk costs, the provision of added value or extended services which encourage consumers to purchase legitimate products should be substantial, and small increases in value-added service strategy wouldn't enhance purchase intentions of consumers much. For low-price strategy, we found that when the wholesale price is above 0.5, the record label's profit starts decreasing. As the wholesale price increases, the retailer increases the price, and consumers have greater motivation to pirate rather than buy legitimate online music.

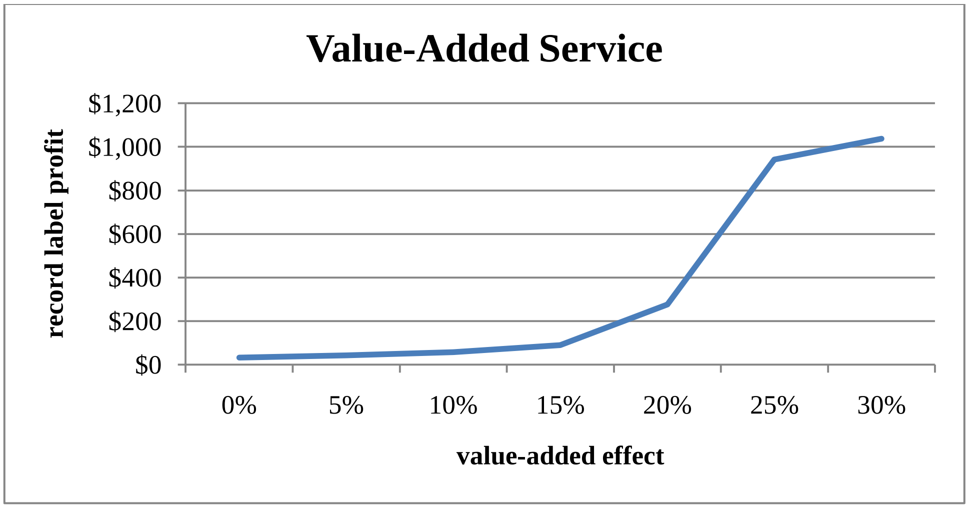
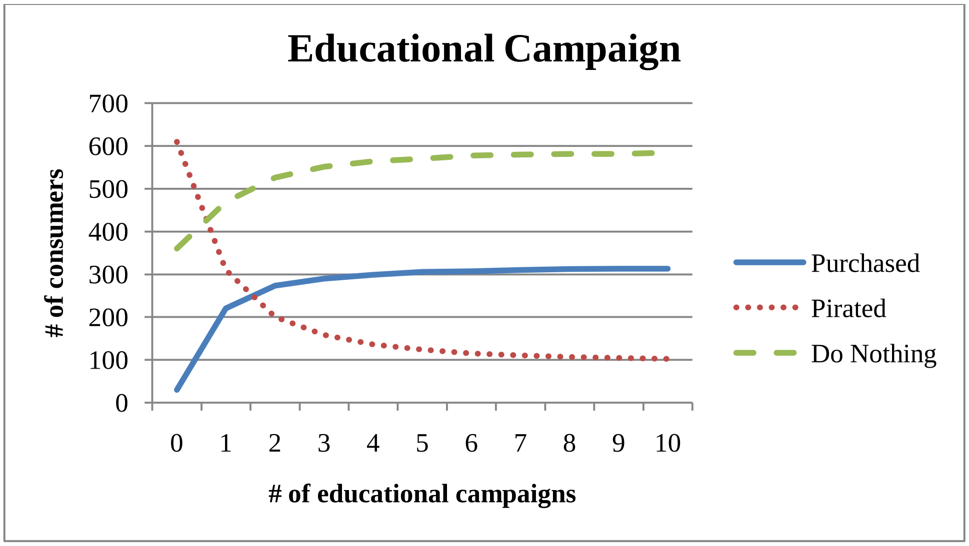
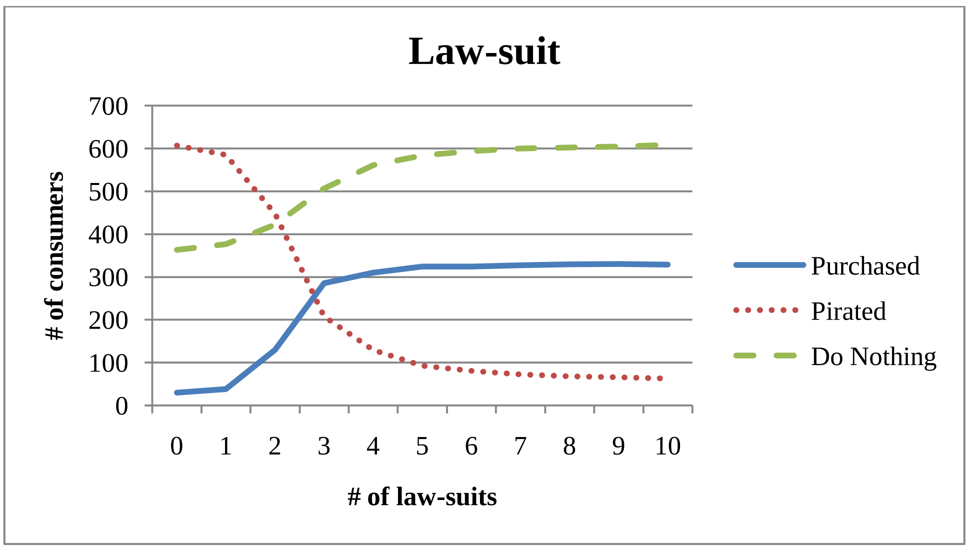
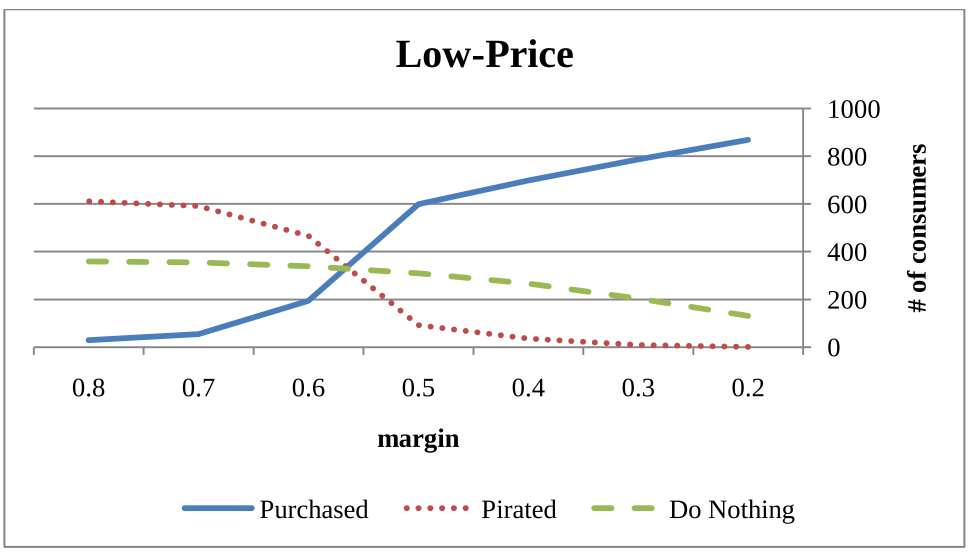


Figure 18: The relationship between value-added services and low-price strategy and record label's profit (r = 0.1, M = 0.15)

One interesting result shown in Figure 19 is that as the record label increases the number of law-suits and educational campaigns, consumers who decided to do nothing (wait) increases. On the other hand, when the record label implements value-added service and low-price strategy, the number of consumers who do nothing actually decreases. This finding indicates that value-added services and low-prices strategy have qualitatively different effects on consumer piracy behavior and consumer surplus compared to legal and educational campaigns.


Educational Campaign
700
600
500
400
300
200
100
0
# of consumers
0 1 2 3 4 5 6 7 8 9 10
# of educational campaigns
Purchased
Pirated
Do Nothing


Law-suit
700
600
500
400
300
200
100
0
# of consumers
0 1 2 3 4 5 6 7 8 9 10
# of law-suits
Purchased
Pirated
Do Nothing


Low-Price
1000
800
600
400
200
0
# of consumers
0.8 0.7 0.6 0.5 0.4 0.3 0.2
margin
Purchased
Pirated
Do Nothing

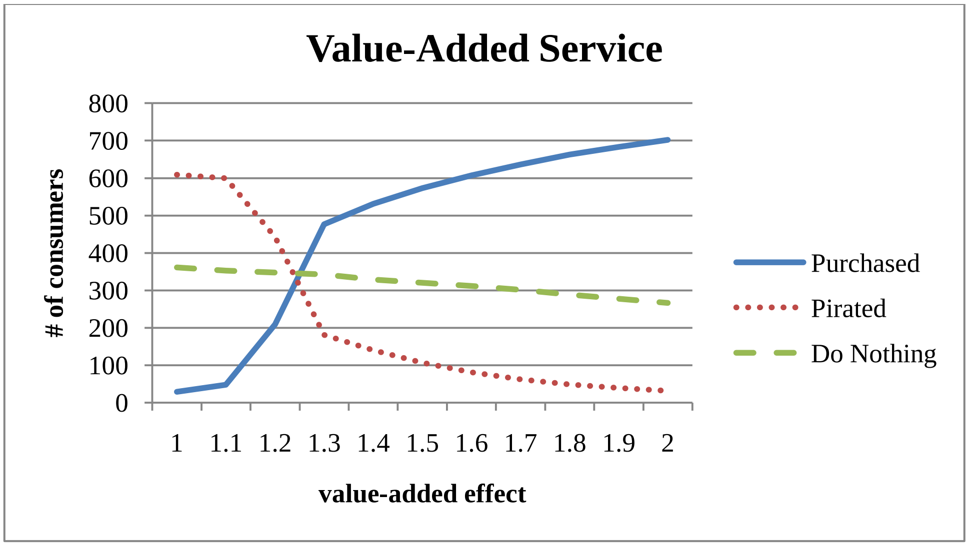


Figure 19: The effects of different piracy control strategies on consumer behavior (r = 0.1, M = 0.15, φ = 0.2, θ = 0.2)

4.4.3 Combined Effect of Piracy Control Strategies on Record Label's Profit

4.4.3.1 Combined Law-Suits and Educational Campaigns with Value-added Service

As shown in Figure 20, when law-suits or educational campaigns and value-added services are implement simultaneously, it provide more profits for the record label while requiring less investment in piracy control (the numbers of optimal law-suits and educational campaigns decreases). Also, we found that the same results hold in the combined cases i.e. when the amount of investment funds is limited and the campaign effectiveness is low, educational campaigns and value-added services combination is more effective than law-suits and value-added services combination. However, as the amount of piracy control investment and the effectiveness of strategies increases, the combined legal and value-added service become more effective strategy (Figure 21).

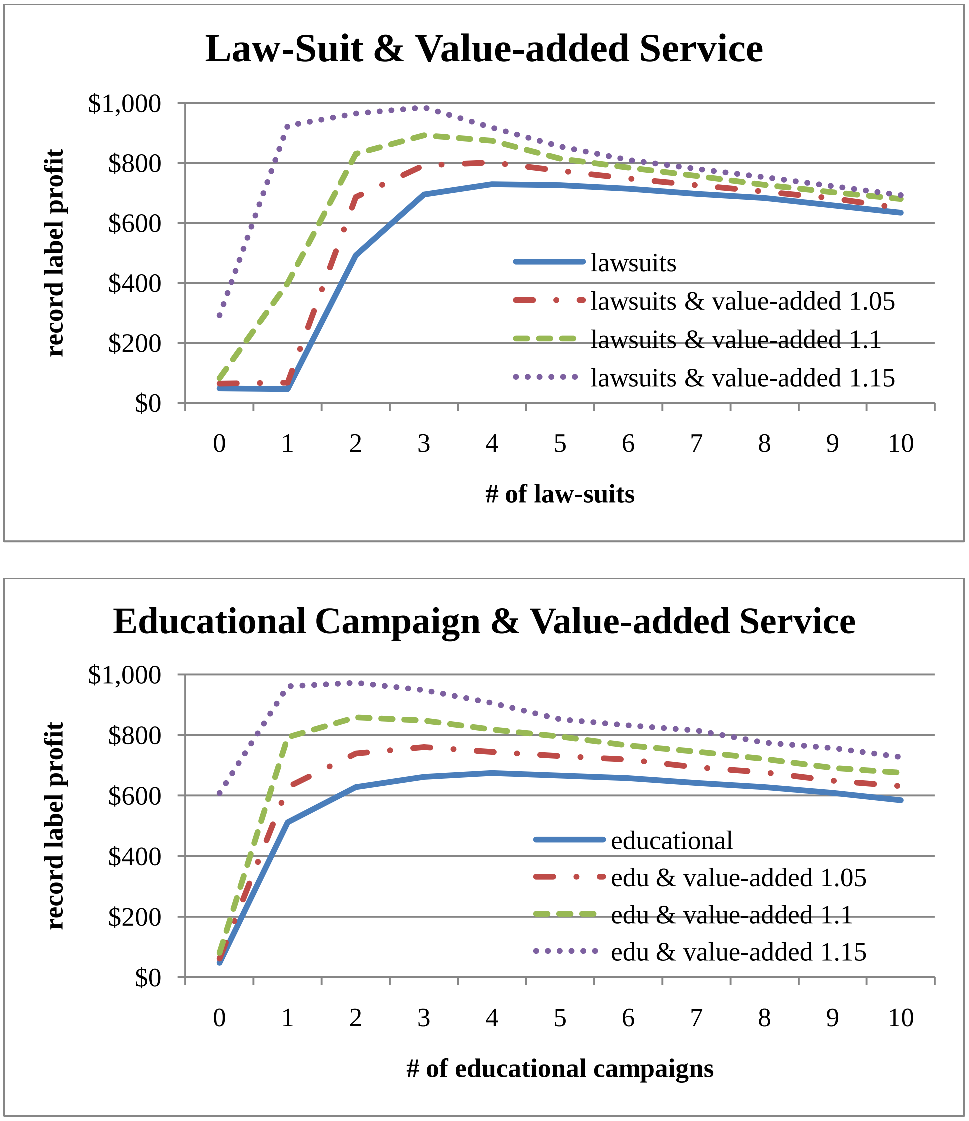


Figure 20: The effects of combined piracy control strategies on record label's profit (r = 0.1, M = 0.15, φ = 0.2, θ = 0.2)

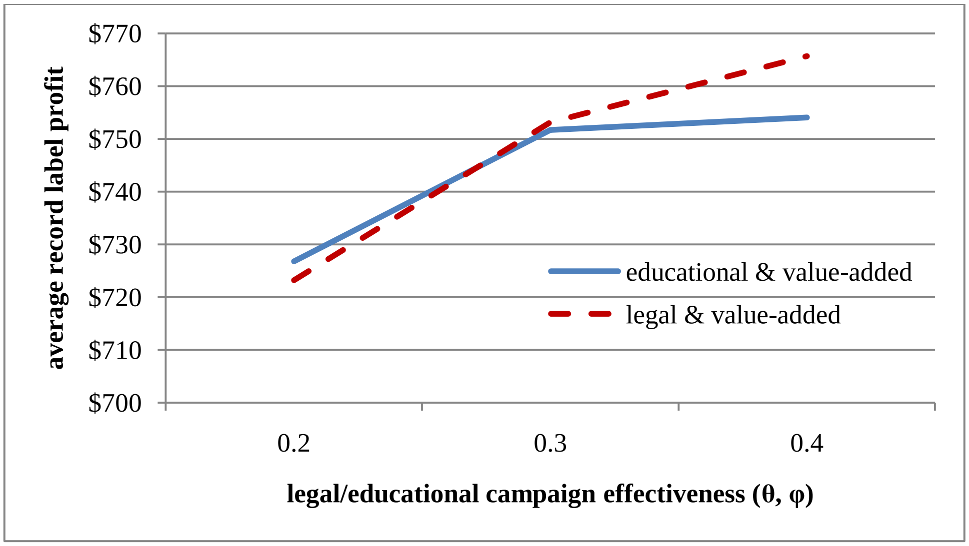
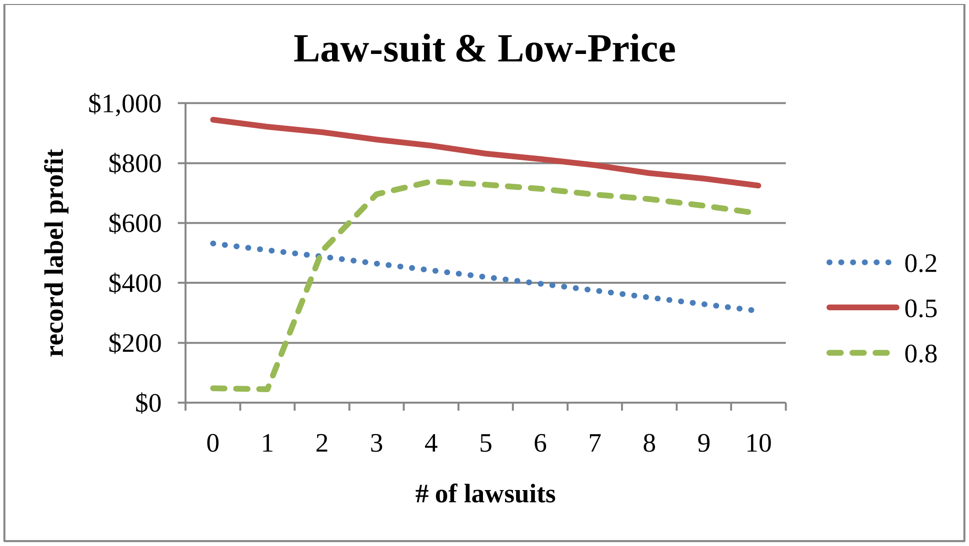


Figure 21: The relationship between effectiveness of legal and educational campaign with value-added services and record label's profit

4.4.3.2 Combined Law-suits and Educational Campaigns with Low-price

For law-suits and low-price combination or educational campaigns and low-price combination, the record label obtains the highest profit when the wholesale price 0.5 (similar to the finding in the low-price strategy). However, the optimal record label profit is achieved when there are no law-suits or educational campaigns. As shown in Figure 22, when the wholesale price is high (0.8), additional investment in piracy control increases the profit because more consumers will pirate without it. However, when the wholesale price is low (0.5 or less), any investments in piracy control wouldn't help the record label. This suggests that it may be better for the record label not to make any investments in piracy control and follow a low-price strategy in some cases.



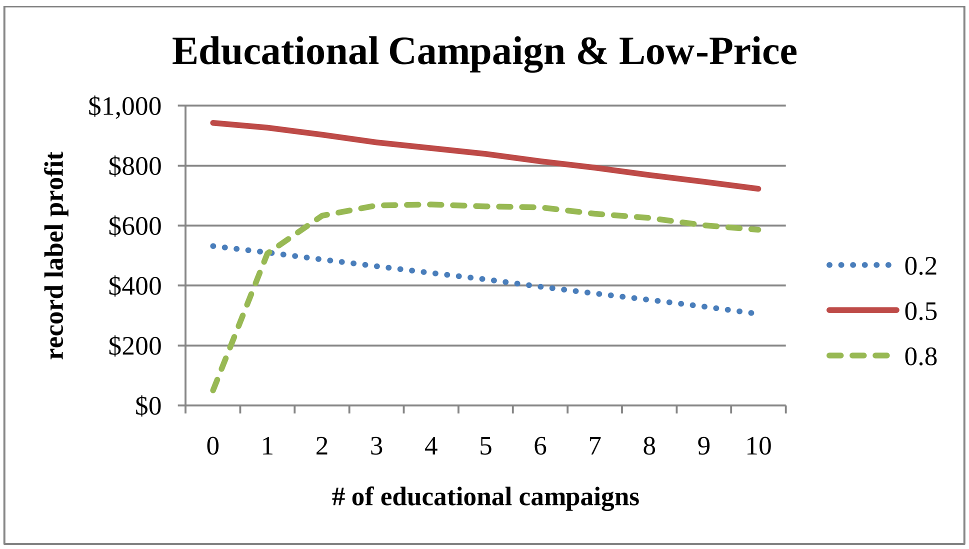


Figure 22: The effects of combined piracy control strategies on record label's profit (r = 0.1, M = 0.15, φ = 0.2, θ = 0.2)

4.4.3.3 Comparison of Combined Piracy Control Strategies on Record Label's Profit

Finally, we compare the effectiveness of combined piracy control strategies to see which strategies provide more profit. Table 28 shows the optimal law-suit and educational campaigns investment, record label, retailer, artist, and total supply chain profits for $r = 0.1$, $M = 0.15$, $\varphi = 0.2$, $\theta = 0.2$.

Table 28: Optimal solution for combined piracy control strategies

	# of Lawsuits	Record Label Profit	Retailer Profit	Artist Profit	Total Profit
Value-added 1.15	4	$951.10	$1,078.88	$137.86	$2,167.84
Low-price 0.5	0	$944.62	$800.52	$122.75	$1,867.89
	# of Educational Campaign	Record Label Profit	Retailer Profit	Artist Profit	Total Profit
Value-added 1.15	2	$971.82	$1,054.10	$134.69	$2,160.61
Low-price 0.5	0	$942.70	$798.90	$122.50	$1,864.10

For all the parameter settings, we compared the profit difference of the record label, retailer, artist, and total chain between value-added services combinations and low-price strategy combinations. Table 29 presents percentage of the cases where the difference in profit is positive (value-added services combination is better than low-price combination). As can be seen, the record label prefers legal and educational campaigns with low-price strategy since it provides more profits for 74% and 67% of the cases respectively. Interestingly, however, from the retailer's, artist's, and total supply chain's perspective, legal and educational campaign with value-added strategy is better than low-price strategy combination. This is because low-price combination strategy does not require any investment in piracy control; thus it would provide more profits for the record label. However, it is better for the retailer, artist, and total supply chain to combine legal and educational strategy with value-added services. In other words, if the players in the supply chain can coordinate, a larger supply chain profit can be achieved with combined value-added service strategy.

Table 29: Comparison of profit difference between combined value-added services and combined low-price strategy

	Record Label	Retailer	Artist	Total Supply Chain
Legal & Value-added	26%	100%	70%	100%
Legal & Low-price[7]	74%	0%	30%	0%
Average Profit Difference (legal & value-added combination – legal & low-price combination)	**-$51.48**	$197.23	$8.76	$228.30
Educational & Value-added	33%	100%	63%	100%
Educational & Low-price	67%	0%	37%	0%
Average Profit Difference (legal & value-added combination – legal & low-price combination)	**-$54.80**	$148.60	$0.33	$172.10

4.5 DISCUSSION AND CONCLUSION

To protect intellectual property and increase legitimate sales, record labels have employed numerous deterrent and preventive piracy control strategies. However, the effect of these strategies on consumer piracy behavior has yet been fully explored. The objectives of this research were to find good piracy control strategies in a market where some piracy is unavoidable, and investigate the impact of different piracy control strategies on consumers, retailers, record labels, and artists. An agent-based modeling approach was applied in pursuit of these objectives by modeling the environment where consumer piracy behaviors are affected by different piracy control strategies.

---

[7] Although we use the combination term, please note that the highest record label profit is obtained without any lawsuits or educational campaigns when the low-price strategy is implemented.

Our numerical experiments suggest that educational strategy is particularly effective when the effectiveness of piracy control strategies and investment budget are low. Given the fact that the record labels may not have enough resources to enforce copyright law against millions of consumers who pirate, it may be more effective to design and deliver public campaigns that attempt to educate consumers about the risks and the negative social impact of piracy than enforcing copyright law via legal sanctions. This may be the reason why the RIAA recently decided to stop filing a legal law-suit against file-sharers and have taken a different approach that relies on the cooperation with ISPs (McBride and Smith 2008).

Preventive and deterrent piracy control strategies have qualitatively different effects on consumer piracy behaviors. Our results indicate that the value-added service and low-price strategies provide consumers greater incentives to purchase legitimate products. When the legal and educational strategies are implemented, many consumers decide to neither pirate nor purchase songs. These strategies are more effective to deter piracy (move consumers from illegal file sharing to doing nothing), rather than providing incentives for legal sales. Also, the effectiveness of piracy control strategies can be improved when multiple strategies are combined. Our analysis shows that when legal or educational campaigns are combined with value-added services strategy, it provides more profits for the record label while requiring less investment in piracy controls. However, when the low-price strategy is implemented, consumers' intention to purchase legitimate songs is already high (or pirating segment is very small), and any investments in legal and educational campaigns wouldn't help to increase the record label's profit. Therefore, careful planning is required when record labels develop piracy control strategies.

Our study has several limitations as well as potential avenues for future research. We focus on the effect of different piracy control strategies on consumer piracy behavior, thus the record label and consumers are the only active agents in our model. Relationships with other important players such as retailers, artists and government with more complex behavior can be considered. This may include different pricing options (e.g. subscription and nonlinear pricing), contracts (e.g. lump-sum and quantity discount) between record label and retailers, artists royalty negotiation, direct distribution channel, and government subsidy or taxation.

Some of the probabilistic variables in the simulation were modeled using uniform and normal distributions. While these are reasonable choices in the absence of other information, other distributions can be used to examine the robustness of the results. Also, we chose the parameter values used in the simulation cautiously, but it is worthwhile to note that those values are more for illustrative purposes to demonstrate the relationship in the system, and may not be empirically valid. For example, we assumed that a legal action and an educational campaign have the same cost. However, if the costs of two actions are different, it may affect some of our results. Lastly, we chose to run the simulation for 50 time periods with 5 repetitions but do not analyze the number of replications and time periods needed to have predetermined level of confidence in the results. A statistical analysis to identify the required number of replications and time periods for each replication will improve the analysis.

CHAPTER 5: CONCLUDING REMARKS

5.1 DISSERTATION OVERVIEW

This dissertation analyzed the effect of digital piracy on online music channel, explored consumer piracy risk cost, and suggested optimal supply chain coordination strategies using multi-method approaches including survey, mathematical modeling, and simulation.

In the first study (Chapter 2), we explored the impact of piracy on digital music supply chain profitability under different contract arrangements between record labels and online retailers. Consumers' piracy risk cost was divided into two cases: 1) linear piracy cost and 2) fixed piracy cost. We also analyzed two contract types: 1) fixed fee contract and 2) per song contract. For each case, we identified an optimal Stackelberg equilibrium and analyzed how different piracy risk costs and contract types affect supply chain pricing, record label and retailer's profits, and supply chain coordination.

In Chapter 3, we developed a theoretical and operational basis for conceptualizing a measurement model of consumer piracy risk using an empirical survey. Adapted from Perceived Risk Theory, we identified components of consumer piracy risk and empirically tested their importance in the context of illegal music downloads. In addition to examining the components of consumer piracy risk, we also explored how consumers assess their piracy risk with respect to the amount of content they pirate.

Chapter 4 provided an alternative methodology to evaluate the relationship between players in the digital supply chain. In particular, we analyzed the effectiveness of piracy control strategies used to dissuade consumers from illegal music downloads. We used an agent-based modeling (ABM) approach to 1) provide an alternative methodology for analyzing the piracy control strategies, 2) find good piracy control strategies in a market where some piracy is unavoidable, and 3) investigate the impact of piracy on consumers, retailers, record labels, and artists.

5.2 DISCUSSION OF FINDINGS AND CONTRIBUTION

There are several ways in which this thesis has contributed to the literature on digital piracy, consumer piracy behaviors, online channel distribution, and supply chain coordination. First, the thesis has demonstrated that although piracy will reduce total supply chain profit, the magnitude of profit loss depends on type of consumers' piracy risk cost and the type of contracts in the supply chain. In addition, changes in consumers' piracy risk cost change the distribution of the profit between the record label and the retailer. As the investment in piracy controls increases, the retailer keeps a larger share of the profit surplus leaving the record label with a smaller share. Also, piracy has larger negative impact on the profitability of music albums containing a large number of popular songs. We demonstrated that a fixed fee full transfer contract will always coordinate the supply chain, and the profitability of the fixed fee contract further increases as 1) online market size increases, 2) consumer piracy risk cost increases, and 3) marginal unit cost decreases.

Second, we extend and support the notion of consumer piracy risk as a multi-dimensional construct formed by performance, time, privacy, moral awareness, and monetary loss risk in the second study. The multi-dimensional conceptualization we propose and test offers detailed information about the structure of consumer piracy risk and the relative importance of each risk component. We found that moral awareness risk is the most important risk component explaining the overall consumer piracy risk. Record labels can design and deliver public campaigns which attempt to educate and inform consumers about the risks and the negative social impact of piracy. Through this educational strategy to control piracy, the music industry can encourage consumers to think critically (or increase psychological or social discomfort) about how they acquire music, and motivate consumers' attitude changes.

Third, many piracy acts may involve pirating more than one song in a session, but it is unclear whether consumer piracy risk is increasing in the amount of content pirated or it is fixed. Our findings suggest that although the relative importance of monetary-loss and privacy risks increases with the amount of content pirated, consumers' overall piracy risk does not change with the amount of content pirated in a session suggesting that consumers' risk cost is in fact fixed. The implications of fixed piracy risk cost where more than one song is pirated in a single session have profound impact on pricing and profitability of the music industry. When the piracy risk cost is fixed, popular songs and/or artists suffer more from piracy. For popular artists, a more drastic solution to the problem of piracy should be considered such as a subscription model that is less vulnerable to piracy while encouraging legitimate sales.

Fourth, the thesis has provided an alternative methodology to analyze the effectiveness of piracy control strategies used to dissuade consumers from illegal music downloads. We used an agent-based modeling (ABM) approach to analyze the effectiveness of various piracy control strategies, find good piracy control strategies in a market where some piracy is unavoidable, and investigate the impact of piracy on consumers, retailers, record labels, and artists. We found that when the effectiveness of piracy control strategies and investment budget are low, it is best to use educational campaign strategy. Also, we demonstrated that the value-added service or low-price strategy provides consumers greater incentives to purchase legitimate products (moving from illegal downloading to the legal segment). However, when the legal or educational strategy is implemented, many consumers in the pirating segment decide not to pirate instead of purchase songs. Therefore, legal and educational strategies are more effective to deter piracy (moving from illegal to doing nothing segment), rather than providing incentives for legal sales. When legal or educational campaigns are combined with value-added services strategy, the combination provides more profits for the record label while requiring less investment in piracy controls. However, when the low-price strategy is implemented, consumers' intention to purchase legitimate songs is already high, and any investments in legal and educational campaigns wouldn't help to increase the record label's profit.

5.3 FUTURE RESEARCH

There are some limitations of the thesis which have been discussed separately at the end of each study (in Chapters 2, 3 and 4). This section presents some ideas for future research. First, this dissertation focuses on the relationship between the record label and online retailer, and does not consider other important players in the chain such as artists and government. Therefore, it would be promising to investigate how artist royalty (e.g. negotiation) and government subsidy or taxation affect digital music supply chain coordination. Also, it would be interesting to examine the impact of different pricing schemes such as subscription pricing, quantity discounts, non-linear pricing, or a mixed per unit and subscription pricing on profits of record labels and online retailers and consumer surplus. Lastly, while we propose that the fixed fee full transfer will fully coordinate the supply chain, our model does not consider the actual value of the lump sum payment by the record label. Thus, it would be promising to investigate the optimal fixed fee payment based on different factors such as the relative bargaining power of the record label and retailer.

REFERENCES

Bagozzi, Richard P. and Youjae Yi, "On the Evaluation of Structural Equation Models," *Journal of the Academy of Marketing Science*, 16, 1, (1988), 74-94.

Bankes, Steven C., "Agent-based modeling: A revolution?," *Proceedings of the National Academy of Sciences*, 2002, 7199-7200.

Barki, Henri, Suzanne Rivardand Jean Talbot, "Toward an Assessment of Software Development Risk," *Journal of Management Information Systems*, 10, 2, (1993), 203-225.

Bauer, Raymond, "Consumer Behavior as Risk Taking," *American Marketing Association*, (1960), 389-398.

Bauer, Raymond, *Consumer Behavior as Risk Taking*, Harvard University Press, Boston, MA, 1967.

Benevenuto, Fabricio, Cristiano Costa, Marisa Vasconcelos, Virgilio Almeida, Jussara Almeidaand Miranda Mowbray, "Impact of Peer Incentives on the Dissemination of Polluted Content," *Proceedings of the 2006 ACM symposium on Applied computing*, Dijon, France, 2006, 1875-1879.

Bhattacharjee, Sudip, Ram D Gopaland G Lawrence Sanders, "Digital music and online sharing: Software piracy 2.0?," *Communications of the ACM*, 46, 7, (2003), 107-111.

Bhattacharjee, Sudip, Ram D. Gopal, Kaveepan Lertwacharaand James R. Marsden, "Impact of Legal Threats on Online Music Sharing Activity: An Analysis of Music Industry Legal Actions," *Journal of Law and Economics*, 49, 1, (2006a), 91-114.

Bhattacharjee, Sudip, Ram D. Gopal, Kaveepan Lertwacharaandand James R. Marsden, "Consumer Search and Retailer Strategies in the Presence of Online Music Sharing," *Journal of Management Information Systems*, 23, 1, (2006b), 129-159.

Bockstedt, Jesse C., Robert J. Kauffmanand Frederick J. Riggins, "The Move to Artist-Led On-Line Music Distribution: A Theory-Based Assessment and Prospects for Structural Changes in the Digital Music Market," *International Journal of Electronic Commerce*, 10, 3, (2006), 7-38.

Cachon, Gerard P. and Martin A. Lariviere, "Supply Chain Coordination with Revenue-Sharing Contracts: Strengths and Limitations," *Management Science*, 51, 1, (2005), 30-44.

Chellappa, Ramnath K. and Shivendu Shivendu, "Economic Implications of Variable Technology Standards for Movie Piracy in a Global Context," *Journal of Management Information Systems*, 20, 2, (2003a), 137-168.

Chellappa, Ramnath K. and Shivendu Shivendu, "Pay now or pay later?: managing digital product supply chains," *Proceedings of the 5th international conference on Electronic commerce,* Pittsburgh, Pennsylvania, 2003b, 230 - 234.

Chellappa, Ramnath K. and Shivendu Shivendu, "Managing Piracy: Pricing and Sampling Strategies for Digital Experience Goods in Vertically Segmented Markets," *Information Systems Research*, 16, 4, (2005), 400-417.

Chellappa, Ramnath K. and Shivendu Shivendu, "Upstream Contracts in Supply Chain for Digital Goods," *Proceedings of the Conference on Information Systems and Technology*, Seattle, WA, 2007, 3-4.

Chen, Y. and I. Png, "Software pricing and copyright enforcement: Private profit vis-a-vis social welfare.," *Proceedings of the 20th International Conference on Information Systems*, Charlotte, NC, 1999, 119-123.

Chen, Yeh-ning and Ivan Png, "Information Goods Pricing and Copyright Enforcement: Welfare Analysis," *Information Systems Research*, 14, 1, (2003), 107-123.

Cheng, Hsing K, Ronald R Simsand Hildy Teegen, "To purchase or to pirate software: An empirical study," *Journal of Management Information Systems*, 13, 4, (1997), 49-60.

Chiang, Wei-yu Kevin, Dilip Chhajedand James D. Hess, "Direct Marketing, Indirect Profits: A Strategic Analysis of Dual-Channel Supply-Chain Design," *Management Science*, 49, 1, (2003), 1-20.

Chin, Wynne W., "Issues and Opinion on Structural Equation Modeling," *MIS Quarterly*, 22, 1, (1998), 7-16.

Chin, Wynne W. and Abhijit Gopal, "Adoption Intention in GSS: Relative Importance of Beliefs," *ACM SIGMIS Database*, 26, 2-3, (1995), 42-64.

Chin, Wynne W., Abhijit Gopaland W. David Salisbury, "Advancing the Theory of Adaptive Structuration: The Development of a Scale to Measure Faithfulness of Appropriation," *Information Systems Research,* 8, 4, (1997), 342-367.

Chiou, Jyh-Shen, Chien-yi Huangand Hsin-hui Lee, "The antecedents of music piracy attitudes and intentions," *Journal of Business Ethics*, 57, 2, (2005), 161-174.

Chiu, Hung-Chang, Yi-Ching Hsiehand Mei-Chien Wang, "How to Encourage Customers to Use Legal Software," *Journal of Business Ethics*, 80, 3, (2008a), 583–595.

Chiu, Hung-Chang, Yuh-May Lin, Monle Lee, Min-En Niehand Hsiang-Chun Chen, "How to discourage online music piracy," *International Journal of Management and Enterprise Development*, 5, 6, (2008b), 723-738.

Chwelos, Paul, Izak Benbasatand Albert S. Dexter, "Empirical Test of an EDI Adoption Model," *Information Systems Research*, 12, 3, (2001), 304-321.

Clemons, Eric K., Bin Guand Karl Reiner Lang, "Newly Vulnerable Markets in an Age of Pure Information Products: An Analysis of Online Music and Online News," *Journal of Management Information Systems*, 19, 3, (2002), 17-41.

Conner, Kathleen Reavis and Richard P. Rumelt, "Software Piracy: An Analysis of Protection Strategies," *Management Science*, 37, 2, (1991), 125-139.

Cronan, Timothy Paul and Sulaiman Al-Rafee, "Factors that Influence the Intention to Pirate Software and Media," *Journal of Business Ethics*, 78, 4, (2008), 527-545.

d'Astous, Alain, Francois Colbertand Daniel Montpetit, "Music Piracy on the Web – How Effective Are Anti-Piracy Arguments? Evidence From the Theory of Planned Behaviour," *Journal of Consumer Policy*, 28, 3, (2005), 289-310.

Edwards, Jeffrey R. and Richard P. Bagozzi, "On the Nature and Direction of Relationships Between Constructs and Measures," *Psychological Methods*, 5, 2, (2000), 155-174.

EFF, "RIAA v. The People: Five Years Later," Electronic Frontier Foundation, 2008.

Featherman, Mauricio S. and Paul A. Pavlou, "Predicting e-services adoption: a perceived risk facets perspective," *International Journal of Human-Computer Studies*, 59, 4, (2003), 451-474.

Fornell, Claes and David F. Larcker, "Evaluating Structural Equation Models with Unobservable Variables and Measurement Error," *Journal of Marketing Research*, 18, 1, (1981), 39-50.

Forsythe, Sandra M. and Bo Shi, "Consumer patronage and risk perceptions in Internet shopping," *Journal of Business Research*, 56, 11, (2003), 867-875.

Garbarino, Ellen and Michal Strahilevitz, "Gender differences in the perceived risk of buying online and the effects of receiving a site recommendation," *Journal of Business Research*, 57, 7, (2004), 768-775.

Gefen, David and Detmar Straub, "A practical guide to factorial validity using PLS-Graph: tutorial and annotated example," *Communications of the Association for Information Systems*, 16, (2005), 91-109.

Givon, Moshe, Vijay Mahajanand Eitan Muller, "Software Piracy: Estimation of Lost Sales and the Impact on Software Diffusion," *Journal of Marketing*, 59, 1, (1995), 29-37.

Good, Nathaniel S. and Aaron Krekelberg, "Usability and privacy: a study of KaZaA P2P file-sharing," *Proceedings of the SIGCHI conference on Human factors in computing systems*, 2003, 137-144.

Gopal, Ram D and G Lawrence Sanders, "Preventive and deterrent controls for software piracy," *Journal of Management Information Systems*, 13, Spring, (1997), 29-47.

Gopal, Ram D and G Lawrence Sanders, "International software piracy: Analysis of key issues and impacts," *Information Systems Research*, 9, 4, (1998), 380-397.

Gopal, Ram D, G Lawrence Sanders, Sudip Bhattacharjee, Manish Agrawaland Suzanne C Wagner, "A Behavioral Model of Digital Music Piracy," *Journal of Organizational Computing and Electronic Commerce*, 14, 2, (2004), 89.

Gravetter, Frederick J and Larry B. Wallnau, *Statistics for the Behavioral Sciences*, Thomson Learning, Belmont, CA, 2004.

Hair, Joseph F., Rolph E. Anderson, Ronald L. Tathamand William C. Black, *Multivariate Data Analysis: With Readings*, Prentice Hall, 2005.

Hong, Seung-Hyun, "The recent growth of the internet and changes in household-level demand for entertainment " *Information Economics and Policy*, 19, 3-4, (2007), 304-318.

Hsieh, J. J. Po-An, Arun Raiand Mark Keil, "Understanding Digital Inequality: Comparing Continued Use Behavioral Models of the Socio-Economically Advantaged and Disadvantaged," *Management Information Systems Quarterly*, 32, 1, (2008), 97-126.

Hui, Kai-Lung and Ivan Png, "Piracy and the Legitimate Demand for Recorded Music," *Contributions to Economic Analysis & Policy*, 2, 1, (2003), article 11.

IFPI, "The Recording Industry 2006 Piracy Report: Protecting Creativity in Music," International Federation of the Phonographic Industry, 2006.

IFPI, "Digital music report," International Federation of the Phonographic Industry, 2008.

IFPI, "Digital Music Report: Key Statistics," International Federation of the Phonographic Industry 2009.

Jacoby, Jacob and Leon B. Kaplan, "The Components of Perceived Risk," *Proceedings of the Third Annual Conference of the Association for Consumer Research*, 1972, 382-393.

Jasper, Cynthia R. and Sara J. Ouellette, "Consumers' perception of risk and the purchase of apparel from catalogs," *Journal of Direct Marketing*, 8, 2, (1994), 23-36.

Jeong, Bong-Keun, Moutaz Khoujaand Kexin Zhao, "Conceptualization and Measurement of Consumer Piracy Risk in the Context of Illegal Music Downloads," (2010a),

Jeong, Bong-Keun, Moutaz Khoujaand Kexin Zhao, "Supply Chain Coordination in the Digital Age," (2010b),

Keil, Mark, Bernard C. Y. Tan, Kwok-Kee Wei, Timo Saarinen, Virpi Tuunainenand Arjen Wassenaar, "A Cross-Cultural Study on Escalation of Commitment Behavior in Software Projects," *Management Information Systems Quarterly*, 24, 2, (2000), 299-325.

Khouja, Moutaz, Mirsad Hadzikadic, Hari K. Rajagopalanand Li-Shiang Tsay, "Application of complex adaptive systems to pricing of reproducible information goods," *Decision Support Systems*, 44, 3, (2008), 725-739.

Khouja, Moutaz and SungJune Park, "Optimal Pricing of Digital Experience Goods Under Piracy," *Journal of Management Information Systems*, 24, 3, (2007), 109-141.

Khouja, Moutaz and Yulan Wang, "The impact of digital channel distribution on the experience goods industry," *forthcoming in European Journal of Operational Research*, (2010),

Kim, Dan J., Donald L. Ferrinand H. Raghav Rao, "A trust-based consumer decision-making model in electronic commerce: The role of trust, perceived risk, and their antecedents," *Decision Support Systems*, 44, 2, (2008), 544-564.

Kim, Sung S. and Jai-Yeol Son, "Out of dedication or constraint? A dual model of post-adoption phenomena and its empirical test in the context of online services," *MIS Quarterly*, 33, 1, (2009), 49-70.

Kwong, Kenneth K, Oliver H M Yau, Jenny S Y Lee, Leo Y M Sinand Alan C B Tse, "The Effects of Attitudinal and Demographic Factors on Intention to Buy Pirated CDs: The Case of Chinese Consumers," *Journal of Business Ethics*, 47, 3, (2003), 223.

Law, Averill M. and W. David Kelton, *Simulation Modeling and Analysis*, McGraw Hill, 2000.

Levin, AM, Dato-on M Conwayand K Rhee, "Money for nothing and hits for free: the ethics of downloading music from peer-to-peer web sites," *Journal of Marketing Theory and Practice*, 12, 1, (2004), 48-60.

Liang, Jian, Rakesh Kumar, Yongjian Xiand Keith W. Ross, "Pollution in P2P File Sharing Systems," *Proceedings of the IEEE INFOCOM*, Miami, FL, 2005, 1174-1185.

Lim, Nena, "Consumers' perceived risk: sources versus consequences," *Electronic Commerce Research and Application*, 2, 3, (2003), 216-228.

Limayem, Moez, Mohamed Khalifaand Wynne W. Chin, "Factors motivating software piracy: A longitudinal study," *IEEE Transaction Engineering Management*, 51, 4, (2004), 414-425.

Littler, Dale and Demetris Melanthiou, "Consumer perceptions of risk and uncertainty and the implications for behaviour towards innovative retail services: The case of Internet Banking," *Journal of Retailing and Consumer Services*, 13, 6, (2006), 431-443.

Liu, Yongmei and Yanlong Zhang, "Supply Chain Coordination with Contracts for Online Game Industry," *Proceedings of the IEEE International Conference on Management of Innovation and Technology*, 2006, 867-871.

McBride, Sarah and Ethan Smith, "Music Industry to Abandon Mass Suits," *Wall Street Journal*, December 19, 2008.

McCorkle, Denny E., "The role of perceived risk in mail order catalog shopping," *Journal of Direct Marketing*, 4, 4, (1990), 26-35.

Miazaki, Anthony D. and Ana Fernandez, "Consumer Perceptions of Privacy and Security Risks for Online Shopping," *Journal of Consumer Affairs*, 35, 1, (2005), 27-44.

Mitchell, Vincent-Wayne, "Consumer perceived risk: conceptualisations and models," *European Journal of Marketing*, 33, 1/2, (1999), 163-195.

Moores, Trevor T. and Jerry Cha-Jan Chang, "Ethicial Decision Making in Software Piracy: Initial Development and Test of a Four-Component Model," *MIS Quarterly*, 30, 1, (2006), 167-180.

Muthoo, Abhinay, *Bargaining Theory with Applications*, Cambridge University Press, 1999.

Nandedkar, Ankur and Vishal Midha, "Optimism in Music Piracy: A Pilot Study," *Proceedings of the International Conference on Information Systems (ICIS)*, Phoenix, Arizona, 2009, Nascimento, Fernando and Wilfried R. Vanhonacker, "Optimal Strategic Pricing Of Reproducible Consumer Products," *Management Science*, 34, 8, (1988), 921-937.

Null, Christopher, "Fake, infected media file attacks half a million victims in a week," Yahoo! Tech, 2008.

O'Rourke, Morgan, "Setbacks in the music piracy war," Risk Management, 2004.

Peace, A Graham, Dennis F Gallettaand James Y L Thong, "Software piracy in the workplace: A model and empirical test," *Journal of Management Information Systems*, 20, 1, (2003), 153-177.

Peter, J. Paul and Michael J. Ryan, "An Investigation of Perceived Risk at the Brand Level," *Journal of Marketing Research*, 13, 2, (1976), 184-188.

Premkumar, G. Prem, "Alternate Distribution Strategies for Digital Music," *Communications of the ACM*, 46, 9, (2003), 89-95.

Premkumar, G., K. Ramamurthyand Sree Nilakanta, "Implementation of electronic data interchange: an innovation diffusion perspective," *Journal of Management Information Systems*, 11, 2, (1994), 157-186.

Qureshi, Israr and Deborah Compeau, "Assessing Between-Group Differences in Information Systems Research: A Comparison of Covariance- And Component-Based SEM," *MIS Quarterly*, 33, 1, (2009), 197-214.

RIAA, "Key Statistics," Recording Industry Association of America, 2008.

Ringle, Christian Marc, Sven Wendeand Alexander Will, "SmartPLS," Hamburg, Germany, (2005),
Roselius, Ted, "Rankings of Risk Reduction Methods," *The Journal of Marketing*, 35, 1, (1971), 56-61.

Shapiro, Carl and Hal R. Varian, *Information Rules*, Harvard Business School Press, Boston, Massachusetts, 1999.

Shin, Seungwon, Jaeyeon Jungand Hari Balakrishnan, "Malware prevalence in the KaZaA file-sharing network," *Proceedings of the 6th ACM SIGCOMM conference on Internet measurement* Rio de Janeriro, Brazil, 2006, 333-338.

Shultz, Clifford J. and Bill Saporito, "Protecting intellectual property: Strategies and recommendations to deter counterfeiting and brand piracy in global markets," *The Columbia Journal of World Business*, 31, 1, (1996), 18-27.

Siegfried, Robert M, "Student Attitudes on Software Piracy and Related Issues of Computer Ethics," *Ethics and Information Technology*, 6, 4, (2004), 215-222.

Sims, Ronald R., Hsing K. Chengand Hildy Teegen, "Toward a Profile of Student Software Piraters," *Journal of Business Ethics*, 15, 8, (1996), 839-849.

Sinha, Rajiv K. and Naomi Mandel, "Preventing Digital Music Piracy: The Carrot or the Stick?," *Journal of Marketing*, 72, 1, (2008), 1-15.

Spence, Homer E., James F. Engeland Roger D. Blackwell, "Perceived Risk in Mail-Order and Retail Store Buying," *Journal of Marketing Research*, 7, 3, (1970), 364-369.

Srbljinovic, Armano and Ognjen Skunca, "An Introduction to Agent Based Modelling and Simulation of Social Processes," *Interdisciplinary Description of Complex Systems*, 1, 1-2, (2003), 1-8.

Stafford, Thomas F. and Andrew Urbaczewski, "Spyware: The Ghost in the Machine," *Communications of the Association for Information Systems*, 14, (2004), 291-306.

Stone, Brad, "Want to Copy iTunes Music? Go Ahead, Apple Says," *New York Times*, January 7, 2009.

Stone, Robert N. and Kjell Gronhaug, "Perceived Risk: Further Considerations for the Marketing Discipline," *European Journal of Marketing*, 27, 3, (1993), 39-50.

Sundararjan, A., "Managing Digital Piracy: Pricing and Protection," *Information Systems Research*, 15, 3, (2004), 287-308.

Tabachnick, Barbara G. and Linda S. Fidell, *Using Multivariate Statistics*, Allyn & Bacon, Boston, 2007.

Takeyama, L., "The welfare implications of unauthorized reproduction of intellectural property in the presence of network externalities.," *Journal of Industrial Economics*, 62, 2, (1994), 155-166.

Tan, Benjamin, "Understanding consumer ethical decision making with respect to purchase of pirated software," *Journal of Consumer Marketing*, 19, 2, (2002), 96-111.

Tan, Jennifer, "Firm Says 2003 Viruses Caused $55B Damage," *Washington Post*, January 16, 2004.

Thong, James Y. L. and Chee-sing Yap, "Testing an Ethical Decision-Making Theory: The Case of Softlifting," *Journal of Management Information Systems*, 15, 1, (1998), 213-237.

Tsay, Andy A. and Narendra Agrawal, "Channel Conflict and Coordination in the E-Commerce Age," *Production and Operations Management*, 13, 1, (2004), 93-110.

Twomey, Paul and Richard Cadman, "Agent-based modelling of customer behaviour in the telecoms and media markets," *Info - The journal of policy, regulation and strategy for telecommunications*, 4, 1, (2002), 56-63.

Veloutsou, Cleopatra and Xuemei Bian, "A cross-national examination of consumer perceived risk in the context of non-deceptive counterfeit brands," *Journal of Consumer Behaviour*, 7, 1, (2008), 3-20.

Wade, Jared, "The Music Industry's War on Piracy," Risk Management, 2004.

Wetzels, Martin, Gaby Odekerken-Schröderand Claudia van Oppen, "Using PLS path modelling for assessing hierarchical construct models: guidelines and empirical illustration," *MIS Quarterly*, 33, 1, (2009), 177-195.

Wolfe, Scott E., George E. Higginsand Catherine D. Marcum, "Deterrence and Digital Piracy: A Preliminary Examination of the Role of Viruses," *Social Science Computer Reviews*, 26, 3, (2008), 317-333.

Xu, Heng, Hao Wangand Hock-Hai Teo, "Predicting the Usage of P2P Sharing Software: The Role of Trust and Perceived Risk," *Proceedings of the 38th Annual Hawaii International Conference on System Sciences*, 2005, 201a.

APPENDIX A: PROOFS

Proof of Proposition 1: Consumer i 's net gain from purchasing μ songs is

$$g_i = \begin{cases} y_i \mu^{\kappa} - \mu p, & \text{if} \mu < \mu_0 \\ y_i \mu_0^{\kappa} - \mu_0 p, & \text{if} \mu \geq \mu_0 \end{cases}$$

For $\mu < \mu_0$, $\frac{d^2 g_i}{d\mu^2} = (\kappa - 1)\kappa\mu^{\kappa-2} y_i \leq 0$. Therefore, the optimal quantity of songs to purchase is given by the solution to the first order condition which gives

$$\mu_i^* = \left(\frac{\kappa y_i}{p}\right)^{\frac{1}{1-\kappa}}$$

Proof of Proposition 2: Centralized chain

1. No Piracy

Substituting the first part of μ^* into Π_{CC}^N and taking the first derivative gives:

$$\frac{d\Pi_{CC}^N}{dp} = -\frac{M\lambda^2 (p - 2c_t)}{16 p^3}$$

The necessary condition for optimality $\frac{d\Pi_{CC}^N}{dp} = 0$ gives $p_1 = 2c_t$. The second derivative of Π_{CC}^N w.r.t p is

$$\frac{d^2\Pi_{CC}^N}{dp^2} = \frac{M\lambda^2 (p - 3c_t)}{8 p^4}$$

1) For $p \leq 3c_t$, $\frac{d^2\Pi_{CC}^N}{dp^2} \leq 0$ and Π_{CC}^N is concave and therefore $p_1 = 2c_t$ is a local maximum on $0 \leq p \leq 3c_t$.

2) For $p > 3c_t$, $\frac{d^2\Pi_{CC}^N}{dp^2} > 0$ and $\frac{d\Pi_{CC}^N}{dp} < 0$, thus Π_{CC}^N is convex decreasing.

From 1) and 2), $p_1 = 2c_t$ is the unconstrained optimal if $\mu_{p_1} \le \mu_0$. If $\mu_{p_1} > \mu_0$, then the largest value of p which result in a consumer purchase quantity of μ_0 is optimal. This value is obtained by setting μ in the equation (2) to μ_0 which yield $p = \frac{\alpha_1 + \beta_1}{2} \kappa \mu_0^{\kappa-1}$.

2. Linear piracy cost

Substituting the first part of μ^* and $\overline{G}^L$ into Π_{CC}^L and taking the first derivative gives:

$$\frac{d\Pi_{CC}^L}{dp} = -\frac{M\lambda^2(c_t(p-2\beta_2)+p\beta_2)}{16p^3\lambda}$$

The necessary condition for optimality $\frac{d\Pi_{CC}^L}{dp} = 0$ gives $p_1 = \frac{2c_t\beta_2}{c_t + \beta_2}$. The second derivative of Π_{CC}^L w.r.t p is

$$\frac{d^2\Pi_{CC}^L}{dp^2} = \frac{M\lambda^2(c_t(p-3\beta_2)+p\beta_2)}{8p^4\lambda}$$

1) For $p \le \frac{3c_t\beta_2}{c_t + \beta_2}$, $\frac{d^2\Pi_{CC}^L}{dp^2} \le 0$ and Π_{CC}^L is concave and therefore $p_1 = \frac{2c_t\beta_2}{c_t + \beta_2}$ is a local maximum on $0 \le p \le \frac{3c_t\beta_2}{c_t + \beta_2}$.

2) For $p > \frac{3c_t\beta_2}{c_t + \beta_2}$, $\frac{d^2\Pi_{CC}^L}{dp^2} > 0$ and $\frac{d\Pi_{CC}^L}{dp} < 0$, thus Π_{CC}^L is convex decreasing.

From 1) and 2), $p_1 = \frac{2c_t\beta_2}{c_t + \beta_2}$ is the unconstrained optimal if $\mu_{p_1} \le \mu_0$. If $\mu_{p_1} > \mu_0$, then the largest value of p which result in a consumer purchase quantity of μ_0 is optimal. This value is obtained by setting μ in the equation (2) to μ_0 which yield $p = \frac{\alpha_1 + \beta_1}{2} \kappa \mu_0^{\kappa-1}$.

3. Fixed piracy cost

Substituting the first part of μ^* and $\overline{G}^F$ into Π_{CC}^F and taking the first derivative gives:

$$\frac{d\Pi_{CC}^F}{dp} = \frac{M\lambda^2}{256p^4(\alpha_2-\beta_2)}(c_t(3\lambda^2 - 32p\beta_2 - 2(\alpha_1+\beta_1)(3\lambda - 8p\sqrt{\mu_0}))$$

$$+2p(-\lambda^2 + 8p\beta_2 + 2(\alpha_1+\beta_1)(\lambda - 2p\sqrt{\mu_0})))$$

The necessary condition for optimality $\frac{d\Pi_{CC}^F}{dp} = 0$ gives two roots

$p_1 = \frac{\lambda^2 - 2\psi\lambda + 8\eta c_t - \zeta_t}{8\eta}$ and $p_2 = \frac{\lambda^2 - 2\psi\lambda + 8\eta c_t + \zeta_t}{8\eta}$, let $\eta = 2\beta_2 - (\alpha_1+\beta_1)\sqrt{\mu_0}$.

1) When $\eta > 0$, $p_2 > p_1$.

$\frac{M\lambda^2}{256(\alpha_2-\beta_2)}$ is negative, the second part of the first derivative can be written as

$8\eta p^{-2} + (-2\lambda^2 + 4(\alpha_1+\beta_1)\lambda - 32c_t\beta_2 + 16c_t(\alpha_1+\beta_1)\sqrt{\mu_0})p^{-3} + (3\lambda^2 c_t - 6\lambda c_t(\alpha_1+\beta_1))p^{-4}$. Since

$\eta > 0$, $\frac{d\Pi_{CC}^F}{dp}$ increases and approaches zero as p goes to positive infinity. This implies

that Π_{CC}^F decreases on $(-\infty, p_1)$, increases on (p_1, p_2), and decreases on $(p_2, +\infty)$.

Therefore, p_2 is the global optimal.

2) When $\eta < 0$, $p_1 > p_2$.

$\frac{M\lambda^2}{256(\alpha_2-\beta_2)}$ is negative, the second part of the first derivative can be written as

$8\eta p^{-2} + (-2\lambda^2 + 4(\alpha_1+\beta_1)\lambda - 32c_t\beta_2 + 16c_t(\alpha_1+\beta_1)\sqrt{\mu_0})p^{-3} + (3\lambda^2 c_t - 6\lambda c_t(\alpha_1+\beta_1))p^{-4}$. Since

$\eta < 0$, $\frac{d\Pi_{CC}^F}{dp}$ decreases and approaches zero as p goes to positive infinity. This

implies that Π_{CC}^F increases on $(-\infty, p_2)$, decreases on (p_2, p_1), and increases on $(p_1, +\infty)$.

According to Equation (5), there is an upper limit of p, $\bar{p}$, in order to make the purchase probability non-negative, and $\Pi_{CC}^{F}(\bar{p})=0$. Therefore, p_2 is the global optimal.

Proof of Proposition 3: Per song contract

1. No piracy

Substituting the first part of μ^* into $\Pi_{PS,RE}^{N}$ and taking the first derivative gives:

$$\frac{d\Pi_{PS,RE}^{N}}{dp}=-\frac{M\lambda^2(p-2w-2c_r)}{16p^3}$$

The necessary condition for optimality $\frac{d\Pi_{PS,RE}^{N}}{dp}=0$ gives $p_1=2(w+c_r)$. The second derivative of $\Pi_{PS,RE}^{N}$ w.r.t p is

$$\frac{d^2\Pi_{PS,RE}^{N}}{dp^2}=\frac{M\lambda^2(p-3w-3c_r)}{8p^4}$$

1) For $p\le 3(w+c_r)$, $\frac{d^2\Pi_{PS,RE}^{N}}{dp^2}\le 0$ and $\Pi_{PS,RE}^{N}$ is concave and therefore $p_1=2(w+c_r)$ is a local maximum on $0\le p\le 3(w+c_r)$.

2) For $p>3(w+c_r)$, $\frac{d^2\Pi_{PS,RE}^{N}}{dp^2}>0$ and $\frac{d\Pi_{PS,RE}^{N}}{dp}<0$, thus $\Pi_{PS,RE}^{N}$ is convex decreasing.

From 1) and 2), $p_1=2(w+c_r)$ is the unconstrained optimal. If $\mu_{p_1}>\mu_0$, then the largest value of p which result in a consumer purchase quantity of μ_0 is optimal. This value is obtained by setting μ in the equation (2) to μ_0 which yield $p=\frac{\alpha_1+\beta_1}{2}\kappa\mu_0^{\kappa-1}$.

Substituting the first part of μ^* and p^* into $\Pi_{PS,RL}^{N}$ and taking the first derivative w.r.t w gives (assuming that $\mu\le\mu_0$):

$$\frac{d\Pi_{PS,RL}^{N}}{dw} = \frac{M\lambda^2(-w+2c_l+c_r)}{64(w+c_r)^3}$$

The necessary condition for optimality $\frac{d\Pi_{PS,RL}^{N}}{dw} = 0$ gives $w_1 = 2c_l + c_r$. The second derivative of $\Pi_{PS,RL}^{N}$ w.r.t w is

$$\frac{d^2\Pi_{PS,RL}^{N}}{dw^2} = \frac{M\lambda^2(w-3c_l-2c_r)}{32(w+c_r)^4}$$

1) For $w \le 3c_l + 2c_r$, $\frac{d^2\Pi_{PS,RL}^{N}}{dw^2} \le 0$ and $\Pi_{PS,RL}^{N}$ is concave and therefore $w_1 = 2c_l + c_r$ is a local maximum on $0 \le w \le 3c_l + 2c_r$.

2) For $w > 3c_l + 2c_r$, $\frac{d^2\Pi_{PS,RL}^{N}}{dw^2} > 0$ and $\frac{d\Pi_{PS,RL}^{N}}{dw} < 0$, thus $\Pi_{PS,RL}^{N}$ is convex decreasing.

From 1) and 2), $w_1 = 2c_l + c_r$ is the unconstrained optimal.

2. Linear piracy cost

Substituting the first part of μ^* and $\overline{G}^L$ into $\Pi_{PS,RE}^{L}$ and taking the first derivative gives:

$$\frac{d\Pi_{PS,RE}^{L}}{dp} = \frac{M\lambda^2(pw+c_r(p-2\beta_2)+(p-2w)\beta_2)}{16p^3\gamma}$$

The necessary condition for optimality $\frac{d\Pi_{PS,RE}^{L}}{dp} = 0$ gives $p_1 = \frac{2\beta_2(w+c_r)}{w+c_r+\beta_2}$. The second derivative of $\Pi_{PS,RE}^{L}$ w.r.t p is

$$\frac{d^2\Pi_{PS,RE}^{L}}{dp^2} = \frac{M\lambda^2(pw+c_r(p-3\beta_2)+(p-3w)\beta_2)}{8p^4\gamma}$$

1) For $p \le \frac{3\beta_2(w+c_r)}{w+c_r+\beta_2}$, $\frac{d^2\Pi^L_{PS,RE}}{dp^2} \le 0$ and $\Pi^L_{PS,RE}$ is concave and therefore $p_1 = \frac{2\beta_2(w+c_r)}{w+c_r+\beta_2}$ is a local maximum on $0 \le p \le \frac{3\beta_2(w+c_r)}{w+c_r+\beta_2}$.

2) For $p > \frac{3\beta_2(w+c_r)}{w+c_r+\beta_2}$, $\frac{d^2\Pi^L_{PS,RE}}{dp^2} > 0$ and $\frac{d\Pi^L_{PS,RE}}{dp} < 0$, thus $\Pi^L_{PS,RE}$ is convex decreasing.

From 1) and 2), $p_1 = \frac{3\beta_2(w+c_r)}{w+c_r+\beta_2}$ is the unconstrained optimal. If $\mu_{p_1} > \mu_0$, then the largest value of p which result in a consumer purchase quantity of μ_0 is optimal. This value is obtained by setting μ in the equation (2) to μ_0 which yield $p = \frac{\alpha_1+\beta_1}{2}\kappa\mu_0^{\kappa-1}$.

Substituting the first part of μ^*, $\overline{G}^L$, and p^* into $\Pi^L_{PS,RL}$ and taking the first derivative gives assuming that $\mu \le \mu_0$):

$$\frac{d\Pi^L_{PS,RL}}{dw} = \frac{M\lambda^2(w^3+3wc_r^2+c_r^3+(w-2c_l)\beta_2^2+c_r(3w^2-\beta_2^2))}{64(w+c_r)^3\gamma\beta_2}$$

The necessary condition for optimality $\frac{d\Pi^L_{PS,RL}}{dw} = 0$ gives $w_1 = \frac{\beta_2^2}{\varphi} - \frac{\varphi}{3} - c_r$. The second derivative of $\Pi^L_{PS,RL}$ w.r.t w is

$$\frac{d^2\Pi^L_{PS,RL}}{dw^2} = \frac{M\lambda^2(w-3c_l-2c_r)\beta_2}{32(w+c_r)^4\gamma}$$

1) For $w \le 3c_l + 2c_r$, $\frac{d^2\Pi^L_{PS,RE}}{dp^2} \le 0$ and $\Pi^L_{PS,RL}$ is concave. Also, $w_1 < 3c_l + 2c_r$. Therefore w_1 is a local maximum on $0 \le w \le 3c_l + 2c_r$.

2) For $w > 3c_l + 2c_r$, $\frac{d^2\Pi^L_{PS,RL}}{dw^2} > 0$ and $\frac{d\Pi^L_{PS,RL}}{dw} < 0$, thus $\Pi^L_{PS,RL}$ is convex decreasing.

From 1) and 2), w_1 is the unconstrained optimal.

3. Fixed piracy cost

Substituting the first part of μ^* and $\overline{G}^F$ into $\Pi^F_{PS,RE}$ and taking the first derivative gives:

$$\frac{d\Pi^F_{PS,RE}}{dp} = \frac{M\lambda^2}{256p^4(\alpha_2-\beta_2)}(8\eta p^2 - 2(8w\eta + \lambda(\lambda - 2\psi))p + 3w\lambda(\lambda - 2\psi) + (3\lambda(\lambda - 2\psi) - 16\eta)c_r)$$

The necessary condition for optimality $\frac{d\Pi^F_{PS,RE}}{dp} = 0$ gives two roots

$$p_1 = \frac{\lambda^2 - 2\psi\lambda + 8\eta\rho - \frac{1}{2}\sqrt{4(\lambda^2 - 2\lambda\psi + 8\eta\rho)^2 - 96\eta\lambda\rho(\lambda - 2\psi)}}{8\eta} \text{ and}$$

$$p_2 = \frac{\lambda^2 - 2\psi\lambda + 8\eta\rho + \frac{1}{2}\sqrt{4(\lambda^2 - 2\lambda\psi + 8\eta\rho)^2 - 96\eta\lambda\rho(\lambda - 2\psi)}}{8\eta}, \text{ let } \eta = 2\beta_2 - (\alpha_1 + \beta_1)\sqrt{\mu_0}\,.$$

1) When $\eta > 0$, $p_2 > p_1$.

$\frac{M\lambda^2}{256(\alpha_2 - \beta_2)}$ is negative, the second part of the derivative can be written as

$$8\eta p^{-2} + (-2\lambda^2 + 4\alpha_1\lambda + 4\beta_1\lambda - 32w\beta_2 - 32c_r\beta_2 + 16w(\alpha_1 + \beta_1)\sqrt{\mu_0} + 16c_r(\alpha_1 + \beta_1)\sqrt{\mu_0})p^{-3}$$

$$+ (3w\lambda^2 + 3c_r\lambda^2 - 6w\alpha_1\lambda - 6w\beta_1\lambda - 6c_r(\alpha_1 + \beta_1)\lambda)p^{-4}\,.$$

Since $\eta > 0$, $\frac{d\Pi^F_{PS,RE}}{dp}$ increases and approaches zero as p goes to positive infinity. This implies that $\Pi^F_{PS,RE}$ decreases on $(-\infty, p_1)$, increases on (p_1, p_2), and decreases on $(p_2, +\infty)$. Therefore, p_2 is the global optimal.

2) When $\eta < 0$, $p_1 > p_2$.

$\frac{M\lambda^2}{256(\alpha_2 - \beta_2)}$ is negative, the second part of the derivative can be written as

$$8\eta p^{-2} + (-2\lambda^2 + 4\alpha_1\lambda + 4\beta_1\lambda - 32w\beta_2 - 32c_r\beta_2 + 16w(\alpha_1 + \beta_1)\sqrt{\mu_0} + 16c_r(\alpha_1 + \beta_1)\sqrt{\mu_0})p^{-3}$$

$$+(3w\lambda^2 + 3c_r\lambda^2 - 6w\alpha_1\lambda - 6w\beta_1\lambda - 6c_r(\alpha_1+\beta_1)\lambda)p^{-4}.$$

Since $\eta < 0$, $\frac{d\Pi_{PS,RE}^F}{dp}$ decreases and approaches zero as p goes to positive infinity. This implies that $\Pi_{PS,RE}^F$ increases on $(-\infty, p_2)$, decreases on (p_2, p_1), and increases on $(p_1, +\infty)$. According to Equation (5), there is an upper limit of p, $\bar{p}$, in order to make the purchase probability non-negative, and $\Pi_{PS,RE}^F(\bar{p}) = 0$. Therefore, p_2 is the global optimal. Also, please note that, in the fixed piracy risk cost case, the closed form solution for w can't be obtained.

Proof of Proposition 4: Fixed fee full transfer contract

The optimal solutions under the fixed fee full transfer contract can be derived by following similar arguments in previous proofs.

Proof of Proposition 5: Fixed fee partial transfer contract

The optimal solutions under the fixed fee partial transfer contract can be derived by following similar arguments in previous proofs.

APPENDIX B: NETLOGO CODE FOR THE SIMULATION MODEL

```
globals
[
retail-price
number-of-legal
number-of-educational
constant-legal
constant-educational
value-added-service
]

breed
[ consumers consumer ]

breed
[ record-labels record-label ]

consumers-own
[
  scale-of-utility ; y
  shape-of-utility ; k
  number-of-songs  ; mu = number of songs the consumer is interested in purchasing in
each time period
  song-valuation   ; y * mu ^ k
  piracy-risk  ; risk cost that consumer attaches to piracy (per act basis)
  initial-piracy-risk ; intial risk cost that consumer attaches to piracy
  previous-period-piracy-risk ; risk cost in the previous period
  net-purchase-gain ; song-valuation - mu * price
  net-piracy-gain ; song-valuation - piracy-risk
  decision ; whether pirate or purchase
  prob-legal-awareness ; probability of legal strategy awareness
  prob-educational-awareness ; probability of educational strategy awareness
  legal-awareness-impact ; 10% increase when aware
  legal-not-awareness-impact ; 10% decrease when not aware
  education-awareness-impact ; 5% increase when aware
  ranval
  social-pressure
]

record-labels-own
[
  wholesale-price ; w
  margin ; M
  legal-investment-cost ;cost for each law-suit
```

```
  educational-investment-cost ; cost for each educational campaign
  total-legal-investment
  total-educational-investment
  royalty-rate
  record-label-profit
  retailer-profit
  artist-profit
  retailer-variable-cost
  value-added-service-cost
]

to setup
  clear-all  ;clear the simulation screen
  setup-record-labels
  setup-consumers
end

to setup-record-labels
  create-record-labels 1
    ask record-labels
  [
  set wholesale-price (wholesalesprice)
  set margin (label-margin) ;reduce the margin for the low-price effect
  set retail-price (1 + margin) * wholesale-price ;(1+M) * w
  set number-of-legal (number-of-legal-action)
  set number-of-educational (number-of-education)
  set constant-legal (legal-awareness-effective) ;0.3
  set constant-educational (education-awareness-effective) ;0.3
  set legal-investment-cost 34 ;total market value for 1000 consumer is around 3400
  set educational-investment-cost 34
  set royalty-rate (artist-royalty-rate)
  set retailer-variable-cost 0.2
  set total-legal-investment legal-investment-cost * number-of-legal
  set total-educational-investment educational-investment-cost * number-of-educational
  set value-added-service-cost 0
  ]
end

;set up consumer properties
to setup-consumers
  create-consumers number-of-consumers
  set-default-shape consumers "dot"
  layout-circle consumers 10
  ask consumers
  [
    set color white
```

```
    ;set initial piracy risk for consumers
    set piracy-risk (random-normal risk-mean risk-sd)

    while [piracy-risk <= 0]
    [set piracy-risk (random-normal risk-mean risk-sd)]

    set initial-piracy-risk piracy-risk
    set previous-period-piracy-risk piracy-risk
    set social-pressure 0.5 ;equal weight for social pressure
    set value-added-service (value-added-effect)
    set legal-awareness-impact (legal-aware-impact)
    set legal-not-awareness-impact (legal-not-aware-impact)
    set education-awareness-impact (education-aware-impact)
    set decision -1  ;consumer has not made a decision yet (default value)
                     ;1 means consumer bought
                     ;2 means consumer pirated
                     ;3 means consumer do nothing
  ]
end

;run simulation
to go
  purchase-decision-consumer
  evaluate-record-label-profit
  change-consumer-risk-by-legal-action
  change-consumer-risk-educational-action
  adjust-social-pressure
end

; decide whether consumer purchases or pirates
to purchase-decision-consumer
  ;make purchase/pirate decision
  ask consumers
    [
      ;set initial utility values for consumers for each period
      set scale-of-utility (random-normal scale-mean scale-sd)
      set shape-of-utility (random-float 1 / 3.333333) + 0.5 ; k range between 0.5 and 0.8
      set number-of-songs ceiling (random-normal song-mean song-sd)

      while [scale-of-utility <= 0]
      [ set scale-of-utility (random-normal scale-mean scale-sd) ]

      while [number-of-songs <= 0]
      [ set number-of-songs ceiling (random-normal song-mean song-sd) ]
```

```
    ;caluate net purchase gain and net piracy gain
    set song-valuation scale-of-utility * number-of-songs ^ shape-of-utility
    ;set net-purchase-gain (value-added-service * song-valuation - number-of-songs *
retail-price)
    ;set net-piracy-gain (song-valuation - piracy-risk)
    ;prevent that the social-pressure becomes 0
     ifelse social-pressure > 0.01
      [
       set net-purchase-gain (1 - social-pressure) * (value-added-service * song-
valuation - number-of-songs * retail-price)
       set net-piracy-gain (social-pressure) * (song-valuation - piracy-risk)
      ]
      [
       set net-purchase-gain 0.99 * (song-valuation - number-of-songs * retail-price)
       set net-piracy-gain 0.01 * (song-valuation - piracy-risk)
      ]

    ifelse (net-purchase-gain < 0 and net-piracy-gain < 0)
    [
     set decision 3 ;3 means consumer do nothing
    ]
    [
     ifelse (net-purchase-gain >= net-piracy-gain)
     [
      ;purchase
      set decision 1 ;1 means consumer purchased
     ]
     [
      ;pirate
      set decision 2 ;2 means consumer pirated
     ]
    ]
  ]
end

;calculate record label, retailer, and artist profit
to evaluate-record-label-profit
 ask record-labels
 [
  if value-added-service = 1.05
  [
   set value-added-service-cost 5
  ]
  if value-added-service = 1.10
  [
```

```
     set value-added-service-cost 10
   ]
   if value-added-service = 1.15
   [
     set value-added-service-cost 20
   ]
  ;set margin margin - 0.01 in the case of price-reduction
  set record-label-profit (wholesale-price - (1 + margin) * wholesale-price * royalty-rate)* (sum [number-of-songs] of consumers with [decision = 1]) - total-legal-investment - total-educational-investment - value-added-service-cost
  set retailer-profit (retail-price - retailer-variable-cost) * (sum [number-of-songs] of consumers with [decision = 1])
  set artist-profit retail-price * royalty-rate * (sum [number-of-songs] of consumers with [decision = 1])
  ]
end

;change consumer risk cost by legal action
to change-consumer-risk-by-legal-action
ask consumers
[
  set prob-legal-awareness 1 - (1 / e ^ (number-of-legal-action * constant-legal))
  set ranval random-float 1
    ifelse prob-legal-awareness > ranval ;if aware of legal action
    [
      set piracy-risk  (1 + legal-awareness-impact) * piracy-risk ; increase the risk cost by 10%
    ]
    [
      ;if unaware of legal-strategy,
      ifelse piracy-risk = initial-piracy-risk ; in the case of first period or the piracy risk cost has never been increased
      [
        set piracy-risk piracy-risk
      ]
      [
        ;else means that the risk cost has been increased at least once, thus can reduce the risk cost by 5% while it is greater than intial-risk
        ifelse piracy-risk > initial-piracy-risk
        [
          set piracy-risk (1 - legal-not-awareness-impact) * piracy-risk
        ]
        [
          set piracy-risk initial-piracy-risk ;the risk cost can't go below initial risk cost
        ]
      ]
```

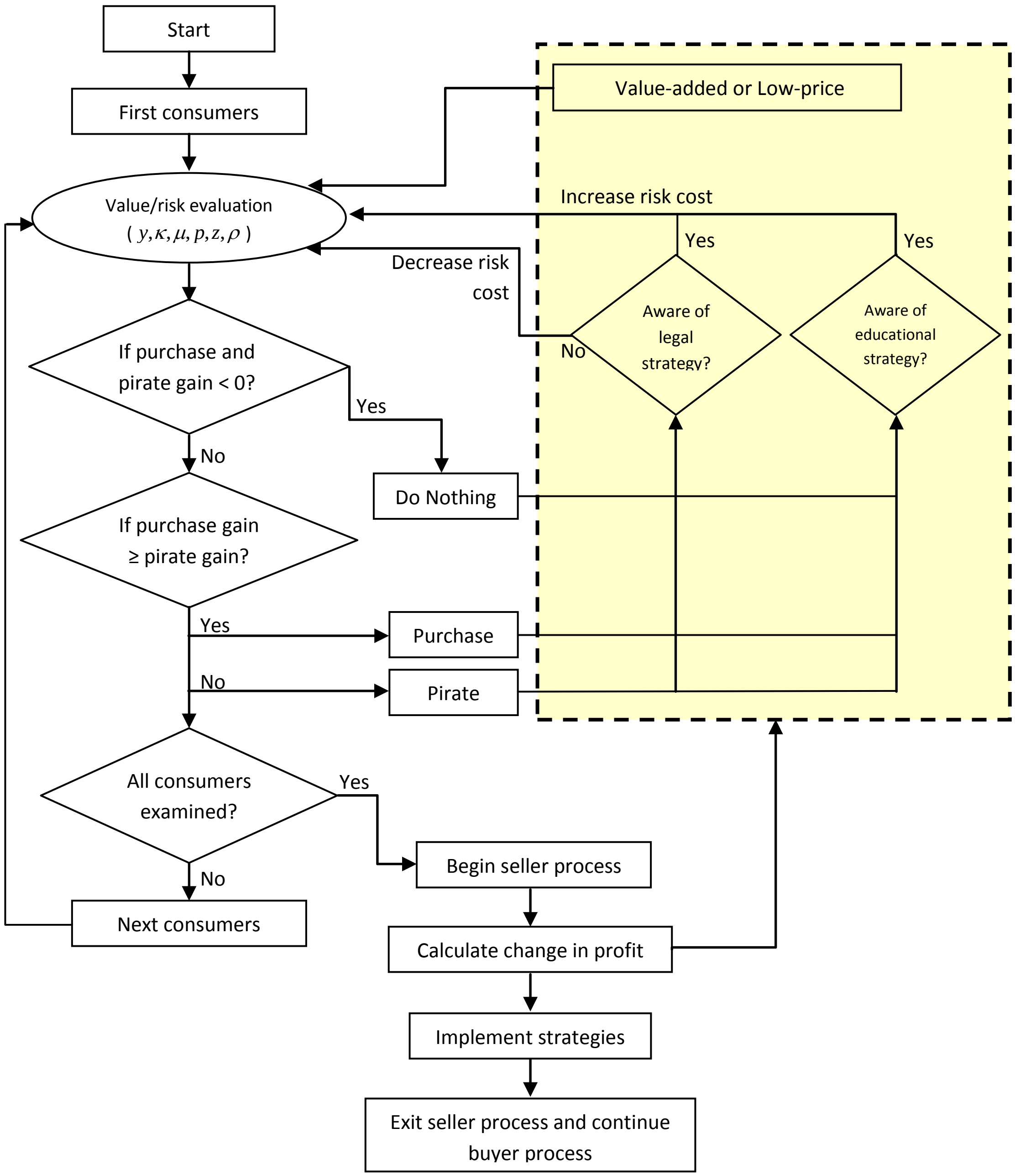
```
  ]
]
end

;change consumer risk cost by educational campaigns
to change-consumer-risk-educational-action
ask consumers
[
 set prob-educational-awareness 1 - (1 / e ^ (number-of-education * constant-educational))
 set ranval random-float 1

  if prob-educational-awareness > ranval ;if aware of legal action
  [
   set piracy-risk (1 + education-awareness-impact) * piracy-risk ; increase the risk cost by 5%
  ]
]
end

to adjust-social-pressure
ask consumers
[
 set social-pressure (count consumers with [decision = 2]) / (count consumers)
]
end
```

APPENDIX C: FLOW DIAGRAM OF THE NETLOGO MODEL



APPENDIX D: SNAPSHOT OF THE NETLOGO MODEL