國立交通大學

管理科學研究所碩士班

碩士畢業論文

數位化時代音樂產業將何去何從?

－以生產力觀點進行全球音樂產業的實證

How Music Industry Be Sustainable in an Era of Digitalization? －An Empirical Study in the Aspect of Productivity for Global Music Firms

研 究 生：洪子鈞

指導教授：蔡璧徽 博士

中 華 民 國 九 十 六 年 一 月

數位化時代音樂產業何去何從?
一以生產力觀點進行全球音樂產業的實證

How Music Industry Be Sustainable in an Era of Digitalization? －An Empirical Study in the Aspect of Productivity for Global Music Firms

研 究 生：洪子鈞　　Student：Z-Jim Hung

指導教授：蔡璧徽　　Advisor：Bi-Hui Tsai

國 立 交 通 大 學

管 理 科 學 系 碩 士 班

碩 士 論 文

A Thesis
Submitted to Department of Management Science
College of Management
National Chiao Tung University
in partial Fulfillment of the Requirements
for the Degree of
Master
in
Management Science

January 2007

Hsinchu, Taiwan, Republic of China

中 華 民 國 九 十 六 年 一 月

ABSTRACT

This article adopts a point of view in productivity to investigate the impacts which are made by the new digital technologies, lawsuit strategies and the business model innovation on the performance of the global music industry, and makes a comparison between the effectiveness of different strategies which intrinsic music firms play during the environmental change. This thesis also tries to identify the key productivity affecting factors, and clarify the process that how these strategic events affect the music industry by the externalities. Thus 51 music related companies are chosen for representing the reactions of global music industry from 1997 to 2005; the Napster's P2P file-sharing system, lawsuits against Napster, and the Apple's iPod plus iTunes business model are concerned as the performance impact factors respectively in our research.

Färe et al. (1992) first introduced the DEA-based Malmquist productivity index to measure the productivity change over time. In this research, therefore, researcher applies the DEA methodology and Malmquist indices to calculate the productivity change of each music firm year by year. In order to reflect the influence of digital music and online content selling, the effects of network externalities and music piracy rate are concerned in our DEA models. Following Tobit regression model is employed to identify the key productivity affecting factors, and clarify the process that how these strategic events affect the music industry by the externalities. The researcher supposes that these events will not only pose influences directly on the performance of music industry, but also via the network externalities chang in an indirect way. In the last part of this article, influences of each event period, including the appearance of Napster's P2P file-sharing system, RIAA filing lawsuits against the Napster for the copyright violation, and the opening of Apple's iTunes Online Music Store, are tested by Tobit models. All of these events, except the appearance of MP3 and P2P software, are positive effects upon the productivity in our hypotheses. Furthermore in our hypothesis, strategy of creating a new business model is expected more powerful than filing a lawsuit against piracy, and the Mann-Whitney rank test is employed for testing.

Results show that music piracy rate is an important external factor for deteriorating the productivity of music industry, and the development of digital music technologies, MP3 and P2P, significantly reduce the productivity by increasing the piracy rate. Henceforth fighting against music piracy and creating a legal digital music transaction platform are becoming critical solutions for reversing the recession of music industry in productivity. On the contrary, filing a lawsuit against music piracy is confirmed an effective solution for reducing the music piracy rate and therefore improving the productivity significantly. Apple's iTunes Online Music Store may bring about a redistribution of interests within music industry, threatening some intrinsic firms, and changing the composition of music industry, so the effectiveness of this business model fall short of our expectation. However since the external environment of music industry is change, creating a right business model is more reasonable for consumers than just filing lawsuits against piracy; therefore managers should still endeavor to create their own blue ocean by finding out a reasonable new music trading model in the era of digitalization.

Keywords: Music Industry; Music Piracy; Productivity; Data Envelopment Analysis; Network Externalities

中文摘要

本研究探討過去十年間音樂數位化過程所造成的產業環境改變，對於全球音樂產業經營績效的影響，並比較廠商實行各種不同競爭策略的執行成效。Färe 等人(1992)以 Cave 等人(1982)提出 Malmquist 生產力指數概念，建立衡量跨時期效率之 DEA 模式。本研究以此基礎進一步將網路經濟下的外部性(Externality)因素影響加入模型考量，利用傳統 CCR 模型加入外生變數(indiscretionary variable)投入項，建構出修正過的 Malmquist 生產函數，並針對 1997 年至 2005 年間的音樂產業資料進行生產力變動分析，觀察並驗證各種競爭策略的執行對於音樂產業生產力變動的影響。

不同於以往短期事件日分析，本研究採用生產力變動觀點，檢驗音樂數位化過程對於全球音樂產業經營績效的長期影響。並透過資料包絡分析法(Data Envelopment Analysis)，以效率前緣的線性最佳生產效率邊界概念，對於音樂產業的效率進行探討。此外研究模型亦考量網路經濟下的外部性(Externality)因素影響(外部性因素包括：網路規模的成長、音樂盜版率的改善等外生環境變數)。利用傳統 CCR 模型加入外生變數(indiscretionary variable)投入項，建構出修正過的 Malmquist 生產函數，對於 1997 年至 2005 年間的音樂產業資料進行生產力變動分析，觀察並驗證各種競爭策略的執行對於音樂產業生產力變動的影響。最後本研究利用 Tobit 迴歸模式以及無母數 Mann-Whitney 檢定，來釐清影響音樂產業生產力變動的因素，並且對於影響音樂產業績效的外部性因素進行探討，以暸解音樂廠商執行競爭策略時，對於其營運績效的影響過程，並將各項研究結果彙整成一個有系統的過程論。

音樂廠商競爭策略包含：數位音樂科技的進步、廠商的法律訴訟策略以及創造新的商業販售模式等三個構面；此三個競爭策略構面，可更進一步分解成多個改變音樂產業結構的事件加以分析，包括：MP3 音樂壓縮技術的發明、Napster 推出點對點線上音樂分享系統、美國唱片產業協會(RIAA)對於 Napster 提出的侵權訴訟、蘋果電腦發展的 iTunes 合法線上音樂販售模式。事件日的選擇參考 CNN、BBC 等國際頗具權威的新聞中心資料；廠商選擇則是根據美國 Standard & Poor 推出的 Compustat 資料庫中的產業編碼，以及參考過往文獻的取樣標準，篩選出 51 家音樂產業公司進行研究。研究樣本公司歷史資料來源則是根據 Compustat 資料庫中所蒐集到的基本投入產出變數，投入項包括員工人數(以反映勞動投入)、固定資產(以反映資本的投入項)；產出項則以公司該年的銷貨收入作為代表；而外生變物資料主要根據國際通訊聯盟(International Telecommunication Union)所公佈的網路普及率資料，以及國際智慧財產權協會(International Intellectual Property Alliance)所公佈的各國的盜版率指標為變數參考依據。

本研究證實盜版問題確實是影響近年音樂產業績效表現的重要因素。盜版率會透過外部性對音樂產業的生產力產生直接影響。因此 MP3 與 P2P 軟體等數位音樂技術的發展是把雙面刃，一方面能促進音樂的傳播，然而在不成熟的智慧財產權保護機制下，同時是造成盜版問題日益嚴重的幫兇，進而透過效率前緣削弱音樂產業的生產力表現，對音樂產業造成重大衝擊。法律訴訟是短期內遏阻非法並增加既有廠商生產力的有效手段。然而長遠而言，在產業環境已經改變的條件下，仍需盡速尋求合理的利益分享機制。創造新的商業模式或許會因為利益的重新分配，對某些既有的產業造成衝擊，所以效果並不如法律訴訟立竿見影。然而當產業面臨整體環境結構轉變時，新的商業模式卻能藉由改善外部環境(例如降低盜版率，建構新的音樂傳播通路加速音樂的傳播等方式)，為產業帶來轉機。因此本研究建議音樂產業的管理者應盡速建立合法的傳播管道，創造屬於自己的藍海，才能有效的促進音樂產業發展。

關鍵字:

音樂產業; 音樂盜版；生產力評估；資料包絡分析；網路外部性

ACKNOWLEDGMENTS

I would like to thank my advisor, Professor Bi-Hui Tsai for her teaching, supervision, and suggestions throughout the work. She offered valuable insight and was open to discuss anything I had on my mind. I would also like to express my sincere gratitude to Prof. Fuh-Hwa Franklin Liu for his valuable guidance in DEA methods and immeasurable patience which brought this thesis to fruition. Thanks are extended to my reader, Prof. Po-Young Chu for his remarkable insights and suggestions on the earlier draft, as well as for his kind solicitude throughout the program.

The scholarly assistance from all the professors in the Management Science Department and the Industrial Engineering & Management Department is always greatly appreciated.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. Introduction

This article adopts a point of view in productivity to investigate the impacts which are made by the new digital technologies, lawsuit strategies and the business model innovation on the performance of the global music industry, and makes a comparison between the effectiveness of different strategies which intrinsic music firms play during the environmental change. This thesis also tries to identify the key productivity affecting factors, and clarify the process that how these strategic events affect the music industry by the externalities.

Argument of this research holds that music piracy rate is an important external factor for deteriorating the productivity of music industry, and the development of digital music technologies, MP3 and P2P, significantly reduce the productivity by increasing the piracy rate. Henceforth fighting against music piracy and creating a legal digital music transaction platform are becoming critical solutions for reversing the recession of music industry in productivity. On the contrary, filing a lawsuit against music piracy is confirmed an effective solution for reducing the music piracy rate and therefore improving the productivity significantly. In addition although creating a new business model, Apple's iTunes Online Music Store for example, may bring about a redistribution of interests within music industry, threatening some intrinsic firms, and changing the composition of music industry, it reforms music piracy problem as well. In the long run, especially in the circumstance of external environment is change, creating a new business model is more effective and reasonable for consumers than just filing lawsuits against piracy; therefore managers should endeavor to create their own blue ocean by finding out a reasonable new music trading model in the era of digitalization.

1.1 Purpose of this research

Based on the dramatic changes in the music industry, the purpose of this research is to investigate the impacts which are made by the new digital technology, such as the MP3 and P2P file-sharing systems, Lawsuit strategy, the RIAA sue the Napster for copyright violation, and the business model innovation, the Apple's Online Music Store, on the productivity of the global music industry. According to our researche, furthermore, this thesis makes a comparison between the effectiveness of different strategies which intrinsic firms may play when the environment is changed, and try to clarify the essential difference of anti-piracy strategies.

Considerable amount of researches and articles had discussed the negative and positive impact of technology change and business model innovation, such as MP3 downloading, P2P file-sharing, and the online music stores, on the performance of intrinsic firms in music industry. Navissi, Naiker, and Upson (2005), for example, used Napster as a proxy for diffuse piracy through the Internet and examine the effects of 11 prominent Napster-related events on the equity value of firms in the US music industry. Finally, the results of their research suggested that Napster's service created wealth in the music industry. Another survey based on the aspect of consumer behavior and culture comparison to explain the music piracy, and tried to find out the best strategy of anti-piracy. Condry (2004) compared the music file-sharing behavior between the US and Japan, and found that a focus on fan participation in media success provides an alternative perspective on how to encourage flourishing music cultures. Asvanund, Clay, Krishnan, and Smith (2004) also claimed that solely shutting down individual file-sharing networks does little to change user behavior according to their discovery of the increasing free-riding behavior on P2P networks. Moreover, the real opportunity is to create blue oceans of uncontested market space, Kim and Mauborgne (2004) proposed this argument in their article published on the Harvard Business Review in October 2004. These previous studies have dropped us a hint that creating an effective business model may do much more advantages for music industry than just filing a lawsuit against piracy, hence. Nevertheless, the previous studies were lacking empirical evidences to prove this viewpoint. Consequently, our research makes some comparisons on the productivity change of the global music firms between these two strategies, filing a lawsuit on Napster and innovate an iTunes Online Music Store business model, and try to illustrate the results further. On the other hand, the network externality has been proofed of significant effects on the E-business and P2P file sharing network in the previous literatures. For example, the study Asvanund et al. (2004) suggested that the optimal size of the P2P network is bounded in their studies. While the network externality, or network size, will change the utilities of users and provides value to them (Strahilevitz, 2002; Saloner and Spence, 2002), it is considered an important attribute of the online music selling in our research.

Our research, first, examines the efficiency change of individual firms, when the new digital music technologies, lawsuit against Napster, and the new business model of iTunes were launched, with DEA models and Malmquist indices. These approaches can not only measure the performance of a firm, but also reflect a long-term aspect that could never be discovered before by the traditional financial measurements. Accordingly, this study adopts such measurements of efficiency, other than traditional financial performance indexes, to demonstrate our assumptions, and the results of our study can be enriched. Furthermore, in order to extract the influence of the era of online content selling, effects of network externality and music piracy rate are concerned in our models. Since different strategic events, such as introducing a P2P file-sharing network, filing a legal action and launching a new business model, will impact the scale of the network, and piracy rate as well; and further, the performance of the music industry will be affected through these externalities change. Therefore, our research examines the efficiency change of individual firms and considers the externalities as external variables in our Data Envelopment Analysis model.

Hence this study examines the productivity variation of 51 global music firms with DEA Malmquist methods, and tests the expected productivity effects of three milestones of digital music evolution, development of MP3 and P2P technologies, RIAA filing lawsuits against Napster for copyright infringement, and the opening of Apple's iTunes Online Music Store, on these music firms by Tobit models. All of these events, except the appearance of MP3 and P2P software, are positive effects upon the productivity in our hypotheses. Researcher also applies a nonparametric approach to confirm the hypothesis that the business model innovation will improve the performance of music companies more than filing litigations. Meanwhile, this thesis tries to clarify the process that these events affect the industry through performance improvement and the externalities, such as network scales and piracy rate change. The researcher supposes that these events will not only pose influences directly on the performance of music industry, but also via externalities change in an indirect way, referring to Figure 1, and employs regression analyses to verify this assumption.

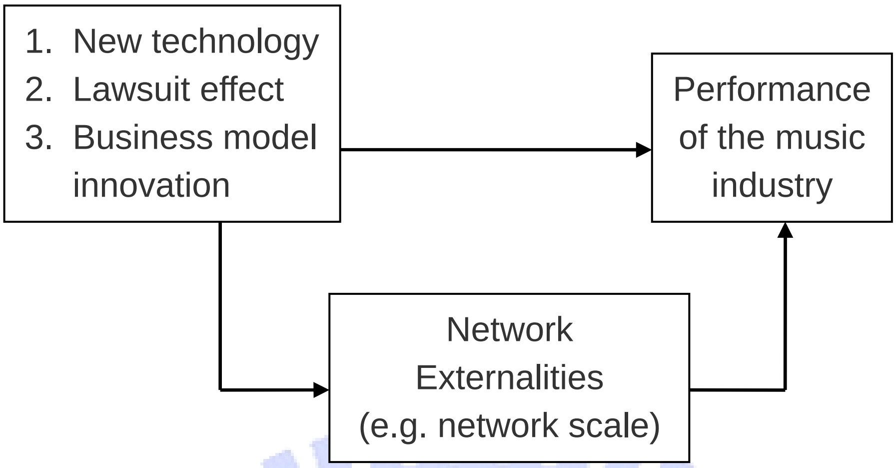


Figure 1 The influences of new technology, lawsuit strategy and business model innovation on the performance of music industry

1.2 Background of the music industry

The music industry was one of the fastest growing sectors of the global service economy in the twentieth century (UNCTAD, 1999), and it is a classical copyright industry based on creative talent and highly specialized assets. When the technological breakthroughs in recording meant that reproduction rather than live performance became the basis of the industry.

In the late 1950s the industry was still relatively small and dominated by the United States market, where sales had reached $500 million. By 1998 over 4 billion records , including any sound recording in various formats such as tapes, records, CDs, DATs, etc., were sold worldwide and generating a total revenue of nearly $39 billion. A further $5 billion was generated from pirated recordings (Andersen, Kozu, and Kozul-Wright, 2000). Besides, music has been increasingly tied to other entertainment products, such as TV, films and videos, and has become basis of the entertainment industry thus generating further revenue streams (Vogel, 2001).

Since the mid-1960s in addition, and accelerating in the 1980s, music industry has tended to become steadily more concentrated (Alexander, 1994) under the dominance of a small number of very large international firms. As of 2006, this market is dominated by the “Big Four record labels”: Universal Music Group (UMG), Sony BMG Music Entertainment, which was merged by Bertelsmann Music Group (BMG) and Sony Music in 2004, EMI Group, and

Warner Music Group. Currently it is estimated that over 85 per cent of the labels in the United States and approximately 80 per cent of the global market is controlled by four major media giants (RIAA, 2004; Wikipedia, 2006). The consolidation of the music industry is shown in figure 2 (Zhu and MacQuarrie, 2003).

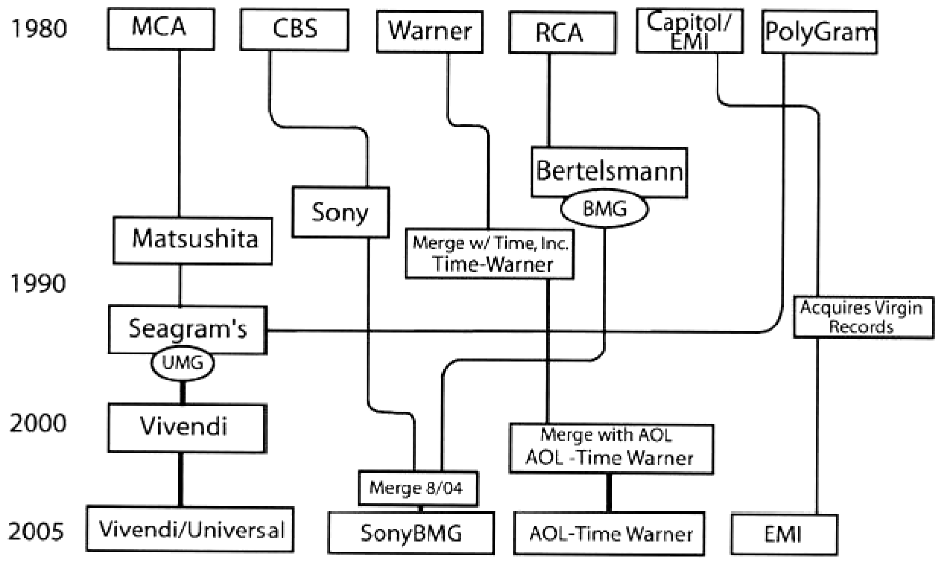


Figure 2 Music industry consolidation in 1980-2005

Nowadays, a music group is consisting of music related companies, and is typically owned by an international conglomerate holding company, which often has non-music divisions as well. A music group controls and consists of music publishing companies, record (sound recording) manufacturers, record distributors, and record labels. Most of these corporations are highly diversified media conglomerates, in which music revenues account for between 12 per cent (Warner Music) and 24 per cent (UMG) of global revenues, and dominate over 80 per cent of the wholesale market by own distribution companies. Only EMI is the major music company that is not part of a conglomerate and remains primarily focused on music (Andersen, Kozul, and Kozul-Wright, 2000).

This phenomenon increases the complexity of sample selection in our research. In our sampling, therefore, 51 companies operating different activities in the music industry, such as music publishing, music retailing, music distribution and music production, is chosen.

1.3 The MP3 and P2P phenomena

The business model of selling the physical music copies, such as discs, tapes, LPs and CDs, has been changed, and the territories which were built by the world media giants have been shaken by several new media storing and data transmitting technologies, MP3s and P2P, in the final decade of the twentieth century.

In 1987, the collaboration between Germany's Fraunhofer Institute and the University of Erlangen resulted in a music compression/ decompression algorithm, Moving Picture Expert Group 1 Audio Layer 3 or MP3, could shrink sound files by 90% without unduly sacrificing quality. In 1992 it was approved as a Motion Picture Experts Group (MPEG) standard and a standard for the compression of audio recordings.

Because music can be copied from CDs and the sizes of the digital music files are significantly reduced with no perceptible loss of quality by the new MP3 technology, transmitting music files via Internet has become much easier than before. Moreover, consumers can play "free" digital music copies on personal computers and special MP3 devices. As a result, the MP3 format has proved significantly more popular than proprietary formats such as Microsoft's Windows Media Audio Player (WMA); and numerous illegal websites, such as MP3.com/music, download.com , listen.com., has been inspired to distribute unauthorized music. In the ongoing years, consumers accessed to a new generation of faster personal computers, modems and Internet connecting speed, it stimulated the larger-scale download of MP3 files. In the August edition of Wired magazine, in addition, Vito Peraino reported that about 846 million new CDs were sold in 1998, but at least 17 million MP3 files are downloaded from the net each day and adds up to almost 3 billion in the first six months of 1999 (Vito Peraino ,1999).

In June 1999, Napster released its controversial peer-to-peer music file sharing software, with which users can share MP3 music files in their own computers directly with other users, to the public. Peer-to-Peer (P2P) technology is a completely new file transmitting methodology which is different from the Client/Server before. The server computers no longer store any content data, such as video files, but the profiles, name of file, size and connecting speed for example, of every end user, which called peers. With this brand-new technology the cyberspace itself became a huge virtual-database sharing myriad resources, hence the user number grew dramatically. By many accounts it was the fastest growing application in the Internet's history, expanding from 30 users to 25 million users in its first 12 months of operation (Strahilevitz, 2002). Furthermore, many P2P file sharing systems have followed Napster, including OpenNap, Scour, iMesh, Gnutella, eDonkey, FreeNet, BitTorroent, and DirectConnect. As of June 2004 the most popular such network is Kazaa, which according to Download.com has been downloaded over 350 million times since its introduction in July 2000 (Asvanund et al., 2004).

Consistent with the booming of the P2P file sharing technology, the phenomenon of illegal digital music files downloading has become much more serious and made a harsh impact on the economy. Research by the independent Pew Internet & American Life project suggests that about 36 million US citizens, equal to 27 per cent of US internet users, have downloaded either music or video files for free that they do not own in other forms, although figures for repeat downloading are less certain (Madden and Rainie, 2005). A perspective is provided by the music industry's claim in the IFPI Music Piracy Report 2005 that one in three music recordings worldwide is pirated, and a US$4.6 billion music pirate market has been created (London and Madrid, 2005).

1.4 The lawsuit against Napster

In order to deterred the behavior of music piracy and reduced the economic loss by music downloading, the media groups did several actions, such as lawsuits, selling authorized online music, and alliance with another industries, last seven years (Molteni and Ordanini, 2003). One of the best-known anti-piracy strategies was the Recording Industry Association of America (RIAA) filing a federal lawsuit against Napster for copyright infringement in December 1999.

RIAA did not sue Napster directly for the copyright infringement, but rather argued that Napster's software enable its users to exchange copyright protected music files for free. Hence, RIAA alleged that Napster was liable for contributory and vicarious copyright infringement. The RIAA suit asked for damages of $100,000 per infringement, with estimated damages in excess of $100 million (Navissi et al., 2005). After approximately two years of intense debates and legal battles, a three-member panel of judges from the Ninth U.S

Circuit Court of Appeals ruled that Napster knowingly encouraged and assisted its users to infringe the record companies' copyrights, and the Napster was eventually ordered to shut down in February 2001

The most recent strategy adopted by copyright holders of bringing legal action against violators may be more successful, even though the proportion of users who are targeted is a small fraction of the total number of users. The success of this strategy depends on raising the implicit cost of sharing for users by raising their legal risks. Increased sharing costs will then raise their propensity to free-ride and may ultimately reduce the utility offered by illicit file trading over P2P networks enough to make the legitimate purchase of the music and attractive option for users. (Asvanund et al., 2004)

Notwithstanding the copyright holders tried to limit unauthorized file sharing by lawsuits, this strategy could only increasing free-riding on another new P2P networks, for example Kazaa became the largest P2P file trading program in 2002, but could not help stopping the music pirating. Besides, shutting down individual file-swapping networks did little to change user behavior, because individual users can simply look for new networks where they can trade files (Asvanund et al., 2004; Condry, 2004). Then again, some researches pointed out that P2P file sharing systems can provide a platform for the consumers to download sample music files, it may potentially stimulate music purchases in a positive way (Navissi et al., 2005).

1.5 The iPod+iTunes business model

Another anti-piracy strategy launched by the media groups and copyright holders recently is forging an alliance with the other industries, such as hardware producers, distribution channels, and internet companies, to "transform" the illegal downloading into authorized content trading. The iPod-plus-iTunes Music Store, which was the outcome of the cooperation between the five major media conglomerates and the Apple Computer, set a milestone of authorized music downloading services.

In 2001, Apple Computer launched a new digital music mobile device, iPod, into the market. This new device included several important functions such as a 5G hard disc space, Advance Audio Code, the file compressing technology designed for music, and Digital Right Management, that can store a large number of the copyrighted digital music. After the Apple making an alliance with big five music giants the Apple's iTunes Online Music Store was opened in April 2003. Therefore consumers can purchase authorized music only cost 99 cents per song via the iTunes Online Music Store, and download the digital music files into their iPods.

In addition, the copyright holders can share 65 per cent of the profit in one song downloading from iTunes Store (Condry, 2004).The label receives 47 cents, while the artist, producer, and songwriter/publisher together receive only 18 cents. In contrast, the artists, songwriters and producers combined could expect about 12 to 18 per cent of the sale price of an album in the era of cassette tapes (Vogel, 2001).

Table 1 Sales of 99 cent songs from Apple's online iTunes Store

	USA
Label	47
Artist	7
Producer	3
Publishing	8
Service provider	17
Distribution affiliate	10
Bandwidth costs	2
Credit card fees	5
Total (cents / song)	99

Source: *Billboard,* 12 July 2003, p. 64.

Because the price of the legal music downloading via iTunes was reasonable, the growth of sell in such music downloading service was quite startling. One million songs had been downloaded in the first week since the Online Music Store was launched, and 0.5 billion songs, according to the report on the website of Apple Computer, has been downloaded until July 2005.

Since the emergence of successful music download services like iTunes is proving not only makes consumers paying for quality content, but the intentions to download illegal music files are diminishing. Figure 3 shows that this system gives consumers a legal platform to buy songs in a reasonable price, and the illegal music trading market will be no longer existed.

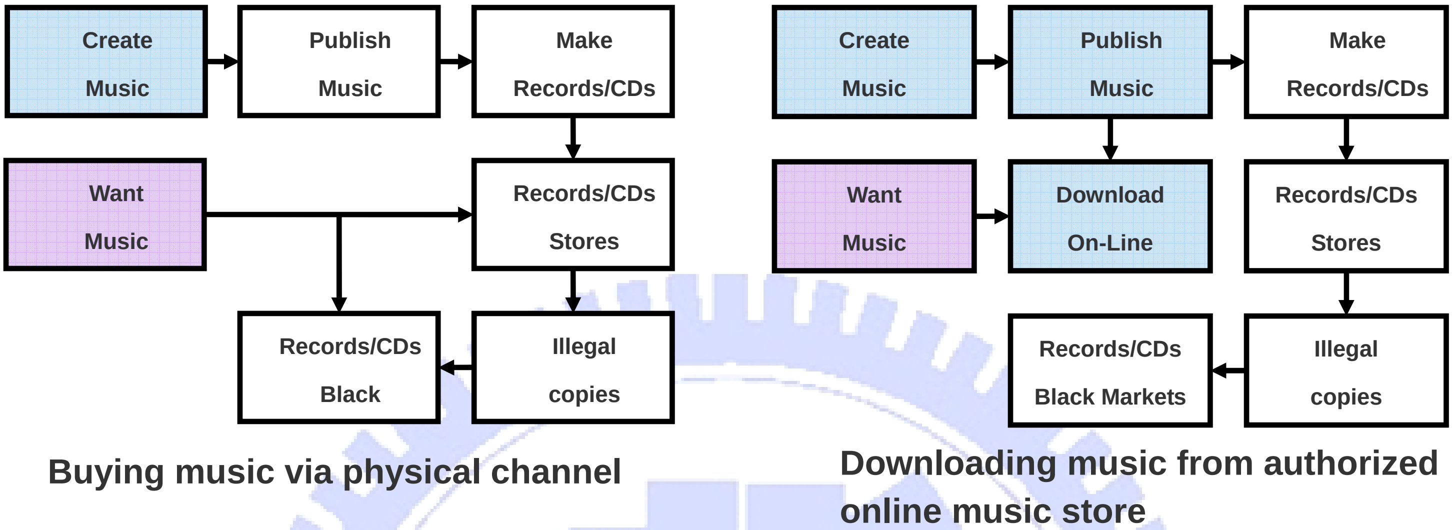


Figure 3 The iTunes cut the connection between the consumers and the physical illegal music trading market

IFPI Commercial Piracy Report 2005 directed that music disc piracy rose 2 per cent to 1.2 billion discs in 2004, which is the lowest level of growth in five years from year 2000 (London and Madrid, 2005). Also, the remarkable success in digital music selling may create a blue ocean business model (Kim and Mauborgne, 2004), and bring forth a new era of on-demand media service.

2. Literature Review

2.1 DEA Method

2.1.1 Introduction of DEA

Data envelopment analysis (DEA), first introduced by Charnes, Cooper, and Rhodes in 1978, is a linear programming based technique for measuring the relative performance extended Farrell's (1957) idea of estimating technical efficiency with respect to a production frontier. The main advantage of frontier efficiency over other performance indicators is that it is an objectively determined quantitative measure that removes the effects of market prices and other exogenous factors that influence observed performance (Bauer et al.,1997). Furthermore, unlike most of the traditional econometric approaches, DEA does not require many restrictions on the underlying production technology, or an exogenous specification of the parametric form of the production correspondences. Thus DEA become a new tool in operational research for measuring technical efficiency.

The resulting CCR model (Charnes, Cooper, and Rhodes, 1978), named after the three authors, is an optimization method of mathematical programming to generalize the Farrell (1957) single-input/ single-output technical efficiency measure to the multiple-input/ multiple-output case by constructing a relative efficiency score of similar Decision Making Units (DMUs) as the ratio of a single virtual output to a single virtual input on a constant returns to scale basis. In 1984, the CCR model was extended by Banker, Charnes, and Cooper (1984) (BCC) to include variable returns to scale. So the basic DEA models are known as CCR and BCC.

Since 1978 over 1,800 articles, books and dissertation have been published (Gattoufi et al., 2004) and DEA has rapidly extended to returns to scale, dummy or categorical variables (Cook, Kress, and Seiford, 1996), discretionary and non-discretionary variables (Banker and Morey, 1986; Kao, 1994), incorporating value judgments (Banker and Morey, 1989), longitudinal analysis (Lang and Golden, 1989), weight restrictions (Thompson et al., 1986), stochastic DEA (Kao and Liu, 2000), non-parametric Malmquist indices (Färe et al., 1992), technical change in DEA and many other topics. Up to now the

DEA measure has been used to evaluate and compare educational departments (Kao and Yang, 1992), health care (Banker, Conrad, and Strauss, 1988), prisons (Ganley and Cubbin, 1987), agricultural production (Fandel, 1998), banking (Oral and Yolalan, 1992), armed forces (Charnes, Clark, Cooper, and Golany, 1984), sports (Sueyoshi, Ohnishi, and Kinase, 1999), market research, transportation (Rouse, Putterill, and Ryan, 1997), courts, benchmarking, index number construction and many other applications.

At the moment researchers follow wide ranges of DEA and related topics. The main research areas of DEA are:

- Returns to scale
- Dummy or categorical variables
- Discretionary and non-discretionary variables
- Incorporating judgment
- Longitudinal analysis
- Weight restriction
- Stochastic DEA
- Non-parametric Malmquist indices
- Technical change in DEA
- Dynamics of Data Envelopment Analysis
- Sensitivity
- DEA Applications
- Other topics

2.1.2 Advantages of DEA

DEA's application for performance measurement is widespread and the multidimensional nature of corporate performance makes it an ideal application area. Data Envelopment Analysis has several advantages associated with its use. First of all, DEA gives a single measure of performance which can take into account all dimensions of corporate activity, and it has the ability to simultaneously handle multiple inputs and outputs without making judgments on their relative importance. Also, it ensures that companies being examined will only be compared to firms which are aiming to secure similar objectives, as indicated by their financial data. In this way, problems can be identified, and specified, by measuring the subject firm's performance against its peers. DEA provides a set of targets for performance improvements that managers can utilize to improve the firm's performance. In addition, the method allows managers to determine and focus on the most important factors in the firms' operations.

Charnes et al. (1994) describe DEA as a new way of organizing and analyzing data, which can result in new managerial and theoretical insights. They highlight the following properties of DEA which make it an attractive approach to data analysis:

- Focus on individual observations in contrast to population averages.
- Produce a single aggregate measure for each DMU in terms of its utilization of input factors to produce desired outputs.
- Can simultaneously utilize multiple outputs and multiple inputs with each being stated in different units of measurement.
- DEA is a non-parametric approach which is value free and does not require specification or knowledge of a priori weights or prices for the inputs and outputs.
- Place no restriction on the functional form of the production relationship.
- The results of efficiency are Pareto optimal.
- Focus on revealed best-practice frontiers rather than on central-tendency properties of frontiers.
- Satisfy strict equity criteria in the relative evaluation of each DMU.
- Can accommodate judgment when desired.
- Produce specific estimates for desired changes in inputs and/or outputs for projecting DMUs below the efficient frontier onto the efficient frontier.
- Can adjust for exogenous variables.
- Can incorporate categorical variables.

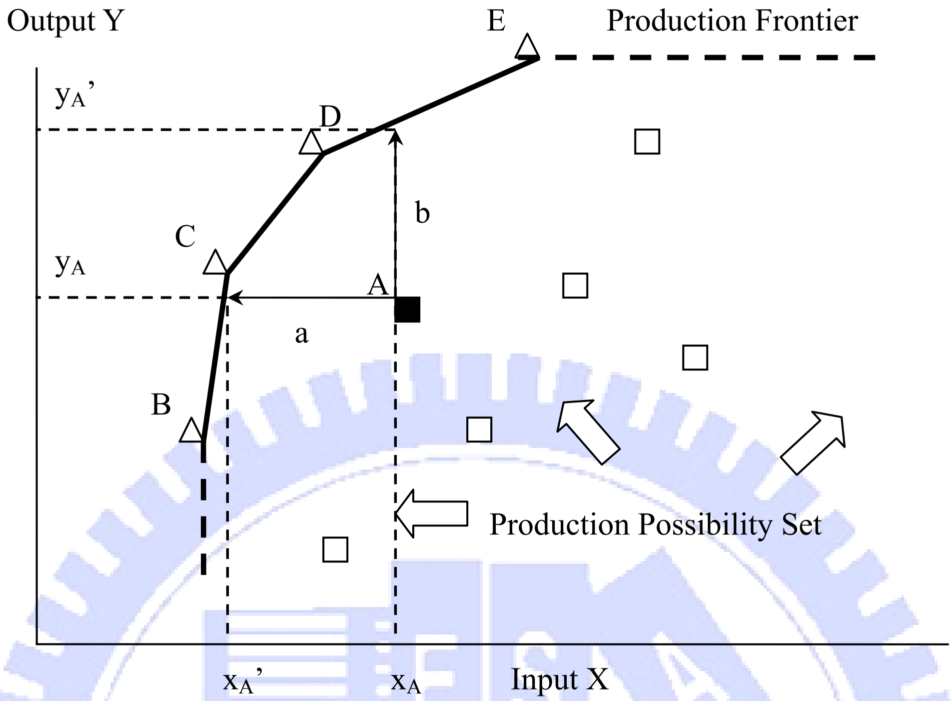
2.1.3 Basic DEA Models

2.1.3.1 CCR Models

DEA was initiated by Charnes Cooper and Rhodes in 1978 in their seminal paper. The paper practiced and extended by means of linear programming production economics concept empirical efficiency put forth some twenty years earlier by Farrell (1957). CCR model (Charnes, Cooper, and

Rhodes, 1978) has the ability to estimate the relative efficiency score, which is lied between 0 and 1, of similar Decision Making Units (DMUs) by constructing an efficient frontier and a weighted ratio of inputs and outputs on a constant returns to scale basis.

This nonparametric approach calculates efficiency in two stages. First an empirical production frontier is found based on the observed inputs and outputs of the DMUs of interest. This frontier representing best practice, Known as the envelopment surface, acts as a benchmark for all DMUs in the analysis. The DMUs are similar production units operating within the same cultural environment. The second stage of the analysis involves the computation of the efficiency score for each DMU as indicated by its distance from the frontier. The efficiency score indicates the proportion by which the unit can increase its outputs without consuming any more inputs, or conversely the proportion by which it can decrease its inputs and maintain the current output level (Pareto optimal). There is an inherent assumption in that the processes considered can be operated fractionally and combined linearly, which means that the production possibility set consists of points representing the observed DMUs and all possible linear combinations thereof. The results of CCR model can be best illustrated by the two dimensional example of Figure 4.



Best Practice DMUs: B,C,D,E

Peer Groups for DMU A:

Input Minimization – {B,C}

Output Maximization – {D,E}

Efficiency of DMU A:

Input Minimization: x_A' / x_A

Output Maximization: y_A / y_A'

Targets for DMU A are indicated by the arrows a and b.

Figure 4 Measuring Technical Input Efficiency with Production Frontier

Two alternative approaches are available in this model to estimate the efficient frontier. One is input-oriented CCR model, and the other is output-oriented CCR model. The following DEA model is an input-oriented model in multiplier form where the inputs are minimized and the outputs are kept at their current levels.

$$\max \quad h_k = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}}$$

$$\text{subject to} \quad \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1 \qquad (j = 1, \cdots, n)$$

$$v_i \ge \varepsilon > 0 \qquad (i = 1, \cdots, m)$$

$$u_r \ge \varepsilon > 0 \qquad (r = 1, \cdots, s)$$

Where h_k: the relative efficiency of object DMU k

x_{ij}: the ith output for DMU j

y_{rj}: the rth output for DMU j

v_i: weight of ith input

u_r: weight of rth output

N: number of DMUs

m: number of input

s: number of output

ε: a non-Archimedean infinitesimal

Model above represents the relative efficiency score that the weighted output/input ratio is maximized on the restriction of the efficiency score cannot greater than one. However, this model can not be solved by linear programming solutions. As a result, Charnes Cooper and Rhodes (1978) added a constraint, $\sum_{i=1}^{m} v_i x_{ik} = 1$, in this model to transform this model a linear programming one. This model is shown below:

$$\max \quad h_k = \sum_{r=1}^{s} u_r y_{rk}$$

$$\text{subject to} \quad \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0 \qquad (j = 1, \cdots, n)$$

$$\sum_{i=1}^{m} v_i x_{ik} = 1$$

$$v_i \ge \varepsilon > 0 \qquad (i = 1, \cdots, m)$$

$$u_r \ge \varepsilon > 0 \qquad (r = 1, \cdots, s)$$

Because the number of constraints, n+1, this model is more than variables, model should transform into the dual model, the envelopment form, in practice.

$$\min \quad \theta_k - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right)$$

$$\text{subject to} \quad \sum_{j=1}^{n} x_{ij}\lambda_j = \theta_k x_{ik} - s_i^-, \quad i = 1,\ldots,m$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j = y_{rk} + s_r^+, \quad r = 1,\ldots,s$$

$$\lambda_j \geq 0, \quad j = 1,\ldots,n$$

$$s_i^- \geq 0, \quad i = 1,\ldots,m$$

$$s_r^+ \geq 0, \quad r = 1,\ldots,s$$

$$\theta_k \ \ is \ \ free$$

Where θ_k: the technical input efficiency of object DMU k

λ_j: the improvable weight of inputs or outputs

s_i^-: slack of inputs

s_r^+: slack of outputs

Let us use the superscript * to denote the optimal value of a variable in this model. In the envelopment form CCR model, once θ_k has been minimized the model seeks the maximum sum of the slack values s_i^- and s_r^+. If any one of these values is positive at the optimal solution to the model it means that the corresponding input or output of DMU k can improve further, after its input levels have been contracted to the proportion θ_k*. On the other hand, if θ_k*= 1 and s_i^-*=0, i=1...m, s_r^+*=0, r=1...s then DMU k is Pareto-efficient because the model has been unable to identify some feasible production point which can improve on some input or output level of DMU k without detriment to some other input or output level.

In practice, because of the difficulty of using a specific value for the model is solved in two phases. During the first phase θ_k is minimized, ignoring the slack values. This yield the minimum value θ_k* of θ_k . Then setting within θ_k =θ_k* the model is solved to maximize $\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+$.

The alternative CCR approach is CCR output-oriented model, which maximizes the outputs of DMUs in their current inputs level. CCR output-oriented model in multiplier form is shown below:

$$\min \quad \frac{1}{g_k} = \frac{\sum_{i=1}^{m} v_i x_{ik}}{\sum_{r=1}^{s} u_r y_{rk}}$$

$$\text{subject to} \quad \frac{\sum_{i=1}^{m} v_i x_{ij}}{\sum_{r=1}^{s} u_r y_{rj}} \geq 1 \qquad (j = 1, \cdots, n)$$

$$v_i \geq \varepsilon > 0 \qquad (i = 1, \cdots, m)$$

$$u_r \geq \varepsilon > 0 \qquad (r = 1, \cdots, s)$$

Where g_k: the relative efficiency of object DMU k

x_{ij}: the ith output for DMU j

y_{rj}: the rth output for DMU j

v_i: weight of ith input

u_r: weight of rth output

N: number of DMUs

m: number of input

s: number of output

ε: a non-Archimedean infinitesimal

Transform above model into the below one as the value-based form in order to complete the calculations:

$$\min \quad \frac{1}{g_k} = \sum_{i=1}^{m} v_i x_{ij}$$

$$\text{subject to} \quad \sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} u_r y_{rj} \geq 0 \qquad (j = 1, \cdots, n)$$

$$\sum_{r=1}^{s} u_r y_{rj} = 1$$

$$v_i \geq \varepsilon > 0 \qquad (i = 1, \cdots, m)$$

$$u_r \geq \varepsilon > 0 \qquad (r = 1, \cdots, s)$$

Construct the dual model and get the CCR output-oriented model in envelopment form:

$$
\begin{aligned}
\max \quad & \frac{1}{g_k} = \phi_k + \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \\
\text{subject to} \quad & \sum_{j=1}^{n} x_{ij}\lambda_j = x_{ik} - s_i^-, \quad i = 1,\dots,m \\
& \sum_{j=1}^{n} y_{rj}\lambda_j = \phi_k y_{rk} + s_r^+, \quad r = 1,\dots,s \\
& \lambda_j \geq 0, \quad j = 1,\dots,n \\
& s_i^- \geq 0, \quad i = 1,\dots,m \\
& s_r^+ \geq 0, \quad r = 1,\dots,s \\
& \phi_k \ \text{is free}
\end{aligned}
$$

Where ϕ_k: the technical output efficiency of object DMU k

λ_j: the improvable weight of inputs or outputs

s_i^-: slack of inputs

s_r^+: slack of outputs

Let us use the superscript * to denote the optimal value of a variable. By definition, φ_k* is the technical output efficiency of DMU k, and the slack variables s_i^- and s_r^+ in model are interpreted in a similar manner to the slack variables. They represent any additional output augmentations and/or input reductions feasible from the frontier points which can improve on any one of the input or output level of DMU k by the factor φ_k*. In the envelopment form CCR output-oriented model, once 1/φ_k has been maximized the model seeks the maximum sum of the slack values s_i^- and s_r^+. If and only if φ_k*= 1 and s_i^-*=0, i=1...m, s_r^+*=0, r=1...s then DMU k is Pareto-efficient because the model has been unable to identify some feasible production point which can improve on some input or output level of DMU k without detriment to some other input or output level.

In practice, model is solved by a two-phase process as was the case with model earlier. During the first phase 1/φ_k is maximized, ignoring the slack values. This yield the maximum value $1/\varphi_k$* of $1/\varphi_k$. Then setting within $\varphi_k=\varphi_k^*$ the model is solved to maximize $\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+$.

It can be shown, see Cooper et al. (2000) section 3.8 that:

The technical input efficiency measure θ_k* yielded by model and the technical output efficiency measure φ_k* yielded by in respect of DMU k are equal.

As CCR models yield equal measures of efficiency under constant returns to scale, either one is sufficient for estimating the technical input or output efficiency of a DMU. However, in cases where inputs are controllable while outputs are exogenous it is more sensible to use CCR model which estimates technical input efficiency. In contrast, where outputs are controllable and inputs are exogenous it makes sense to use CCR model (Thanassoulis, 2001).

2.1.3.2 BCC Models

In 1984 Banker, Charnes, and Cooper (1984) (BCC) relaxed the assumption of constant returns to scale (CRS) in the CCR model and generated a variable returns to scale (VRS) model, named as BCC model, and VRS means that the scale of operation affects the input-output relationship. If (x, y) is a non-zero feasible input-output correspondence, the VRS assumption means that average productivity denoted by the ratio y/x is dependent on scale of production.

Consider a set of DMUs (j=1,…,N) operating under VRS and let DMU k be Pareto-efficient. Solve CCR model in respect of DMU k and let the superscript * to a variable denote its optimal value CCR model, and the returns to scale condition can be identified by following criteria (Thanassoulis , 2001):

- If $\sum_{j=1}^{n} \lambda_j > 1$ for all optimal solutions for CCR model then DRS hold locally at DMU k;
- If $\sum_{j=1}^{n} \lambda_j = 1$ for at least one optimal solutions for CCR model then CRS hold locally at DMU k;

- If $\sum_{j=1}^{n}\lambda_j < 1$ for all optimal solutions for CCR model then IRS hold locally at DMU k;

Also there are two alternative approaches, input-oriented approach and output-oriented approach, to estimate the efficient frontier in BCC model. The BCC input-oriented model below can be generated by adding a constraint, $\sum_{j=1}^{n}\lambda_j = 1$, into CCR input-oriented model in envelopment form.

$$
\begin{aligned}
\min \quad & \theta_k - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \\
\text{subject to} \quad & \sum_{j=1}^{n} x_{ij}\lambda_j = \theta_k x_{ik} - s_i^-, \quad i = 1,\ldots,m \\
& \sum_{j=1}^{n} y_{rj}\lambda_j = y_{rk} + s_r^+, \quad r = 1,\ldots,s \\
& \sum_{j=1}^{n} \lambda_j = 1 \\
& \lambda_j \geq 0, \quad j = 1,\ldots,n \\
& s_i^- \geq 0, \quad i = 1,\ldots,m \\
& s_r^+ \geq 0, \quad r = 1,\ldots,s \\
& \theta_k \ \ is \ \ free
\end{aligned}
$$

And the dual model of above model, value-based model, is shown below:

$$
\begin{aligned}
\max \quad & h_k = \sum_{r=1}^{s} u_r y_{rk} - u_0 \\
\text{subject to} \quad & \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} - u_0 \leq 0 \quad (j = 1,\cdots,n) \\
& \sum_{i=1}^{m} v_i x_{ik} = 1 \\
& v_i \geq \varepsilon > 0 \quad (i = 1,\cdots,m) \\
& u_r \geq \varepsilon > 0 \quad (r = 1,\cdots,s) \\
& u_0 \text{ is free}
\end{aligned}
$$

The output-oriented BCC envelopment form model is shown as follow:

$$
\begin{aligned}
\max \quad & \frac{1}{g_k} = \phi_k + \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \\
\text{subject to} \quad & \sum_{j=1}^{n} x_{ij}\lambda_j = x_{ik} - s_i^-, \quad i = 1,\ldots,m \\
& \sum_{j=1}^{n} y_{rj}\lambda_j = \phi_k y_{rk} + s_r^+, \quad r = 1,\ldots,s \\
& \sum_{j=1}^{n} \lambda_j = 1 \\
& \lambda_j \geq 0, \quad j = 1,\ldots,n \\
& s_i^- \geq 0, \quad i = 1,\ldots,m \\
& s_r^+ \geq 0, \quad r = 1,\ldots,s \\
& \phi_k \ \ is \ \ free
\end{aligned}
$$

The output-oriented BCC value-based form model is shown as model below:

$$
\begin{aligned}
\min \quad & \frac{1}{g_k} = \sum_{i=1}^{m} v_i x_{ij} + v_0 \\
\text{subject to} \quad & \sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} u_r y_{rj} + v_0 \geq 0 \quad (j = 1,\cdots,n) \\
& \sum_{r=1}^{s} u_r y_{rj} = 1 \\
& v_i \geq \varepsilon > 0 \quad (i = 1,\cdots,m) \\
& u_r \geq \varepsilon > 0 \quad (r = 1,\cdots,s) \\
& v_0 \text{ is free}
\end{aligned}
$$

Figure 5 shows different efficiency frontiers of DMUs on the CRS and VRS basis single input-output DEA model. The frontier of BCC model is constructed by lines in different slopes, and it reveals that the expanding ratio of outputs can be increase, decrease or keep constant with the increasing of inputs. On the other hand, the frontier of CCR model is in a line with a constant slope.

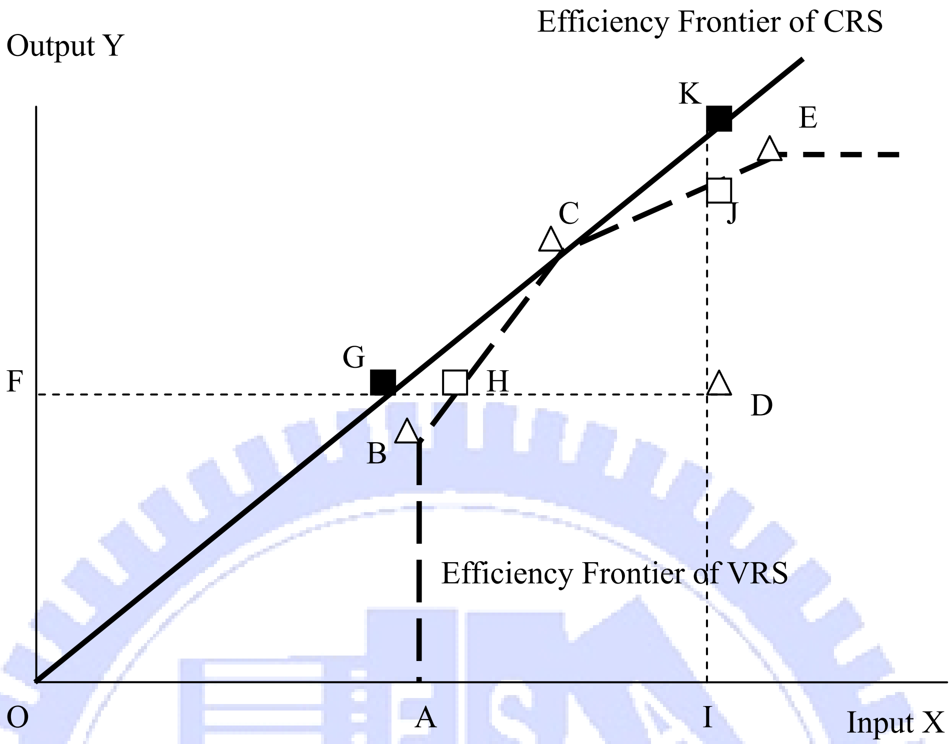


Figure 5 CRS and VRS Frontiers in DEA Models

On the constant returns to scale, taking DMU D with concern under the same output level OF, the technical efficiency (TE) of DMU D can be presented as TE_D= FG/FD. On the variable returns to scale case in contrast, the pure technical efficiency (PTE) of DMU D can be presented as PTE_D= FH/FD under the same output level OF. And the scale efficiency of DMU D is: SE_D= TE_D / PTE_D =FG/FH. If SE is equal to one, the DMU is in a constant returns to scale condition; if SE is less than one presenting that scale effects exist in the performance of this DMU.

When a DMU is on the IRS condition, lies between DMU B and DMU C, a manager should increase inputs and the scale level of this DMU as well to improve the efficiency. In addition, when a DMU is on the DRS condition, lies between DMU C and DMU E, a manager should decrease inputs and the scale level of this DMU as well to improve the efficiency. Thus managers can identify the reason of inefficiency caused by inappropriate inputs or outputs scale, and perceive the ideal scale size to operate a DMU through BCC model (Thanassoulis, 2001).

2.1.4 Assessing Efficiency under Exogenously Fixed Input-Output Variables

Basic DEA models, CCR and BCC model, measure the efficiency of a DMU in terms of the maximum radial contraction to its input levels or expansion to its output levels feasible under efficient operation. However, such measures are not suitable in contexts where at least one of the variables to be radially contracted or expanded is exogenously fixed, in the sense that it is not controllable by the DMUs. One of the modified-DEA models has the ability to handle exogenously fixed or non -discretionary inputs and outputs though.

Banker and Morey (1986) extended basic DEA models, that they can be used for assessing efficiency under exogenously fixed input-output variables as a result, and illustrated the impact of a non-discretionary input in an analysis of fast food restaurants. Figure 6 helps to illustrate their approach.

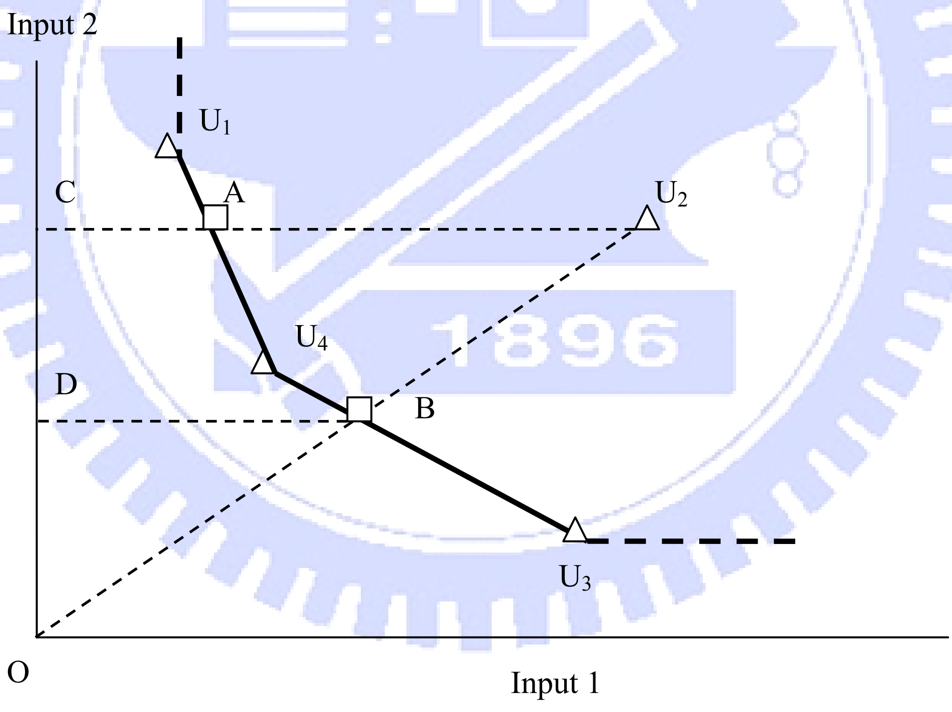


Figure 6 Input Efficiency while Input 2 is Exogenously Fixed

Figure 6 depicts a set of DMUs operating a CRS technology using two inputs to secure one output. Output has been standardized to one unit. Assume that input 1 is controllable by the DMU but input 2 is exogenously fixed. The basic input-oriented DEA model uses B as an efficient referent point for DMU

U_2 and so the efficiency measure it yields is: OB/OU_2. This measure, however, reflects the uniform contraction to its input levels per unit of output, where the implied reduction to the level of input 2 is CD. But this reduction to the level of input 2 is not feasible while input 2 is exogenously fixed. The extension to the basic DEA model put forth by Banker and Morey (1986) assesses the efficiency of DMU U_2 with reference to the maximum feasible contraction to input 1, which is not exogenously fixed, controlling for the level of input 2, which is exogenously fixed. Thus the Banker and Morey (1986) extended DEA model would measure the efficiency of DMU U_2 in Figure 6 with reference to point A. The resulting efficiency measure will be CA/CU_2.

Models below show respectively the modifications to the basic input oriented CRS and VRS DEA models developed by Banker and Morey (1986) for dealing with exogenously fixed input-output variables in the general case. The corresponding output oriented models can be deduced by analogy.

Model relates to DMUs (j=1…N) using m inputs to secure s outputs. The inputs are partitioned into two subsets {D} and {not D} consisting respectively of discretionary (i.e. under managerial control) and non-discretionary (i.e. exogenously fixed) inputs. If the DMUs operate under CRS then the technical input efficiency of DMU k isθ_k*, where θ_k* is the optimal value of θ_k in:

$$\min \quad \theta_k - \varepsilon\left(\sum_{i=1, i\in\{D\}}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right)$$

$$\text{subject to} \quad \sum_{j=1}^{n} x_{ij}\lambda_j = \theta_k x_{ik} - s_i^-, \quad i \in \{D\} \ \text{(under managerial control)}$$

$$\sum_{j=1}^{n} x_{ij}\lambda_j = \sum_{j=1}^{n} \lambda_j x_{ik} - s_i^-, \quad i \notin \{D\} \ \text{(exogenously fixed)}$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j = y_{rk} + s_r^+, \quad r = 1,\ldots,s$$

$$\lambda_j \geq 0, \quad j = 1,\ldots,n$$

$$s_i^- \geq 0, \quad i = 1,\ldots,m$$

$$s_r^+ \geq 0, \quad r = 1,\ldots,s$$

$$\theta_k \ \ is \ \ free$$

Where h_k: the relative efficiency of object DMU k

x_{ij}: the ith output for DMU j

y_{rj}: the rth output for DMU j

v_i: weight of ith input

u_r: weight of rth output

D: subset of the discretionary inputs

N: number of DMUs

m: number of input

s: number of output

ε: a non-Archimedean infinitesimal

Above model differs from the basic DEA CCR model for assessing technical input efficiency under CRS in three respects. Firstly, θ_k measures the radial contraction feasible only in respect of the discretionary rather than all inputs. Secondly, the slacks of exogenously fixed inputs are not reflected within the summation term in the objective function. Thus the efficiency measure arrived at by means of this model reflects the extent to which DMU k can contract radially only those of its inputs which are not exogenously fixed. Finally, the non-discretionary input levels of DMU k on the right hand side of respective constraints in model are multiplied by $\sum_{j=1}^{n} \lambda_j$. This ensures that the most productive scale size yielded by the model in respect of DMU k does not require larger levels on the non-discretionary inputs than those of DMU K.

Assume now that DMUs relating to model above operate a VRS technology. Then to assess the pure technical input efficiency of DMU k model below is used.

$$\min \quad \theta_k - \varepsilon\left(\sum_{i=1, i\in\{D\}}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right)$$

$$\text{subject to} \quad \sum_{j=1}^{n} x_{ij}\lambda_j = \theta_k x_{ik} - s_i^-, \quad i \in \{D\} \text{ (under managerial control)}$$

$$\sum_{j=1}^{n} x_{ij}\lambda_j = x_{ik} - s_i^-, \quad i \notin \{D\} \text{ (exogenously fixed)}$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j = y_{rk} + s_r^+, \quad r = 1,\ldots,s$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0, \quad j = 1,\ldots,n$$

$$s_i^- \geq 0, \quad i = 1,\ldots,m$$

$$s_r^+ \geq 0, \quad r = 1,\ldots,s$$

$$\theta_k \ \textit{is free}$$

Model differs from the basic CCR model for assessing technical input efficiency under VRS in two aspects. Firstly, θ_k measures the radial contraction feasible only in respect of the discretionary rather than all inputs. Secondly, the slacks of exogenously fixed inputs are not reflected within the summation term in the objective function. Thus the efficiency measure arrived at by means of above model reflects the extent to which DMU k can contract radially only those of its inputs which are not exogenously fixed.

As the input variables, employees, capital assets, domestic piracy rate, and internet population, in our sample data can be divided into two categories, under managerial control and exogenously fixed. Our research will adapt the CCR input-orient model, which is modified by exogenously fixed inputs, to construct the Malmquist indices and inspect the productivity movement between two periods. The methodology of Malmquist indices, which can present the cross-period productivity change, will be illustrated in the next section.

2.1.5 Assessing Productivity Change by DEA: Malmquist Indices

DEA-based Malmquist productivity index, which was first introduced by Färe et al. (1989), measures the productivity change over time. In multi-input multi-output contexts a unit’s productivity is defined as the ratio of an index of its output levels to an index of its input levels, and the change over time of this measure reflects the change in the unit's productivity (Thanassoulis, 2001). The DEA-based Malmquist productivity index can be decomposed into two components: one is measuring the technical change (efficiency change) and the other measuring the frontier shift (boundary shift). Also, the DEA-based Malmquist productivity index can either be input or output-oriented. Consequently, the Malmquist productivity index can be input-oriented when the outputs are fixed at their current levels or output-oriented when the inputs are fixed at their current levels. This section will illustrate the Malmquist Indices with input-oriented DEA models, because our research considers the possible radial reductions of all inputs when the outputs are fixed at DMUs' current levels.

As far as Figure 7 is concerned, the Malmquist index measures productivity change can be illustrated graphically in a single output and two inputs two periods DEA model. Let a company operate at point F^t in period t and at point F^{t+1} in period t+1; f_t and f_{t+1} are the frontiers which are constructed by DMUs of the period t and t+1 respectively.

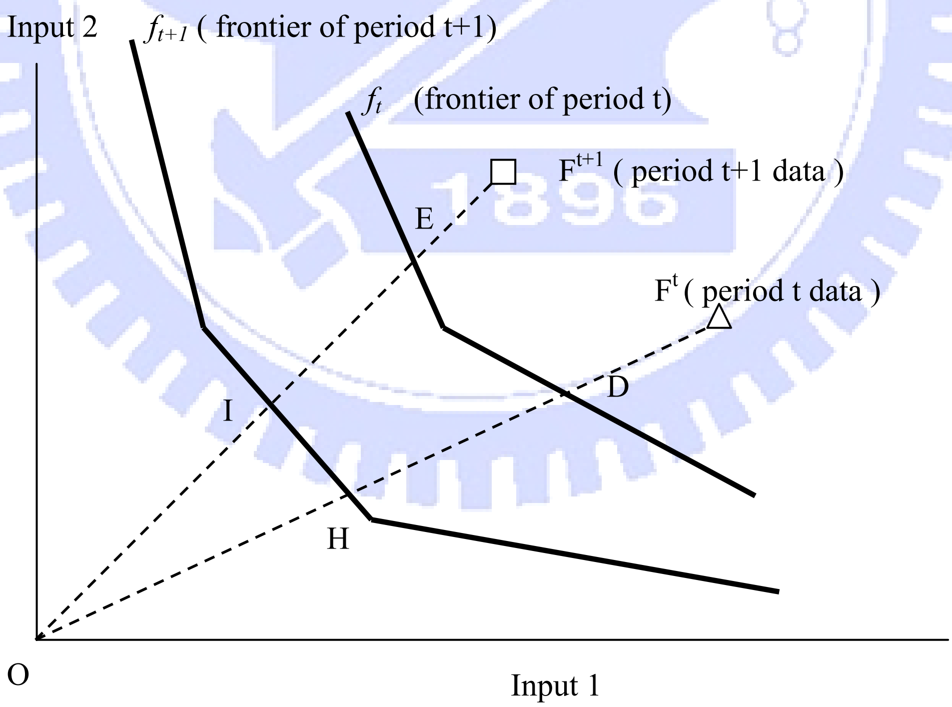


Figure 7 Measure The Frontier Shift Over Two Periods

Take the frontier of period t, f_t ,in Figure 7 as concern, the technical input efficiency of company F is OD/OF^t in period t and OE/OF^{t+1} in period t+1. Thus its productivity change based on the frontier period t is the ratio of the efficiencies, $(OE/OF^{t+1}) \div (OD/OF^t)$, in two periods. The productivity change based on the frontier period t+1 is the ratio of the efficiencies, $(OI/OF^{t+1}) \div (OH/OF^t)$, likewise. The geometric mean of these two ratios is taken to measure the productivity change of this company. Thus the productivity change of the company operating at F^t in period t and at F^{t+1} in period t+1 in Figure 7 is

$$\{[\frac{OE}{OF^{t+1}} \div \frac{OD}{OF^t}] \times [\frac{OI}{OF^{t+1}} \div \frac{OH}{OF^t}]\}^{1/2} = \underbrace{[\frac{OI}{OF^{t+1}} \div \frac{OD}{OF^t}]}_{\text{'Catch-up' component}} \times \underbrace{[\frac{OE}{OI} \div \frac{OD}{OH}]^{1/2}}_{\text{'Boundary shift' component}}$$

The catch-up term in above equation is a measure of how much closer to the boundary the company is in period t+1 compared to period t. OI/OF^{t+1} measures the distance of the company from the t+1 efficient boundary and OD/OF^t its distance from the efficient boundary in period t. If the catch up term is one the company has the same distance in periods t+1 and t from the respective efficient boundaries. If the catch up term is over one the company has moved closer to the period t+1 boundary than it was the period t boundary and the converse is the case if the catch up term is under one.

The boundary shift term measures the movement of the boundary between period t and t+1 at two locations: The ratio OE/OI measures the distance of the two boundaries at the input mix of the company in period t+1. The ratio OD/OH measures the distance of the two boundaries at the input mix of the came company in period t. The boundary shift term is over one because both of the foregoing ratios are over one, which represents productivity gain by the industry and the input levels in period t+1 is lower than in period t. In contrast, if the boundary shift term under one would signal that the industry has registered productivity loss as input level would on average be higher in period t+1 compared to period t, controlling for output. Moreover, the productivity would neither gain nor loss on average while the boundary shift term is equal to one. These concepts would be presented in following mathematical forms.

Suppose there are n DMUs, each DMUj (j =1,2…,n) produces a vector of outputs $y_j^t = (y_{1j}^t \dots y_{sj}^t)$ by using a vector of inputs $x_j^t = (x_{1j}^t \dots x_{mj}^t)$ at each time period t, t=1,…,T. The CCR DEA model can be expressed as (Charnes et al., 1978):

$$\Theta_1 = \theta_k^t(x_k^t, y_k^t) = \min_{\theta_k,\lambda_j} \quad \theta_k$$

$$\text{subject to} \quad \sum_{j=1}^{n} x_{ij}^t \lambda_j \le \theta_k x_{ik}^t, \quad i = 1,\ldots,m$$

$$\sum_{j=1}^{n} y_{rj}^t \lambda_j \ge y_{rk}^t, \quad r = 1,\ldots,s$$

$$\lambda_j \ge 0, \quad j = 1,\ldots,n$$

Where $x_k^t = (x_{1k}^t \ldots x_{mk}^t)$ and $y_k^t = (y_{1k}^t \ldots y_{sk}^t)$ are the input and output vectors of DMU k among others. If Θ_1=1, then DMU k is efficient, on the empirical production frontier (EPF), in time period t; otherwise, if Θ_1<1, then DMU k is inefficient. Similarly, by replacing x_j^t and y_j^t with x_j^{t+1} and y_j^{t+1} the technical efficiency, $\theta_k^{t+1}(x_k^{t+1}, y_k^{t+1})$, for DMU k at the time period t+1 can be calculated.

$$\Theta_4 = \theta_k^{t+1}(x_k^{t+1}, y_k^{t+1}) = \min_{\theta_k,\lambda_j} \quad \theta_k$$

$$\text{subject to} \quad \sum_{j=1}^{n} x_{ij}^{t+1} \lambda_j \le \theta_k x_{ik}^{t+1}, \quad i = 1,\ldots,m$$

$$\sum_{j=1}^{n} y_{rj}^{t+1} \lambda_j \ge y_{rk}^{t+1}, \quad r = 1,\ldots,s$$

$$\lambda_j \ge 0, \quad j = 1,\ldots,n$$

From t to t+1, DMU_k's technical efficiency may change and the EPF may shift. Based upon CCR model, the radial Malmquist productivity index can be calculated via (Färe et al., 1994a, b).

(i) Comparing x_j^t to EPF at time t, namely, calculating Θ_1= $\theta_k^t(x_k^t, y_k^t)$;

(ii) Comparing x_j^{t+1} to EPF at time t, namely, calculating Θ_4=

$\theta_k^{t+1}(x_k^{t+1}, y_k^{t+1})$;

(iii) Comparing x_j^t to EPF at time t+1, that is, calculating Θ_2= $\theta_k^{t+1}(x_k^t, y_k^t)$ through the following linear program:

$$\Theta_2 = \theta_k^{t+1}(x_k^t, y_k^t) = \min_{\theta_k, \lambda_j} \quad \theta_k$$

$$\text{subject to} \quad \sum_{j=1}^{n} x_{ij}^{t+1}\lambda_j + \lambda_{n+1}x_{ik}^t \le \theta_k x_{ik}^t, \quad i = 1, \ldots, m$$

$$\sum_{j=1}^{n} y_{rj}^{t+1}\lambda_j + \lambda_{n+1}y_{rk}^t \ge y_{rk}^t, \quad r = 1, \ldots, s$$

$$\lambda_j \ge 0, \qquad j = 1, \ldots, n+1$$

(iv) Comparing x_j^{t+1} to EPF at time t, namely, calculating Θ_3= $\theta_k^t(x_k^{t+1}, y_k^{t+1})$ through the following linear program:

$$\Theta_3 = \theta_k^t(x_k^{t+1}, y_k^{t+1}) = \min_{\theta_k, \lambda_j} \quad \theta_k$$

$$\text{subject to} \quad \sum_{j=1}^{n} x_{ij}^t\lambda_j + \lambda_{n+1}x_{ik}^{t+1} \le \theta_k x_{ik}^{t+1}, \quad i = 1, \ldots, m$$

$$\sum_{j=1}^{n} y_{rj}^t\lambda_j + \lambda_{n+1}y_{rk}^{t+1} \ge y_{rk}^{t+1}, \quad r = 1, \ldots, s$$

$$\lambda_j \ge 0, \qquad j = 1, \ldots, n+1$$

The Malmquist productivity index (MPI) is defined as (Färe et al., 1992)

$$MPI_k = [\frac{\theta_k^t(x_k^t, y_k^t) \times \theta_k^{t+1}(x_k^t, y_k^t)}{\theta_k^t(x_k^{t+1}, y_k^{t+1}) \times \theta_k^{t+1}(x_k^{t+1}, y_k^{t+1})}]^{1/2} = [\frac{\Theta_1 \times \Theta_2}{\Theta_3 \times \Theta_4}]^{1/2}.$$

MPI_k, a geometric mean of two Caves et al.'s (1982) Malmquist productivity indices, measures the productivity change between periods t and t+1. Färe et al. (1992) define that $MPI_k > 1$ indicates productivity gain; $MPI_k < 1$ indicates productivity loss; and $MPI_k = 1$ means no change in productivity from time t to t+1. Furthermore, Färe et al. (1992) decompose Malmquist productivity index into two components:

$$
\begin{aligned}
MPI_k &= [\frac{\theta_k^t(x_k^t, y_k^t) \times \theta_k^{t+1}(x_k^t, y_k^t)}{\theta_k^t(x_k^{t+1}, y_k^{t+1}) \times \theta_k^{t+1}(x_k^{t+1}, y_k^{t+1})}]^{1/2} \\
&= \frac{\theta_k^{t+1}(x_k^{t+1}, y_k^{t+1})}{\theta_k^t(x_k^t, y_k^t)} [\frac{\theta_k^t(x_k^{t+1}, y_k^{t+1}) \times \theta_k^t(x_k^t, y_k^t)}{\theta_k^{t+1}(x_k^{t+1}, y_k^{t+1}) \times \theta_k^{t+1}(x_k^t, y_k^t)}]^{1/2} \\
&= \frac{\Theta_4}{\Theta_1} [\frac{\Theta_3 \times \Theta_1}{\Theta_4 \times \Theta_2}]^{1/2} \\
&= TEC_k \times FS_k
\end{aligned}
$$

The first component $TEC_k = \Theta_4/\Theta_1$, presenting the catch-up term in above equation, measures the change in technical efficiency. It is a measure of how much closer to the boundary the company is in period t+1 compared to period t. If TEC_k is equal to one, the particular DMU k (maybe a company) has the same distance in periods t+1 and t from the respective efficient boundaries. If TEC_k is over one, the company has moved closer to the period t+1 boundary than it was to the period t boundary and the converse is the care if the TEC_k is under one.

The second component $FS_k = [\frac{\Theta_3 \times \Theta_1}{\Theta_4 \times \Theta_2}]^{1/2}$ measures the technology frontier shift , which is the same with the boundary shit in Malmquist equation, between time period t and t+1. Färe et al. (1992,1994a) point out that a value of FS_k greater than one indicates a positive shift or technical progress, a value of FS_k less than one indicates a negative shift or technical regress, and value of FS_k equal to one indicates no shift in technology frontier.

As the literature review has already mentioned before, one of the advantages of the DEA technique is not having to determine an explicit definition of the production function. Hence in our research, the DEA-based Malmquist indices would be applied to inspect the cross-period productivity change of the music industry from 1997 to 2005. These indices, furthermore, would help researchers to evaluate the effects of different competitive strategies on the performance of the music firms individually, and the whole music industry as well.

2.2 The Tobit Model (Censored Regressions)

In some settings, the dependent variable is only incompletely observed due to censoring. For example, in survey data, data on incomes above a specified level are often top-coded to protect confidentiality. Similarly desired consumption on durable goods may be censored at a small positive or zero value. Tobin James (1958) has carried out a model, the Tobit model or censored regressions, by means of the maximum likelihood estimation to perform the relationships for limited dependent variables, and to use the results for further analysis.

Since efficiency scores computed from the DEA model are censored at one, Chu et al. (2003) used the multi-factor Tobit model to examine factors that might explain the observed differences in inefficiency across departments in addition to the Physician Compensation Program, PCP, in Taiwan hospitals. Moreover, additional dummy variables were included in the Tobit model to clarify the relationship between the introduction of PCP and revenue efficiency of large Taiwanese teaching hospitals. Therefore this research following prior literatures (Chu et al., 2003) and uses the Tobit model to control for factors that may explain the observed differences in productivity change across music firms.

In the Tobit model, there is an asymmetry between observations with positive values of Y and those with negative values. In this case, the model becomes:

$$Y_t = \begin{cases} \alpha + \beta X_t + \varepsilon_t & \text{if } Y_t > 0 \\ 0 & \text{if } Y_t \leq 0 \end{cases}$$

The basic assumption behind this model is that there exists an index function $Y_t=\alpha+\beta X_t+\varepsilon_t$ for each economic agent being studied. If $Y_t \leqq 0$, the value of the dependent variable is set to zero. $Y_t > 0$, the value of the dependent variable is set to Y_t. Supposeε_i has the normal distribution with mean zero and variance σ^2, and note that $Z= \varepsilon_t / \sigma$ is a standard normal random variable. Denote by f(z) the probability density of the standard normal variable Z, and by F(z) its cumulative density, that is $P[Z \leqq z]$. Then the joint probability density for those observations for which Y_t is positive is given by the following expression:

$$P_1 = \prod_{i=1}^{i=m} \frac{1}{\sigma} f[\frac{Y_i - \alpha - \beta X_i}{\sigma}]$$

Where Π denotes the product and m is the number of observations in the subsample for which Y_i is positive. For the second subsample, of size n, for which the observed Y_j is zero, the random variable $\varepsilon_j \leqq -\alpha-\beta X_j$. The probability for this event is:

$$P_2 = \prod_{j=1}^{j=n} P[\varepsilon_j \le -\alpha - \beta X_j]$$

$$= \prod_{j=1}^{j=n} F[\frac{-\alpha - \beta X_j}{\sigma}]$$

The joint probability for the entire sample is therefore given by $L=P_1P_2$. Because this is nonlinear in αand β, the OLS procedure is not appropriate here. The procedure for obtaining estimates of αand β, the maximum likelihood procedure, is to maximize L with respect to the parameters. Among others, the computer programs EViews, LIMDEP, SAS, SHAZAM, and TSP have procedures for estimating the Tobit model. For the easiness and user friendly functions, the tools of EViews computer program are applied to perform maximum likelihood estimation of Tobit models in this research.

2.3 Mann-Whitney Test

DEA, which applies the linear programming approach, is a nonparametric method for measuring comparative performance. This approach, hence, places no restriction on the functional from of the production relationship, even requires no specification on priori weights for the inputs and outputs variables. Consequently the statistic distribution of the efficiencies, or productivity changes, is unable to be portrayed (Charnes and Cooper 1980). If there are two groups of DMUs whose efficiency, or productivity change, difference are requiring to be tested, the nonparametric statistics approach, such as the Wilcoxon rank sum test, Mann-Whitney rank test, and the Kruskal-Wallis test, are used for the applications of DEA models. Since Brockett and Golany (1996) introduced the concept, in the context of DEA, of organizing decision making units into subgroups in order to determine if one subgroup outperforms another. Brockett and Golany (1996), therefore, determined the efficient frontier for each subgroup in order to determine which input and output scenarios are dominant within each subgroup, and first proposed to use the Mann-Whitney rank test in this kind of analysis.

The Mann-Whitney U test is the most popular of the two independent samples tests. It is equivalent to the Wilcoxon rank sum test and the Kruskal-Wallis test for two groups (Daniel, 1978). Mann-Whitney tests that two sampled populations are equivalent in location. The observations from both groups are combined and ranked, with the average rank assigned in the case of ties. The number of ties should be small relative to the total number of observations. If the populations are identical in location, the ranks should be randomly mixed between the two samples. The number of times a score from group 1 precedes a score from group 2 and the number of times a score from group 2 precedes a score from group 1 are calculated. In other words, the idea is to rank the series from smallest value, rank 1, to largest, and to compare the sum of the ranks from subgroup 1 to the sum of the ranks from subgroup 2. If the groups have the same median, the values should be similar. The procedure for Mann-Whitney rank test, which test the difference of DEA scores between two independent groups, is listed below.

1. Ranking order all n DMUs by their efficiency ratings in the DEA model. In case of a tie, use the mid-rank for the tied observations.
2. Compute R_i = the sum of rankings of DMUs in the ith group.
3. Compute the Mann-Whitney rank test statistic:

$$U_1 = n_1 \cdot n_2 + \frac{n_1 \cdot (n_1 + 1)}{2} - R_1$$

$$U_2 = n_1 \cdot n_2 + \frac{n_2 \cdot (n_2 + 1)}{2} - R_2$$

$$U = Min(U_1, U_2)$$

   The U statistic is simple, but tedious, to calculate. For each case in group 1, the number of cases in group 2 with higher ranks is counted. Tied ranks count as 1/2. This process is repeated for group 2. The Mann-Whitney U statistic displayed in the table is the smaller of these two values.
4. For n_1, n_2 ≧ 10 compute the following statistic:

$$Z = \frac{U - \frac{n_1 \cdot n_2}{2}}{\sqrt{\frac{n_1 \cdot n_2 (n_1 + n_2 + 1)}{12}}}$$

5. Z has an approximately standard normal distribution. Therefore the null hypothesis that two programs have the same distribution of efficiency scores will be rejected at a level of significance α if $Z \leqq -Z_{\alpha/2}$ or $Z \geqq Z_{\alpha/2}$, where $Z_{\alpha/2}$ denotes the upper $\alpha/2$ percentile of the standard normal distribution.

SPSS computer program reports the normal approximation to the U statistic and the p-values for a two-sided test. For details, see Sheskin (1997). In this research, the Mann-Whitney rank test analysis will be applied to compare the difference of productivity change between two business strategies, launching a new business model and filing a lawsuit against piracy, in the music industry.

3. Data

3.1 Events selection

This research investigates the impacts which are made by different operational strategies and environmental change on music industry in the last decade. The change of environment and operational strategies which are practiced by music companies can be discussed in three dimensions, the new digital technologies, lawsuit strategies, and the business model innovation, respectively. These dimensions, furthermore, can be divided into several milestones in the last decade: MP3 music compression technology, Napster's P2P file-sharing system, lawsuits against Napster, and the Apple's iPod plus iTunes business model for legal online music purchasing. Figure 8 shows the time-span and milestones of operational strategy evolution in music industry last decade.

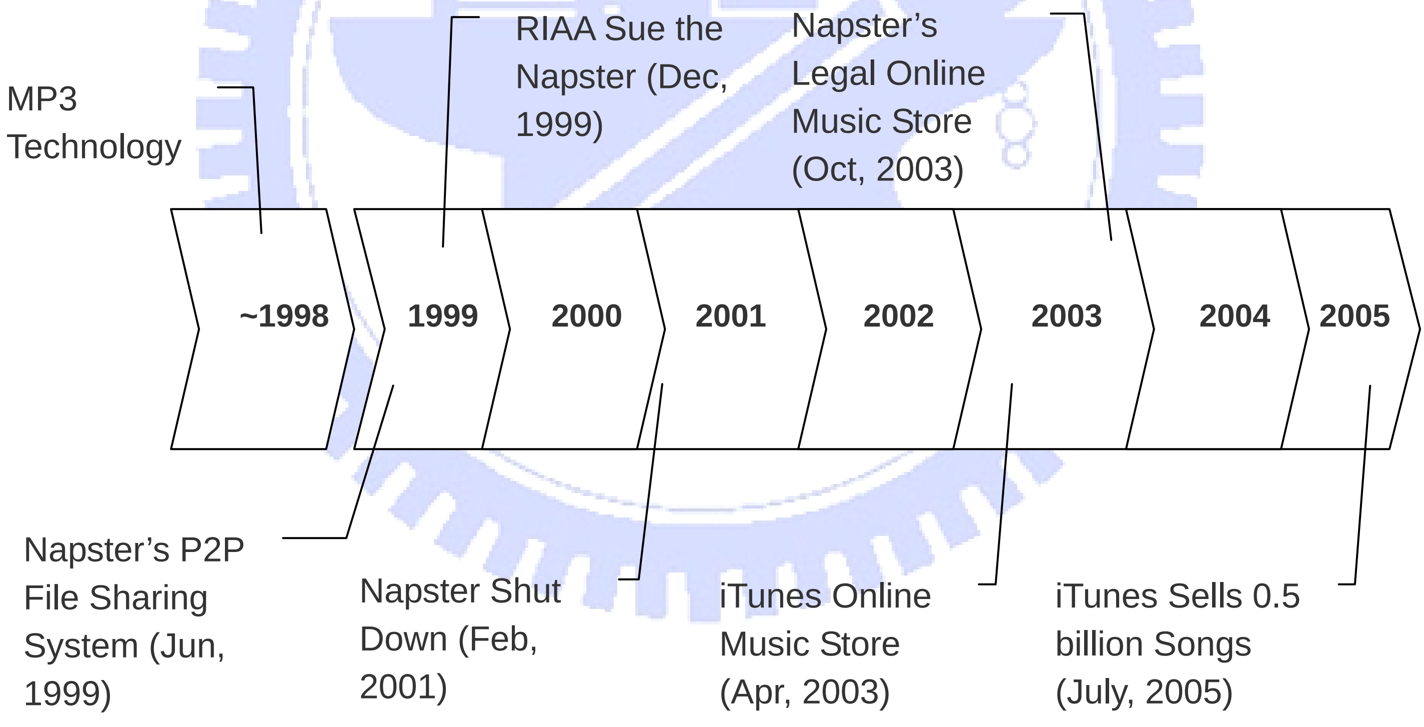


Figure 8 Sequence of Music Industry Related Events

Hence, three prominent environmental or strategic events periods are examined in our research: development of MP3 and P2P technologies, RIAA filing lawsuits against Napster for copyright infringement, and the opening of

Apple’s iTunes Online Music Store respectively. These events periods are expected to influence the effectiveness of music industry. According to the earliest release of music-industry-related news in the Wall Street Journal, the New York Times, RIAA Press releases, CBS News.com, CNET News.com, CNN.com, Apple's PR website, and Apple Chief Financial Office Release, events are selected to inspect their influences on the music industry.

Table 2 is the summary of major events involving music industry from June 1999 to July 2005 selected after examining the previous news. These events including: the opening of Napster, RIAA sue the Napster for the copyright violation, the judgment on Napster was determined, the opening of Apple’s iTunes Online Music Store, and the 0.5 billion songs was sold via the iTunes. Table 2 also classifies these events into positive and negative events for the performance of music industry. According to the hint which previous studies (Navissi et al., 2004; Asvanund et al, 2004; Kimand and Mauborgne, 2004) have dropped to us that creating an effective business model may do much more than filing a lawsuit, all of these events except the opening of Napster are positive effects upon the performance of music industry in our hypotheses. And operating a brand-new business model is hypothesized to do much more impact, than filing a lawsuit against piracy, on the productivity of music industry.

Table 2 Summary of Major Events Involving Music Industry

Event	Influence on Music Industry	Published Date	News Summary	News Source
Napster is available on the internet	Negative	June, 1999	Shawn Fanning, 18, creates the Napster application and service while a freshman at Northeastern University. London programmer Ian Clarke completes the original Freenet design as a student at Edinburgh University, Scotland, and makes it available on the Internet.	RIAA Press Release
RIAA sues Napster for copyright infringement	Positive	December 7, 1999	RIAA said on Tuesday (December 7, 1999) it has filed a lawsuit against the makers of the MP3-trading program Napster, accusing them of "operating a haven for music piracy on an unprecedented scale."	• CNET News.com Online • RIAA Press Release
Napster shut down	Positive	February 12, 2001	The 9th U.S. Circuit Court of Appeals rules that Napster knew its users were violating copyright laws through its music file-sharing service, but the court allowed the Web site to stay in business until a lower court redrafts its injunction. The three-judge panel specifically cited a memo drafted by Napster's co-founder Sean Parker as evidence the Web site knew its users were violating copyright laws. In that memo, the court said, Parker said the company needed to remain ignorant about the "real names" of the users because "they are exchanging pirated music." For that reason, the court found that Napster was involved in "contributory and vicarious infringement," and had full knowledge that it was allowing its users to infringe upon copyright laws.	• Wall Street Journal Online • CNN.com online

Table 2 Summary of Major Events Involving Music Industry (continue)

Event	Influence on Music Industry	Published Date	News Summary	News Source
Napster pay a settlement fee	Positive	September 24, 2001	To settle a lawsuit, Napster strikes a deal with the National Music Publishers' Association to pay $26 million for past unauthorized use of music and $10 million down payment on future royalties.	CBS News.com
Apple's Online Music Store for iTunes	Positive	April 28, 2003	Apple launches the iTunes Music Store, a revolutionary online music store that lets customers quickly find, purchase and download the music they want for just 99 cents per song, without subscription fees. Moreover, the iTunes Music Store features over 200,000 songs from music companies including BMG, EMI, Sony Music Entertainment, Universal and Warner.	Apple's PR website
iTune sell 0.5 billion songs	Positive	July 22, 2005	Apple's iTunes store has just hit the 500,000,000 download mark (in only 19 countries). The iTunes Music Store continues to be the world's leading online music service. It operates in 19 countries which represents about 70% of the global music business.	• CNET News.com Online • Apple Chief Financial Office Release

3.2 Sample selection

This research analyzes the performance changes of the music industry in a worldwide point of view from years 1997 to 2005. In our sample, there are 51 companies operating different activities in the music industry, such as music publishing, music retailing, music distribution and music production. A music publisher is an agent, who deals in the marketing of songs; a music distributor, or music retailer, is a channel disseminating music in a physical or virtual way; a music producer is an organization who manufactures licensed music copies.

These music firms are identified from Edgar Scan, Standard & Poor's Compustat, and Datastream databases. And these firms are predominantly from the SIC codes 3652 (Media—Music Production and Publishing) and 5735 (Specialty Retail — Music, Video, Books & Entertainment — Record & Pre-recorded Tape Stores). Moreover, based on the previous article (Navissi et al., 2005) and the MSN Finance.com, the music firms can be divided into three sub-industries further, the music retailing, publishing, and production industry respectively. A list of sample firms and sampling period of firms are reported in Appendix 1 and Appendix2 respectively.

3.3 Variables Selection

This research examines the productivity change in music industry from 1997 to 2005 by means of Data Envelopment Analysis (DEA) methodology, which is a linear programming based technique for measuring the relative performance with respect to a production frontier. As the review of literatures has already mentioned, one of the advantages of the DEA technique is that DEA method do not have to determine an explicit definition of the production function. Thus, DEA does not go deeply into the transformation of inputs into outputs, constituting itself as a "black box" model and focusing on the problem of specification in the selection of inputs and outputs. This non-parametric efficiency production function concept is portrayed in Figure 9, and this figure also shows the relationship of inputs, outputs and exogenously fixed variables in our research.

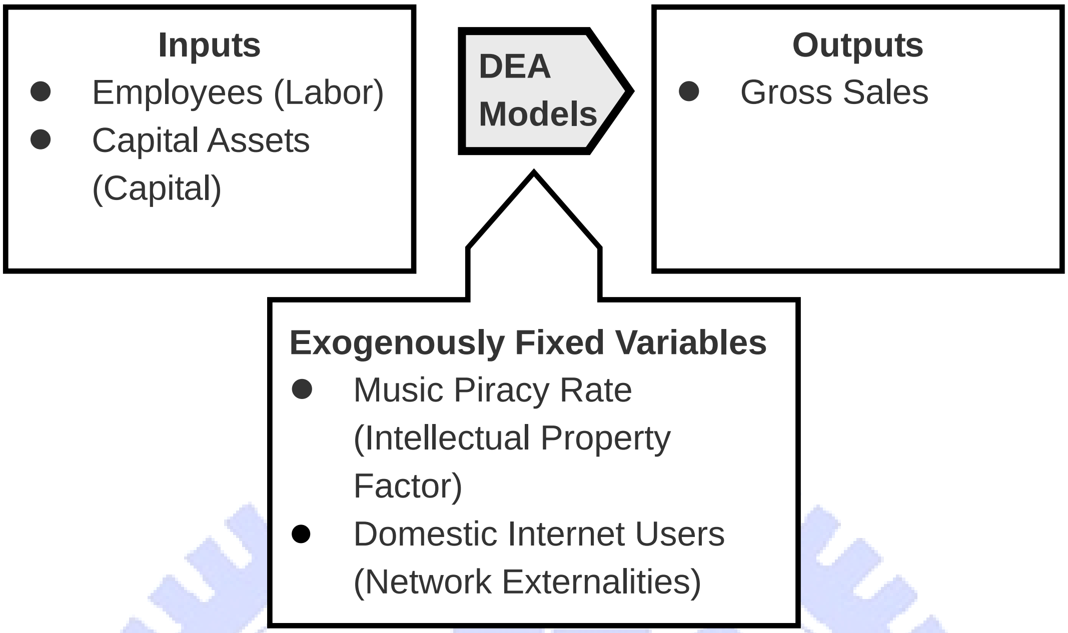


Figure 9 Production Function of Sales in Music Industry

The calculations in our DEA models are based upon two inputs (i) Employees (thousands people), (ii) Capital Assets (Millions of dollars); one outputs (i) Gross Sales (Millions of dollars); and two exogenously fixed variables (i) Music Piracy Rate (%), (ii) Domestic Internet Users (per hundred inhabits). The number of employees represents the labor input level of a music company, likewise the capital assets reveals the valuation of tangible fixed property as the capital input level of a music company. These two inputs, reflecting the labor and capital levels, portray the basic economical productivity function. The gross sales represents the gross income received from all divisions of a company, therefore this item is regarded as an output variable in our model. In addition, according to the previous literatures about the economics of network (Katz and Shapiro, 1985), the network externalities will change the utilities of users and provide value to them. Hence the influences of externality factors are considered as an important attribute of the online music selling in our research. The music piracy rates and internet populations are included in our DEA model as exogenously-fixed variables consequently.

The basic financial data of music firms, such as employees, capital assets, and gross sales, are collected from Standard & Poor's Compustat database. Furthermore, the exogenously-fixed variables, the music piracy rates and the internet populations, are gathered from the International Telecommunication Union (ITU) and International Intellectual Property Alliance (IIPA) websites respectively. Input and output variables in our DEA models are as tabled below.

Table 3 Input and Output Variables in the DEA Models

Variables	Units	Definition
Inputs		
Employees	thousands people	This item represents the number of company workers as reported to shareholders.
Capital Assets	Millions of dollars	This item represents the valuation of tangible fixed property used in the production of revenue.
Outputs		
Gross Sales	Millions of dollars	This item represents the gross income received from all divisions of the company.
Exogenously Fixed Variables		
Music Piracy Rate	%	This item represents the illegal music trading level in the domestic country which the company is located.
Domestic Internet Users	per 100 inhabits	This item represents the internet population in the domestic country which the company is located.

Figure 10 shows the variation of exogenously fixed variables, music piracy rate and domestic internet user, in our sampling time-span, from 1997 to 2005. The internet facilities all around the world were not well constructed until 1997, and therefore it is hard to collect data of internet population in every country before 1997. This restriction makes the time-span in our DEA model shorten, from 1997 to 2005, consequently. However this change will do no influence on the result nor the conclusion in our research at all since all events which we are interested in were happening after 1998.

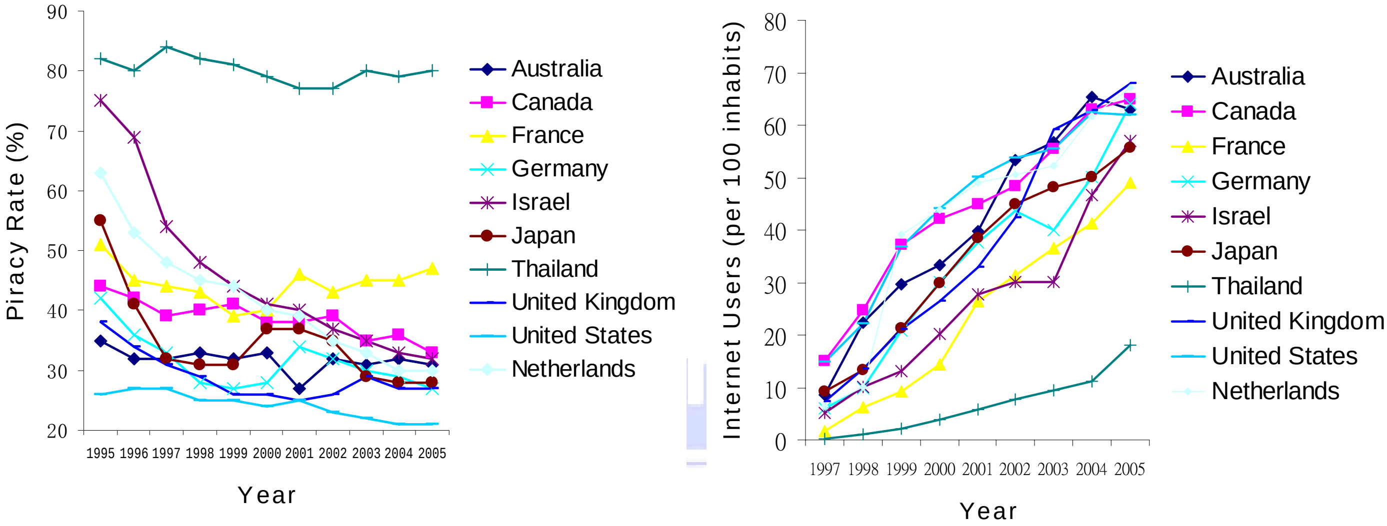


Figure 10 Change of Exogenously Fixed Variables from 1995 to 2005

The DEA technique presumes the existence of an "isotonicity" relationship (Golany et al., 1989), which means an increase in any input should not result in a decrease in any output, among inputs and outputs data. Moreover, a weak relation to inputs and strong relation to outputs indicates a preference towards classifying such factor as and input, while a reversed outcome will point towards viewing such factor as and output. A correlation analysis is therefore performed in Table 4. The correlation coefficients between the selected one output and two input factors are positive, and simultaneously show highly correlation each other in the DEA model. These input and output factors, which were chosen herein, hold an "isotonicity" relationship, and therefore they can be applied to analyze production efficiency within one DEA model. Thus we employed two inputs and one outputs, two exogenous factors in addition, for DEA model. According to Golany et al. (1989), the number of DMUs should be at least twice the total number of factors considered when using the DEA model. In this study numbers of DMUs each year are greater than 24 firms, at least twice the selected five factors for the DEA model. We hence conclude that the developed DEA model holds high construct validity.

Table 4 Correlation Analysis of Inputs and Outputs in DEA Models

Correlation Matrix	Piracy Rate (E)	Internet Users (E)	Sales (O)	Employees (I)	Capital Assets (I)
Piracy Rate (E)	1	-0.469	0.199	0.192	0.163
Internet Users (E)	-0.469	1	-0.125	-0.178	-0.136
Sales (O)	0.199	-0.125	1	0.836	0.867
Employees (I)	0.192	-0.178	0.836	1	0.863
Capital Assets (I)	0.163	-0.136	0.867	0.863	1

Furthermore according to the 99.5 per cent confidence interval, the outliers in the sample, which may decrease the accuracy of DEA scores, can be identified and delete them from the sampling data. The final result of sample firm selection is list on Appendix 2.

4. Hypotheses and Methodology

4.1 Hypotheses

Since the MP3 formate and the P2P file-sharing were invented during the last decade of twenty centry, consumers can download “free” digital music copies on personal computers and special MP3 devices. This illegal digital music files downloading behavior had become much more serious and made a harsh impact on the economy. In order to deterred the behavior of music piracy and reduced the economic loss by music downloading, the media groups did several actions, such as lawsuits, selling authorized online music, and alliance with another industries, last seven years (Molteni and Ordanini, 2003). One of the best-known anti-piracy strategies was the Recording Industry Association of America (RIAA) filing a federal lawsuit against Napster for copyright infringement in December 1999. The most recent strategy adopted by copyright holders of bringing legal action against violators may be more successful, even though the proportion of users who are targeted is a small fraction of the total number of users. Another anti-piracy strategy launched by the media groups and copyright holders recently is forging an alliance with the other industries, such as hardware producers, distribution channels, and internet companies, to “transform” the illegal downloading into authorized content trading. The iPod-plus-iTunes Music Store, which was the outcome of the cooperation between the five major media conglomerates and the Apple Computer, set a milestone of authorized music downloading services. Because the price of the legal music downloading via iTunes was reasonable, the growth of sell in such music downloading service was quite startling.

According to these stories, this research analyzes the Malmquist productivity indices, which represent the productivity change over two years, with DEA method and hypothesizes that all of these music related events are positive effects upon the performance of music industry except the invention of MP3 and Napster P2P file-sharing service. If an event stimulates productivity progress of music firms, the value of DEA Malmquist productivity indices display more than one; if an event injures the productivity of music firms, the DEA Malmquist productivity indices display less than one. The hypotheses of this study are listed below.

H1: The copyright-protection-lacking digital music technologies, such as MP3 and P2P, are negative related to the productivity of music firms.

H2: Filing a lawsuit against piracy makes a positive impact on the productivity of music firms.

H3: Launching a brand-new business model is positive related to the productivity of music firms.

Furthermore previous studies (Navissi et al., 2004; Asvanund et al, 2004; Kim and Mauborgne, 2004) hinted us that creating an effective business model may do much more than filing a lawsuit. Therefore in our hypothesis operating a brand-new business model is hypothesized to do much more impact, than filing a lawsuit against piracy, productivity. A Mann-Whitney test is employed to compare the intensity of productivity change between these two anti-piracy strategies.

H4: Launching a new business model do more impact on the productivity than filing a lawsuit against piracy.

4.2 Methodology

4.2.1 Malmquist Indices in Exogenous-Variables Concerned CCR Input-Oriented Model

The objective of this research is to investigate the impacts which are made by the new digital technologies, lawsuit strategies and the business model innovation on the performance and efficiency of the global music industry, and makes a comparison of the effectiveness between different strategies which intrinsic music firms play when the environment is changed. Moreover, the methodology of Malmquist indices can present the cross-period productivity change. As a result, the Malmquist indices method would be applied to inspect the cross-period productivity change of the music industry in our research. These indices would help us to evaluate the effects of different competitive strategies on the performance of the music industry from 1997 to 2005. In our sample, there are 51 companies operating different activities in the music industry, such as music publishing, music retailing, music distribution and music production.

The calculations of Malmquist indices are based upon two inputs (i) Employees (thousands people), (ii) Capital Assets (Millions of dollars); one outputs (i) Gross Sales (Millions of dollars); and two exogenously fixed variables (i) Music Piracy Rate (%), (ii) Domestic Internet Users (per hundred inhabits). In addition, cause the input variables, employees, capital assets, domestic piracy rate, and internet population, in our sample data can be divided into two categories, under managerial control and exogenously fixed, this research will adapt the CCR input-orient model, which is modified by exogenously fixed inputs, to construct the Malmquist indices and inspect the productivity movement between two periods. The models and steps to construct the modified Malmquist indices are shown below:

Suppose there are n DMUs, each DMU_k (k =1,2…,n) produces a vector of outputs $y_k^t = (y_{1k}^t \ldots y_{sk}^t)$ by using a vector of inputs $x_k^t = (x_{1k}^t \ldots x_{mk}^t)$ at each time period t, t=1,…,T.

(i) Firstly compare x_k^t to empirical production frontier (EPF) at time t, and calculate $\Theta_1 = \theta_k^t(x_k^t, y_k^t)$ by the CCR exogenously-modified model (Banker and Morey, 1986),:

$$\Theta_1 = \theta_k^t(x_k^t, y_k^t) = \min_{\theta_k, \lambda_j} \quad \theta_k$$

$$\begin{aligned} \text{subject to} \quad & \sum_{j=1}^{n} x_{ij}^t \lambda_j \le \theta_k x_{ik}^t, \quad i \in \{D\} \text{ (under managerial control)} \\ & \sum_{j=1}^{n} x_{ij}^t \lambda_j \le \sum_{j=1}^{n} \lambda_j x_{ik}^t, \quad i \notin \{D\} \text{ (exogenously fixed)} \\ & \sum_{j=1}^{n} y_{rj}^t \lambda_j \ge y_{rk}^t, \quad r = 1, \ldots, s \\ & \lambda_j \ge 0, \quad j = 1, \ldots, n \end{aligned} \tag{1}$$

(ii) Secondly compare x_k^{t+1} to EPF at time t+1, and calculate the technical efficiency for DMU k at the time period t+1,$\Theta_4 = \theta_k^{t+1}(x_k^{t+1}, y_k^{t+1})$;

$$\Theta_4 = \theta_k^{t+1}(x_k^{t+1}, y_k^{t+1}) = \min_{\theta_k, \lambda_j} \quad \theta_k$$

$$\begin{aligned} \text{subject to} \quad & \sum_{j=1}^{n} x_{ij}^{t+1} \lambda_j \le \theta_k x_{ik}^{t+1}, \quad i \in \{D\} \text{ (under managerial control)} \\ & \sum_{j=1}^{n} x_{ij}^{t+1} \lambda_j \le \sum_{j=1}^{n} \lambda_j x_{ik}^{t+1}, \quad i \notin \{D\} \text{ (exogenously fixed)} \\ & \sum_{j=1}^{n} y_{rj}^{t+1} \lambda_j \ge y_{rk}^{t+1}, \quad r = 1, \ldots, s \\ & \lambda_j \ge 0, \quad j = 1, \ldots, n \end{aligned} \tag{2}$$

(iii) Next, comparing x_j^t to EPF at time t+1, that is, calculating Θ_2 = $\theta_k^{t+1}(x_k^t, y_k^t)$ through the following linear program: (3)

$$\Theta_2 = \theta_k^{t+1}(x_k^t, y_k^t) = \min_{\theta_k, \lambda_j} \quad \theta_k$$

$$\begin{aligned}
\text{subject to} \quad & \sum_{j=1}^{n} x_{ij}^{t+1}\lambda_j + \lambda_{n+1}x_{ik}^t \le \theta_k x_{ik}^t, \quad i \in \{D\} \quad \text{(under managerial control)} \\
& \sum_{j=1}^{n} x_{ij}^{t+1}\lambda_j + \lambda_{n+1}x_{ik}^t \le \sum_{j=1}^{n} \lambda_j x_{ik}^t, \quad i \notin \{D\} \quad \text{(exogenously fixed)} \\
& \sum_{j=1}^{n} y_{rj}^{t+1}\lambda_j + \lambda_{n+1}y_{rk}^t \ge y_{rk}^t, \quad r = 1,\ldots,s \\
& \lambda_j \ge 0, \quad j = 1,\ldots,n+1
\end{aligned}$$

(v) Finally, comparing x_j^{t+1} to EPF at time t, namely, calculating Θ_3= $\theta_k^t(x_k^{t+1}, y_k^{t+1})$ through the following linear program: (4)

$$\Theta_3 = \theta_k^t(x_k^{t+1}, y_k^{t+1}) = \min_{\theta_k, \lambda_j} \quad \theta_k$$

$$\begin{aligned}
\text{subject to} \quad & \sum_{j=1}^{n} x_{ij}^t\lambda_j + \lambda_{n+1}x_{ik}^{t+1} \le \theta_k x_{ik}^{t+1}, \quad i \in \{D\} \quad \text{(under managerial control)} \\
& \sum_{j=1}^{n} x_{ij}^t\lambda_j + \lambda_{n+1}x_{ik}^{t+1} \le \sum_{j=1}^{n} \lambda_j x_{ik}^{t+1}, \quad i \notin \{D\} \quad \text{(exogenously fixed)} \\
& \sum_{j=1}^{n} y_{rj}^t\lambda_j + \lambda_{n+1}y_{rk}^{t+1} \ge y_{rk}^{t+1}, \quad r = 1,\ldots,s \\
& \lambda_j \ge 0, \quad j = 1,\ldots,n+1
\end{aligned}$$

The Malmquist productivity index (MPI) can be defined and decomposed into two components (Caves et al., 1982; Färe et al., 1992), the technical efficiency change and the frontier shift, as below.

$$\begin{aligned}
MPI_k &= \left[\frac{\theta_k^t(x_k^t, y_k^t) \times \theta_k^{t+1}(x_k^t, y_k^t)}{\theta_k^t(x_k^{t+1}, y_k^{t+1}) \times \theta_k^{t+1}(x_k^{t+1}, y_k^{t+1})}\right]^{1/2} \\
&= \frac{\theta_k^{t+1}(x_k^{t+1}, y_k^{t+1})}{\theta_k^t(x_k^t, y_k^t)}\left[\frac{\theta_k^t(x_k^{t+1}, y_k^{t+1}) \times \theta_k^t(x_k^t, y_k^t)}{\theta_k^{t+1}(x_k^{t+1}, y_k^{t+1}) \times \theta_k^{t+1}(x_k^t, y_k^t)}\right]^{1/2} \\
&= \frac{\Theta_4}{\Theta_1}\left[\frac{\Theta_3 \times \Theta_1}{\Theta_4 \times \Theta_2}\right]^{1/2} \\
&= TEC_k \times FS_k
\end{aligned} \qquad (5)$$

MPI_k measures the productivity change between periods t and t+1. Färe et al. (1992) define that $MPI_k > 1$ indicates productivity gain; $MPI_k < 1$ indicates productivity loss; and $MPI_k = 1$ means no change in productivity from time t to t+1. Furthermore, Färe et al. (1992) decompose Malmquist productivity index into two components, technical efficiency change (TEC_k) and frontier shift (FS_k), which represent the improvement or deterioration of DMUs and efficiency frontier separately.

The first component $TEC_k = \Theta_4/\Theta_1$ is used to measure the change in technical efficiency; on the other hand, it is a measure of how much closer to the boundary the company is in period t+1 compared to period t. If TEC_k is one, the particular DMU k (maybe a company) has the same distance in periods t+1 and t from the respective efficient boundaries. If TEC_k is over one, the company has moved closer to the period t+1 boundary than it was to the period t boundary and the converse is the care if the TEC_k is under one.

As for the second component $FS_k = [\frac{\Theta_3 \times \Theta_1}{\Theta_4 \times \Theta_2}]^{1/2}$, it measures the technology frontier shift between time period t and t+1. Färe et al. (1992,1994a) point out that a value of FS_k greater than one indicates a positive shift or technical progress, a value of FS_k less than one indicates a negative shift or technical regress, and value of FS_k equal to one indicates no shift in technology frontier.

4.2.2 Tobit Regressions

The Malmquist indices, such as MPI, TEC, and FS, represent the change of productivity of decision make units, and the observations are censored at zero as these variables are ratios of two positive efficiency variables. Thus the Tobit regression models are used to perform the relationships for limited dependent variables, the Malmquist indices of music firms, with independent variables, such as input changes, output changes, exogenous variable changes, and dummy variables, in order to identify the key variables which influence the productivity change of music industry. The Malmquist indices, MPI, TEC, and FS respectively, are set as the dependent variables in (6), and are censored to zero in the Tobit models; the change of attributes, such as piracy rate change, number of internet users change, sales change, number of employees change, and the change of fixed assets, between two years are set to be the independent variables of the Tobit models. Results of these Tobit models will illustrate that how the business strategies affect the productivity changes of music industry through the internal variables and exogenous variables changes, and fertilize the results of Malmquist indices analysis with two stages evidences.

$$Y_{jt} = \begin{cases} \alpha + \beta_1 PC_{jt} + \beta_2 IUC_{jt} + \beta_3 SC_{jt} + \beta_4 EC_{jt} + \beta_5 CC_{jt} + \varepsilon_{jt} & \text{, if } Y_j > 0 \\ 0 & \text{, if } Y_j \leq 0 \end{cases} \qquad (6)$$

where

Y_{jt} : dependent variable. Dependent variables are set to the TEC, FS, and MPI of the DEA Malmquist Indices in jth firm, respectively.

PC_{jt} : piracy change in jth firm between period t to t+1.

IUC_{jt} : number of internet user change in jth firm between period t to t+1.

SC_{jt} : sales change in jth firm between period t to t+1.

EC_{jt} : number of employees change in jth firm between period t to t+1.

CC_{jt} : capital change in jth firm between period t to t+1.

α : an intercept coefficient.

β_k : slope of kth independent variable, for k= 1,…,5.

ε_{jt} : the error terms which are assumed to be a normal distribution with mean zero and variance σ^2.

t : sampling period, from year 1997 to year 2005.

The Tobit models, considered dummy variables in addition, are made use of testing the hypotheses one to hypotheses three, listed in chapter 4.1, in our research further. Dummy variables, D_i, in these Tobit models are symbolized different business strategies of the music industry; while i=1 represents the events of filing lawsuits; i=2 represents the appearance of Apple's Online Music Store; and i=3 represents the influence of the MP3 and P2P technology. Results of these Tobit models will test the affection of the business strategies on the productivity changes of music industry, and improve the conclusions making by Malmquist analysis with two stages evidences as well. Model (7) to model (9) represents the relationship between independent variables, dummy variables and the MPI of music firms.

$$MPI_{jt} = \begin{cases} \alpha + \beta_1 PC_{jt} + \beta_2 IUC_{jt} + \beta_3 SC_{jt} + \beta_4 EC_{jt} + \beta_5 CC_{jt} + \gamma_1 D_{1jt} + \varepsilon_{jt} & \text{,if } Y_j > 0 \\ 0 & \text{, if } Y_j \leq 0 \end{cases} \qquad (7)$$

Where

MPI_{jt} : dependent variable. MPI of the DEA Malmquist Indices in jth firm.

PC_{jt} : piracy change in jth firm between period t to t+1.

IUC_{jt} : number of internet user change in jth firm between period t to t+1.
SC_{jt} : sales change in jth firm between period t to t+1.
EC_{jt} : number of employees change in jth firm between period t to t+1.
CC_{jt} : capital change in jth firm between period t to t+1.
D_{1jt} : dummy variable in the multi-regression model. D_1 represents the events of filing lawsuits, event occurred during year 2000 to year 2002. $\begin{cases} D_{1jt} = 1 \text{, if } t=2000, 2001, 2002 \\ D_{1jt} = 0 \text{, otherwise} \end{cases}$
α : an intercept coefficient.
β_k : slope of kth independent variable, for k= 1,…,5.
ε_{jt} : the error terms which are assumed to be a normal distribution with mean zero and variance σ^2.
t : sampling period, from year 1997 to year 2005.

$$MPI_{jt} = \begin{cases} \alpha + \beta_1 PC_{jt} + \beta_2 IUC_{jt} + \beta_3 SC_{jt} + \beta_4 EC_{jt} + \beta_5 CC_{jt} + \gamma_2 D_{2jt} + \varepsilon_{jt} & \text{,if } Y_j > 0 \\ 0 & \text{, if } Y_j \leq 0 \end{cases} \quad (8)$$

Where
MPI_{jt} : dependent variable. MPI of the DEA Malmquist Indices in jth firm.
PC_{jt} : piracy change in jth firm between period t to t+1.
IUC_{jt} : number of internet user change in jth firm between period t to t+1.
SC_{jt} : sales change in jth firm between period t to t+1.
EC_{jt} : number of employees change in jth firm between period t to t+1.
CC_{jt} : capital change in jth firm between period t to t+1.
D_{2jt} : dummy variable in the multi-regression model. D_2 represents the event period of Apple's Online Music Store, event occurred during year 2003 to year 2005. $\begin{cases} D_{2jt} = 1 \text{, if } t=2003, 2004, 2005 \\ D_{2jt} = 0 \text{, otherwise} \end{cases}$
α : an intercept coefficient.
β_k : slope of kth independent variable, for k= 1,…,5.
ε_{jt} : the error terms which are assumed to be a normal distribution with mean zero and variance σ^2.
t : sampling period, from year 1997 to year 2005.

$$MPI_{jt} = \begin{cases} \alpha + \beta_1 PC_{jt} + \beta_2 IUC_{jt} + \beta_3 SC_{jt} + \beta_4 EC_{jt} + \beta_5 CC_{jt} + \gamma_3 D_{3jt} + \varepsilon_{jt} & \text{,if } Y_j > 0 \\ 0 & \text{, if } Y_j \leq 0 \end{cases} \quad (9)$$

Where
MPI_{jt} : dependent variable. MPI of the DEA Malmquist Indices in jth firm.
PC_{jt} : piracy change in jth firm between period t to t+1.

IUC_{jt} : number of internet user change in jth firm between period t to t+1.
SC_{jt} : sales change in jth firm between period t to t+1.
EC_{jt} : number of employees change in jth firm between period t to t+1.
CC_{jt} : capital change in jth firm between period t to t+1.
D_{3jt} : dummy variable in the multi-regression model. D_3 represents the event period of Apple's Online Music Store, event occurred during year 1997 to year 1999. $\begin{cases} D_{3jt} = 1 \text{, if } t=1997, 1998, 1999 \\ D_{3jt} = 0 \text{, otherwise} \end{cases}$
α : an intercept coefficient.
β_k : slope of kth independent variable, for k= 1,…,5.
ε_{jt} : the error terms which are assumed to be a normal distribution with mean zero and variance σ^2.
t : sampling period, from year 1997 to year 2005.

Model (10) to model (12) represents the relationship between independent variables, dummy variables and the TEC of music firms.

$$\text{TEC}_{jt} = \begin{cases} \alpha + \beta_1 PC_{jt} + \beta_2 IUC_{jt} + \beta_3 SC_{jt} + \beta_4 EC_{jt} + \beta_5 CC_{jt} + \gamma_1 D_{1jt} + \varepsilon_{jt} & \text{,if } Y_j > 0 \\ 0 & \text{, if } Y_j \le 0 \end{cases} \quad (10)$$

Where
TEC_{jt} : dependent variable. TEC of the DEA Malmquist Indices in jth firm.
PC_{jt} : piracy change in jth firm between period t to t+1.
IUC_{jt} : number of internet user change in jth firm between period t to t+1.
SC_{jt} : sales change in jth firm between period t to t+1.
EC_{jt} : number of employees change in jth firm between period t to t+1.
CC_{jt} : capital change in jth firm between period t to t+1.
D_{1jt} : dummy variable in the multi-regression model. D_1 represents the events of filing lawsuits, event occurred during year 2000 to year 2002. $\begin{cases} D_{1jt} = 1 \text{, if } t=2000, 2001, 2002 \\ D_{1jt} = 0 \text{, otherwise} \end{cases}$
α : an intercept coefficient.
β_k : slope of kth independent variable, for k= 1,…,5.
ε_{jt} : the error terms which are assumed to be a normal distribution with mean zero and variance σ^2.
t : sampling period, from year 1997 to year 2005.

$$\text{TEC}_{jt} = \begin{cases} \alpha + \beta_1 PC_{jt} + \beta_2 IUC_{jt} + \beta_3 SC_{jt} + \beta_4 EC_{jt} + \beta_5 CC_{jt} + \gamma_2 D_{2jt} + \varepsilon_{jt} & \text{,if } Y_j > 0 \\ 0 & \text{, if } Y_j \le 0 \end{cases} \quad (11)$$

Where

TEC_{jt} : dependent variable. MPI of the DEA Malmquist Indices in jth firm.

PC_{jt} : piracy change in jth firm between period t to t+1.

IUC_{jt} : number of internet user change in jth firm between period t to t+1.

SC_{jt} : sales change in jth firm between period t to t+1.

EC_{jt} : number of employees change in jth firm between period t to t+1.

CC_{jt} : capital change in jth firm between period t to t+1.

D_{2jt} : dummy variable in the multi-regression model. D_2 represents the event period of Apple's Online Music Store, event occurred during year 2003 to year 2005. $\begin{cases} D_{2jt} = 1 \text{ , if } t=2003, 2004, 2005 \\ D_{2jt} = 0 \text{ , otherwise} \end{cases}$

α : an intercept coefficient.

β_k : slope of kth independent variable, for k= 1,…,5.

ε_{jt} : the error terms which are assumed to be a normal distribution with mean zero and variance σ^2.

t : sampling period, from year 1997 to year 2005.

$$TEC_{jt} = \begin{cases} \alpha + \beta_1 PC_{jt} + \beta_2 IUC_{jt} + \beta_3 SC_{jt} + \beta_4 EC_{jt} + \beta_5 CC_{jt} + \gamma_3 D_{3jt} + \varepsilon_{jt} & \text{,if } Y_j > 0 \\ 0 & \text{, if } Y_j \le 0 \end{cases} \quad (12)$$

Where

TEC_{jt} : dependent variable. MPI of the DEA Malmquist Indices in jth firm.

PC_{jt} : piracy change in jth firm between period t to t+1.

IUC_{jt} : number of internet user change in jth firm between period t to t+1.

SC_{jt} : sales change in jth firm between period t to t+1.

EC_{jt} : number of employees change in jth firm between period t to t+1.

CC_{jt} : capital change in jth firm between period t to t+1.

D_{3jt} : dummy variable in the multi-regression model. D_3 represents the event period of Apple's Online Music Store, event occurred during year 1997 to year 1999. $\begin{cases} D_{3jt} = 1 \text{ , if } t=1997, 1998, 1999 \\ D_{3jt} = 0 \text{ , otherwise} \end{cases}$

α : an intercept coefficient.

β_k : slope of kth independent variable, for k= 1,…,5.

ε_{jt} : the error terms which are assumed to be a normal distribution with mean zero and variance σ^2.

t : sampling period, from year 1997 to year 2005.

Model (13) to model (15) represents the relationship between independent variables, dummy variables and the FS of music firms.

$$FS_{jt} = \begin{cases} \alpha + \beta_1 PC_{jt} + \beta_2 IUC_{jt} + \beta_3 SC_{jt} + \beta_4 EC_{jt} + \beta_5 CC_{jt} + \gamma_1 D_{1jt} + \varepsilon_{jt} & ,\text{if } Y_j > 0 \\ 0 & ,\text{if } Y_j \le 0 \end{cases} \quad (13)$$

Where

FS_{jt} : dependent variable. TEC of the DEA Malmquist Indices in jth firm.

PC_{jt} : piracy change in jth firm between period t to t+1.

IUC_{jt} : number of internet user change in jth firm between period t to t+1.

SC_{jt} : sales change in jth firm between period t to t+1.

EC_{jt} : number of employees change in jth firm between period t to t+1.

CC_{jt} : capital change in jth firm between period t to t+1.

D_{1jt} : dummy variable in the multi-regression model. D_1 represents the events of filing lawsuits, event occurred during year 2000 to year 2002.
$\begin{cases} D_{1jt} = 1 & ,\text{ if } t=2000, 2001, 2002 \\ D_{1jt} = 0 & ,\text{ otherwise} \end{cases}$

α : an intercept coefficient.

β_k : slope of kth independent variable, for k= 1,…,5.

ε_{jt} : the error terms which are assumed to be a normal distribution with mean zero and variance σ^2.

t : sampling period, from year 1997 to year 2005.

$$FS_{jt} = \begin{cases} \alpha + \beta_1 PC_{jt} + \beta_2 IUC_{jt} + \beta_3 SC_{jt} + \beta_4 EC_{jt} + \beta_5 CC_{jt} + \gamma_2 D_{2jt} + \varepsilon_{jt} & ,\text{if } Y_j > 0 \\ 0 & ,\text{if } Y_j \le 0 \end{cases} \quad (14)$$

Where

FS_{jt} : dependent variable. MPI of the DEA Malmquist Indices in jth firm.

PC_{jt} : piracy change in jth firm between period t to t+1.

IUC_{jt} : number of internet user change in jth firm between period t to t+1.

SC_{jt} : sales change in jth firm between period t to t+1.

EC_{jt} : number of employees change in jth firm between period t to t+1.

CC_{jt} : capital change in jth firm between period t to t+1.

D_{2jt} : dummy variable in the multi-regression model. D_2 represents the event period of Apple's Online Music Store, event occurred during year 2003 to year 2005. $\begin{cases} D_{2jt} = 1 & ,\text{ if } t=2003, 2004, 2005 \\ D_{2jt} = 0 & ,\text{ otherwise} \end{cases}$

α : an intercept coefficient.

β_k : slope of kth independent variable, for k= 1,…,5.

ε_{jt} : the error terms which are assumed to be a normal distribution with mean zero and variance σ^2.

t : sampling period, from year 1997 to year 2005.

$$FS_{jt} = \begin{cases} \alpha + \beta_1 PC_{jt} + \beta_2 IUC_{jt} + \beta_3 SC_{jt} + \beta_4 EC_{jt} + \beta_5 CC_{jt} + \gamma_3 D_{3jt} + \varepsilon_{jt} & \text{,if } Y_j > 0 \\ 0 & \text{, if } Y_j \leq 0 \end{cases} \quad (15)$$

Where

FS_{jt} : dependent variable. MPI of the DEA Malmquist Indices in jth firm.

PC_{jt} : piracy change in jth firm between period t to t+1.

IUC_{jt} : number of internet user change in jth firm between period t to t+1.

SC_{jt} : sales change in jth firm between period t to t+1.

EC_{jt} : number of employees change in jth firm between period t to t+1.

CC_{jt} : capital change in jth firm between period t to t+1.

D_{3jt} : dummy variable in the multi-regression model. D_3 represents the event period of Apple's Online Music Store, event occurred during year 1997 to year 1999. $\begin{cases} D_{3jt} = 1 \text{, if } t=1997, 1998, 1999 \\ D_{3jt} = 0 \text{, otherwise} \end{cases}$

α : an intercept coefficient.

β_k : slope of kth independent variable, for k= 1,…,5.

ε_{jt} : the error terms which are assumed to be a normal distribution with mean zero and variance σ^2.

t : sampling period, from year 1997 to year 2005.

For the easiness and user friendly functions, the tools of EViews computer program, version 3.0, are applied to compute the empirical results of Tobit models in this research.

4.2.3 Mann-Whitney Test

The Mann-Whitney rank test analysis, which test the hypothesis of launching a new business model do more impact on the productivity than filing a lawsuit against piracy, in this research is done as follows:

1. Ranking order all n DMUs by their Malmquist Productivity Indices in the DEA model. In case of a tie, use the mid-rank for the tied observations.
2. Compute R_1 = the sum of rankings of DMUs in the group which the lawsuits were taking place; R_2 = the sum of rankings of DMUs in the group which a new business model were performing.
3. Compute the Mann-Whitney rank test statistic:

$$U_1 = n_1 \cdot n_2 + \frac{n_1 \cdot (n_1 + 1)}{2} - R_1$$
$$U_2 = n_1 \cdot n_2 + \frac{n_2 \cdot (n_2 + 1)}{2} - R_2 \qquad (16)$$
$$U = Min(U_1, U_2)$$

The Mann-Whitney U statistic displayed in the table is the smaller of these two values.

4. For n_1, n_2 ≧ 10 compute the following statistic:

$$Z = \frac{U - \frac{n_1 \cdot n_2}{2}}{\sqrt{\frac{n_1 \cdot n_2 (n_1 + n_2 + 1)}{12}}} \qquad (17)$$

5. Z has an approximately standard normal distribution. Therefore the null hypothesis that two strategies have the same distribution of productivity change scores will be rejected at a level of significance α if $Z \leqq -Z_{\alpha/2}$ or $Z \geqq Z_{\alpha/2}$, where $Z_{\alpha/2}$ denotes the upperα/2 percentile of the standard normal distribution.
6. Similarly the single tail null hypothesis, launching a new business model do no more impact on the productivity than filing a lawsuit against piracy, will be rejected while the two tails hypothesis is rejected. The negative Z statistics indicate that the rank sums are lower than their expected values.

For simplifying the trivial ranking process, SPSS computer program are used to report the normal approximation to the U statistic and the p-values for a two-sided test in our research.

5. Empirical Results

5.1 Production Frontier Analysis

This research employs the proposed approach of Malmquist Indices in Exogenous-Variables Concerned CCR Input-Oriented Model (refer to chapter 4.2) to analyze the performance changes of the music industry in a worldwide point of view from years 1997 to 2005. In our sample, there are 51 companies operating different activities in the music industry, such as music publishing, music retailing, music distribution and music production. The calculations of Malmquist indices are based upon two inputs (i) Employees (thousands people), (ii) Capital Assets (Millions of dollars); one outputs (i) Gross Sales (Millions of dollars); and two exogenously fixed variables (i) Music Piracy Rate (%), (ii) Domestic Internet Users (per hundred inhabits). The sample statistics, which describe and summarize sample data, for every DEA variables are listed on Table 5 year by year from 1997 to 2005. Sample mean and mode behalf the centrality of data; standard error, kurtie, skewness, minimum and maximum value of data represent the shape of distribution.

Table 5 Sample Statistics in the DEA model from 1997 to 2005

		Piracy Rate(%)	Internet Users(per 100 inhabits)	Gross Sales(million dollars)	Employees(1,000 people)	Capital Assets(million dollars)
1997	Sample Mean	31.737	12.460	2119.309	11.469	606.198
	Standard Error	1.751	0.687	877.798	5.928	328.169
	Median	27.000	14.930	140.959	1.590	16.790
	Mode	27.000	14.930	-	-	-
	Kurtie	15.042	1.162	16.245	31.288	15.449
	Skewness	3.585	-1.498	3.804	5.431	4.033
	Min	27.000	0.250	0.004	0.014	0.012
	Max	84.000	15.000	28679.364	221.157	9146.653
	Confidence(99.5%)	5.228	2.050	2620.441	17.697	979.663

Table 5 Sample Statistics in the DEA model from 1997 to 2005(continue)

		Piracy Rate(%)	Internet Users(per 100 inhabits)	Gross Sales(million dollars)	Employees(1,000 people)	Capital Assets(million dollars)
1998	Sample Mean	28.756	19.488	1993.671	10.344	677.670
	Standard Error	1.557	0.843	948.938	5.855	397.328
	Median	25.000	22.200	80.919	0.701	18.925
	Mode	25.000	22.200	-	0.149	-
	Kurtie	20.960	2.702	23.733	34.715	22.799
	Skewness	4.266	-1.820	4.619	5.746	4.712
	Min	25.000	1.010	0.139	0.024	0.005
	Max	82.000	24.800	35362.583	235.610	14261.588
	Confidence(99.5%)	4.627	2.504	2819.456	17.395	1180.531
1999	Sample Mean	28.114	31.766	2216.630	10.883	790.817
	Standard Error	1.397	1.348	1078.890	6.373	492.938
	Median	25.000	36.700	131.463	0.648	20.271
	Mode	25.000	36.700	-	-	-
	Kurtie	25.574	2.110	27.916	37.975	30.359
	Skewness	4.735	-1.700	5.021	6.024	5.373
	Min	25.000	2.170	0.092	0.007	0.010
	Max	81.000	37.240	43879.020	275.591	20116.840
	Confidence(99.5%)	4.133	3.988	3192.605	18.858	1458.682
2000	Sample Mean	27.868	38.646	2489.098	12.059	918.501
	Standard Error	1.587	1.561	1155.751	6.864	552.199
	Median	24.000	44.060	182.491	0.925	25.480
	Mode	24.000	44.060	-	-	-
	Kurtie	20.680	3.935	19.973	30.492	22.428
	Skewness	4.188	-1.963	4.244	5.373	4.652
	Min	24.000	3.790	1.454	0.026	0.400
	Max	79.000	44.060	39239.586	253.286	18765.484
	Confidence(99.5%)	4.737	4.660	3450.199	20.491	1648.448

Table 5 Sample Statistics in the DEA model from 1997 to 2005(continue)

		Piracy Rate(%)	Internet Users(per 100 inhabits)	Gross Sales(million dollars)	Employees(1,000 people)	Capital Assets(million dollars)
2001	Sample Mean	29.057	44.043	3107.951	17.060	1151.488
	Standard Error	1.674	1.657	1567.133	11.003	691.205
	Median	25.000	50.100	270.152	1.143	39.913
	Mode	25.000	50.100	-	-	-
	Kurtie	16.373	5.579	22.165	31.228	18.124
	Skewness	3.716	-2.089	4.493	5.492	4.245
	Min	25.000	5.800	6.101	0.001	0.231
	Max	77.000	50.100	51056.137	381.504	20824.779
	Confidence(99.5%)	5.026	4.974	4704.462	33.032	2074.964
2002	Sample Mean	28.156	48.578	3745.806	8.215	776.236
	Standard Error	1.860	1.666	1997.845	3.162	393.917
	Median	23.000	53.800	338.284	1.067	45.419
	Mode	23.000	53.800	-	0.065	-
	Kurtie	15.132	11.093	22.579	10.490	11.870
	Skewness	3.531	-2.957	4.555	3.226	3.511
	Min	23.000	7.700	6.250	0.027	0.162
	Max	77.000	53.800	60970.273	80.632	9830.000
	Confidence(99.5%)	5.621	5.035	6037.722	9.557	1190.464
2003	Sample Mean	27.600	52.155	2674.719	7.014	509.575
	Standard Error	2.055	1.803	1240.272	2.860	279.199
	Median	22.000	55.580	364.985	1.060	50.367
	Mode	22.000	55.580	-	0.218	-
	Kurtie	16.892	11.865	13.126	12.544	21.560
	Skewness	3.801	-3.171	3.546	3.486	4.488
	Min	22.000	9.560	5.984	0.013	0.101
	Max	80.000	59.190	32099.676	73.221	8017.991
	Confidence(99.5%)	6.242	5.478	3768.005	8.689	848.220

Table 5 Sample Statistics in the DEA model from 1997 to 2005(continue)

		Piracy Rate(%)	Internet Users(per 100 inhabits)	Gross Sales(million dollars)	Employees(1,000 people)	Capital Assets(million dollars)
2004	Sample Mean	27.593	57.567	2956.436	7.468	528.504
	Standard Error	2.268	2.133	1260.012	3.069	274.400
	Median	27.000	62.280	396.130	1.300	60.180
	Mode	21.000	62.280	-	-	-
	Kurtie	14.458	11.729	8.048	14.186	16.325
	Skewness	3.503	-3.145	2.924	3.610	3.922
	Min	79.000	65.300	26650.842	76.266	6879.300
	Max	27.000	27.000	27.000	27.000	27.000
	Confidence(99.5%)	6.957	6.540	3864.342	9.414	841.559
2005	Sample Mean	27.667	60.567	2382.005	7.798	399.500
	Standard Error	2.587	2.048	1059.970	3.859	208.038
	Median	24.000	62.000	277.064	1.061	23.954
	Mode	21.000	62.000	-	-	-
	Kurtie	13.350	15.041	7.735	15.677	10.783
	Skewness	3.431	-3.606	2.909	3.830	3.294
	Min	59.000	50.000	19475.045	88.489	4330.677
	Max	21.000	18.000	8.955	0.027	0.323
	Confidence(99.5%)	80.000	68.000	19484.000	88.516	4331.000

Excel-Solver function, refer to Zhu (2003), is applied to construct DEA models in this research. Therefore Malmquist productivity indices (MPI), which represent the productivity changes between two years, and two decomposed components, the technical efficiency change (TEC) and the frontier shift (FS), of the music firms can be calculated from 1997 to 2005. MPI measures the productivity change between two years. MPI >1 indicates productivity gain, MPI_k <1 indicates productivity loss, and MPI =1 means no change in productivity from year t to t+1. TEC is a measure of how much closer to the boundary the company is in year t+1 compared to year t. If TEC=1, the particular company has the same distance in years t+1 and t from the respective efficient boundaries. If TEC>1, the company has moved closer to the year t+1 boundary than it was to the year t boundary and the converse is the care if the TEC <1. FS measures the technology frontier shift between year t and t+1. If a value of FS >1 indicates a positive shift or technical progress, FS<1 indicates a negative shift or technical regress, and FS=1 indicates no shift in technology frontier. The empirical results of Malmquist indices of each music company from 1997 to 2005 list on Table 6, Table 7, and Table 8 respectively. Furthermore Table 9 summarizes the average scores of Malmquist indices, which represent the technical efficiency changes, frontier shifts, and productivity changes of whole music industry from 1997 to 2005, and it's sub-industries as well.

Table 6 Technical Efficiency Change of Music Firms from 1997 to 2005

TEC	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05
Music Retailing & Distribution								
ARTISTDIRECT INC	-	0.115	1.329	2.097	0.549	3.410	1.441	0.416
AUDIOHIGHWAY.COM	-	4.746	-	-	-	-	-	-
BARNESANDNOBLE.COM	4.605	1.252	1.124	2.086	1.176	0.949	-	-
CDNOW INC	2.066	0.615	-	-	-	-	-	-
CDWAREHOUSE INC	1.054	0.653	2.330	0.701	-	-	-	-
CINRAM INTERNATIONAL INC	1.822	0.698	0.908	1.271	1.014	1.418	2.281	0.648
HANDLEMAN COMPANY	2.203	0.568	0.901	1.224	1.093	0.875	1.460	0.986
HASTINGS ENTERTAINMENT INC	1.971	0.638	1.162	0.752	0.917	0.957	1.807	1.726
HMV GROUP PLC	-	-	-	-	1.092	1.066	1.681	0.992
INTEGRITY MEDIA INCORPORATED	1.339	0.881	1.023	1.561	0.772	0.993	-	-
INTERMIX MEDIA INC	-	0.161	1.917	0.893	0.918	1.070	1.546	1.160
K-TEL INTERNATIONAL INC	1.883	0.811	1.233	0.847	0.392	1.337	-	-
MP3.COM	-	0.180	3.232	-	-	-	-	-
MTS INC	-	-	-	1.204	1.220	-	-	-
MUSICLAND STORES CORP	1.782	0.553	-	-	-	-	-	-
NATIONAL RECORD MART INC	1.880	0.648	1.015	-	-	-	-	-
SHINSEIDO CO LTD	1.694	1.178	0.999	0.962	0.975	1.067	1.188	0.417
TRANS WORLD ENTMT CORP	1.887	0.690	1.020	1.009	0.980	1.025	1.838	1.286
VALLEY MEDIA INC	4.514	0.552	0.844	-	-	-	-	-
WHEREHOUSE ENTMT INC	1.435	0.844	1.144	0.880	-	1.598	-	-
Average	2.153	0.877	1.345	1.191	0.925	1.314	1.655	0.954

Table 6 Technical Efficiency Change of Music Firms from 1997 to 2005 (continue)

TEC	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05
Music Publishing								
4 KIDS ENTERTAINMENT INC	2.325	1.843	1.000	0.352	0.772	1.574	1.121	0.437
AUDIBLE INC	-	1.065	2.142	3.171	1.279	2.113	1.451	0.482
AVEX GROUP HOLDINGS INC	1.000	1.000	1.000	0.572	0.926	0.928	1.007	0.154
BERTELSMANN AG	1.416	1.000	0.862	1.138	0.937	1.139	1.409	0.676
BEYOND INTERNATIONAL GROUP	1.167	0.847	1.337	1.039	0.982	1.165	1.946	0.287
CHRYSALIS GROUP PLC	1.507	1.020	1.093	1.038	1.168	1.070	1.300	0.634
EMI GROUP PLC	1.307	1.000	1.033	1.145	1.049	1.030	1.489	0.605
FOX ENTERTAINmeNT GROUP	1.440	0.872	0.985	0.984	0.998	1.110	2.945	-
GMM GRAMMY PCL	1.491	1.000	1.486	0.471	0.555	0.890	2.330	2.821
ISRAEL LAND DEVELOPMENT	1.361	2.673	-	-	-	-	-	-
JACK WHITE PRODUCTIONS	-	-	0.205	1.009	0.937	1.653	1.539	-
MEDIA BAY INC	0.451	1.464	0.795	1.557	1.000	1.000	1.000	0.202
NEWSTAR MEDIA INC	1.232	0.767	-	-	-	-	-	-
ROJAM ENTERTAINMENT HLD	-	-	-	-	2.512	2.087	2.749	1.000
SANCTUARY GROUP PLC	-	1.376	1.509	1.268	1.021	1.077	1.991	0.704
SONY MUSIC ENTMT(JAPAN) INC	1.050	1.495	0.800	0.756	0.956	0.468	3.187	-
VIVENDI UNIVERSAL SA	1.224	1.000	1.073	0.915	6.516	0.654	1.043	0.270
WARNER MUSIC GROUP CORP	1.310	0.881	1.004	0.606	1.156	1.598	0.965	1.068
Average	1.306	1.206	1.088	1.068	1.423	1.222	1.717	0.719
Music Production								
GENER8XION ENTERTAINMENT	6.544	0.196	-	-	-	-	-	-
MAKEMUSIC INC	3.611	0.722	0.033	-	1.092	1.420	3.562	1.724
METATEC INTL INC	0.995	1.060	0.943	1.891	0.745	-	-	-
PARADISE MUSIC & ENTERTAINMENT INC	1.637	0.693	1.682	1.522	-	-	-	-
PLANET ENTERTAINMENT CORP	-	-	0.572	-	-	-	-	-
PLATINM ENTERTAINMENT INC	-	0.529	-	-	-	-	-	-
STEINWAY MUSICAL INSTRUMENTS INC	1.531	0.586	0.719	1.382	1.002	1.071	1.395	0.759
ZOMAX INC/MN	1.200	1.660	0.900	1.228	0.921	0.884	1.469	1.153
Average	2.586	0.778	0.808	1.506	0.940	1.125	2.142	1.212

Table 7 Frontier shift of Music Firms from 1997 to 2005

FS	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05
Music Retailing & Distribution								
ARTISTDIRECT INC	-	1.043	1.076	0.937	1.048	1.054	0.585	0.863
AUDIOHIGHWAY.COM	-	0.147	-	-	-	-	-	-
BARNESANDNOBLE.COM	0.705	0.458	0.992	0.924	1.049	1.046	-	-
CDNOW INC	0.643	0.940	-	-	-	-	-	-
CDWAREHOUSE INC	0.334	0.498	0.996	1.434	-	-	-	-
CINRAM INTERNATIONAL INC	0.626	1.127	1.084	0.914	1.050	1.056	0.869	1.834
HANDLEMAN COMPANY	0.642	1.296	1.074	0.914	1.050	1.069	0.686	1.014
HASTINGS ENTERTAINMENT INC	0.574	0.488	0.987	1.371	1.050	1.079	0.577	0.579
HMV GROUP PLC	-	-	-	-	1.050	1.073	0.655	0.773
INTEGRITY MEDIA INCORPORATED	0.834	0.757	0.992	0.853	1.049	1.045	-	-
INTERMIX MEDIA INC	-	1.190	0.987	1.146	1.050	1.079	0.604	0.862
K-TEL INTERNATIONAL INC	0.546	1.111	1.005	1.301	1.376	1.262	-	-
MP3.COM	-	0.885	1.018	-	-	-	-	-
MTS INC	-	-	-	0.878	1.050	-	-	-
MUSICLAND STORES CORP	0.594	0.682	-	-	-	-	-	-
NATIONAL RECORD MART INC	0.445	0.569	1.041	-	-	-	-	-
SHINSEIDO CO LTD	0.819	0.633	0.992	0.922	1.049	1.043	0.877	0.899
TRANS WORLD ENTMT CORP	0.571	0.645	1.019	0.992	1.050	1.075	-	0.778
VALLEY MEDIA INC	0.253	1.217	1.009	-	-	-	0.611	-
WHEREHOUSE ENTMT INC	0.355	0.544	0.983	1.392	-	1.026	-	-
Average	0.567	0.791	1.017	1.075	1.077	1.076	0.683	0.950

Table 7 Frontier shift of Music Firms from 1997 to 2005 (continue)

FS	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05
Music Publishing								
4 KIDS ENTERTAINMENT INC	0.774	0.737	1.000	0.929	1.049	1.052	0.814	1.780
AUDIBLE INC	-	0.200	1.113	0.840	1.050	1.168	0.519	0.952
AVEX GROUP HOLDINGS INC	0.913	1.000	1.000	1.152	1.043	1.003	1.008	2.349
BERTELSMANN AG	0.662	0.590	1.106	0.876	1.042	1.049	0.761	1.280
BEYOND INTERNATIONAL GROUP	0.834	0.910	0.992	0.908	0.761	1.032	0.990	2.738
CHRYSALIS GROUP PLC	0.754	0.578	1.094	0.831	1.050	1.065	0.739	1.207
EMI GROUP PLC	0.731	0.638	1.049	0.835	1.049	1.052	0.791	1.307
FOX ENTERTAINmeNT GROUP	0.834	1.071	0.992	1.031	1.047	1.012	0.618	-
GMM GRAMMY PCL	0.261	1.000	1.009	1.434	1.427	1.181	0.484	1.130
ISRAEL LAND DEVELOPMENT	0.834	0.233	-	-	-	-	-	-
JACK WHITE PRODUCTIONS	-	-	1.025	0.996	1.050	1.077	0.585	-
MEDIA BAY INC	0.813	0.827	1.095	0.948	1.025	1.040	0.737	1.381
NEWSTAR MEDIA INC	0.834	0.757	-	-	-	-	-	-
ROJAM ENTERTAINMENT HLD	-	-	-	-	1.049	1.058	0.726	1.033
SANCTUARY GROUP PLC	-	0.403	0.992	0.915	1.049	1.048	0.746	0.933
SONY MUSIC ENTMT(JAPAN) INC	0.725	0.413	1.035	0.851	1.049	1.054	0.790	-
VIVENDI UNIVERSAL SA	0.756	0.827	0.908	0.947	1.040	1.002	1.008	3.494
WARNER MUSIC GROUP CORP	0.834	0.842	0.992	1.564	1.047	1.026	0.817	1.321
Average	0.754	0.689	1.027	1.004	1.052	1.057	0.758	1.608
Music Production								
GENER8XION ENTERTAINMENT	0.283	1.159	-	-	-	-	-	-
MAKEMUSIC INC	0.387	0.920	1.009	-	1.224	1.194	0.480	0.523
METATEC INTL INC	0.822	0.477	0.992	0.931	1.048	-	-	-
PARADISE MUSIC & ENTERTAINMENT INC	0.482	1.071	1.072	0.908	-	-	-	-
PLANET ENTERTAINMENT CORP	-	-	1.028	-	-	-	-	-
PLATINM ENTERTAINMENT INC	-	1.006	-	-	-	-	-	-
STEINWAY MUSICAL INSTRUMENTS INC	0.671	0.668	1.126	0.821	1.050	1.059	0.763	1.399
ZOMAX INC/MN	0.638	0.432	1.116	0.852	1.050	1.066	0.694	1.006
Average	0.547	0.819	1.057	0.878	1.093	1.106	0.646	0.976

Table 8 Productivity Change (MPI) of Music Firms from 1997 to 2005

MPI	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05
Music Retailing & Distribution								
ARTISTDIRECT INC	-	0.120	1.430	1.965	0.575	3.592	0.842	0.359
AUDIOHIGHWAY.COM	-	0.699	-	-	-	-	-	-
BARNESANDNOBLE.COM	3.246	0.574	1.116	1.927	1.233	0.993	-	-
CDNOW INC	1.328	0.578	-	-	-	-	-	-
CDWAREHOUSE INC	0.352	0.325	2.321	1.006	-	-	-	-
CINRAM INTERNATIONAL INC	1.140	0.787	0.984	1.161	1.065	1.498	1.983	1.188
HANDLEMAN COMPANY	1.415	0.737	0.967	1.118	1.148	0.935	1.002	1.000
HASTINGS ENTERTAINMENT INC	1.132	0.311	1.147	1.032	0.963	1.033	1.042	1.000
HMV GROUP PLC	-	-	-	-	1.147	1.144	1.101	0.767
INTEGRITY MEDIA INCORPORATED	1.118	0.667	1.015	1.331	0.811	1.037	-	-
INTERMIX MEDIA INC	-	0.192	1.893	1.024	0.964	1.155	0.934	1.000
K-TEL INTERNATIONAL INC	1.028	0.900	1.239	1.102	0.540	1.688	-	-
MP3.COM	-	0.159	3.289	-	-	-	-	-
MTS INC	-	-	-	1.057	1.281	-	-	-
MUSICLAND STORES CORP	1.058	0.377	-	-	-	-	-	-
NATIONAL RECORD MART INC	0.836	0.369	1.057	-	-	-	-	-
SHINSEIDO CO LTD	1.388	0.745	0.991	0.887	1.023	1.114	1.042	0.375
TRANS WORLD ENTMT CORP	1.078	0.445	1.040	1.000	1.030	1.102	-	1.000
VALLEY MEDIA INC	1.143	0.671	0.852	-	-	-	1.122	-
WHEREHOUSE ENTMT INC	0.509	0.460	1.124	1.225	-	1.640	-	-
Average	1.198	0.506	1.364	1.218	0.982	1.411	1.133	0.836

Table 8 Productivity Change (MPI) of Music Firms from 1997 to 2005 (continue)

MPI	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05
Music Publishing								
4 KIDS ENTERTAINMENT INC	1.801	1.358	1.000	0.327	0.810	1.655	0.912	0.778
AUDIBLE INC	-	0.213	2.385	2.665	1.343	2.467	0.754	0.459
AVEX GROUP HOLDINGS INC	0.913	1.000	1.000	0.659	0.966	0.931	1.015	0.363
BERTELSMANN AG	0.938	0.590	0.954	0.997	0.976	1.195	1.072	0.865
BEYOND INTERNATIONAL GROUP	0.974	0.770	1.327	0.943	0.747	1.203	1.927	0.786
CHRYSALIS GROUP PLC	1.136	0.590	1.196	0.863	1.226	1.140	0.961	0.765
EMI GROUP PLC	0.956	0.638	1.083	0.957	1.101	1.083	1.177	0.790
FOX ENTERTAINmeNT GROUP	1.201	0.934	0.977	1.014	1.045	1.124	1.820	-
GMM GRAMMY PCL	0.390	1.000	1.499	0.676	0.792	1.052	1.128	3.187
ISRAEL LAND DEVELOPMENT	1.135	0.623	-	-	-	-	-	-
JACK WHITE PRODUCTIONS	-	-	0.211	1.004	0.984	1.781	0.901	-
MEDIA BAY INC	0.367	1.210	0.871	1.476	1.025	1.040	0.737	0.279
NEWSTAR MEDIA INC	1.028	0.581	-	-	-	-	-	-
ROJAM ENTERTAINMENT HLD	-	-	-	-	2.636	2.208	1.996	1.033
SANCTUARY GROUP PLC	-	0.555	1.498	1.160	1.071	1.129	1.486	0.657
SONY MUSIC ENTMT(JAPAN) INC	0.761	0.616	0.828	0.644	1.003	0.494	2.518	-
VIVENDI UNIVERSAL SA	0.925	0.827	0.974	0.867	6.774	0.655	1.051	0.943
WARNER MUSIC GROUP CORP	1.093	0.742	0.996	0.949	1.210	1.640	0.788	1.411
Average	0.973	0.765	1.120	1.013	1.482	1.300	1.265	0.947
Music Production								
GENER8XION ENTERTAINMENT	1.849	0.227	-	-	-	-	-	-
MAKEMUSIC INC	1.399	0.664	0.033	-	1.337	1.696	1.711	0.902
METATEC INTL INC	0.818	0.505	0.936	1.761	0.781	-	-	-
PARADISE MUSIC & ENTERTAINMENT INC	0.789	0.742	1.804	1.382	-	-	-	-
PLANET ENTERTAINMENT CORP	-	-	0.588	-	-	-	-	-
PLATINM ENTERTAINMENT INC	-	0.532	-	-	-	-	-	-
STEINWAY MUSICAL INSTRUMENTS INC	1.027	0.391	0.810	1.134	1.051	1.133	1.065	1.062
ZOMAX INC/MN	0.766	0.718	1.005	1.047	0.967	0.943	1.020	1.159
Average	1.108	0.540	0.863	1.331	1.034	1.257	1.265	1.041

Table 9 Mean Malmquist Indices of Music Industries from 1997 to 2005

Whole Music Industry								
	97/98	**98/99**	**99/00**	**00/01**	**01/02**	**02/03**	**03/04**	**04/05**
TEC	1.880	0.989	1.149	1.173	1.176	1.237	1.746	0.859
FS	0.641	0.756	1.028	1.017	1.066	1.071	0.723	1.310
MPI	1.089	0.613	1.179	1.136	1.238	1.329	1.226	0.922
Music Retailing & Distribution								
	97/98	**98/99**	**99/00**	**00/01**	**01/02**	**02/03**	**03/04**	**04/05**
TEC	2.153	0.877	1.345	1.191	0.925	1.314	1.655	0.954
FS	0.567	0.791	1.017	1.075	1.077	1.076	0.683	0.950
MPI	1.198	0.506	1.364	1.218	0.982	1.411	1.133	0.836
Music Publishing								
	97/98	**98/99**	**99/00**	**00/01**	**01/02**	**02/03**	**03/04**	**04/05**
TEC	1.306	1.206	1.088	1.068	1.423	1.222	1.717	0.719
FS	0.754	0.689	1.027	1.004	1.052	1.057	0.758	1.608
MPI	0.973	0.765	1.120	1.013	1.482	1.300	1.265	0.947
Music Production								
	97/98	**98/99**	**99/00**	**00/01**	**01/02**	**02/03**	**03/04**	**04/05**
TEC	2.586	0.778	0.808	1.506	0.940	1.125	2.142	1.212
FS	0.547	0.819	1.057	0.878	1.093	1.106	0.646	0.976
MPI	1.108	0.540	0.863	1.331	1.034	1.257	1.265	1.041
Annotation:								
Period	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05
Events	MP3	P2P	Lawsuit		Napster Lose		iTunes	Sell on Net
Period	D1		D2				D3	
Events	Digital Music Technologies without Copyright Protection		RIAA Filing Lawsuits on Napster				Innovation of iTunes Online Music Store Business Model	

According the empirical results of DEA Malmquist analysis summarized on Table 9, several phenomena can be discovered. First, the MP3 format provided a new way to save digital music efficiently, and millions of MP3 files had been downloaded for free before 1998. As a result, the whole music industry faced an impact of enormous scale of music piracy. The frontier shift indices had significant decline on music retailing & distribution, music publishing, music production and whole music industry before 1998, and represented the exogenous factors shifted in a negative way, music piracy rate increase. The backward frontier shift on music publishing industry, 0.754, simultaneously declined the productivity, 0.973, hence.

By observing the DEA Malmquist indices from 1998 to 1999, the productivity indices of the music industry, and it's sub-industries as well, performed very serious declines at the same time. The MPI indices, which portray the productivity change between two years, of music retailing & distribution, music publishing, music production, and whole music industry are 0.506, 0.765, 0.540, and 0.613 respectively, and reveal deteriorations of music industry productivity in that period. Moreover, data show that this huge decline was caused by backward shifts of frontiers, frontier shift indices equal to 0.791, 0.689, 0.819, and 0.756 respectively, in the music industry, and demonstrate that the P2P technology, first launched by Napster, indeed accelerated the diffusion of music copyright violation, and fell music industry into decay as a result. In addition, the technical efficiency change indices, which represent the operation performance of individual firms, of music retailing, music production, and whole music industry also performed worse, TEC equal to 0.877, 0.778, and 0.989 respectively.

In December 1999, RIAA filed a federal lawsuit against Napster for copyright infringement. Based on the DEA Malmquist indices from year 1999 to 2000, the negative trend of frontier shift stopped, frontier shift index of whole music industry equal to 1.028, and this result can be interpreted as a slightly restraint of illegal music transmission by means of filling a lawsuit. However, the technical efficiency change index of music production industry still performed worse, 0.808, likewise the productivity deteriorated, 0.863, in that period. After approximately two years of legal battles, Napster was eventually ordered to shut down in February 2001. In order to settle a lawsuit, moreover, Napster strikes a deal with the National Music Publishers' Association to pay $26 million for past unauthorized use of music and $10 million down payment on future royalties (CBSNews.com, 2001). The great amount of settlement fee reflected on the technical efficiency progress, TEC equal to 1.423, of music publishing industry directly. Furthermore, the piracy problem had eased since the frontier shift indices acted in a positive way, 1.077, 1.052, 1.093, and 1.066, in the period of 2001 to 2002.

After the Apple Computer making an alliance with big five music giants the Apple’s iTunes Online Music Store was opened in April 2003. Hence, consumers can purchase authorized music only cost 99 cents per song via the iTunes Online Music Store, and download the digital music files into their iPods. This iPods plus iTunes business model created a new opportunity for legal online music trading, because every part of music industry, including label, artist, producer, and songwriter/publisher, can receive a share of income from online music selling. Therefore, the technical efficiencies, which may influence productivity change further, in every part of the music industry became better in period 2003 to 2004. The TEC indices of music retailing & distribution, music publishing, music production and whole music industry were 1.655, 1.717, 2.142, and 1.746; the MPI indices were 1.133, 1.265, 1.265, and 1.226, respectively.

Apple's purchase model for music was vastly outgrowing competing subscription services. And lest anyone question the business value of the iTunes Music Store, it was making profit for Apple as well as revenue. Until July 2005, 0.5 billion songs were sold via Apple’s iTunes Music Store, and share of legally purchased and downloaded music in the United States had actually increased to above 80% as measured by Nielsen SoundScan (2005). The iTunes Music Store became the world's leading online music service, operating in 19 countries, which represent about 70% of the global music business. Since the emergence of successful music download services like iTunes was proving not only made consumers paying for quality content, but the intentions to download illegal music files were diminishing. Table 9 shows that the frontier shifted positively in the whole music industry and the music publishing industry as well, 1.310 and 1.608 respectively, from 2004 to 2005. However critics in the music industry, in turn, had complained privately that Apple Computer was hoarding cash by holding down song prices to protect sales of Apple's more lucrative iPod music player, and compressed the profit margin of music firms. Consequently, the technical efficiency change indices of music industry, the music publishing industry especially, acted negatively, 0.859 and 0.719, in this period. Moreover, the iTunes Music Store also made a recession on the inherent music retailing industry, and the Malmquist indices of music retailing industry performed backward, 0.954, 0.950, and 0.836, in the period of 2004 to 2005.

5.2 Identify the Key Factors

The second part of this research, after the deriving of the Malmquist indices by DEA method, is identifying the key variables which will affect the productivity improvement, and portrays the process that strategic decisions working on the performance of music industry. In this part, the statistic regression analyses will be employed to test the influence of external factors, such as the piracy rate change and the internet scale change, internal factors, such as sales change, number of employees change, and capital change, on the productivity change process. Furthermore, the factors that change the piracy rate will be extracted by the regression analyses as well, and the process that strategic decisions swaying the performance of music industry via the externalities will be made clear. According to a series of statistic regression analyses, a process theory will be brought out. Thus researchers will comprehend the mechanism responsible for performance variation, and grasp the managerial implication implied.

Accordingly, this research employed the Tobit models to identify the key factors affecting the Malmquist indices, MPI, TEC, and FS, which symbolize different aspects of the productivity variation in the music industries. Therefore the Malmquist indices, MPI, TEC, and FS, are set to be the dependent variables in the Tobit models respectively, and the dependent variables are censored at zero. In addition the change of DEA variables, such as the change of piracy rate, internet population, sales, number of employees, and the fixed assets level, are set to be the independent variable in these Tobit models to clarify the relationships between the DEA results and the variables considered. The empirical results of Tobit model (6), calculated by EViews 3.0 computer program, of the Tobit regression for Malmquist indices are listed on Table 10.

Table 10 Estimated Tobit Models for Malmquist Indices

Dependent Variable	MPI	TEC	FS
Intercept	1.3221*** 20.7831 (0.0000)	1.3061*** 13.2223 (0.0000)	1.1128*** 27.4277 (0.0000)
Piracy Rate Change	-0.0349** -2.0004 (0.0455)	0.0249 0.9198 (0.3577)	-0.0395*** -3.5531 (0.0004)
Internet User Change	0.0357*** 4.5816 (0.0000)	0.0088 0.7302 (0.4653)	0.0234*** 4.7046 (0.0000)
Sales Change	5.64E-05*** 4.2037 (0.0000)	5.92E-05*** 2.8408 (0.0045)	-1.00E-05 -1.1740 (0.2404)
Employees Change	-0.0122*** -5.3583 (0.0000)	-0.0110*** -3.1030 (0.0019)	0.0005 0.3718 (0.7100)
Capital Change	-7.29E-05* -1.6943 (0.0902)	-6.54E-05 -0.9791 (0.3275)	-2.80E-05 -1.0198 (0.3078)

The coefficient, t-value, and p-value (in parentheses) are given for each variable.

***, **, and * indicate significant levels at 10%, 5%, and 1%, respectively.

Table 10 lists three Tobit models with different dependent variables, MPI, TEC, and FS respectively, and these models derive several implications in the Malmquist results hence. Considering the model with a dependent variable of TEC, the result of Tobit regression analysis comes out a significant relationship between the TEC index and the change of internal variables over years. For example, the sales change behaves positively with the TEC and the number change of employees negatively, in contrast, in the 99 percent significant level. As for the model with a dependent variable of FS, the result of Tobit regression analysis comes out a significant relationship between FS index and the change of external variables over years. For example, the change of piracy rate affect negatively with the FS and the number change of internet users positively, on the other hand, in the 99 percent significant level. Because the MPI is the cross product of the TEC and FS indices, referring to chapter 2.1.5, the result of MPI model is a combination of the other two models. The Tobit model with the dependent variable of MPI draws several conclusions about music industry significantly: the sales growth increasing the productivity of music firms; redundant inputs, such as the employees and capital levels, decreasing the productivity performance of music firms; piracy problem significantly decreasing the productivity of music industry; and the increasing in internet scale will improve the productivity performance in the music industry.

These statistic regression results provide further explanatory comments about DEA Malmquist productivity analyses in our research. Meanwhile, these empirical results will help us to portray a theory of productivity variation process, thus this model of process is drawn in Figure 11 for further implications.

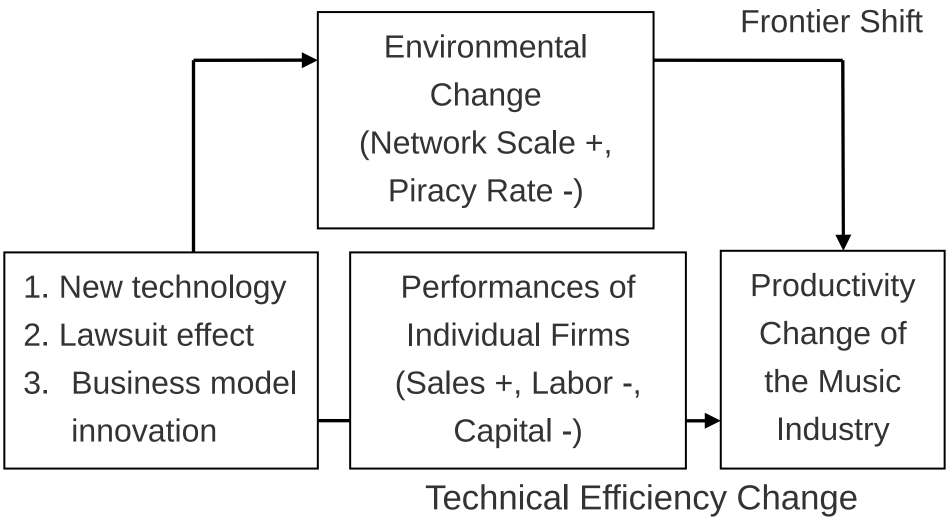


Figure 11 Process of strategic decisions affect the performance of music industry

Results of this section indicate that the environmental change and business strategies will lead the variation of productivity performance of music industry via two aspects, the interior performance change of individual firm and the exterior environmental condition change. The interior performance change of individual firm can be demonstrated by the Malmquist index of TEC and the exterior environmental condition change by the Malmquist index of FS in contrast. As regards the interior performance change of individual firm, decreasing inputs and increasing outputs will both improve the productivity performances of music firms. In the exterior environmental condition change, moreover, increasing piracy rate will worsen the productivity performance, but internet scales growth will improve the productivity performance.

5.3 Hypotheses Testing

In order to provide new evidences for the performance, that different strategic decisions working upon the music industry, this research will test four hypotheses listed further.

H1: The copyright-protection-lacking digital music technologies, such as MP3 and P2P, are negative related to the productivity of music firms.
H2: Filing a lawsuit against piracy makes a positive impact on the productivity of music firms.
H3: Launching a brand-new business model is positive related to the productivity of music firms.
H4: Launching a new business model do more impact on the productivity than filing a lawsuit against piracy.

The Tobit regressions again and Mann-Whitney rank test will be applied, in this section, to test these hypotheses separately. Hypotheses one, two, and three will employ Tobit models with dummy variables, which representing different event periods, and hypothesis four will employ Mann-Whitney rank test for testing. The Tobit models, model (7) to model (15), will test the influence of different business strategic events, including new digital technologies, lawsuits, and new business model, on the Malmquist indices. The empirical results of these Tobit models are computed by EViews 3.0 computer program.

In the point of view of the whole music industry, the empirical results of the Tobit regression for Malmquist Indices with the different business strategies are listed on Table 11 to Table 13 below.

Table 11 Regression Analysis on MPI in Music Industry

Equation	(7)	(8)	(9)
Intercept	1.1785*** 14.8156 (0.0000)	1.3618*** 18.8733 (0.0000)	1.2811*** 19.7935 (0.0000)
Piracy Rate Change	-0.0243 -1.3877 (0.1652)	-0.0378** -2.1517 (0.0314)	-0.0156 -0.8327 (0.4050)
Internet User Change	0.0293*** 3.6776 (0.0002)	0.0386*** 4.7267 (0.0000)	0.0214** 2.2631 (0.0236)
Sales Change	5.68E-05*** 4.3009 (0.0000)	5.64E-05*** 4.2123 (0.0000)	5.69E-05*** 4.2965 (0.0000)
Employees Change	-0.0122*** -5.4303 (0.0000)	-0.0122*** -5.3319 (0.0000)	-0.0124*** -5.4962 (0.0000)
Capital Change	-6.67E-05 -1.573 (0.1156)	-7.42E-05* -1.7292 (0.0838)	-6.25E-05 -1.4644 (0.1431)
D1	0.1879*** 2.924 (0.0034)	—	—
D2	—	-0.0944 -1.1569 (0.2473)	—
D3	—	—	-0.2209*** -2.6056 (0.0092)

The coefficient, t-value, and p-value (in parentheses) are given for each variable.

***, **, and * indicate significant levels at 10%, 5%, and 1%, respectively.

Table 12 Regression Analysis on TEC in Music Industry

Equations	(10)	(11)	(12)
Intercept	1.4908*** 12.0071 (0.0000)	1.2736*** 11.3450 (0.0000)	1.3678*** 13.5989 (0.0000)
Piracy Rate Change	0.0113 0.4139 (0.6789)	0.0273 0.9986 (0.3179)	-0.0041 -0.1424 (0.8867)
Internet User Change	0.0171 1.3706 (0.1705)	0.0065 0.5081 (0.6114)	0.0304** 2.0698 (0.0385)
Sales Change	5.87E-05*** 2.8498 (0.0044)	5.92E-05*** 2.8440 (0.0045)	5.84E-05*** 2.8388 (0.0045)
Employees Change	-0.0111*** -3.1517 (0.0016)	-0.0111*** -3.1233 (0.0018)	-0.0108*** -3.0731 (0.0021)
Capital Change	-7.34E-05 -1.1098 (0.2671)	-6.43E-05 -0.9630 (0.3355)	-8.11E-05 -1.2240 (0.2209)
D1	-0.2417** -2.4100 (0.0160)	—	—
D2	—	0.0772 0.6084 (0.5429)	—
D3	—	—	0.3328** 2.5264 (0.0115)

The coefficient, t-value, and p-value (in parentheses) are given for each variable.

***, **, and * indicate significant levels at 10%, 5%, and 1%, respectively.

Table 13 Regression Analysis on FS in Music Industry

Equations	(13)	(14)	(15)
Intercept	0.9839*** 19.7201 (0.0000)	1.1137*** 24.1379 (0.0000)	1.0591*** 26.826 (0.0000)
Piracy Rate Change	-0.0300*** -2.7322 (0.0063)	-0.0396*** -3.5220 (0.0004)	-0.0143 -1.2491 (0.2116)
Internet User Change	0.0177*** 3.5298 (0.0004)	0.0235*** 4.4897 (0.0000)	0.0046 0.8059 (0.4203)
Sales Change	-9.72E-06 -1.1737 (0.2405)	-1.00E-05 -1.1741 (0.2403)	-9.39E-06 -1.1621 (0.2452)
Employees Change	0.0006 0.4081 (0.6832)	0.0005 0.3730 (0.7091)	0.0003 0.2450 (0.8064)
Capital Change	-2.24E-05 -0.8427 (0.3993)	-2.80E-05 -1.0205 (0.3074)	-1.43E-05 -0.5505 (0.5819)
D1	0.1686*** 4.1843 (0.0000)	—	—
D2	—	-0.0022 -0.0430 (0.9657)	—
D3	—	—	-0.2891*** -5.5913 (0.0000)

The coefficient, t-value, and p-value (in parentheses) are given for each variable.

***, **, and * indicate significant levels at 10%, 5%, and 1%, respectively.

In the scope of whole music industry, several findings are reveled on Table 11 to Table 13. The Tobit model with the first dummy variable, which reflects the influence of lawsuits, finds out that filing lawsuits against piracy can enhance the productivity significantly, and therefore hypothesis two in our research, filing a lawsuit against piracy makes a positive impact on the productivity of music firms, is confirmed. Furthermore this improvement is mainly caused by the forward shit of efficiency frontier, representing the improvement of external environment in whole music industry, instead of the technical efficiency change. Similarly, The Tobit model with the third dummy variable, which reflects the MP3 and P2P affections, finds out that MP3 and P2P technologies may impair the productivity significantly, and therefore hypothesis one in our research, the copyright-protection-lacking digital music technologies are negative related to the productivity of music firms, is confirmed. Furthermore this deterioration is mainly caused by the backward shit of efficiency frontier, representing the deterioration of external environment in whole music industry, and does much more affection than the benefits of technical efficiency improvement. However when our Tobit model is taken the second dummy variable, which reflects the influence of Apple's new iTunes business model, into consideration, an insignificant result is derived, and the hypothesis three in our research is failed to verified.

In order to know why the hypothesis three is failed to verified, the sub-industries, such as music retailing, music publishing, and music production industry, are tested separately in our research further to get more detail information about the mechanism that strategic events, especially the Apple related events, effecting the performance of music industry. These results are shown from Table 14 to Table 22 following. First of all, the empirical results of the Tobit regression for Malmquist Indices, with the different business strategies, in music retailing industry are listed on Table 12 below.

Table 14 Regression Analysis on MPI in Music Retailing Industry

Equations	(7)	(8)	(9)
Intercept	1.1553*** 7.5731 (0.0000)	1.4969*** 11.327 (0.0000)	1.3235*** 10.4271 (0.0000)
Piracy Rate Change	0.0108 0.2792 (0.7800)	-0.0132 -0.3442 (0.7306)	0.0105 0.2522 (0.8009)
Internet User Change	0.0345** 2.4260 (0.0153)	0.0562*** 3.9443 (0.0001)	0.0325* 1.7224 (0.0850)
Sales Change	0.0005** 1.9901 (0.0466)	0.0005* 1.9419 (0.0521)	0.0005** 1.9776 (0.0480)
Employees Change	-0.0993 -1.2698 (0.2042)	-0.1214 -1.5697 (0.1165)	-0.1198 -1.5107 (0.1309)
Capital Change	8.91E-05 0.0758 (0.9395)	0.0004 0.3463 (0.7291)	0.0004 0.2936 (0.7690)
D1	0.2504** 2.1916 (0.0284)	—	—
D2	—	-0.2798* -1.8512 (0.0641)	—
D3	—	—	-0.1692 -1.0508 (0.2933)

The coefficient, t-value, and p-value (in parentheses) are given for each variable.

***, **, and * indicate significant levels at 10%, 5%, and 1%, respectively.

Table 15 Regression Analysis on TEC in Music Retailing Industry

Equations	(10)	(11)	(12)
Intercept	1.5684*** 6.5941 (0.0000)	1.3181*** 6.3575 (0.0000)	1.4895*** 7.7639 (0.0000)
Piracy Rate Change	0.0633 1.0499 (0.2937)	0.0814 1.3491 (0.1773)	0.0303 0.4835 (0.6287)
Internet User Change	0.0271 1.2197 (0.2226)	0.0136 0.6104 (0.5415)	0.0591** 2.0734 (0.0381)
Sales Change	0.0007* 1.8395 (0.0658)	0.0007* 1.8123 (0.0699)	0.0007* 1.8160 (0.0694)
Employees Change	-0.0886 -0.7265 (0.4675)	-0.0467 -0.3852 (0.7001)	-0.0991 -0.8272 (0.4081)
Capital Change	-0.0002 -0.1029 (0.9180)	-0.0007 -0.4086 (0.6828)	-8.58E-06 -0.0047 (0.9962)
D1	-0.2858 -1.6045 (0.1086)	—	—
D2	—	-0.0056 -0.0235 (0.9812)	—
D3	—	—	0.5535** 2.2744 (0.0229)

The coefficient, t-value, and p-value (in parentheses) are given for each variable.

***, **, and * indicate significant levels at 10%, 5%, and 1%, respectively.

Table 16 Regression Analysis on FS in Music Retailing Industry

Equations	(13)	(14)	(15)
Intercept	0.7811*** 11.904 (0.0000)	1.1280*** 17.6675 (0.0000)	0.9334*** 16.6003 (0.0000)
Piracy Rate Change	-0.0126 -0.7551 (0.4502)	-0.0372** -2.0006 (0.0454)	0.0010 0.0543 (0.9566)
Internet User Change	0.0032 0.5151 (0.6064)	0.0241*** 3.5050 (0.0005)	-0.0117 -1.3992 (0.1617)
Sales Change	2.40E-05 0.2198 (0.8260)	1.83E-05 0.1480 (0.8823)	3.60E-05 0.3146 (0.7530)
Employees Change	-0.0623* -1.8517 (0.0641)	-0.0954** -2.5547 (0.0106)	-0.0724** -2.0610 (0.0393)
Capital Change	-0.0003 -0.5623 (0.5738)	0.0002 0.3058 (0.7597)	-0.0002 -0.3290 (0.7421)
D1	0.2970*** 6.0438 (0.0000)	—	—
D2	—	-0.1960*** -2.6841 (0.0073)	—
D3	—	—	-0.3514*** -4.9268 (0.0000)

The coefficient, t-value, and p-value (in parentheses) are given for each variable.

***, **, and * indicate significant levels at 10%, 5%, and 1%, respectively.

In the scope of music retailing industry, findings reveled on Table 14 to Table 16 are basically consisting with the previous findings of the whole music industry listed on Table 11 to Table 13. The digital technologies do a negative influence on productivity and lawsuits positively in contrast. However, the productivity of music retailing industry is significantly worsened in the period of Apple's iTunes business model launching. This finding can be interpreted as that the Apple's iTunes business model provided a new, but legal, way for music transactions, and ate the market share of inherent music retailers away.

Next, the empirical results of the Tobit regression for Malmquist Indices, with the different business strategies, in music publishing industry are listed on Table 17 to Table 19 below.

Table 17 Regression Analysis on MPI in Music Publishing Industry

Equations	(7)	(8)	(9)
Intercept	1.3841*** 8.5812 (0.0000)	1.2390*** 8.3009 (0.0000)	1.2624*** 9.4566 (0.0000)
Piracy Rate Change	-0.0008 -0.0253 (0.9798)	0.0110 0.3490 (0.7271)	-0.0125 -0.3670 (0.7136)
Internet User Change	0.0038 0.2135 (0.8309)	-0.0007 -0.0373 (0.9702)	0.0122 0.6319 (0.5274)
Sales Change	5.57E-05*** 2.7576 (0.0058)	5.62E-05*** 2.7611 (0.0058)	5.52E-05*** 2.7380 (0.0062)
Employees Change	-0.0115*** -3.3463 (0.0008)	-0.0115*** -3.3135 (0.0009)	-0.0118*** -3.2820 (0.0010)
Capital Change	-6.88E-05 -1.0612 (0.2886)	-6.08E-05 -0.9318 (0.3514)	-7.58E-05 -1.1636 (0.2446)
D1	-0.2050 -1.4613 (0.1439)	—	—
D2	—	0.0334 0.2038 (0.8385)	—
D3	—	—	0.2909 1.6347 (0.1021)

The coefficient, t-value, and p-value (in parentheses) are given for each variable.

***, **, and * indicate significant levels at 10%, 5%, and 1%, respectively.

Table 18 Regression Analysis on TEC in Music Publishing Industry

Equations	(10)	(11)	(12)
Intercept	1.1198*** 14.0633 (0.0000)	1.0990 15.2261 (0.0000)	1.1495*** 18.1502 (0.0000)
Piracy Rate Change	-0.0390** -2.4628 (0.0138)	-0.0385** -2.5177 (0.0118)	-0.0199 -1.2309 (0.2184)
Internet User Change	0.0254*** 2.8567 (0.0043)	0.0229*** 2.5816 (0.0098)	0.0146 1.5996 (0.1097)
Sales Change	-9.35E-06 -0.9378 (0.3483)	-9.35E-06 -0.9494 (0.3424)	-8.51E-06 -0.8899 (0.3735)
Employees Change	0.0007 0.39037 (0.6963)	0.0005 0.3083 (0.7578)	0.0005 0.2772 (0.7816)
Capital Change	-2.64E-05 -0.8258 (0.4089)	-2.67E-05 -0.8476 (0.3966)	-1.44E-05 -0.4656 (0.6415)
D1	0.0620 0.8945 (0.3710)	—	—
D2	—	0.1548* 1.9548 (0.0506)	—
D3	—	—	-0.2868*** -3.3979 (0.0007)

The coefficient, t-value, and p-value (in parentheses) are given for each variable.

***, **, and * indicate significant levels at 10%, 5%, and 1%, respectively.

Table 19 Regression Analysis on FS in Music Publishing Industry

Equations	(13)	(14)	(15)
Intercept	1.1635*** 10.9652 (0.0000)	1.2527*** 12.7606 (0.0000)	1.2413*** 14.1517 (0.0000)
Piracy Rate Change	-0.0317 -1.5040 (0.1326)	-0.0391* -1.8769 (0.0605)	-0.0232 -1.0391 (0.2987)
Internet User Change	0.0184 1.5549 (0.1200)	0.0210* 1.7457 (0.0809)	0.0125 0.9928 (0.3208)
Sales Change	5.43E-05*** 4.0858 (0.0000)	5.39E-05*** 4.0276 (0.0001)	5.46E-05*** 4.1261 (0.0000)
Employees Change	-0.0124*** -5.4787 (0.0000)	-0.0124*** -5.4349 (0.0000)	-0.0126*** -5.5659 (0.0000)
Capital Change	-6.76E-05 -1.5840 (0.1132)	-7.26E-05* -1.6926 (0.0905)	-6.25E-05 -1.4610 (0.1440)
D1	0.1317 1.4267 (0.1536)	—	—
D2	—	-0.0113 -0.1048 (0.9165)	—
D3	—	—	-0.1991* -1.7029 (0.0886)

The coefficient, t-value, and p-value (in parentheses) are given for each variable.

***, **, and * indicate significant levels at 10%, 5%, and 1%, respectively.

In the scope of music publishing industry, results of Tobit models confirm again that MP3 and P2P technologies affect badly on the music publishers. Moreover, the Apple's iTunes business model is confirmed significantly doing goods for the technical efficiency change, and has contributions to the internal performance of individual music publishers.

Also, the empirical results of the Tobit regression for Malmquist Indices, with the different business strategies, in music production industry are listed on Table 20 to Table 22 below.

Table 20 Regression Analysis on MPI in Music Production Industry

Equations	(7)	(8)	(9)
Intercept	1.62930*** 4.9809 (0.0000)	1.0138*** 3.1824 (0.0015)	1.3880*** 4.6770 (0.0000)
Piracy Rate Change	0.1113 0.8822 (0.3777)	0.1666 1.2681 (0.2048)	0.0790 0.5776 (0.5635)
Internet User Change	0.0415 1.3519 (0.1764)	0.0037 0.1126 (0.9103)	0.0536 1.2663 (0.2054)
Sales Change	0.0073* 1.6941 (0.0902)	0.0076* 1.7388 (0.0821)	0.0082* 1.8639 (0.0623)
Employees Change	-0.6336 -1.0283 (0.3038)	-0.6235 -0.9981 (0.3182)	-0.5795 -0.9115 (0.3620)
Capital Change	-0.0156 -0.8162 (0.4144)	-0.0142 -0.7304 (0.4651)	-0.0173 -0.8723 (0.3830)
D1	-0.4488* -1.8464 (0.0648)	—	—
D2	—	0.5094 1.5410 (0.1233)	—
D3	—	—	0.3697 0.9855 (0.3243)

The coefficient, t-value, and p-value (in parentheses) are given for each variable.

***, **, and * indicate significant levels at 10%, 5%, and 1%, respectively.

Table 21 Regression Analysis on TEC in Music Production Industry

Equations	(10)	(11)	(12)
Intercept	0.8169*** 8.0154 (0.0000)	1.1097*** 10.5514 (0.0000)	0.9219*** 9.7397 (0.0000)
Piracy Rate Change	-0.0274 -0.6977 (0.4854)	-0.0511 -1.1790 (0.2384)	-0.0027 -0.0607 (0.9516)
Internet User Change	0.0015 0.1591 (0.8735)	0.0190* 1.7663 (0.0773)	-0.0104 -0.7692 (0.4418)
Sales Change	-0.0020 -1.4738 (0.1405)	-0.0022 -1.5524 (0.1206)	-0.0024* -1.7048 (0.0882)
Employees Change	0.2122 1.1051 (0.2691)	0.2004 0.9715 (0.3313)	0.1865 0.9199 (0.3576)
Capital Change	-0.00330 -0.5471 (0.5842)	-0.0038 -0.5870 (0.5572)	-0.0022 -0.3509 (0.7256)
D1	0.2350*** 3.1032 (0.0019)	—	—
D2	—	-0.2095* -1.9201 (0.0548)	—
D3	—	—	-0.2645** -2.2109 (0.0270)

The coefficient, t-value, and p-value (in parentheses) are given for each variable.

***, **, and * indicate significant levels at 10%, 5%, and 1%, respectively.

Table 22 Regression Analysis on FS in Music Production Industry

Equations	(13)	(14)	(15)
Intercept	1.1994*** 7.2595 (0.0000)	1.2701 7.9712 (0.0000)	1.2196*** 8.4142 (0.0000)
Piracy Rate Change	0.0007 0.0112 (0.9911)	-0.0036 -0.0554 (0.9558)	0.0116 0.1741 (0.8617)
Internet User Change	0.0378** 2.4386 (0.0147)	0.0418** 2.5621 (0.0104)	0.0317 1.5349 (0.1248)
Sales Change	0.0035 1.6052 (0.1084)	0.0034 1.5447 (0.1224)	0.0034 1.5795 (0.1142)
Employees Change	-0.2816 -0.9046 (0.3656)	-0.2881 -0.9221 (0.3564)	-0.2877 -0.9265 (0.3542)
Capital Change	-0.0120 -1.2337 (0.2173)	-0.0120 -1.2297 (0.2188)	-0.0115 -1.1930 (0.2328)
D1	0.0680 0.5540 (0.5796)	—	—
D2	—	-0.0333 -0.2016 (0.8402)	—
D3	—	—	-0.1104 -0.6025 (0.5468)

The coefficient, t-value, and p-value (in parentheses) are given for each variable.

***, **, and * indicate significant levels at 10%, 5%, and 1%, respectively.

In the scope of music production industry, results show that the influences of strategic events are mainly taking place on the changes of technical efficiency, which represent the affections on internal factors of individual music producers. The digital technologies do a negative influence, and lawsuits do a positive influence on TEC indices. In addition, the Apple's iTunes business model worsens the TEC index of music publishers significantly for the shrinking of interests sharing. According to the empirical results of these sub-industries, from Table 14 to Table 22, the reason of insignificance in our third hypothesis test can be concluded that new business model like iTunes may stimulate the reallocation of interests. Therefore some inherent companies will take the advantages, and some be eliminated from this industry at the same time.

Finally all the empirical results above, from Table 11 to Table 22, are summarized on Table 23.

Table 23 Summary of the Empirical Results

	Events	MPI	TEC	FS
Whole Music Industry	MP3 & P2P	−***	+**	−***
	Lawsuits	+***	−**	+***
	Apple Online Music Store	−	+	−
Music Retailing Industry	MP3 & P2P	−	+**	−***
	Lawsuits	+**	−	+***
	Apple Online Music Store	−*	−	−***
Music Publishing Industry	MP3 & P2P	+	−***	−*
	Lawsuits	−	+	+
	Apple Online Music Store	+	+*	−
Music Production Industry	MP3 & P2P	+	−**	−
	Lawsuits	−*	+***	+
	Apple Online Music Store	+	−*	−

***, **, and * indicate significant levels at 10%, 5%, and 1%, respectively.

According to the results of Tobit models in the whole scope of music industry, in brief, hypotheses one and two in this research are confirmed, meaning that digital music technologies are negative related and filing a lawsuit against piracy is positive related to the productivity change of music industry. Hypothesis one is confirmed by the Tobit model with the third dummy variable, and evidences show that the MP3 and P2P technologies may significantly impair the productivity. On the other hand, the hypothesis two is confirmed by the Tobit model with the first dummy variable, regression results reveal that lawsuits against piracy can enhance the productivity with 99 percent significant level. However based on the whole scope of music industry Tobit models, hypothesis three in our research is failed to verify. This outcome means that launching a new business model like Apple's iTunes Music Store is not necessary for the improvement of productivity in every music related industries. Further investigation in particular music related industry, accordingly, are used to find out the reason of the fail validation in hypothesis three. Evidences show that productivities of music retailers and producers are significantly worsened in the period of Apple's iTunes business model launching, and productivities of music publishers are improved in such period. Hence the reason of insignificance in our third hypothesis test is concluded as a relocation of interests happened while the Apple's iTunes business model launching: some industries are benefited from this change, but some are not.

In the last part of this section, hypothesis four, launching a new business model do more impact on the productivity than filing a lawsuit against piracy, will be tested. The Mann-Whitney rank tests are used to compare medians of Malmquist productivity indices between two independent events groups, filing lawsuits and Apple's iTunes business model launching, on the basis of nonparametric analysis. SPSS computer program reports the normal approximation to the U statistics and the p-values for two-sided tests on Table 24.

Table 24 Mann-Whitney Tests in Malmaquist Indices for Different Business Strategies

Ranks				
	Group	N	Mean Rank	Sum of Ranks
MPI	iTunes	51	78.53	4005.00
	Lawsuits	130	95.89	12466.00
	Total	181	-	-
TEC	iTunes	51	100.43	5122.00
	Lawsuits	130	87.30	11349.00
	Total	181	-	-
FS	iTunes	51	62.27	3176.00
	Lawsuits	130	102.27	13295.00
	Total	181	-	-

Test Statistics			
Test Variables	MPI	TEC	FS
Mann-Whitney U	2679.000	2834.000	1850.000
Wilcoxon W	4005.000	11349.000	3176.000
Z	-2.006	-1.517	-4.620
Asymp. Sig. (2-tailed)	.045**	.129	.000***

1. The Mann-Whitney U statistic displayed in the table is the smaller of these two values. (In this research U_1 is smaller)
2. Grouping variable represented the events that Apple iTunes Online Music Store launching, and the RIAA filing lawsuits against Napster respectively.
3. The negative Z statistics indicate that the rank sums are lower than their expected values.
4. ***, **, and * indicate significant levels at 10%, 5%, and 1%, respectively.

Results of the two-tails Mann-Whitney tests appear significance, p-values are smaller than 0.05, in the MPI and FS indices, and the Z statistics for every tests have negative signs. Therefore the single tail null hypothesis, filing a lawsuit against piracy do no more impact on the productivity than launching a new business model, is rejected as the rejection of two tails hypothesis, and the four hypothesis in our research is confirmed as a contrary result consequently. Besides the productivity vantage of filing lawsuits against piracy is mainly coming from the superior improvement of frontier shift, implying the lawsuits may cause a greater improvement of external environment. These findings reinforce the importance of filing lawsuits against piracy in a harsh circumstance.

6. Conclusion

6.1 Managerial implication

This research applied an aspect of productivity to investigate the impacts which were made by the new digital technologies, lawsuit strategies and the business model innovation on the performance of the global music industry, and made a comparison between the effectiveness in different business strategies which intrinsic music firms played during the environmental change. Furthermore, researcher also identified the key factors affecting the productivity, and portrayed a process that strategic decisions working on the performance of music industry.

The empirical results of Tobit models in the whole scope of music industry show that digital music technologies are negative related and filing a lawsuit against piracy is positive related to the productivity change of music industry. However based on the whole scope of music industry Tobit models, result shows that launch a new business model like Apple's iTunes Music Store is not necessary for the improvement of productivity in every music related industries. For further investigation in particular music related industry, evidences support that productivities of music retailers and producers are significantly worsened in the period of Apple's iTunes business model launching, and productivities of music publishers are improved in such period. Hence the reason of insignificance in our third hypothesis test is concluded as a relocation of interests happened while the Apple's iTunes business model launching: some industries are benefited from this change, but some are not. Moreover, the two-tails Mann-Whitney tests appear significance in the MPI and FS indices, this result represents hypothesis that filing a lawsuit against piracy do no more impact on the productivity than launching a new business model is rejected. Besides the productivity vantage of filing a lawsuit against piracy is mainly coming from the superior improvement of frontier shift, implying the lawsuits may cause a greater improvement of external environment.

According to these findings in this study, music piracy in recent years was confirmed as a serious problem which can reduce the productivities of music firms directly. Hence the development of digital music technologies, such as MP3 and P2P software, that promotes a new song is the same that steals it away. Piracy rate increased significantly, in the events period of MP3 and P2P technologies, since these digital music technologies, without copyright protecting, encouraged the spread of piracy music. Through an increasing of piracy rate, the productivities of music firms were therefore severely deteriorated by these kinds of copyright-protection-lacking digital music technologies, and deteriorations caused by music piracy even did much more affection than the benefits of technical efficiency improvement. Henceforth fighting against music piracy and creating a legal digital music transaction platform were becoming critical solutions for reversing the recession of music industry in productivity.

Filing a lawsuit against music piracy was confirmed an effective solution for reducing the music piracy rate and therefore improving the productivity significantly. However in the long run, especially in the circumstance of external environment is change, creating a brand-new sustainable business model was confirmed a better way to convert music piracy into a reasonable purchasing behavior, and enhanced the productivity of music industry. Apple's iTunes Online Music Store may bring about a redistribution of interests within music industry, threatening some intrinsic firms, and changing the composition of music industry, so the effectiveness of this business model fall short of our expectation. However since the external environment of music industry is change, creating a "correct" business model is more reasonable for consumers than just filing lawsuits against piracy; therefore managers should still endeavor to create their own blue ocean by finding out a reasonable new music trading model in the era of digitalization.

6.2 Contribution

Differ from the previous research (Navissi et al., 2005) which adopted event study to investigate the lawsuits influence on the short-term security prices of music firms; this study applied an aspect of productivity change to examine the impacts made by environmental change and different business strategies, and compared the effectiveness of different business strategies. This long-term productivity study also added the externalities into consideration, thus the environment variations can be reflected in our model. Furthermore, this thesis portrayed a process that strategic events affect the music industry by the external factors, such as the piracy rate change and the internet scale change and the internal factors, such as sales change, labor scale change, and the capital change. Hence clarified the key factors affecting the productivity of music industry, and suggested managers a direction to improve the performance of music firms. Finally, our findings confirmed the effectiveness of anti-piracy lawsuits, meanwhile reinforced the importance of providing a new business model in a harsh circumstance, encouraging managers to create their own blue oceans for keeping their companies not only sustainable, but superior, in an era of digitalization.

6.3 Further Research

This study also opens up prospects for future research. As for the Malmquist productivity analysis, several factors, such as market structure and intangible-assets-creating-abilities of music firms, are worthy to take into consideration in the DEA model for getting further inspirational implications. Since the DEA Malmquist productivity analysis can work with a wide set of variables, reduce the complexity into an outcome which can be easily understood, and at the same time reflect the long-term reaction of industries, this tool can also be applied on other contents industries, such as e-books, digital movies, digital television, and online games industries.

Aside from applying a long-term DEA productivity approach to investigate the process of strategic impacts, there are many other ways, such as financial ratio analyses, short-term events study, and TSP models, can be employs to confirm the robustness of our research. Moreover for operational applications, based on our empirical implications, it is a critical task for future study that researchers should find out a better business model to promote the legal digital music market, and other contents industries as well.

APPENDICES

Appendix 1 Firms and Operational Activities in Sample

Name	Country	Activity
4 KIDS ENTERTAINMENT INC	US	Music Publishing
ARTISTDIRECT INC	US	Music Distribution
AUDIBLE INC	US	Audio Books
AUDIOHIGHWAY.COM	US	Music Distribution
AVEX GROUP HOLDINGS INC	JP	Music Publishing
BARNESANDNOBLE.COM	US	Music Retail
BERTELSMANN AG	German	Music Publishing
BEYOND INTERNATIONAL GROUP	Australia	Music Publishing
CDNOW INC	US	Music Retail
CDWAREHOUSE INC	US	Music Retail
CHRYSALIS GROUP PLC	UK	Music Publishing
CINRAM INTERNATIONAL INC	US	Music Distribution
EMI GROUP PLC	UK	Music Publishing
EMUSIC.COM INC	US	Music Distribution
FOX ENTERTAINMENT GROUP	US	Music Publishing
GENER8XION ENTERTAINMENT	US	Music Promotion
GMM GRAMMY PCL	Thailand	Music Publishing
HANDLEMAN COMPANY	US	Music Retail
HASTINGS ENTERTAINMENT INC	US	Music Retail
HMV GROUP PLC	UK	Music Retail
IMPRINT RECORD INC	US	Music Production
INTEGRITY MEDIA INCORPORATED	US	Music Retail
INTERMIX MEDIA INC	US	Music Distribution
ISRAEL LAND DEVELOPMENT	Israel	Music Publishing
JACK WHITE PRODUCTIONS	German	Music Publishing
K-TEL INTERNATIONAL INC	US	Music Retail
MAKEMUSIC INC	US	Music Software
MEDIA BAY INC	US	Audio Books
METATEC INTL INC	US	Music Production
MP3.COM	US	Music Distribution
MTS INC	US	Music Distribution
MUSICLAND STORES CORP	US	Music Retail
NATIONAL RECORD MART INC	US	Music Retail

NEWSTAR MEDIA INC	US	Audio Books
PARADISE MUSIC & ENTERTAINMENT INC	JP	Music Production
PLANET ENTERTAINMENT CORP	US	Music Production
PLATINM ENTERTAINMENT INC	US	Music Production
POLYGRAM NV	Netherlands	Music Publishing
QUALITY DINO ENTERTAINMENT INC	US	Music Production
ROJAM ENTERTAINMENT HLD	JP	Music Publishing
SANCTUARY GROUP PLC	UK	Music Publishing
SHINSEIDO CO LTD	JP	Music Retail
SONY MUSIC ENTMT(JAPAN) INC	JP	Music Publishing
SPEC'S MUSIC INC	US	Music Retail
STEINWAY MUSICAL INSTRUMENTS INC	US	Music Instruments
TRANS WORLD ENTMT CORP	US	Music Retail
VALLEY MEDIA INC	US	Music Retail
VIVENDI UNIVERSAL SA	FR	Music Publishing
WARNER MUSIC GROUP CORP	US	Music Publishing
WHEREHOUSE ENTMT INC	US	Music Distribution
ZOMAX INC/MN	US	Music Production

Appendix 2 Firms in Sample from 1997 to 2005

Name	97	98	99	00	01	02	03	04	05
4 KIDS ENTERTAINMENT INC	○	○	○	○	○	○	○	○	○
ARTISTDIRECT INC		○	○	○	○	○	○	○	○
AUDIBLE INC	○	○	○	○	○	○	○	○	○
AUDIOHIGHWAY.COM		○	○						
AVEX GROUP HOLDINGS INC	○	○	○	○	○	○	○	○	
BARNESANDNOBLE.COM	○	○	○	○	○	○	○		○
BERTELSMANN AG	○	○	○	○	○	○	○	○	○
BEYOND INTERNATIONAL GROUP	○	○	○	○	○	○	○	○	○
CDNOW INC	○	○	○						
CDWAREHOUSE INC	○	○	○	○	○				
CHRYSALIS GROUP PLC	○	○	○	○	○	○	○	○	○
CINRAM INTERNATIONAL INC	○	○	○	○	○	○	○	○	○
EMI GROUP PLC	○	○	○	○	○	○	○	○	○
EMUSIC.COM INC			○	○					
FOX ENTERTAINMENT GROUP	○	○	○	○	○	○	○	○	
GENER8XION ENTERTAINMENT	○	○	○						
GMM GRAMMY PCL	○	○	○	○	○	○	○	○	○
HANDLEMAN COMPANY	○	○	○	○	○	○	○	○	○
HASTINGS ENTERTAINMENT INC	○	○	○	○	○	○	○	○	○
HMV GROUP PLC					○	○	○	○	○
IMPRINT RECORD INC									
INTEGRITY MEDIA INCORPORATED	○	○	○	○	○	○	○		
INTERMIX MEDIA INC		○	○	○	○	○	○	○	○
ISRAEL LAND DEVELOPMENT	○	○	○						
JACK WHITE PRODUCTIONS			○	○	○	○	○	○	
K-TEL INTERNATIONAL INC	○	○	○	○	○	○	○		
MAKEMUSIC INC	○	○	○	○	○	○	○	○	○
MEDIA BAY INC	○	○	○	○	○	○	○	○	○
METATEC INTL INC	○	○	○	○	○	○			
MP3.COM		○	○	○					
MTS INC				○	○	○			
MUSICLAND STORES CORP	○	○	○						
NATIONAL RECORD MART INC	○	○	○	○					
NEWSTAR MEDIA INC	○	○	○						
PARADISE MUSIC & ENTERTAINMENT	○	○	○	○	○				

INC									
PLANET ENTERTAINMENT CORP			○	○					
PLATINM ENTERTAINMENT INC		○	○						
POLYGRAM NV	○								
QUALITY DINO ENTERTAINMENT INC	○								
ROJAM ENTERTAINMENT HLD					○	○	○	○	○
SANCTUARY GROUP PLC		○	○	○	○	○	○	○	○
SHINSEIDO CO LTD	○	○	○	○	○	○	○	○	○
SONY MUSIC ENTMT(JAPAN) INC	○	○	○	○	○	○	○	○	
SPEC'S MUSIC INC	○								
STEINWAY MUSICAL INSTRUMENTS INC	○	○	○	○	○	○	○	○	○
TRANS WORLD ENTMT CORP	○	○	○	○	○	○	○	○	○
VALLEY MEDIA INC	○	○	○	○					
VIVENDI UNIVERSAL SA	○	○	○	○	○	○	○	○	○
WARNER MUSIC GROUP CORP	○	○	○	○	○	○	○	○	○
WHEREHOUSE ENTMT INC	○	○	○	○	○				
ZOMAX INC/MN	○	○	○	○	○	○	○	○	○
Number of Sample Firms	**38**	**41**	**44**	**38**	**35**	**32**	**30**	**27**	**24**
Number of Outliers	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**

REFERENCES

Alexander, P. (1994). *Entry barriers, release behaviour and multi-product firms in the music recording industry.* Review of Industrial Organizations, 9.

Andersen, B., Kozul, Z., and Kozul-Wright, R. (2000). *Copyrights, competition* and development: The case of the music industry. United Nations Discussion Paper Series No. 143.

Asvanund, A., Clay, K., Krishnan, R., Smith, M. D. (2004). *An Empirical Analysis of Network Externalities in Peer-to-Peer Music-Sharing Network.* Information Systems Research, Jun 2004, Vol. 15, No. 2, pp.155-174

Banker, R. D. and Morey, R. C. (1986). *Efficiency analysis for exogenously fixed inputs and outputs.* Operations Research, Vol. 34, pp. 513-521.

Banker, R. D. and Morey, R. C. (1989). *Incorporating value judgements in efficiency analysis.* Research in Government and Nonprofit Accounting, Vol. 5, pp. 245-267.

Banker, R. D., Charnes, A., and Cooper, W. W. (1984). *Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis.* Management Science, Vol. 30 pp.1078-1092

Banker, R. D., Conrad, R. F., and Strauss, R. P. (1988). *A comparative application of data envelopment analysis and translog methods:an illustrative study of hospital production.* Management Science, Vol. 32(1), pp. 30-44.

Bauer, P. W., Berger, A. N., Ferrier, G. D., and Humphrey, D. B. (1997). *Consistency Conditions for Regulatory Analysis of Financial Institutions: A* Comparison of Frontier Efficiency Methods. Journal of Economics and Business. New York: Mar/Apr, Vol. 50, Iss. 2, pp. 85-115

Binder, J. (1985). *On the Use of the Multivariate Regression Model in Event Studies.* Journal of Accounting Research, Spring, Vol. 23, pp. 370-383.

Brockett, P. L. and Golany, B. (1996). *Using Rank Statictic for Determining Programmatic Efficiency Differences in Data Envelopment Analysis***,** Management Science, Vol. 42, pp. 467-472.

Caves, D. W., Christensen, L. R., Diewert, W. E. (1982). *The economic theory of index numbers and themeasurement of input, output,an d productivity.* Econometric, 50 (6), pp. 1414–1939.

Charnes, A. and Cooper, W. W. (1980). *Management Science Relations for Evaluation and Management Accountability.* Journal of Enterprise Management, Vol. 2, pp. 160-162.

Charnes, A., Clark, C. T., Cooper, W. W., and Golany, B. (1984). *A developmental study of data envelopment analysis in measuring the efficiency of maintenance units in the US air forces.* Annals of Operation Research, Vol. 2(1), pp. 95-112.

Charnes, A., Cooper, W. W., and Rhodes, E. (1978). *Measuring the efficiency of decision making units.* European Journal of Operational Research, Vol. 2, pp. 429-444.

Charnes, A., Cooper, W. W., and Seiford, L. M. (1994). *Data Envelopment Analysis: Theory, Methodology and Application.* Charnes et al. Editors, Kluwer Academic Publishers.

Chen, Y. (2003). *A non-radial Malmquist productivity index with an illustrative application to Chinese major industries.* Int. J. Production Economics 83, pp. 27–35.

Chen, Y., and Ali, A. I. (2004). *DEA Malmquist productivity measure: New insights with an application to computer industry.* European Journal of Operational Research, 159, pp. 239–249.

Chu, H. L., Liu, S. Z., Romeis, J. C., Yaung, C. L. (2003). *The initial effects of physician compensation programs in Taiwan hospitals: Implications for staff model HMOs.* Health Care Management Science; 6(1): 17-26.

Condry, I. (2004). *Cultures of music Piracy: An ethnographic comparison of the US and Japan.* International Journal of Cultural Studies, Volume 7(3), pp.343-363

Cook, W. D., Kress, M., and Seiford, L. (1996). *Data Envelopment Analysis in the Presence of Both Quantitative and Qualitative Factors.* Journal of Operational Research Society, Vol. 47, pp. 945-953.

Cooper, W. W., Seiford, L. M., and Tone, K. (2000). *Data Envelopment Analysis: A comprehensive text with models, applications, references and DEA-Solver software.* Kluwer Academic Publishers.

Daniel, W. W. (1978). *Applied Nonparametric Statistics.* Houghton Mifflin Co., Boston.

Fandel, P. (1998). *Data envelopment analysis application in agricultural production efficiency.* Central European Journal for Operations Research and Economics, Vol. 6(3-4), pp. 159-166.

Färe, R., Grosskopf, S., Lindgren, B., and Roos, P. (1989). *Productivity Developments in Swedish Hospitals: A Malmquist Output Index Approach.* Discussion Paper No 89-3, Southern Illinois University, Illinois.

Färe, R., Grosskopf, S., Lindgren, B., and Roos, P. (1992). *Productivity Changes in Swedish Pharmacies 1980-1989: A Non-Parametric Malmquist Approach,* Journal of Productivity Analysis, Vol. 3, pp. 85-101.

Färe, R., Grosskopf, S., Lindgren, B., and Roos, P. (1994a). *Production Frontiers.* Cambridge University Press, Cambridge.

Färe, R., Grosskopf, S., Lindgren, B., and Roos, P. (1994b). *Productivity developments in Swedish hospitals: A Malmquist output index approach. In: Charnes, A., Cooper, W.W., Lewin, A.Y., Seiford, L.M. (Eds.), Data Envelopment Analysis: Theory, Methodology and Applications.* Kluwer Academic Publishers, Boston.

Farrell, M. J. (1957). *The measurement of productive efficiency.* Journal of the Royal Statistical Society, Series A, Vol. 120, Part 3, pp. 253-281.

Farrell, M. J. and Fieldhouse, M. (1962). *Estimating efficient production functions under increasing returns to scale.* Journal of the Royal Statistical Society, Series A, Vol.125, Part 2, pp. 252-267.

Ganley, J. A. and Cubbin, J. S. (1987). *Performance indicators in prisons.* Public Money, December, pp. 57-59.

Gattoufi, S. et al. (2004). *A Taxonomy for Data Envelopment Analysis.* Socio-Economic Planning Sciences, Vol. 38, pp. 141-158.

Golany, B. and Roll, Y. (1989). *An application procedure for data envelopment analysis.* Omega, International Journal of Management Science, Vol. 3, pp. 237-250.

Kao, C. (1994). *Efficiency Improvement in Data Envelopment Analysis.* European Journal of Operational Research, Vol. 73, pp. 487-497.

Kao, C. and Liu, S. T. (2000). *Fuzzy Efficiency Measures in Data Envelopment Analysis.* Fuzzy Sets and Systems, Vol. 113, pp.427-437.

Kao, C. and Yang, Y. C. (1992). *Evaluation of junior colleges of technology: the Taiwan case.* European Journal of Operational Research, 72(1) pp.43-51.

Katz, M. and Shapiro, C. (1985). *Network Externalities, Competition and Compatibility*. American Economic Review, Vol. 75, pp. 424-440.

Kim, W. C. and Mauborgne, R. (2004). *Blue Ocean Strategy.* Harvard Business Rev., October, pp.76-84

Kutner, M. H., Nachtsheim, C. J., Neter, J., and Li, W. (2005). *Applied Linear Statistical Models.* McGraw-Hill Publisher, 5^{th} edition.

Lang, J. R. and Golden, P. A. (1989). *Evaluating the efficiency of Sbdcs with data envelopment analysis: a longitudinal approach*. Journal of Small Business Management, 27(2).

London and Madrid (2005). *One in three music discs is illegal but fight back starts to show results.* IFPI Commercial Piracy Report 2005, Jun 23 2005. (http://www.ifpi.org)

Madden, M. , Rainie, L. (2005). *Music and Video Downloading moves beyond P2P.* Pew Internet & American Life Project, PEW/INTERNET, Mar. (http://www.pewinternet.org)

Millon-Cornett, M., and Tehranian, H. (1989). *Stock Market Reactions to the Depository Institutions Deregulation and Montary Control Act of 1980.* Journal of Banking and Finance, March, Vol. 13, pp. 81-100.

Molteni, L. and Ordanini, A. (2003). *Consumption Patterns, Digital Technology and Music Downloading.* Long Range Planning, 36, pp. 389-406

Navissi, F., Naiker, V., and Upson, S. (2005). *Securities Price Effects of Napster-Related Events.* Journal of Accounting Auditing & Finance, Spring, Vol.20, No. 2, pp. 167-183.

Oral, M. and Yolalan, R. O. (1992). *An Empirical Study on Measuring Operating Efficiency and Profitability of Bank Branches.* European Journal of Operational Research, Vol. 46(3), pp. 282-294.

Peraino, Vito (1999). *The Law of Increasing Returns.* Wired Magazine, August 1999/Iss.7.08

RIAA (various years). *Annual Reports*. Washington, DC, Recording Industry Association of America.

Rouse, P., Putterill, M., and Ryan, D. (1997). *Towards a general managerial framework for performance measurement: a comprehensive highway maintenance application.* The Journal of Productivity Analysis, Vol. 8(2), pp. 127-149.

Salinger, M. (1992). *Standard Error in Event Studies.* Journal of Financial and Quantitative Analysis, March, Vol. 27, pp. 39-53.

Saloner, G. and Spence, A. M. (2002). *Creating Value and Capturing Value: Perspectives and Cases on Electronic Commerce.* John Wiley and Sons, New York.

Sheskin, D. J. (1997). *Parametric and Nonparametric Statistical Procedures*. CRC Press.

Strahilevitz, L. J. (2002). *Charismatic code, social norms, and the emergence of cooperation on the file-swapping networks.* Virginia Law Rev. 89(May) 505-596.

Sueyoshi, T., Ohnishi, K., and Kinase, Y. (1999). *A benchmark approach for baseball evaluation*. European Journal of Operational Research, Vol. 115(3), pp.429-448.

Thanassoulis, E. (2001). *Introduction to the Theory and Application of Data Envelopment Analysis: A foundation text with integrated software*. Kluwer Academic Publishers.

Thompson, R. G., Singleton, F. D. Jr., Thrall, R. M., and Smith, B. A. (1986). *Comparative Site Evaluations for Locating a High-Energy Physics Lab in Texas.* Interfaces, Vol. 16, No.6, pp. 35-49.

Tobin, J. (1958). *Estimation of Relationships for Litmited Dependent Variables.* Econometrica 26, pp. 24-36.

UNCTAD (1999). *Jamaica: The Science, Technology and Innovation Policy Review.* New York and Geneva, United Nations.

Vogel, L. H. (2001). *Entertainment industry economics: A guide for financial analysis.* 5th edn. New York: Cambridge University Press.

Wikipedia (2006). *World Music Market.* Wikipedia The Free Encyclopedia, 31 July. (http://en.wikipedia.org)

Zhu, J. (2003). *Quantitative Models for Performance Evaluation and Benchmarking: Data Envelopment Analysis with Spreadsheets and DEA Excel Solver*. Kluwer Academic Publishers.

Zhu, K., MacQuarrie, B. (2003). *The Economics of Digital Bundling: The Impact of Digitization and Bundling on the Music Industry*. COMMUNICATIONS OF THE ACM, September, Vol. 46, No. 9ve

CHINESE REFERENCES

高強, 黃旭男, and T. Sueyoshi (2003). *管理績效評估:資料包絡分析法 Management Performance Evaluation: Data Envelopment Analysis.* 華泰文化.

WEBSITES

International Telecommunication Union (ITU)
International Intellectual Property Alliance (IIPA)