Innovation and Competition in Standard-Based Industries: An Analysis of the High Definition U.S. Home Video Market

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

This paper examines the competitive dynamics in a standard-based industry through a historical examination of the U.S. home video industry. It analyzes how the Blu-ray technology wins the battle of the high definition DVD market over HD-DVD technology, by focusing on the aspects of the first-mover advantages, network effects. The analysis suggests that the success in the network-based industry partially support to traditional argument on first-mover advantages; they were important only to the point that the first mover takes advantages of the lead time to develop a network of complementary products. This study illustrates that building a network of complementary products and installed base should be the primary goal to succeed in the standard setting competition.

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Dedication

This is dedicated to my family and friends who supported me through my time at the University of Waterloo.

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Chapter 1 Introduction

The ability of a firm to establish its technology as the standard is a critical determinant to its long-term success in a competitive market environment. Many well-known historical cases provide good examples of the importance of standards setting. One example is the case of the adoption of QWERTY typewriter keyboard (David 1985). The QWERTY format was originally developed by trial and error in the 1860s to reduce the tendency of type bars to clash and jam when keys were struck in rapid succession. Though the format was considered inferior to alternative designs, the skills of typists became a complementary product and consumers were locked in the QWERTY standard (Hill 1997). Even after the development of computer in which the clashing and jamming issues are not important factors in designing a keyboard, the QWERTY format continues to dominate the market as the main standard.

Another example of the importance of standard is the decline of the Apple computer in the 1980s, frequently attributed to Apple's reluctance to share its operating system with software developers. In comparison, the rise of Microsoft and Intel is attributed to their liberal policy of sharing the operating system, which has been used by over 90% of computer users until 1998 (Ramsey 1998). However, with the new design and architectural innovations of the Apple computer, the market share of the firm is on the rise. According to Wakabayashi (2008), Apple has steadily gained market share against PCs. In the June 2008 quarter, Apple accounted for 8.5 percent of U.S. computer shipments, a rise of 38 percent from a year earlier, which outpaced the overall U.S. computer market growth of 4.2 percent. The new

design and color of the Apple computer, which significantly stands out compare to other ordinary computers, attracted consumers and contributed to Apple's recent success. However, in the U.S. home video market, the design of home video machines did not affect firms' success in the past as none of the manufacturers' machines look much different from each other.

In the U.S. home video market, there was a famous standards competition between VHS and Betamax (Beta) formats in the late 1970s. The Beta format was introduced in 1975 by the Sony Corporation, and the VHS was introduced in 1976 by the JVC (Victor Company of Japan) supported by its parent company, Matsushita Electric. The VHS format became the standard in the VCR market, though Beta format was introduced earlier and was considered technically superior (Cusumano, Mylonadis, and Rosenbloom 1992). Recently, in the high definition DVD market, intensive standard war has been engaged between Sony-led Blu-ray technology and Toshiba-led HD-DVD technology, and the Blu-ray technology became the standard.

The objective of this thesis is to examine the factors that affect the market dominance in the standard war, using the recent example of the competition between Blu-ray and HD-DVD technologies in the home video market. Several studies have examined the theoretical and empirical analysis of the processes and outcomes of the standard-setting competition in some markets including the Beta and VHS technologies in home video player (Cusumano et al. 1992, Gallagher and Park 2002, Ohashi 2003, Park 2004). Due to the very recent resolution of the standard war in high definition video market in 2008, there is not enough empirical data to examine the factors that contributed the adoption of the Blu-ray technology.

This thesis instead relies on the previous experiences in similar industries to explore what key strategic issues determined the outcome in a standards-based industry in general and a high definition video market in particular. This thesis can provide some guideline for firms' strategy in standards-based industries.

This paper examines the history of the home video market standards competition between Beta and VHS in the 1970s. The main three theories that are used to analyze the previous Beta versus VHS standards competition and other standards competitions—are applied to the recent standard war between Blu-ray and HD-DVD. The three theories include the first-mover advantages, network effects, and architectural innovation. Firms' patent data related to Blu-ray and HD-DVD are collected from the U.S. patent and trademark office and analyzed to describe firms' interest in technology and their management strategies. Of particular interest are the patterns of publishing patents of major electronics firms before and after the high definition standards competition.

This paper is divided into five sections. Section 2 establishes the theoretical background and the assumptions through various literatures. Section 3 describes the overview of the U.S. home video market. The analysis of the standard setting in high definition home video market is examined in section 4, with patent data. The conclusion related to the results to management recommendations, and future research perspectives is discussed in section 5.

Chapter 2 Literature Review

Industry standard is a technology or format that is generally accepted by members of an industry. There exist several studies which investigate the factors that affect the survival of firms in standards-setting industries. Koski and Kretschmer (2005) explain that standardization accelerates the new technology entry and diffusion, although within standards competition triggers less aggressive price competition than between standards competition. Hill (1997) gives examples of companies in the industries where technological standards are important, such as Apple Computer, Ericsson, Iomaga, Intel, Microsoft, Qualcomm, and Sony.

According to Arthur (1989), in markets where two or more incompatible increasing return technologies compete, small changes in the initial conditions either due to the result of chance or firms' strategy may result in one technology's gaining of a sufficient lead and becoming the de facto standard, with other competing technologies becoming locked out. Only first-movers are able to impact markets considerably from making small initial condition changes since the technologies are new. This undoubtedly shows the importance of becoming a first-mover. Several economists argue that this can occur even when the dominant technology is clearly inferior to other designs (Cooper and Schendel 1976, David 1985, Hill 1997).

The strategic options that a firm might adopt in order to establish its technology as a standard include patents licensing, strategic alliances, and diversification into complementary

product. These options can be classified into three main groups that affect the wining of standards competitions; the first-mover advantages, network effects, and architectural innovation.

2.1 First-mover Advantages

The concept of first-mover advantages initially emerged from anecdotal and empirical evidences which show that first movers' competitive performance tend to be better than that of later entrants (Suarez and Lanzolla 2007). The pioneering research funded by the U.S. Federal Trade Commission in the 1970s show that, in both the prescription drug and cigarette product markets, first entrants tend to enjoy enduring performance advantages over later entrants.

This concept of "first-mover advantage" have attracted lots of attention afterwards, and several theoretical explanations are suggested regarding why the first movers tend to earn "profits in excess of the cost of capital", why they achieve a larger market share, or why they survive longer than competitors (Suarez and Lanzolla 2007).

Deeds and Hill (1996) argue the importance of rapid development and introduction of new products, in order to gain early cash flows for greater financial independence, external visibility and legitimacy as soon as possible, and to increase the likelihood of survival.

The first-mover advantages are defined in terms of the ability of pioneering firms to earn positive economic profits. Lieberman and Montgomery (1988) suggest that first-mover advantages arise endogenously within a multi-stage process. In the first stage, some asymmetry is generated, enabling one particular firm to gain a head start over rivals. This first-mover opportunity may occur because of the firm's unique resources or foresight or

simply luck. Once this asymmetry is generated, a variety of mechanisms may enable the firm to utilize its position, which enhances the magnitude or durability of the first-movers' profits. Lieberman (1988) emphasizes that the initial asymmetry is critical for first-mover advantages to arise.

In service sectors, Tufano (1989) studies how investment banks are compensated for their investments in developing new products, and found that there were early mover advantages in the form of lower costs of trading, underwriting, and marketing in financial services. Investment banks that create new products do not charge higher prices in the short period of 'monopoly' before imitative products appear. Consequently, banks capture a larger share of underwritings with innovations than with imitative products. Nehrt (1998) studies the maintainability of first mover advantages when environmental regulations differ between countries. Also, Suarez and Lanzolla (2007) study how the pace of market evolution and technology evolution potentially enables or disables first mover advantage. The ability to gain first-mover advantages is true in any industries where the relative effectiveness of patent protection leads to patent races in which a "winner takes all" scenario exists (Gilbert and Newbery 1982).

2.1.1 Factors that affect the first mover advantages

Lieberman and Montgomery (1988) show that first-mover advantages generally arise from three primary sources: technology leadership, pre-emption of assets, and buyer switching costs. First-movers can gain advantage through maintaining leadership in technology. Also, the first-mover firm may gain advantage by pre-empting rivals in getting hold of scarce assets. Here, the first-mover gains advantage by controlling the assets that

already exist, rather than those created by the firm through development of new technology. Moreover, first-mover advantages may also arise from buyer switching costs. With switching costs, late entrants must invest extra resources to lure customers away from the first-mover firm.

Other studies stress the importance of path dependence in the evolution of technologies, (Arthur 1989, Ruttan 1997). Path dependence implies that future success is to a large extent dependent on past achievements, which results in increasing returns from following a particular path. Path dependence may then lead to market entrenchment if a variant of new technology, produced by an innovator, leads to a cumulative advantage (increasing returns) over later entrants. It has been argued that this could preclude entry even when the newer versions of a technology are superior, due to the high switching costs (Agarwal and Gort 2001). The classic example of first-mover advantages caused by high switching costs is the QWERTY format standard.

2.1.2 Factors that are related to first mover disadvantages

The first-mover disadvantages, or second-mover advantages, are those advantages enjoyed by late-mover firms. Lieberman and Montgomery (1998) show late-movers may benefit from the first movers' experiences: the ability to 'free-ride' on first-movers' investments, resolution of technological and market uncertainty, technological discontinuities that provide 'gate-ways' for new entry, and various types of 'incumbent inertia' that make it difficult for the incumbent to adapt to environmental change.

Late-movers may be able to 'free-ride' on a pioneering firm's investments in a number of areas, including R&D, buyer education, and infrastructure development. Late-

movers can gain advantage through resolution of market or technological uncertainty. Werner-felt and Karnani (1987) studied the effects of uncertainty on the attractiveness of early versus late market entry. Entry in an uncertain market obviously involves a high degree of risk. They argue that early entry is more attractive when the firm can influence the way that uncertainty is removed or reduced at least. Since the replacement technology often appears while the old technology is still growing, it may be difficult for an entrant to perceive the threat and take ample preventative steps. Weakness of the first-mover advantage is often enhanced by 'incumbent inertia'. Locked-into a specific set of fixed assets, the firm may be reluctant to increase existing product lines, or become organizationally inflexible (Lieberman and Montgomery 1988).

Christensen et al. (1998) shows that firms that entered many years before, in the stage of the industry's development characterized by broader variety in product architecture and low volume-per-model manufacturing, faced a higher probability of failure. This suggests that the capabilities and cultures they developed in the competitive environment might not have equipped them well for the competition that characterizes the industry after the dominant design emerged. They show that in the rigid disk drive industry, entry strategies that entail market risk (entering an emerging market with proven component technology) may be less risky than strategies that entail technological risk (entering an established market with new, higher-performance component technology).

2.2 Network Effects

In modern industries such as computer, information and consumer electronic technologies, a consumer's benefit of consuming a product or a firm's success of introducing a new product depends on the number of people who purchased compatible products (called "network effect"). Katz and Shapiro (1985) distinguish this externality between direct and indirect network effects.[1] Direct network effect arises where there is a direct physical effect of the number of purchasers on the quality of the product, and a typical example is telephone network in which the value of telephone directly depends on the number of other consumers (network size) who have joined the network.[2] For indirect network effect, the value of a product does not depend directly on the physical effect but indirectly on the availability of complementary products. For example, the size of installed base of hardware (i.e., cumulative sale of hardware products) affects software developers' incentive to introduce new software varieties that are compatible with the hardware product.

Many products have little or no value in isolation, but generate value when combined with others (Economides 1996). Examples include: camera bodies and lenses, which together provide photographic services; home video components and programming, which together provide entertainment services. Hence, the expected utility of the primary product, and thus its sales, increases as more complements become available; in turn, this availability of complements depends on the installed base of the primary product (Stremersch et al. 2007). Examples given are products that are strongly complementary, although they need not be

[1] They also consider another type of externality arisen from durable goods, in which the quality and availability of post-purchase service depends on the size of network.

[2] Other analyses of direct network effect include computer software Gandal (1994) and automated teller machines Saloner and Shepherd (1995).

consumed in fixed proportions (Katz and Shapiro 1994). In summary, the amount of software that is available for a certain technology has a positive influence on the utility of the entire hardware-software system to the consumer (Church and Gandal 1992), drawing more new customers to adopt the new hardware and thus increasing hardware sales and the installed base of hardware. In turn, the hardware installed base positively affects software companies' decisions to make software titles available (Gandal 2002).

Some authors have argued that growth in software availability may precede growth of hardware sales (Srinivasan et al. 2004). Church and Gandal (1992) claim that software availability needs to achieve a critical mass for hardware to become a viable alternative and for hardware sales to take off. The reason is that consumers need a sign of sufficient software availability before they adopt the hardware. Moreover, software companies may invest in software provision before any marked hardware sales occur. For example, Microsoft invested in the CD-ROM long before any significant sales of CD-ROM hardware occurred. Because the CD-ROM was the first mass-market high-capacity medium that might prove useful in copyright protection, Microsoft envisioned the dramatic advantages it might have for software delivery and installation (Stremersch et al. 2007). Also, some theoretical work on network externality has typically employed a game-theoretic approach to analyze competitive behaviour between incompatible technologies with different installed bases (Katz and Shapiro 1986, Farrell and Saloner 1986).

Empirical investigations on network externality, on the other hand, have focused on demonstrating direct and indirect network effects in a variety of industries (Gandal et al. 1999). These studies find that after adjusting for differences in quality, the value of a product

in these categories increases as the installed base or availability of complementary products increases (Basu et al. 2003).

2.2.1 Direct Network Externality

In case of direct network effects it is relatively uncontroversial that they can give rise to a network, or adoption, externality. Individuals when they join a network characterized by direct network effects do so, on the basis of their private benefits and do not take into account that others on the network are also made better off by their decision to join (Church, Gandal and Krause 2008).

Figure 1 shows a feature in a simple star telephone network. A phone call from B to E is composed of BS and SE. S is defined as switching services in the figure. Networks where these services are distinct are names 'two-way' networks in Economides and White (1994). When BS and SE are identical it is called 'one-way' network. It is critical that the relationship in both one-way and two-way networks is the complementarity between the pieces of the network. This critical economic relationship is also often observed between different classes of goods in non-network industries. Economides and White (1994) point out that a pair of vertically related industries is formally equivalent to a one-way network.

Despite the importance of the direct network externality, it is not likely to play a crucial role in setting the standards in the high definition standards competition. As noted, the value of direct network is attained from an immediate result of other users adopting the same system; in the home video market, consumers do not get direct benefit from adopting the same system. In contrast, direct network externality is more pervasive in information and network technologies such as facsimile, telephone, ATM, and internet industries.

2.2.2 Indirect Network Externality

Theoretical work on indirect network externality has modeled the positive effect of the availability and variety of compatible complementary products on the valuation of a hardware product. The hardware-software relationship has also been extended to service industry, where, for instance, the existence of an auto-servicing network or a network of refueling franchises increases the value of the product (Basu et al. 2003). Indirect network externalities are gaining economic significance in technology markets, because hardware and software are typically provided by independent firms, and both sets of firms have an incentive to free-ride on each others' demand creation efforts (Gupta, Jain and Sawhney 1999).

Historically, indirect network externalities have influenced the outcome of technology competition in many markets, including AM stereo, color television, videocassette recorders, CD players, and personal computers. More recently, as analog technologies gave way to digital technologies that require new software, indirect network externalities played an important role in the evolution of a wide range of technology markets (Basu et al. 2003).

Empirical research on indirect network externality has focused primarily on the relationship between software availability and hardware sales. Bayus (1987) estimates a model for CD sales as a function of CD players, as well as others factors such as consumer awareness and purchase intentions. Gupta et al. (1999) have demonstrated the need for incorporating indirect network externality effects in forecasting the demand of HDTV, which depends on the availability of digital programming. Specifically, these authors show that

ignoring the indirect network externality can introduce a significant bias in predicted sales of HDTV (Basu et al. 2003).

Stremersch et al. (2007) empirically examine whether software availability leads hardware sales, or vice versa. Business analysts and academics have casually observed that a critical mass of software titles is required for hardware sales to take off, where it is the point of transition between the introduction stage and the growth stage of a growth curve.

Furthermore, when the network effect is indirect, consumption benefits do not depend directly on the size of the network (the total number of consumers who purchase compatible products) per se. Rather individuals care about the decisions of others because of the effect that has on the incentive for the provision of complementary products. It is not only restricted to consumer electronics which is the most common example.

As mentioned, indirect network effects also give rise to a problem popularly called "chicken-and-egg" paradox; that is, consumers wait to adopt the hardware until enough software is available, and software manufacturers delay releasing software until enough consumers have adopted the hardware (Gupta et al. 1999). A recent example is the high-definition television (HDTV) market. The expected utility of HDTV sets to consumers (and thus HDTV set sales) increases as more HD broadcasting becomes available. Conversely, broadcasters will make more HD broadcasting available as the number of consumers who own HDTV sets increases. For HDTV to succeed, this chicken-and-egg paradox must be resolved (Gandal 2002). In other words, when hardware and software products are supplied by different sets of firms, and when hardware manufacturers rely on software firms to supply software (Cusumano et al. 1992). The chicken-and-egg problem arises because hardware

firms want software firms to spur sales of new hardware products by offering a wide selection of software for the new products, but software firms in turn want to wait until the new hardware products have achieved significant market penetration, before committing to the new hardware platforms. Neither the hardware firms nor the software firms want to move first to invest in market creation (Gupta et al. 1999).

Any industries where network effect is vital, the market pose challenges for coordination among firms-and sometimes consumers as well. A firm may gain little by introducing a new video format, such as in this paper HD-DVD, unless programming will be available to play on that format. Naturally, issues of coordinating investment arise in any market; for example, firms in an industry have to reach the right level of capacity (Katz and Shapiro 1994).

2.3 Architectural Innovation

The distinction between refining and improving an existing design and introducing a new concept that departs in a significant way from past practice is one of the central notions in the existing literature on technical innovation (Morse and Moch 1977). Incremental innovation introduces relatively minor changes to the existing product, exploits the potential of the established design, and often reinforces the dominance of established firms. Radical innovation, in contrast, is based on a different set of engineering and scientific principles and often opens up whole new markets and potential applications (Fixson and Park 2008, Henderson and Clark 1990).

The distinction between radical and incremental innovation has produced important insights, but it is fundamentally incomplete. Clark (1987) showed that there is growing evidence that there are numerous technical innovations that involve apparently modest changes to the existing technology but that have quite dramatic competitive consequences.

One of the most well known examples of architectural innovation is the case of Xerox, the pioneer of plain-paper copiers. Xerox lost half of its market share and suffered serious financial problems due to lack of acknowledging the market appropriately. The competitors` copiers were much smaller and reliable; nevertheless, the new products only needed little engineering knowledge.

One stream of research has focused on firms' abilities to confront technological change as a primary determinant of survival. While the findings of these researchers have sometimes seemed disjointed and even at odds with one another, some integrative studies have recently emerged that suggest how technological, cultural, managerial, and competitive forces can interact to affect firms' probabilities of survival (Cooper and Schendel 1976).

Chapter 3 Industry Overview

3.1 Previous Standards Competitions

Format competitions have been around for centuries: Thomas Edison favored phonograph cylinders but lost out to discs. The most famous case was the standards competition between VHS and Beta video-cassette formats in the home video market which started in the late 1970s and ended in the 1980s (Economist[A] 2007). Although there have been three major generations (VCR, DVD, and HD-DVD) in the evolution of the home video market, after the first standard-based competition, another competition between Blu-ray and HD-DVD had occurred without learning the lesson of hardship from the first competition between Beta and VHS.

Even with firms' willingness on a common standard before going to market, negotiations proved often difficult, since companies tend to have interests in various aspects of a product even if it may be a similar functioning product, in this case, Blu-ray and HD-DVD. It is obvious that companies will lean towards to developing a product which costs the least, hence yielding the most profit. What they are capable of producing is always taken into consideration and, therefore, pursuing different goals among each other in the same industry is not a surprise.

This is where the historical analysis of the U.S. home video industry begins. As noted above, there has been three major distinctive generations in the evolution of home video electronics. The last one between Blu-ray and HD-DVD is analyzed in the paper. Although

each generation has unique aspects, there are a few general themes in the home video market that are consistent of across generations.

a) Capacity of the recording media. Between Beta and VHS, the length of the tape played an important role. Similarly for HD-DVD, the capacity of the disc was important for the quality of the picture.

b) Home video machines were first introduced in Japan about a year earlier than in the U.S. market. However, success in Japan does not appear to have influenced the outcome in the U.S. market. For example, Beta appeared to be successful in Japan but VHS gained a huge success in VHS with different strategy.

c) Profit margins on software, historically video cassettes, but more recently on discs, have been higher than on the hardware.

d) Despite their common ancestry and technical similarities two machines competing against each other were always incompatible.

e) Three theories—first-mover advantage, network effects, architectural innovation—are mainly used to explain the result of standards competition.

Appendix A summarizes the high definition home video market chronology according to rival machines and their respective manufactures, introduction date, and some specifications.

3.1.1 The First Generation

The Beta format was the first compact, inexpensive, reliable, and easy-to use VCR, and it accounted for the majority of VCR production during 1975-77 and enjoyed steadily increasing sales until 1985. Nonetheless, it fell behind the VHS in market share during 1978 and steadily lost share thereafter. Several theories can be applied to explain Beta's loss against VCR. However, in particular, failing to utilize architectural innovation and network effects are the main reasons of Beta's loss. Unlike the VHS, Beta could not record for the full three hours needed to cover a baseball game, and Beta's lacking support in prerecorded tapes resulted in consumers not being able to find the movie titles they want easily at local rental store. Sony matched most of these moves but with a lag and with less effect. In subsequent years, the greater abundance of VHS tapes gave consumers greater incentives to choose VHS players, which then led tape distributors to stock more VHS tapes, in a reinforcing pattern (Cusumano et al. 1992). There are many studies on both management and economics which highlight the strategic challenges that can explain the case of Beta and VHS (Benner and Tushman 2003, Cusumano et al. 1992, Lieberman and Montgomery 1998).

Moreover, unlike the CD-player, which was merely a better record-player, the VCR replaced no other household gadget. The only video recorders at the time were huge Ampex reel-to-reel machines used by television stations to rebroadcast live shows in later time zones. Evidence of sales showed that manufacturers who tried selling play-only VCRs did not sell many machines. Sales of play-only VCRs were low, indicating that the ability to record was crucial. Although, the Beta lost out unlike the VHS machine, it could not record for the full three hours needed to cover a baseball game (Economist[B] 2007).

3.1.2 The Second Generation

For the second generation format standards competition of the home video market, several companies were also involved. Sony and Philips proposed a new technology called Multi Media Compact Disc (MMCD), while Toshiba and its allies pushed a rival standard called Super Density (SD) compact disc. After much power struggle, a standards competition was averted when Hollywood demanded a single format. Hence the industry managed, in 1995, to agree on a common format that was a compromise between two rival proposals. Sony compromised, and the result was the Digital Versatile Disc (DVD), which is very similar to SD but borrowed some elements from MMCD (Economist[C] 2004). Since the format for DVD was based more on Toshiba's technology, rather than the rival format devised by Sony, it is seen as Toshiba's success.

3.2 High Definition Standards Competition

3.2.1 Hardware

The latest standard-based competition was between Blu-ray and High-Definition Digital Versatile Disc (HD-DVD). The appearance of the high-definition video standards competition evolved as two major Japanese companies, Sony and Toshiba, started to develop their own technologies. As a mean of distributing high-definition video, neither Blu-ray nor HD DVD is unique. Both offer more convenient ways of delivering high-definition video to television sets, and both provide more capacity to the existing DVD (Economist[B] 2007).

The standards competition for high definition differs from the first generation of home video format. When VCR was introduced decades ago, consumers were anxious to buy these machines which would allow them to record television shows off the air for the first time (i.e., "time-shifting") as it was for playing videos in their household. The first VCRs were unique and attracted all the consumers, unlike the later ones (Economist[B] 2007).

Also, similar to previous standards competitions, the high-definition standards competition can be traced back to 2000 when companies began experimenting with using new blue lasers in optical disc systems (PCWorld 2008). Many Hollywood studios backed Sony's Blu-ray, because of its larger capacity. Nonetheless, Toshiba, which had spent large sums developing its HD-DVD format, refused to give in (Economist[A] 2007). Hence, what started in 2000 as technical research became a battle between the world's largest electronics companies and movie studios, with the consumer caught in the middle (PCWorld 2008).

As mentioned, the two new formats rely on blue lasers, which can discern finer details than the red lasers used in DVD players, to squeeze more data on to each disc. This capacity can be used in two ways: to boost quality, by providing a more detailed "high definition" picture, or to increase quantity, enabling more footage (at DVD quality) to fit on a single disc (Economist[C] 2004). Because the wavelength of blue light is shorter than that of the red lasers used in DVD, less physical space is needed to record each bit of data. As a result, more information can be recorded on a DVD-sized disc. This extra space was needed to store the new high-definition video and TV services that were starting to be commercialized around that time (PCWorld 2008).

Moreover, whoever wins the standards competition will profit handsomely from the royalties for the technology; this is why the two parties are trying their best to win. In the HD-DVD standards competition, around 70 companies have contributed intellectual property to Blu-ray, and slightly fewer to HD-DVD. The licensing fee for Blu-ray Disc is significant profit for Sony. Player makers pay US$20,000 to license Blu-ray while the content-protection system license carries a US$120,000 annual fee and additional charge of US$0.10 per player. Media makers pay US$8,000 annually and US$0.02 per disc for the copy protection system (Blu-ray Disc Association License Office 2008). HD-DVD's royalty information is not available as Toshiba halted production of HD-DVD players. However, according to Nikkei Business Daily, the high-definition standards war cost Toshiba approximately $986 million.

3.2.2 Software

Hollywood was the most influential in setting the new standards for both HD-DVD and DVD. Recently Blu-ray has won the standards competition, even though the discs are slightly more expensive to produce and the players cost more. That is because it has broader industry support, including the backing of four of the biggest Hollywood studios. And with recent Blockbuster's decision, Blu-ray for the home video market is the winner in the high-definition market (Economist[A] 2007). Money was an issue in having support of Hollywood studios. Toshiba gave Paramount and DreamWorks Animation a combined $150 million in financial incentives for their business and it also offered to pay Warner Brothers substantial incentives to come down on its side; although, exact figure is unknown, it is believed that Sony offered even higher than Toshiba (Barnes 2008).

However, it is possible that, despite Blockbuster's decision, both video formats—Blu-ray and HD DVD—will coexist for some time. With its arm-lock on the consumer-electronics industry, the Blu-ray alliance (including Philips, Samsung, LG, Pioneer and Matsushita as well as Sony) is more likely to succeed in the living room. In turn, the HD-DVD group, with its extensive background in computing (members include Intel, Microsoft, and NEC), can expect a greater share of the computer market (Economist[B] 2007).

One can ask if the history will repeat itself every time a new technology is introduced in the home video market. When VCR was first introduced, the Beta machine may have been technically superior to its VHS rival, but it was a dead-end design. By contrast, the VHS machine had a flexible concept that could be continually refined. Within a couple of years, Sony's Beta technology had been trounced—and, shortly thereafter, the machines were collector's items. Thus, far the story of VHS is similar to that of Blu-ray, but here the similarities end (Economist[B] 2007).

Chapter 4 Theoretical Analysis

4.1 First-mover Advantages

If a firm sees first-mover advantages in a standards based market, the firm can then decide whether to invest resources in searching for first-mover opportunities or wait for less risky second-mover advantages to come. Moreover, when a specific first-mover opportunity arises, managers must decide how to exploit it. Cusumano et al. (1992) shows that Sony, for example, aggressively pursues first-mover advantages from new product innovation, and its rival, Matsushita, generally lets Sony and others innovate; Matsushita then takes a position based on its manufacturing and marketing capabilities. Matsushita invests in R&D to be ready to enter the market when it begins rapid growth, but the firm will not launch new products until others have tested the market. Sony is again the first-mover in the high definition home video competition, and Toshiba imitates what Matsushita has done, became the second-mover. Sony announced its development of Blu-ray at Japan's Ceatec show in 2000, and Toshiba announced its plan for future generation home video player in 2002. The choice between the two strategies (becoming the first-mover or second-mover) depends on the firm's specific characteristics and skills. Sony is well known for its excellent entrepreneurial vision and new product R&D (examples include Walkman, remote control, etc) and tends to find first-mover advantages attractive, whereas Toshiba or Matsushita, firms having relative skill bases in manufacturing and marketing may not (Lieberman and Montgomery 1988).

There certainly are more than two firms competing in the home video competition, and one can ask when is the point that a firm is considered as a second mover upon entry to the market. Gort and Klepper (1982)'s analysis can be generalized to separate the stages in the product cycle to distinguish the stage prior to second-movers' entry. The model is not empirically tested because the necessary data are hard to obtain for the study period.

To distinguish between the first-mover, Blu-ray, returns interval and start of HD-DVD entry, the second-mover, data on annual net entry rates for a particular product is needed. To determine the cutoff year for the first-mover returns interval, the series need to be partitioned into three categories. The first and third categories should contain years in which the net entry rate reflect the first-mover returns interval and start of the second-mover entry. The net entry rates of the T consecutive "in-between" years of the second category are labeled $x_1, x_2, \dots, x_T$. To choose an optimal dividing year j such that observations $x_1, x_2, \dots, x_j$ are classified in the first-mover returns interval and $x_{j+1}, x_{j+2}, \dots, x_T$are classified in start of the second-mover entry. This can be accomplished by using a three-step procedure studied in Agarwal and Gort (2001).

Step 1. For each *j*=1, 2, …, T, compute

$$d_1(j) = \sum_{i=1}^{j} \frac{x_1}{j} \quad and \quad d_2(j) = \sum_{i=j+1}^{T} \frac{x_i}{(T-j)} \quad (1)$$

where x_i is net entry rates of the T consecutive ``in-between`` years

Step 2. The choice of the dividing year is limited to those values of *j* for which

$$|d_1(j) - \mu_1| \leq \left|\frac{(\mu_1 - \mu_2)}{2}\right| \quad and \quad |d_2(j) - \mu_2| \leq \left|\frac{(\mu_1 - \mu_2)}{2}\right|, \qquad (2)$$

where $\mu_1$and μ_2 represent the mean rate of net entry in categories 1 and 2. If there were no values of *j* satisfying the above equation, then all observations can be classified in the first-mover returns interval if $|d_1(j) - \mu_1| \leq |d_2(j) - \mu_2|$ and in start of the second-mover entry otherwise.

Step 3. If there are multiple values of j satisfying (2), then we selected the value of *j* from this set that maximized$|d_1(j) - d_2(j)|$.

Step 2 requires that the mean of the observations classified in each of the two stages is closer to the sample mean of the observations initially classified in those stages than in the alternative stage. Step 3 ensures that, among the classifications that would satisfy step 2, the classification that is chosen maximizes the difference between the means of the points classified in the two alternative stages.

Also, Bohlmann et al. (2002) provides theoretical and empirical evidence that first-mover advantages are difficult to sustain in product categories with high "vintage effects"-that is, where product quality significantly improves over time. Blu-ray and HD-DVD, both formats are already superior; hence, both formats are hard to be significantly improved over a short period of time. Consequently, following Bohlmann et al. (2002)'s analysis, it is not difficult for Sony to sustain the first-mover advantages. Similarly, another study conducted by Christensen et al. (1998) finds that, in the fast-changing rigid disk drive industry, "the notion of first mover advantage is not applicable". Because first-mover firms faced a higher probability of failure in rigid disk drive industry, and this suggests that the capabilities and

cultures they developed in that competitive environment might not have equipped them well for the competition that characterized the industry after the dominant design emerged.

When consumers perceive "technological uncertainty", which is the case of committing on either Blu-ray or HD-DVD, consumers tend not to commit themselves to product-specific learning (Carpenter and Nakamoto 1989). This phenomenon is particularly relevant for experience goods, such as Blu-ray and HD-DVD, that can be evaluated only after purchase (Nelson 1980) and for standards competition situations in which hardware firms of two or more incompatible technologies compete for market dominance (Kalish and Lilien 1986).

The high definition standards competition resembles the VCR standards competition. In the same way as in the first standards competition, Sony's Blu-ray technology is superior to Toshiba's HD-DVD. Appendix B summarizes the two generations of home video technologies and other related information. The first generation technology is omitted since papers published regarding the first generation are abundant, and the technology is much different from the third generation; consequently, the comparison is not as useful between the first and the third. Both HD formats have same level of resolution and audio soundtracks. However, Blu-ray has bigger disc capacity; therefore, Blu-ray has longer recording time. Blu-ray also started with more hardware firms' support and it still was the case in 2008 (Blu-ray Disc Association 2008). Studio support was balanced between the two formats until 2008; however, the balance tipped towards Blu-ray in 2008. This is discussed in the next section of this chapter. Similar to the first generation, Sony`s player price is higher than its competitor.

Although the high definition standards competition has similar aspects compare to the first one, Sony learned from its mistake of not having an alliance of hardware firms supporting its technology, and took the right steps to succeed in this competition by forming an alliance with major electronics hardware firms and software firms (such as Hollywood studios).

Technology leadership is one of factors that make first-mover advantages to arise. Hence, when a specific first-mover opportunity arises, managers must decide whether and how to exploit it. As mentioned, Sony aggressively pursues first-mover advantages from new product innovation. Sony's inspiration of leadership in technology is apparent from the past generations of home video market. Investment in innovation is driven by expectation of transitory monopoly returns that innovations are supposed to yield. There have always been two strategies for protecting these monopoly returns: the first relies on patents; the second, on developing innovations in secrecy and getting to the market first (Agarwal and Gort 2001). The nature of electronics industry does not allow a firm to develop innovations in secrecy as a result Sony definitely relies on patents.

The high definition home video technology is considered as a rapid technology evolution although ordinary consumers cannot see much difference. According to Suarez and Lanzolla (2007), rapid technology evolution also influences the effectiveness of patents and other forms of intellectual property protection. The economics literature on patenting has shown that a firm's ability to protect its underlying product technology varies across industries. It is generally recognized that competitors typically gain access to detailed information on the product within a year of development. Also, empirical evidence suggests

that about 60 percent of successful innovations are imitated within four years (Mansfield et al. 1991). In the high definition home video competition, various firms have contributed intellectual property to both Blu-ray and HD-DVD. Table 1 and 2 show the number of patents filed for both Blu-ray and HD-DVD between year 2000 and 2007. It is apparent that the number of patents filed outnumbered those for Blu-ray, and this a good indication of firms favoring and supporting Blu-ray format over HD-DVD, since issuing patents in particular technology undoubtedly involves significant amount of money.

Suarez and Lanzolla (2007) discuss a fast pace of technology evolution may give latecomers plenty of opportunities to "invent around" a patent and come up with improved products that do not necessarily infringe on patent rights. In the high definition competition, two electronics firms, Sony and Toshiba developed the core technologies for high definition machines; however, three other big electronics firms filed more patents that are related to the two core technologies. More number of the core technology related patents filed by firms other than Sony and Toshiba, would bring a higher possibility of coming up with improved products that do not need the core technology.

Tables 3 and 4 show the firms other than Sony and Toshiba filed more patents. However, Sony and Toshiba were expected to profit handsomely from the royalties for the core technology for at least some time; this can be the reason that the two parties tried their best to win. HD-DVD royalty information is not known due to its loss; however, Toshiba would have made similar profit if Toshiba won the competition (Royalty information given in section 3.2.1).

In addition, first-movers may attempt to deter entry of late entrants through strategies of spatial pre-emption. As described in Lieberman and Montgomery (1988), pre-emptable 'space' can be interpreted broadly to include not only geographic space, but also shelf space. Sony launched Blu-ray player ahead of Toshiba which put Sony to a better situation to establish positions in geographic or shelf space. However, Sony did not gain first-mover advantages because of its high-price of the player, which was $3,815 at the time it was first introduced in 2003. The price of the player was undoubtedly not an accessible price for ordinary customers to buy a home video machine. This prevented one of the major factors, pre-emption of assets, for first-mover advantages to arise; hence, buyer switching cost did not incur as well. Since the buyer switching cost did not incur, the late entrants did not have to worry about investing extra resources to lure customers away from the first-mover firm. The following year Toshiba unveiled its HD-DVD player at CES. Sony further worked hard to get other hardware firms on its side and had HP and Dell join the Blu-ray Disc group in 2004. As Hollywood studios were divided into two groups supporting either format, Sony and Toshiba had discussions about having one format in 2005 but they did not work out well. Not having successful discussions in the high definition format urged Toshiba to launch the world's first HD-DVD player at the price of $936 in 2006. Between Sony Blu-ray player's introduction date and Toshiba HD-DVD player's launching date, the market uncertainty for the high definition industry was at least reduced by gathering the Hollywood studios' and other hardware firms' support for the high definition technologies. Also, the price of HD-DVD player was much more accessible (approximately one fourth of Blu-ray player's price) to customers comparing to the price of Blu-ray. With the help of lower priced high definition

player, Toshiba sold more players than the Blu-ray introduced three years ahead (relevant data available in Appendix A). Sony instead, packed PlayStation 3 with Blu-ray Disc drive without increasing the price of the game console, which was other way of lowering the cost of purchasing a Blu-ray player.

The late-mover, Toshiba, enjoyed the late-mover's advantages. Sony provided some clue of the market uncertainty to Toshiba by launching the Blu-ray player ahead of HD-DVD. The price of HD-DVD player was much less than the Blu-ray player and more customers were able to buy the player, showing Toshiba's attempt to incur buyer's switching cost. Despite of having late-mover advantages, Toshiba was not able to offset the result of network effects favoring Sony, which caused the competition to end. Network effects are discussed more in detail in the next section.

First –mover advantages may also arise from buyer switching costs. Switching costs usually arise from the buyer's investments in purchasing seller's product or its transaction cost. Once the buyer adapt to characteristics of the first mover-product, Blu-ray, and its complimentary goods, then the buyer would find it costly to switch to other technology. However, all of this did not happen because of the unattractive high Blu-ray player price; this resulted in only few early adaptors to purchase the new technology machine. Consequently, buyer switching cost did not incur.

Also, as noted in the literature review, path dependence is another factor for the first-mover advantages to arise. However, this factor was not applicable to the winning of Sony's high definition competition. Sony lost out to Victor Company of Japan (JVC) in the first U.S. home video competition (Toshiba was not considered as the core technology competitor);

therefore, this result did not benefit not only Sony nor Toshiba to gain first-mover advantages.

4.2 Network Effects

A situation in which consumer coordination is vital arises when consumers must choose durable hardware, as when they purchase a device to play a new format of pre-recorded movie. In making such a choice, each consumer will have to form expectations about the availability of software for either Blu-ray or HD-DVD formats. In the presence of economies of scale in the production of software, the availability of software will depend on what other consumers do, giving rise to positive-feedback effects (Stremersch et al. 2007). Therefore, the actions of hardware firms indirectly impact the decisions of software firms through the effect of these actions on consumer demand for the whole product. Conversely, the actions of software firms indirectly impact the decisions of hardware firms through the impact of these actions on consumer demand for the whole product (Gupta et al. 1999). Hence, the network effects plays a critical role in the high definition home video industry between the actions of hardware firms and software firms, created by the direct dependence of consumer demand for the whole product on the action of hardware firms as well as software firms. This interdependence is illustrated in Figure 2.

In history, the decisive factors in the VCR standards competition were a few. One of Sony's mistakes was that it did not work hard enough to get more companies together in a 'family' to support the Beta format (Morita 1986). On the other hand, JVC, in the number two position, did try harder and was more effective at forming alliances in support of VHS

(Morita 1986). Allowing partners to share in development also improved the VHS in ways that JVC might not have pursued itself. Sony has always been uniquely innovative with consumer products that incorporate advanced electronics. Therefore, it has never shipped its products to other companies for distribution under different labels, preferring to build up its name and reputation and to avoid sharing the benefits of its innovations with other distributors (Cusumano et al. 1992). Sony did realize that they would have to license the Beta format to ensure its widest distribution; however, it was unwilling to compromise on its standard or to help potential licensees with OEM shipments (Ohashi 2003). Sony's reluctance in building VCRs for its licensees was clearly one of the major factors that contributed to losing the standards competition. On the contrary, in the high definition standards competition, Sony learned from the mistake and did work hard to form alliances in support of its technology-Blu-ray. Sony made Blu-ray alliance-player makers to pay fees to license Blu-ray technology. Similarly, Toshiba also made HD-DVD alliance-player makers to pay fees to license HD-DVD technology. Conversely to the VCR case, the movements by Sony and Toshiba facilitated a large production of both format players.

In the high definition home video market, the world's major player makers had joined either alliance by the beginning of 2004; however, Hollywood studios' decision was more important in setting the standards for high definition. Table 5 in appendix C shows the market share of Hollywood studios' market share by year. In 2004, the distribution of Hollywood studio's support was evenly spread out between the two formats (HD-DVD supporters in bold). The decision of the studios to support either format did not stay constant as it was easier for the studios to change manufacturing disc facilities to support a better

format, which they thought would bring a better profit for them rather than staying with one format. Consequently, the studios changed their decision back and forth a few times until the weight of market share went off balance in 2008. On January 4th, 2008 Warner Brothers announced that it would stop issuing HD-DVD movies in the coming months and this essentially signaled the end of the standards competition. Warner Brothers had the second largest market share in the movie industry. Its support only for Blu-ray meant significant for both manufacturers and consumers. Particularly, with Warner Brothers announcement consumers would have narrower choice of purchasing the movie software if they have HD-DVD player instead of Blu-ray player. Also, only a few days after Warner Brothers announcement, Wal-Mart, the world's largest retailer, announced that it would phase out HD-DVD off its selves. The day after Wal-Mart's announcement, Toshiba halted production of HD-DVD and this ended the high definition standards competition. More detailed chronological announcements can be found in Appendix A.

In the view of the fact that Toshiba—the HD-DVD technology leader—halted its production after its HD-DVD distributors and studios stopped supporting its technology, shows Toshiba's failure of gaining indirect network effects. Therefore, it can be concluded that the indirect network effects have played a critical role in the high definition standards competition.

4.2.1 Model

This section proposes a model of demand for HD DVD players that can be used to for future empirical study of high definition home video market. The following model is adopted and incorporated from various sources (Berry 1994, Church et al. 2008, McFadden 1977) to

be used for high definition home video market empirical study. The model is not empirically tested because the necessary data are hard to obtain for the study period.

As mentioned, indirect network effect depends on expectations of the number of available software supplied with hardware. In order to analyze the indirect network effects, finding the demand of the HD DVD players is important. The demand system is derived from a random-utility discrete choice model of consumer behavior. The utility of consumer i for product j depends on the characteristics of the product and the consumer: $U(x_j, \xi_j, p_j, v_i, \theta_d)$ where x_j, ξ_j, p_j and $\theta_d$are observed product characteristics, unobserved product characteristics, and price and demand parameters, respectively (Berry 1994).

In the model, the household is used as the purchasing entity. It is assumed that a household has a unit demand for a HD DVD player, that is, it buys either one HD DVD player or none at all. Each consumer is rational utility maximizer, i chooses product j if and only if j maximizes utility,

$$i\ chooses\ j \Leftrightarrow u_{ij} \geq u_{ik}\ for\ all\ k \neq j$$

Let each consumer chooses j among j+1, where j+1 is the option of not purchasing a HD DVD player.

$$u_{ij} = \sum_k x_{jk}\beta_k + \alpha p_j + \xi_j + \epsilon_{ij}$$

where u_{ij} is consumer i's utility from consuming product j that belongs to format either Blu-ray or HD-DVD. The kth component of this vector is denoted by x_{jk} and β_k is the mean level

of the taste parameter for component k. The vector x_j is product j's observed attributes. Let $p_j$be a real price, and $\xi_j$stand for the mean of consumers' valuations of an unobserved product characteristic such as product quality of HD DVD player brand j with $E(\xi_j) = 0$.

Following Berry (1994), decompose u_{ij} into ϵ_{ij} and δ_j:

$$\delta_j = \sum_k x_{jk}\beta_k + \alpha p_j + \xi_j$$

It is common in traditional logit and probit models to assume that the variation in consumer tastes enters only through the additive term ϵ_{ij}, which is assumed to be identically and independently distributed across consumers and choices. In the model with identically and independently distributed consumers tastes, only the mean utility levels, δ_j, differentiate the product. Therefore, all properties of market demand, including market shares and elasticities, are determined solely by the δ_j (Berry 1994).

4.3 Hardware firms

During a standards competition, it is interesting to analyze the behaviour not only of software firms (Hollywood studios) but also of hardware firms (manufacturer). Having bigger firms on one side of technology is a big advantage. The reason is that, the movement of bigger hardware firms to support one technology yields architectural innovation since they clearly have superior funds available compare to smaller firms to enhance the technology.

Blu-ray and HD-DVD technologies are similar in function but they are technically different in regard to manufacturing processes. Hence, in order to take advantages of the new

technology that exists after the high definition standards competition, hardware firms had to make a huge commitment to investing in one technology. Initially, LG, Matsushita, Philips, Pioneer, Samsung, and Sony committed to Blu-ray, and Intel, Microsoft, NEC, and Toshiba committed to HD-DVD. Numerous factors are generally considered in order for a firm to make a commitment to one technology: the network of complement product firms, profit margin, investment cost, introduction date, storage capacity of a disc, etc. As noted in the earlier section, network effects play an important role in this aspect. Moreover, investment cost is an important factor for most of the hardware firms but especially for smaller firms. It is known that a DVD player or disc producing facility can be converted to an HD-DVD player or disc producing facility at much lower cost than a Blu-ray player or disc producing facility; hence, it is handsomely attractive to many hardware firms as well as to software firms. Lower investment cost can also easily reflect a higher profit margin. Although the facility converting cost is lower for HD-DVD, it is not the only important factor which will be used to decide make a commitment. There are many other factors, but they are weighted differently for hardware firms, and this is evident in the high definition standard war. Despite the fact that the cost of converting facility is lower for HD-DVD, most major hardware firms supported Blu-ray. One important factor of making decisions is the storage capacity of a disc, which can be learned from the history. The storage capacity of the medium played an important role in the winning of VHS in the U.S. home video market standards competition in the 1980s; hence it cannot be overlooked. Having a higher capacity disc enables software firms to contain a higher quality home video on disc, and provides some room for innovative software, not limiting to director or actor interview, undisclosed scene, etc. Therefore, this

could also be seen as a potential leading factor in the high definition standards competition, allowing the technology last longer. Appendix B compares specifications between Blu-ray and HD-DVD (DVD information is included for comparison purposes).

Even after their commitment to one technology, it is sometimes seen that hardware firms switch their supporting technology to the other as soon as they find that their supporting technology is inferior to the other. The earlier they make a better decision, the better for the company in making profits in the future. Moreover, it is crucial to be on the right side before they invest more in building massive production facilities.

During a standards competition, manufacturing firms risk the most in investing in one technology. However, manufacturing firms can gain substantial first mover advantages if they make the right strategic decision. Often it is considered as an irreversible investment. Several real options theories can be applied to determine the suitability of a firm's investment. Traditional approach would be to determine whether the expected net present value (ENPV) exceeds zero. The traditional approach implicitly assumes that if the expenditures are irreversible; it cannot be delayed—if not undertaken now it cannot be undertake in the future. For example, ENPV of immediate investment can be calculated as below:

$$\mathrm{ENPV} = -\mathrm{I} + \mathrm{P}_0 + \left[\frac{1+\mathrm{i}}{\mathrm{i}}\mathrm{E}(\mathrm{P}_1)\right]\frac{1}{1+\mathrm{i}}$$

where I is initial investment cost of setting up the high definition facility, P_0 is price of high definition player, and i is risk-free rate.

In addition, with the facts mentioned in mind, firms can as well delay commitment in either technology if ENPV is negative, thereby reducing their risk in losing investment on one technology. On the other hand, firms can use hedging strategy. Two manufacturing firms, LG and Samsung, have developed a player which plays both Blu-ray and HD-DVD formats. This significantly reduced the risk of the firm being unable to switch to other technology when one technology wins. Also, the introduction of the player encouraged hesitant consumers to buy a high definition player.

Toshiba's recent financial report after losing in the standards competition shows the importance of winning the competition. Toshiba's loss of the standards competition prevented the firm's HD-DVD facilities from making profits for the firm. The loss left the firm with insufficient funds to invest in other future opportunities.

4.4 Architectural Innovation

Although, two other main theories can be applied to explain the results of the high definition standards competition, architectural innovation is not sufficient to explain the results of the high definition competition. Manufacturing firms are divided into Blu-ray and HD-DVD camps in the beginning stage and they co-operated within camp to enhance their technology. This significantly reduced the chance of architectural innovation to rise by an individual firm.

In the first home video competition, manufacturers offered various new technologies, including wireless remote control, half-speed and one-third speed machines, multi-function machines (scan, slow, and still), high fidelity (hi-fi) sound to attract consumers (Cusumano et

al. 1992). However, in the high definition home video competition, the technologies of both formats are superior, and ordinary consumers could not see the difference in quality or technological difference between Blu-ray and HD-DVD even though Blu-ray is technically a little bit better than HD-DVD; hence, it is hard to say that one technology is significantly superior to the other. Appendix B compares specifications between Blu-ray and HD-DVD (DVD information is included for comparison purposes).

4.5 Patents

Comparison between Blu-ray and HD-DVD can also be drawn from analyzing the patents information. Detailed patents data collection method is described in Appendix D. The author is not an expert in electric engineering field; hence, there is a slight chance that the data may have not been allocated to the right category. Cluster analysis is conducted to analyze if any pattern of filed patents contributed to the winning of Blu-ray in the high definition home video competition. It has been argued that the nature of technology is cumulative, so it is firm and country specific. Although both formats are considered to be superior, there is a possibility that hardware firms may prefer some specific technology over the other.

The high definition home video industry is considered as a high-tech. Although, ordinary consumers will not notice much difference between the two formats, hardware firms may have different views.

Patents' reference cited information can be used to evaluate the possibility of hardware firms' willingness to adopt one technology over the other. As mentioned, the two

formats are incompatible; hence the formats are based on two different technologies; otherwise there would be only one format. This fact designated most of the hardware firms to focus on one technology except for LG whom introduced a dual-format player in 2007. Patents references cited must be the ones that are related to either one technology and this is a good signal of which format was preferred for R&D by the hardware firms (If a Blu-ray related patent reference is cited, it would mostly benefit the enhancement of Blu-ray format and vice versa.).

By observing the number of Blu-ray and HD-DVD related patents references cited there is a significant difference between the two formats. The comparison between the two formats is given in Table 5. Blu-ray related patents cited references 679 times in total whereas HD-DVD related patents cited references 232 times, which shows that many Blu-ray related patents tried to enhance its technology based on what exists for Blu-ray. Moreover, the average number of reference citation is 13.1 for Blu-ray and 12.6 for HD-DVD, showing that Blu-ray patents filed have much higher total number of patents references cited compare to HD-DVD but the average number of patents references cited is only differ by 0.5. There are 32 patents that cited Blu-ray related patents more than 50 times, and only 15 patents that cited HD-DVD related patents more than 50 times. One can induce that there would have been more R&D concentration on Blu-ray technology.

Geographical proximity is important to the extent to which different lines of innovative activity influence one another, because of the existence of knowledge spillovers that are geographically bounded (Ketelhohn 2006). Tables from 6 to 9 shows top 8 Blu-ray and HD-DVD patents filed by country and city accordingly. Top 3 by country shows that

Japan, Korea and U.S. are included for both formats. However, at city-level only Japan and Korea is included in Top 3 for both formats. Top 3 for Blu-ray represents 68% of total of top 8 patents filed and 70% of total of top 8 patents filed for HD-DVD. Sony and Toshiba's R&D center is located in Japan and the core technology for both format were invented in Japan, however it is interesting to note that Suwon-Si, Korea is heavily clustered (46%) for HD-DVD filed patents despite the fact of Toshiba's R&D location. This indicates that considerably less HD-DVD R&D activities had happened from its origin compare to Blu-ray. It can be induced that Sony may have offered more incentives for followers in Japan, which may have resulted in knowledge spillovers to enhance the Blu-ray technology.

Table 3 and 4 shows the number of patents filed by hardware firms by year. Blu-ray clearly has more patents filed between 2000 and 2007 compare to HD-DVD. Sony began licensing Blu-ray technology in early 2003 (detail discussed in section 3.2.1), and table 3 shows the number of filed patents dramatically increased in the same year, which attracted many major hardware firms. It is unknown when HD-DVD licensing began during the study period, however it can be induced that HD-DVD licensing began after Blu-ray licensing started by looking at the fact that Toshiba showed HD-DVD prototype just before Blu-ray licensing has began.

Table 10 and 11 shows the number of patents filed by U.S. Classification number. For both formats' patents, most of them are classified in U.S. Classification number 369. This number is classified for dynamic information storage or retrieval (United States Patent and Trademark Office 2008). Blu-ray related patents are filed more diversely compare to HD-DVD. Blu-ray related filed patents are diversified into three groups for top 60% whereas

55% of HD-DVD related filed patent fall into only one class, showing that Blu-ray R&D activity is more diversified.

Chapter 5 Conclusion

5.1 General

Working around industry standards and complementary networks require much more than dealing with price and quality that were the primary elements in traditional generic competitive strategies (Porter 1980). Cusumano et al. (1992) showed how competitive strategies can control the dynamic power of the mass-consumer market to make a winner out of a second mover with extensive technological skills but a weak starting position in manufacturing and distribution capabilities by providing the VCR story.

This paper presents an historical and theoretical analysis of the U.S. high definition home video industry. The history reveals changes of technologies, competitors, complementors, and firm strategies over a reasonably short period of time. The high definition home video industry as well as the home video game industry studied in Gallagher and Park (2002) offers much potential for theoretical development and validation of existing theoretical claims especially because of the existence of clear market leaders and followers, and its rapid technological change.

The paper focused on important strategic issues:

1) First-mover advantages
2) Network effects
3) Architectural innovation

The key finding in this study is that success in the high definition home video industry requires much more than just technological innovation or being a first-mover in the market. Technological innovation is essential and being a first-mover helpful, but not sufficient, toward building a dominant position in the market. Although, architectural innovation did not play a critical role in the competition, new technology innovation is always the key in setting a new standard format in a standard-based industry. Once a new format standards competition starts, the strategic focus shifts from technological innovation into traditional competitive strategies to build a network of complementary products and installed base. Historical evidences show that Sony created a winning alignment of Blu-ray producers from the beginning by the way its mangers conducted the formation of alliances, which differs from the first home video competition where Sony pressed commitment and reputation. This alliance brought huge added benefits in addition to the network alliance of complementary firms for Blu-ray. Consequently, an effective strategy to become a winner in the standards competition appears to be building a network of complementary products and subsequently installed base.

As theories discussed in the paper suggest, the discussion partially support to traditional argument on first-mover advantages; they were important only to the point that first movers used their time to develop a network of complementary products. Therefore, this study evidently illustrates that building a network of complementary products and installed base should be the primary goal to compete in this type of industry. Also for R&D, network effects were important in gathering major hardware firms to invest in one technology. Sony began licensing Blu-ray technology earlier than HD-DVD, and the number of patents filed

for Blu-ray were clustered in its technology origin, Japan, rather than elsewhere, which may have been affected as an advantageous factor for Blu-ray technology with knowledge spillover.

The final contest, the tipping of Warner Brothers decision provided direct evidence to draw conclusions about between and within standard competition. The alliances that Sony formed for production and distribution proved to be the decisive factors in the triumph of Blu-ray over HD-DVD.

Finally, it is hoped that this historical and theoretical analysis will offer valuable insights to practicing managers. It is also worthwhile to note the research conducted by Gallagher and Park (2002) show that the firms with good understanding of prior history, change, and market development performed well in high technology industry

5.2 Future Research

Only few studies related to first-mover advantages, network effects, and architectural innovation have been done using data from other industries in international settings. More studies are needed to test the relevance of first-mover advantages, network effects, and architectural innovation results in different international locations and different industries. Also, empirical analysis of the high definition home video competition is needed when the necessary data becomes available.

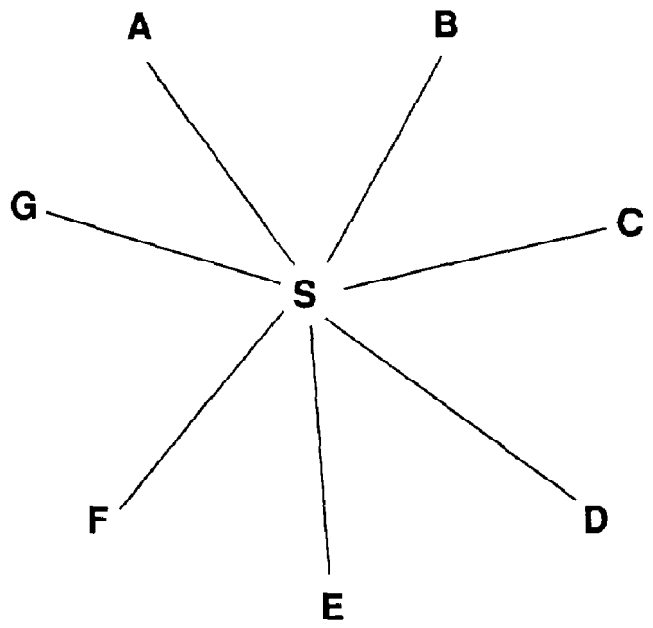

Figure 1 A simple star network. Source: (N. Economides 1996)

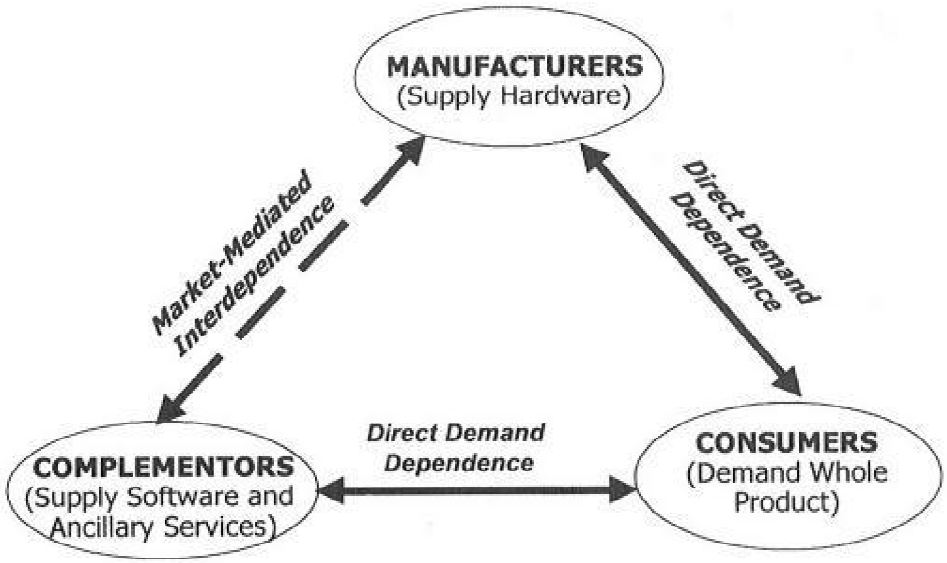

Figure 2 Market-Mediated Interdependence Between Manufacturers and Complementors in Markets with Indirect Network Externalities. Source: Gupta (1999)

Row Labels	Number of Patents
Samsung Electronics Co., Ltd.	62
Matsushita Electric Industrial Co., Ltd.	56
Sony Corporation	43
LG Electronics Inc.	25
Koninklijke Philips Electronics N.V.	20
Grand Total	**206**

Table 1 Number of Blu-ray related patents filed by Top 5 firms

Row Labels	Number of Patents
Samsung Electronics Co., Ltd.	84
LG Electronics Inc.	17
Matsushita Electric Industrial Co., Ltd.	15
Target Technology Company, LLC	8
General Electric Company	8
Grand Total	**132**

Table 2 Number of HD-DVD related patents filed by Top 5 firms

Blu-ray

Count of Number	Column Labels								
Row Labels	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**Total**
Koninklijke Philips Electronics N.V.	1	2	3	10	3	1			20
LG Electronics Inc.				13	11	1			25
Matsushita Electric Industrial Co., Ltd.			1	20	23	4	8		56
Samsung Electronics Co., Ltd.				16	14	12	13	6	61
Sony Corporation		3	2	4	11	13	9	1	43
Total	**1**	**5**	**6**	**63**	**62**	**31**	**30**	**7**	**205**

Table 3 Top 5 firms which filed Blu-ray technology related patents by year

HD-DVD

Count of Filed	Years								
Row Labels	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**Total**
General Electric Company		1	1	3	3				8
LG Electronics Inc.	2	3	4	4	1		1		15
Matsushita Electric Industrial Co., Ltd.	1	2	2	2	3	1	3		14
Samsung Electronics Co., Ltd.	14	12	11	10	11	5	11	5	79
Target Technology Company, LLC					2	3	3		8
Total	**17**	**18**	**18**	**19**	**20**	**9**	**18**	**5**	**124**

Table 4 Top 5 firms which filed Blu-ray technology related patents by year

	Total # Patents Ref Cited	Avg # of Ref Cited	# of Patents Ref > 50 times
Blu-ray	679	13.1	32
HD-DVD	232	12.6	15

Table 5 Blu-ray and HD-DVD Patents' References Cited Comparison

Blu-ray

Country	# of Patents Filed	Percentage Clustered
JP	178	44%
KR	90	22%
US	75	19%
NL	27	7%
TW	19	5%
FR	8	2%
DE	6	1%
HK	2	0%
Grand Total	405	100%

Table 6 Number of Blu-ray patents filed by country

HD-DVD

Country	# of Patents Filed	Percentage Clustered
KR	102	46%
JP	53	24%
US	49	22%
TW	14	6%
NL	2	1%
FR	1	0%
BM	1	0%
BE	1	0%
Grand Total	223	100%

Table 7 Number of HD-DVD patents filed by country

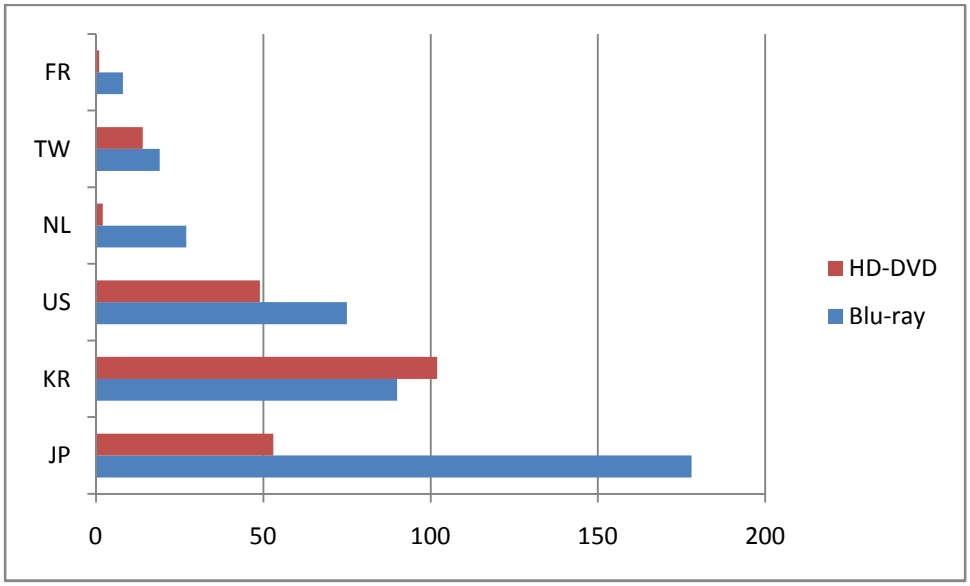

Figure 3 Number of Blu-ray and HD-DVD patents comparison by country

Blu-ray

City	# of Patents Filed	Percentage Clustered
(Tokyo, JP)	94	29%
(Suwon-si, KR)	64	20%
(Osaka, JP)	58	18%
(Eindhoven, NL)	27	8%
(Seoul, KR)	26	8%
(Hsin-Chu, TW)	17	5%
(Irvine, CA)	8	3%
(Kadoma, JP)	7	2%
(Schenectady, NY)	6	2%
(Yokohama, JP)	6	2%
(Boulogne-Billancourt, FR)	6	2%
Grand Total	319	100%

Table 8 Number of Blu-ray patents filed by city

HD-DVD

City	# of Patents Filed	Percentage Clustered
(Suwon-si, KR)	84	46%
(Tokyo, JP)	26	14%
(Seoul, KR)	18	10%
(Osaka, JP)	17	9%
(Irvine, CA)	11	6%
(Hsin-Chu, TW)	10	5%
(Niskayuna, NY)	5	3%
(Kanagawa, JP)	3	2%
(Milpitas, CA)	3	2%
(Richmond, VA)	3	2%
(Schenectady, NY)	3	2%
Grand Total	183	100%

Table 9 Number of HD-DVD patents filed by city

Blu-ray

U.S. Classification #	Count	Percentage Clustered
369	471	35%
514	167	12%
544	156	12%
428	109	8%
510	104	8%
375	89	7%
546	85	6%
257	62	5%
435	59	4%
548	53	4%
Grand Total	1355	100%

Table 10 Number of Blu-ray patents filed by U.S. classification number

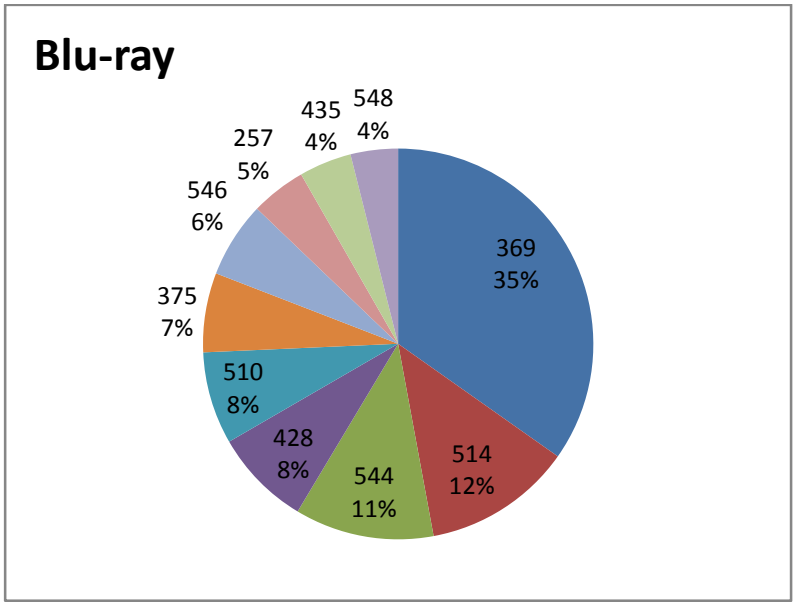

Figure 4 Number of Blu-ray patents filed by U.S. classification number

HD-DVD

U.S. Classification #	Count	Percentage Clustered
369	318	55%
428	55	9%
359	44	8%
386	39	7%
714	26	4%
430	24	4%
348	22	4%
726	18	3%
257	18	3%
522	15	3%
Grand Total	579	100%

Table 11 Number of HD-DVD patents filed by U.S. classification number

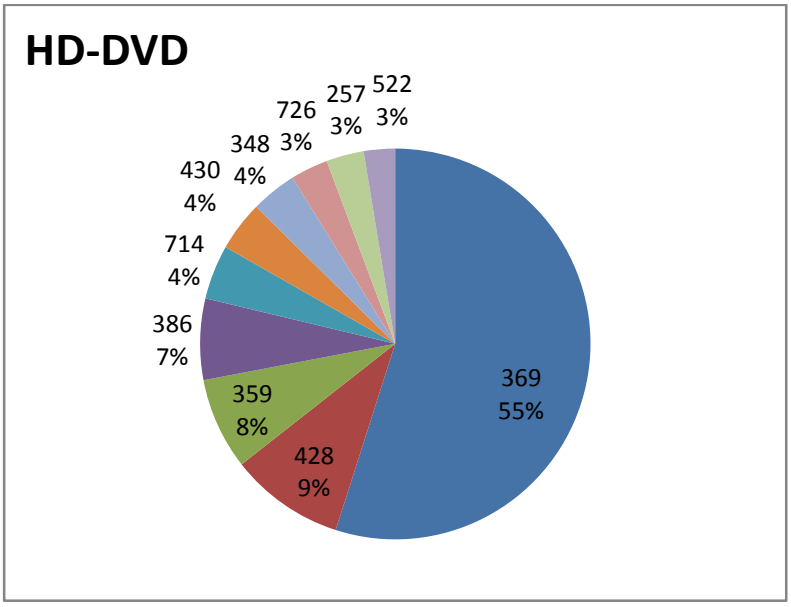

Figure 5 Number of HD-DVD patents filed by U.S. classification number

Appendices

Appendix A: HD DVD Industry Chronology, 2000-2008

Year	Date	Description
2000	Oct. 05	Sony and Pioneer unveil DVR Blue at Japan's Ceatec show. The format would go on to form the basis for first-generation Blu-ray Disc BD-RE.
	Nov. 01	Sony announces the development of Ultra Density Optical (UDO), a blue-laser optical disc format proposed to replace magneto-optical discs.
2002	Feb. 19	Led by Sony, nine of the world's largest electronics companies unveil plans for Blu-ray Disc.
	Aug. 29	Toshiba and NEC propose to the DVD Forum the next-generation optical disc format that will become HD DVD.
	Oct. 01	Prototypes of both formats are unveiled at Japan's Ceatec exhibition. Sony, Panasonic, Sharp, Pioneer and JVC showed prototype Blu-ray Disc recorders while Toshiba showed a prototype under the name Advanced Optical Disc (AOD).
2003	Feb. 13	Licensing of Blu-ray Disc begins. Player makers pay US$20,000 to license Blu-ray while the content-protection system license carries a $120,000 annual fee and additional charge of $0.10 per player. Media makers pay $8,000 annually and $0.02 per disc for the copy protection system.
	Apr. 07	Sony announces its Blu-ray Disc-based Professional Disc format for data archiving applications.
	Apr. 10	Sony puts on sale in Japan the world's first Blu-ray Disc recorder, the BDZ-S77. It's based on a 23G-byte cartridge version of the BD-RE disc and costs 450,000 Yen (US$3,815 at the time). The machine and a later model from Panasonic lack support for prerecorded movies that will launch later and prove an expensive early step into next-generation video.
	May. 28	Mitsubishi Electric joins the Blu-ray Disc group.
2004	Jan. 07	Toshiba unveils its first prototype HD DVD player at CES. The player includes backwards compatibility with DVD.
	Jan. 12	Hewlett-Packard and Dell put their support behind Blu-ray Disc.
	Jun. 10	The first commercial version of HD DVD-ROM is approved by the DVD Forum.
	Sep. 21	Sony announces the PlayStation 3 will use Blu-ray Disc.
	Nov. 29	Paramount Pictures, Universal Pictures, Warner Bros. Pictures, HBO and New Line Cinema announce support for HD DVD.
	Dec. 09	Disney announces support for Blu-ray Disc.

2005	Jan. 07	Backers of both formats promise players and movies in North America by the end of the year -- something that never materialized.
	Mar. 24	Talk and hope of a common format as Ryoji Chubachi, then Sony's president-elect, says: "Listening to the voice of the consumers, having two rival formats is disappointing and we haven't totally given up on the possibility of integration or compromise."
	Apr. 21	Sony and Toshiba begin discussions on the possibility of a single format. The talks ultimately go nowhere.
	Aug. 18	Lions Gate Home Entertainment and Universal Music Group decide to back Blu-ray Disc.
	Sep. 27	Microsoft Corp. and Intel Corp. put their weight behind HD DVD.
	Oct. 03	Paramount Home Entertainment says it will offer movies on both HD DVD and Blu-ray Disc.
	Dec. 16	Hewlett-Packard decides to drop exclusive support for Blu-ray Disc and back both formats.
2006	Jan. 04	Bill Gates announces at CES that Microsoft will offer an add-on HD DVD drive for the Xbox 360 console.
	Mar. 10	Blu-ray Disc-supporter LG Electronics surprises the industry with news that it's developing an HD DVD drive.
	Mar. 31	Toshiba launches the world's first HD DVD player, the HD-XA1. It cost 110,000 Yen (US$936 at the time) in Japan.
	Nov. 11	Sony's PlayStation 3, which packs a Blu-ray Disc drive, goes on sale in Japan.
	Dec. 29	Hackers report success in breaking through part of the AACS copy protection that's on both HD DVD and Blu-ray Disc.
2007	Jan. 07	Seeking to end the battle, LG Electronics unveils a dual-format player, while Warner Bros. shows a prototype disc that holds both an HD DVD and Blu-ray Disc layer so is compatible with players for both formats.
	Apr. 17	Sales of HD DVD players in North America hit 100,000 since launch.
	Aug. 01	Microsoft cuts the price of its HD DVD player for the Xbox 360 from US$199 to US$179 and starts offering five free movies.
	Aug. 20	Paramount and Dreamworks Animation both drop Blu-ray Disc in favor of HD DVD.
	Sep. 13	Sony says it will use Blu-ray Disc in all high-def video recorders in Japan.
	Nov. 07	The price of Toshiba HD DVD players drops to US$100 with rebates as the holiday shopping season begins.
	Nov. 11	Sony begins selling a lower cost version of the PlayStation 3.

2008	Jan. 04	Warner Bros. drops its bombshell: it will stop issuing HD DVD movies in the coming months and rely exclusively on Blu-ray Disc. In response the HD DVD Promotion Group cancels its CES news conference.
	Jan. 06	Akio Ozaka, head of Toshiba America Consumer Products, says at CES: "We remain firm in the belief that HD DVD is the format best suited to the wants and needs of consumers." In response Sony CEO Howard Stringer, with a grin on his face, says "All of us at Sony are feeling blue today."
	Jan. 14	Toshiba cuts the price of HD DVD players with the HD-A3 seeing a retail price of US$150.
	Feb. 11	NetFlix and BestBuy say they will phase out HD DVD.
	Feb. 15	Wal-Mart, the world's largest retailer, says it will phase out HD DVD by June.
	Feb. 16	Japanese public broadcaster NHK reports Toshiba has halted production of HD DVD players. Several additional local media reports confirm and The Nikkei business daily says Toshiba has decided to stop developing the format any further.

Source: (IDG News Service 2008)

Appendix B: Blu-ray and HD-DVD Comparision

Feature	DVD	HD DVD	Blu-ray
Maximum native resolutions supported via HDMI	EDTV (480p)	HDTV (720p, 1080i, 1080p)	HDTV (720p, 1080i, 1080p)
Maximum image-constrained native resolutions supported via component video	EDTV (480p)	EDTV+ (960x540)	EDTV+ (960x540)
Disc capacity	4.7GB (single layer)	15GB (single layer)	25GB (single layer)
	8.5GB (dual layer)	30GB (dual layer)	50GB (dual layer)
		51GB (prototype triple layer)	100GB (prototype quad layer)
Video capacity (per dual-layer disc)	SD: approximately 3 hours	SD: approximately 13 hours	SD: approximately 23 hours
	HD: n/a	HD: 5.1 or 3.3 hours, depending on encoding method	HD: 8.5 or 5.6 hours, depending on encoding method
Audio soundtracks3	Dolby Digital EX, DTS-ES	Uncompressed linear PCM, Dolby TrueHD, DTS-HD Master Audio, Dolby Digital Plus, DTS-HD High Resolution, Dolby Digital, DTS	Uncompressed linear PCM, Dolby TrueHD, DTS-HD Master Audio, Dolby Digital Plus, DTS-HD High Resolution, Dolby Digital, DTS
Manufacturer support (home theater)	All	Toshiba, LG, Thomson/RCA, Onkyo, Samsung	Hitachi, Mitsubishi, LG, Sharp, Sony, Panasonic, Samsung, Philips, Thomson/RCA
Manufacturer support (PC storage)	All	Microsoft, Intel, HP, NEC, Toshiba	Apple, Dell, BenQ, HP, LG, Panasonic, Philips, Pioneer, Samsung, Sony, TDK

Studio support	All	Paramount, Studio Canal, Universal, Warner (until end of May 2008), the Weinstein Company, DreamWorks Animation	Sony Pictures (including MGM/Columbia TriStar), Disney (including Touchstone, Miramax), Fox, Warner, Lions Gate
Compatible video game consoles	PlayStation 2, PlayStation 3, Xbox, Xbox 360	Xbox 360 (via external HD DVD accessory, sold separately)	PlayStation 3
Player prices	$99 and less	$130 (Xbox 360 accessory); $150 and more (stand-alone players); $999 for combo player	$399 (PlayStation 3); $499 and more (stand-alone players); $999 for combo player
Movie prices	$6 and more (retail)	$20 to $28 (retail)	$20 to $28 (retail)
Number of titles available at the end of 2007	50,000-plus	about 330	about 360
Players are backward compatible with existing DVD videos	Yes	Yes	Yes
Set-top recorders available now	Yes	No	No
"Managed copy" option	No	Yes	Yes
Copy protection/digital rights management6	Macrovision, CSS	AACS, ICT	AACS, ICT, BD+, BD-ROM Mark
Region-coded discs and players	Yes	No (currently; could change in future)	Yes

Source: (HD-DVD Promotion Group 2007), (Blu-ray Disc Association 2008)

Appendix C: Market Share of Major Distributors

Distributor	2000	2001	2002	2003	2004	2005	2006	2007
Paramount Pictures	10.57%	11.00%	7.46%	7.09%	**6.73%**	9.28%	10.21%	15.67%
Warner Bros.	11.45%	14.85%	11.70%	12.60%	**13.16%**	16.26%	12.70%	14.77%
Buena Vista	14.94%	10.93%	12.78%	16.76%	12.47%	10.38%	16.00%	13.99%
Universal	14.62%	11.48%	9.74%	11.78%	**9.77%**	11.20%	8.69%	11.41%
Sony Pictures	11.69%	8.87%	16.80%	12.84%	14.27%	8.53%	16.69%	10.72%
20th Century Fox	9.82%	10.55%	10.69%	8.88%	9.87%	15.27%	14.99%	10.53%
New Line	5.03%	7.15%	9.77%	10.04%	**4.25%**	4.72%	2.71%	5.06%
Other	21.88%	25.17%	21.06%	20.01%	29.48%	24.36%	18.01%	17.85%
Total	100%	100%	100%	100%	100%	100%	100%	100%

Table 12 Top 7 Hollywood studio market share by year

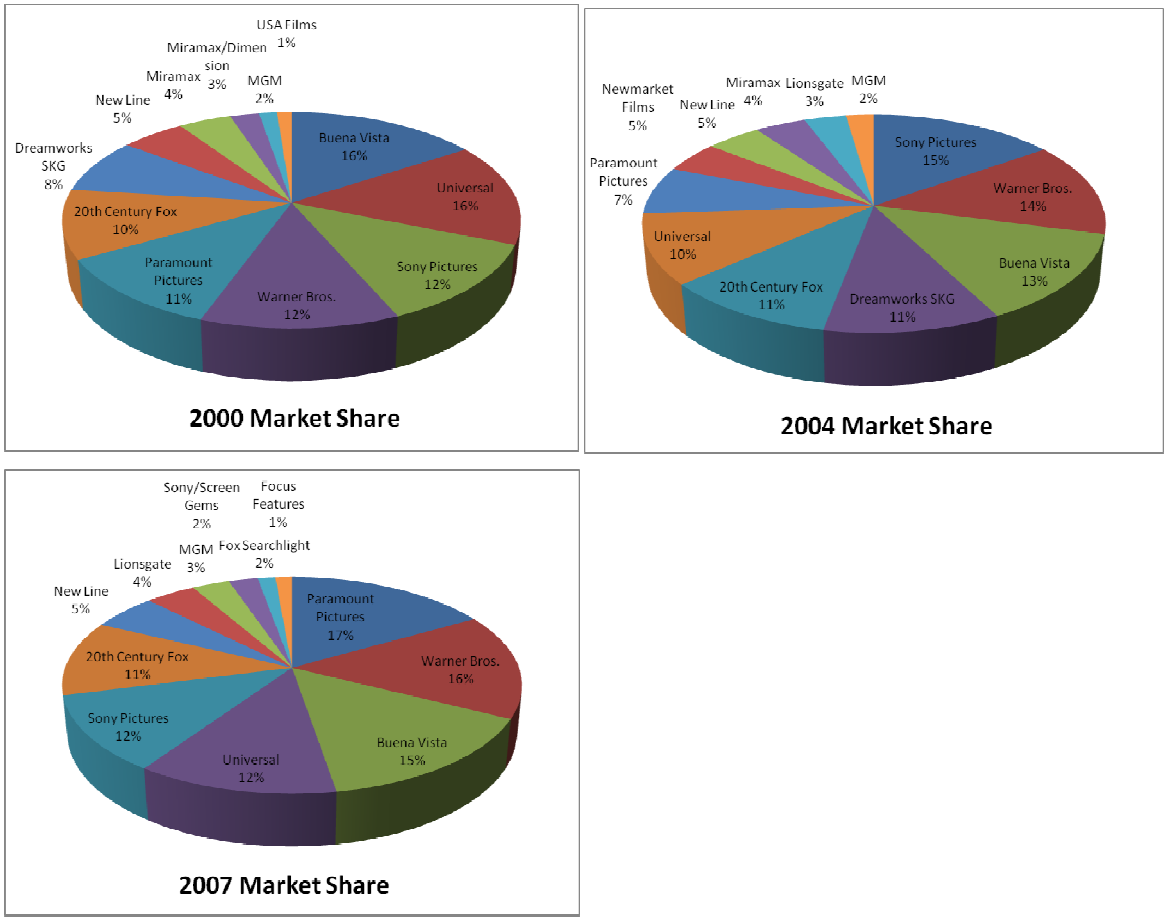

Figure 6 Market Share by year. Source: (Nash Information Services, LLC.)

Appendix D: Patents Data Collection

Data Collection Method

Patent data used in this study were extracted from the U.S. patent and trademark office webpage, a federal agency in the department of commerce which has promoted the progress of science for over 200 years. The patent data available on the website mostly contains detailed technological information which only engineers in the patents related field will understand. The website provides sufficient technological and performance specifications of each patent developed by each assignees. Moreover, it also contains some straightforward, helpful information for the purpose of this study. The necessary study data were extracted using three fields - title, abstract, and description - available from the advanced patent search query webpage. Typically, Blu-ray technology is classed under five main patent names, representing its evolution: Blu-ray, BD-RE, UDO, BDZ and dvr-blue. Patent data were extracted if any of the five names of Blu-ray were included in the three fields mentioned above (Table 1). It is a remarkably complete patent data set for the industry-not a sample of firms, but complete high definition home video market patent information. HD-DVD is primarily known by two different names: HD-DVD and AOD. Similarly, the same methods as for Blu-ray were used to extract patent data for HD-DVD.

Blu-ray	HD-DVD
((TTL/((((blu-ray OR bd-re) OR udo) OR bdz) OR dvr-blue) OR ABST/((((blu-ray OR bd-re) OR udo) OR bdz) OR dvr-blue)) OR SPEC/((((blu-ray OR bd-re) OR udo) OR bdz) OR dvr-blue)	((TTL/(AOD OR hd-dvd) OR ABST/(AOD OR hd-dvd)) OR SPEC/hd-dvd)

Table 13 Search Queries

Data Clean-up Method

Blu-ray patent terms, such as UDO (Ultra Density Optical) and BDZ, have applications in areas other than Blu-ray. For instance, Udo is a person's name in German, a type of plant, it also can stand for User Device Operation. Likewise, BDZ can mean an abbreviation for benzodiazepines in chemistry, or it can be used in Finance as differentials.

Similarly, the HD-DVD term, AOD (Advanced Optical Disc) has meanings other than HD-DVD. Specifically, AOD is an abbreviation for Argon Oxygen Decarburization in chemistry. Subsequently, any patents unrelated to HD-DVD per se were removed. Since Blu-ray is a subset of the HD-DVD term, some patent data extracted for HD-DVD included Blu-ray in the patent information; hence, patents with the Blu-ray term in title or abstract were queried, manually inspected, and removed if they did not satisfy the criteria. Ultimately, the entire patents data set used for study was individually inspected for inclusion. Inspecting the title and abstract of each patent allowed irrelevant Blu-ray or HD-DVD patent data collected to be removed. Where patent data was insufficient to determine eligibility, claim and description of the patent were followed-up.

Since there was no extant of a technical expert with both Blu-ray and HD-DVD knowledge in the study, if the inspected patent data included any of the following terms, then they were included: data, optical, medium, conductor, motion picture, signal, music, video. Otherwise, data were removed.

Patents that were included in both Blu-ray and HD-DVD were re-inspected for eligibility of being included in both dataset, and irrelevant ones were removed.

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