Can Nintendo Get its Crown Back? Examining the Dynamics of the U.S. Video Game Console Market

by

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Abstract

Several generations of video game consoles have competed in the market since 1972. Overall, the entire market shares many similar characteristics, such as network effects and switching cost, which are found in other network-based markets. However, on closer examination, the video game console industry experienced several generations of technological change with each generation bringing a different competitive environment and different set of competitors from the previous one. Consistent with the Schumpeterian market model, both new and later entrants have competed successfully with their strong portfolios of technological innovations. Yet, some firms with dominant market position and strong complementary assets were not able to extend their advantage to the next generation. The dynamic cause and effect relationships associated with the multi-generation video game console industry makes an intriguing subject for economic research. This thesis provides a conceptual framework for analyzing the elements and dynamics of the competitive video game console market. Using qualitative findings and empirical data found in recent research literature on market competition and innovation, a historical analysis of the video game console market was performed. In addition, a system dynamics model was created to validate and support the analysis of the industry. The results from the simulation of the model under various competitive scenarios not only confirm some of the findings from established studies done in this area but also provide us with new qualitative insights into the dynamics operating in the market.

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1 Introduction

Since the Magnavox Odyssey was officially released to the market in 1972 as the first commercial video game console, the video game console industry has grown to a market of $18.1 billion in sales (Crandall and Sidak, 2006). [1] Today, as Sony, Nintendo, and Microsoft enter a new round of battle for market dominance with their next-generation consoles, many people wonder which company will emerge as the market leader after the latest round of console wars? Intense rivalry among companies competing in the U.S. video game console market has always been a common phenomenon. Despite its relative youth, the 35-year old video game console industry already underwent six eras of technological shifts. In the face of technological shift, each generation brought new sets of competitors, innovations, and market dynamics different from the previous one. Consistent with the Schumpeterian market model, new or later entrants not only competed successfully in the market, but in some cases, emerged as market leaders through the possession of strong complementary products and assets. Yet, there were also firms with dominant market position and strong complementary assets that were not able to extend their advantage to the next generation. The video game console industry, with a high turnover in market leaders and rapid technological changes, offers a rich case for developing theories on innovation diffusion, economics, competition, and strategic management. The objective of this thesis is to capture and analyze the dynamic cause and effect relationships of a network-based market exhibiting multiple generations of product.

[1] The estimated sale figures for the video game console market segment include sales of hardware and software.

1.1 Motivation

Examining the factors that contribute to the success and failure of firms competing in a competitive environment, this thesis seeks to enrich the discussion about the evolution of the video game console industry. Many factors fundamental to innovations and competition are discussed, but the focus is primarily on addressing the following questions:

1. How will technological discontinuities bring forth new dynamics that change the competitive rules on which companies operate?
2. How does timing of market entry affect the competitiveness of a firm?
3. What role do complementary assets play in the market?

The primary interest of this thesis is not to refute traditional theoretical frameworks but to provide clarity and enable decision-makers to align traditional strategies and policies with market conditions and factors critical to competing successfully in this market. The posed questions above are addressed by applying:

- Inductive-driven mode of reasoning through historical observations and analysis of the industry.
- Holistic-driven mode of reasoning through system dynamics modeling and simulation of the industry.

First, an inductive-driven analysis of the video game console industry is performed by drawing from the history and available empirical data of the industry. The historical analysis answers the three questions using established theoretical frameworks on competition, innovation diffusion, and strategic management. Next, a holistic-driven analysis is performed by applying system dynamics to capture both the factors and processes operating in the market system. The central principle of system dynamics states that system structure drives system behavior. Thus, the understanding of the processes operating within the market system is crucial to understanding the larger competitive environment and the evolution of the video game console market. The process of creating a system dynamics model enables the researcher to examine how complex system behaviors emerge from a multiplicity of simple linkages within a system. Together, both analysis methodologies complement each other and provide insights to the dynamics of this industry.

1.2 An Overview of Theoretical Frameworks

Let us begin the discussion of the dynamics of the video game console market with the presentation of pertinent definitions and background.

1.2.1 Key Definitions

A list of commonly used terms and their definitions are provided as follows:

- Generation – a period of technology when new innovations emerge to enable a new wave of products that provide new values or meet the needs of customers.
- Market pioneer – the first firm to sell a product in a new generation of a market.
- Market leader – the firm that achieves the highest market share among its competitors at the end of a generation of a market.

Some of the definitions were borrowed and modified from Golder and Tellis's (1993) paper on first-mover advantage. Notably, the use of the term "pioneer" in this thesis refers to "market pioneer" instead of "product pioneer," which is consistent with the term "pioneer" or "first mover" in other studies. Also, the word "era" is sometimes used synonymously with "generation."

1.2.2 Innovations and Dominant Design

The early stages of any industrial evolution are identified with periods of instability, marked with numerous experiments of the underlying technology in defining a product design. The design architecture of a product, on which subsequent products in the industry are based, is called a dominant design (Abernathy and Utterback, 1975). As a dominant design emerges, the industry tips and the design of products in the industry stabilizes around it. Stable design standards enable the market to enter periods of equilibrium (Gallagher and Park, 2002) for which the adoption of the technology can take place at a more accelerated pace (Utterback and Abernathy, 1975). As industry shifts away from experimentation and product innovation, the focus in the industry becomes the incremental improvements made to the dominant design and manufacturing process (Tushman and Anderson 1986). During this time the market changes dramatically. Companies not only have to compete on innovative designs but also on efficient manufacturing processes and the possession of critical resources. As a result, not many firms survive this tumultuous transition.

Dominant design does not have to emerge in the beginning of an industrial evolution. A technological shift between two generations can be so substantial that the previous dominant design is rendered obsolete and new standards emerged as a result. Change in dominant design that occurs when the industry has reached a certain level of maturity has implications. Henderson and Clark (1995) observe that architectural innovation, defined as innovation that changes the way the components of a product are linked together, brings new rules to the industry that may act to tip the technological standard in the market. This shift in technological innovation between generations is substantial enough that incumbents are likely to struggle as they adopt the new innovation with their high degree of incumbent inertia. Thus the authors suggest that architectural innovation potentially destroys the usefulness of existing knowledge of a firm. On the other hand, such technological innovation may give other competitors the ability to gain market share at the expense of the incumbent, which explains why a new entrant like Sony ended as the leader with the introduction of the Playstation.

1.2.2.1 De Facto Standard

While establishing a dominant design is a critical objective for firms competing in the market, this precept does not necessarily confer advantage to the firm that creates that design. A successful design needs to be set by the market either as a formal or de facto standard (Anderson and Tushman, 1990; Gallagher and Park, 2002). Often it is the consumers who decide what standard to eventually adopt. For instance, Sony successfully established the dominant design of videocassette recording (VCR) through U-matic, an earlier format from which video home system (VHS) and Betamax were based. However, the choice of consumers during the commercialization of VCR some years later established Matsushita VHS as the de facto standard (Cusumano, Mylonadis, and Rosenbloom, 1992). Once dominant design and market standards are determined, market dynamics shift from a battle between firms with competing standards to a battle among firms competing with products sharing the same standards (Gallagher and Park, 2002). For example, once VHS became the market de facto standard in the U.S., Sony halted production of Betamax recorders and began manufacturing VHS recorders for the country.

1.2.2.2 Complementary Assets

Technology is not the only determinant in conferring advantage to firms. Afuah and Grimaldi (2005) put forth the notion that "an architectural innovation usually triggers not only the need for new interactions and linkages ... it also triggers the need for new complementary assets." In terms of a new product generation market, the extent of product change and the usefulness of entrant's existing resource base determine the success of market debut (Lieberman and Montgomery, 1998). Mere innovation alone cannot guarantee market success. In fact, it is quite common to find competitors to have profited more from an innovation than the firm that first commercialized it. In the seminal work by Teece (1986), the author explains that "when imitation is easy, markets don't work well, and the profits from innovation may accrue to the owners of certain complementary assets, rather than to the developers of the intellectual property." If complementary assets play such an important role, what are complementary assets? According to Teece (1986), complementary assets are "the capabilities and assets that are required to support a particular innovation, other than those fundamentally associated with the innovation." In other words, complementary assets play a pivotal role in shaping a firm's ability to profit from innovations.

1.2.2.3 Relevance to Thesis

Using the established principles of innovation diffusion and dominant design, this thesis discusses innovation occurring in the video game console industry. In an industry where new standards can potentially emerge in every generation, we are interested in exploring the dynamics spanning multiple generations of innovations in this industry. An area worth looking into is the apparent change of market leadership that occurs whenever a technological change is significant.

1.2.3 First-Mover Advantage

There are huge incentives for market pioneers to capture first-mover advantage. Benefits of first-mover advantage include the control of key resources and the creation of barriers to entry for followers (Robinson and Fornell, 1985). In short, first-mover advantage seems to offer firms a good lead in the competitive race of gaining market share. Yet, despite all its rewards, pioneers face mounting risks and cost by being the first in the market. A later entrant with lower operational cost, superior technology, and the opportunity to learn from the pioneer often enables the competitor to achieve eventual market leadership (Lieberman and Montgomery 1988). In a high-technology industry where discontinuity of technology is a common occurrence, the pioneers who cannot learn from the successes and failures of other firms, are rarely rewarded from innovations. A rush to release products to the market may not be a good strategy for creating and sustaining competitiveness in a firm without a close examination of the firm's resource base and market conditions. The remaining section highlights theories for and against first-mover advantage. For example, even though EMI was the first to develop the computed axial tomography (CAT) scanner, it was firms with experience in medical instrumentation like GE and Technicare that eventually stripped EMI of its market share (Teece, 1986).

1.2.3.1 Theories for First-Mover Advantage

Theories arguing for first-mover advantage us the following four principal factors proposed by various scholars in the field (Lieberman and Montgomery, 1988; Farrell and Klemperer, 2006):

- Preemption of assets.
- Technological leadership.
- Buyer switching costs.
- Network effects.

1.2.3.1.1 Preemption of Assets

The shepherd's job is to lead a herd of sheep to green pastures upon which the herd can graze. Likewise, by being the first in the market, the pioneering firm preempts scarce assets, such as suppliers and distribution channels conducive for the development and production of products by the company. Moreover, early acquisitions are likely to result in economies of scale early, which may ultimately lower production cost for the first-mover.

1.2.3.1.2 Technological Leadership

Similar to the shepherd who acquires green pastures for grazing sheep, an early lead in developing innovative products can bestow technical leadership to the first mover. First-mover advantage in technology means the firm may acquire an early lead in acquiring knowledge in designing more innovative products than its competitors. By establishing some form of pre-emptive technology lock-in, the firm is now in a better position to establish a dominant design successfully in the market. An early lead will often bestow sufficient time for the firm to learn from experience, thereby allowing it to develop more efficient, innovative production processes, which over time translates to reduced operational cost.

1.2.3.1.3 Switching Costs

First-movers are driven by the prospects of attaining customer lock-in and high consumer switching cost. Their motivation is if a consumer makes a substantial investment in a product by the time competing products enter the market, the consumer has less incentive to switch due to higher cost and stronger brand loyalty.

1.2.3.1.4 Network Effect

Network effect is defined as the phenomenon which causes the value of a product to be proportional to the number of other customers who use the product. In other words, the larger the network of users of a product, the greater the value derived from that network. In markets that exhibit strong network effect, a first mover stands to gain and benefit from the exponential growth in sales as more people purchase the product.

1.2.3.2 Theories against First-Mover Advantage

Critics of first-mover advantage abound. Various scholars have suggested why first-movers may be at a disadvantage with the following factors

- Free-rider effects.
- Firm's adaptability.
- Incumbent inertia.
- Commitment of resources.

1.2.3.2.1 Free-rider Effects

Certain market conditions present opportunities for competing firms to acquire early movers' resources, including technology, production process, and distribution channels. In many cases, the cost of innovating often exceeds the cost of imitating. Free-riding occurs when the acquisition of resources may become less than a fair share of the costs of the production. This is why followers may profit more from an innovation than the innovator; the investments by imitators are usually lower than those by innovators (Lieberman and Montgomery, 1988).

1.2.3.2.2 Firm's Adaptability

Technology or market condition changes allow competing firms a stand the chance to implement less costly production processes or to produce products implemented by better technology. In addition, market dynamics and changes in consumer preferences may present opportunities with similar effects as those of technological shifts. These changes require the pioneer to maintain the ability to detect market changes and adapt quickly when circumstances arise. Notably, a risk remains if the pioneer is incapable of meeting market changes or competitive threats that late entrants pose.

1.2.3.2.3 Incumbent Inertia

Lieberman and Montgomery (1988) suggest the "vulnerability of first-mover is often enhanced by incumbent inertia." Companies suffering from incumbent inertia are so assured of their market power that they often fail to detect or address threats from new competitors. Incumbent inertia is frequently motivated by profit maximizing rationale, which often leads to the wrong response in maintaining the market leadership initially captured by the pioneering firm.

1.2.3.2.4 Commitment of Resources

Pioneers may not be willing to commit the necessary resources needed to succeed once they are in the market. Justifications for such inaction include funding deprivation, high capital cost, short-sightedness, or complacency. In the long run, the lack of commitment may starve the company of the resources it needs to grow in the new market and as a result, the company can quickly lose its competitiveness.

1.2.3.3 Relevance to Thesis

The order of market entry is widely written on subject in management and economic research literature. However, from these studies there is not a clear conclusion to support or refute strategic advantage associated with market pioneers. From our market data, we found that several first-movers even those with a substantial early market launch were not able to capitalize on first-mover advantage successfully. For example, 3DO Interactive Multiplayer launched a year ahead of its competitors and was quickly displaced by competing products introduced later. This thesis strives to understand the linkages between complementary assets and entry the company's entry timing in order to gain further insights to first-mover advantage.

1.2.4 Network Effects

Economists Michael Katz and Carl Shapiro (1985) first defined network effect as "the utility derived from consumption of these goods or services increases as additional consumers purchase the same goods and services." According to Katz and Shapiro (1985), and later Economides (1996), network effects can be broadly classified as either direct or indirect. Direct network effects are generated in situations with direct effects of the agents within a network consuming the same good. Examples of direct network effects are the Internet and telephone. Indirect network effects arise from the consumption of a base good and its complementary goods so that the value of the base goods increase as the consumption of complementary goods increases. A complementary good is defined as a good that is consumed with another good. All hardware/software systems, such as CD, VCR, and video game console, belong to this category of network effects.

Network effects from many real world industrial systems lead to a self-reinforcing state that causes exponential growth in the system (Gandal, Kende, and Rob, 2000; Economides and Himmelberg, 1995). A good example of this phenomenon is the fax machine. The ownership of a fax machine by one individual does little to the boost the sales of fax machines, but a network of even a few thousand users indirectly benefits other owners of a fax machine and further drives up demand for fax machines (Economides and Himmelberg, 1995). The overall value of a product often increases exponentially with increased ownership (Shapiro and Varian, 1998) and a first mover in a market exhibiting strong network effects can effectively capture a significant portion of the market early on. It is commonly known in the business of hardware/software systems that software sells hardware (Gandal, Kende, and Rob, 2000). This is a marketing strategy that reflects the effects of complementary goods. Through this consumption, the demand of one good becomes directly proportional to the demand of the other good. Take the case of the personal computer (PC) industry, the utility that a consumer gets from owning a PC is not directly affected by other users owning the PC as much as it is with other users owning the software.

1.2.4.1 Relevance to the Thesis

The video game console industry, like any other network-based industry exhibits a strong mutual dependency between hardware and software. Recently, an extensive body of research and publications provided an in-depth, empirical analysis of the indirect network effects of the video game console industry (Clements and Ohashi, 2004, Hu and Prieger, 2005; Strube et al, 2007). Other studies rely on qualitative, historical analysis of the indirect network effects of the industry (Gallagher and Park, 2002; Schilling, 2003). This thesis incorporates some of the findings found in the referenced literature into a system dynamics model.

1.3 Thesis Organization

Chapter One begins with a brief presentation on pertinent concepts. The chapter takes an in-depth look at complementary goods, network effects, and market entry timing. Chapter Two provides an overview of the history of game console. Chapter Three is devoted to a historical analysis of the industry. For empirical evidence, the chapter draws from marketing data published in the industry. The inductive-driven analysis is then followed by a holistic-driven analysis described in Chapter Four. A system dynamics model is developed and simulated using both hypothetical and real empirical data to analyze the interactions within the market system. The chapter also reports the results from the simulations of the system dynamics model and compares the results with the empirical evidence previously presented in Chapter Three. Finally, the thesis closes with conclusions and implications in Chapter Five.

2 The Video Game Console Market

The video game console industry, with a relatively short product cycle, is characterized by multiple generations of products within its 35 year history. Competition has remained intense and companies have struggled to stay the course of the business. Moreover, each incumbent market leader faced difficulties maintaining their market position when the industry shifted from one generation to another. Despite intense competition and high barriers to entry, we have seen many companies, notably Microsoft and Sony, enter the game console market and achieved a high degree of success.

2.1 Industry Overview

The video game console industry structure is summarized in Figure 1. On the hardware side (the right side of the diagram), the console manufacturers (e.g. Nintendo and Sony) develop, produce, and sell consoles to the consumers. Console manufacturers purchase components from hardware suppliers (e.g. Intel and nVidia) and may sometime enter partnership with component suppliers to develop next-generation components such as multimedia chips. On the software side of the value chain (the left side of the diagram), game publishers (e.g. Electronic Arts and SquareSoft) distribute games to the consumers. Console manufacturers get a portion of revenue from the sale of games by game publisher through licensing agreements made between these two entities. Sometimes, certain stipulations may be added to the licensing agreement forbiddomg software publishers from producing a game title on different platforms, hence enforcing some form of game exclusivity for that console (e.g. Grand Theft Auto on the Sony Playstation 2).

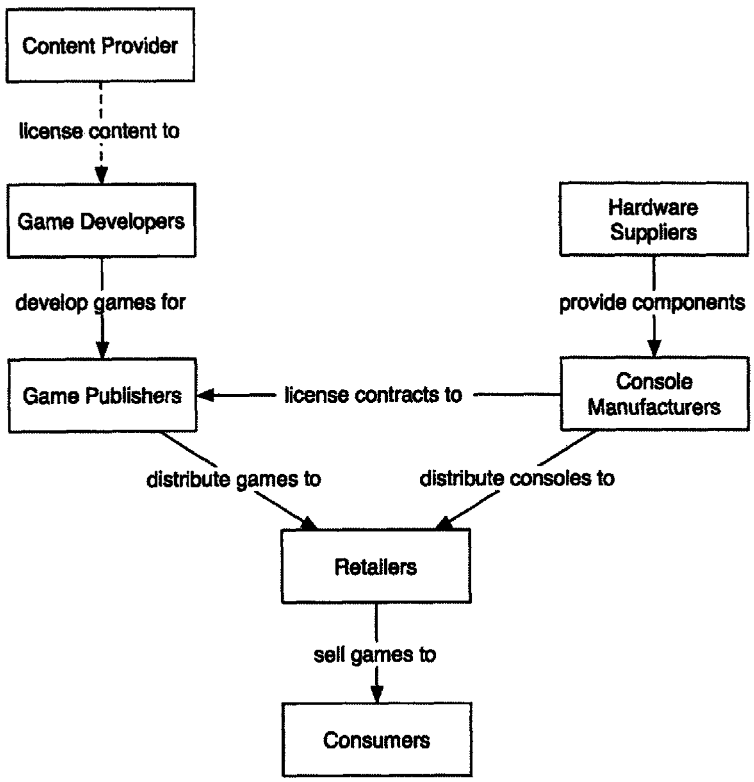

Figure 1 – The value chain of the game console industry[2]

Most game publishers also function as game developers by relying on internal software development teams for game development (e.g. Electronic Arts). Other game publishers use external game studios (e.g. Bioware and Westwood Studios) for game development. Today, intellectual content, storylines, and characters from content providers such as

[2] Source: Adapted from P. Coughlan. *Note on Home Video Game Technology and Industry Structure*. Harvard Business School Case 9-700-107, Harvard Business School Publishing, Boston, MA, 2000; J. Strube, S. Schade, P. Schmidt, and P. Buxmann. *Simulating Indirect Network Effects in the Video Game Market*. Proceedings of the 40th Hawaii International Conference on System Sciences (HICSS'07), pp. 160b, 2007.

National Football League (NFL), Star Wars, and Marvel Comics are becoming increasingly integral to games as franchised content can help to differentiate a game from its competition.

2.2 Generations of Game Console

While video games existed before 1972, they were mostly confined to academic and government labs. The commercialization of video games in the home market segment began with the introduction of the Magnavox Odyssey. The first and second generations of consoles ushered in an era of high market growth in the late 70's and early 80's. However a flood of unauthorized, poor quality games saturated the market and by 1983 led to the demise of the U.S. video game console market. After two years of minimal activities, the market reemerged with the introduction of the Nintendo Entertainment System (NES). Through intense market competitiveness and rapid innovations, the industry developed into the multi-billion dollar industry of today. Figure 2 shows the real introductory prices adjusted for inflation using 2006 prices while Table 1 summarizes the different generations of game consoles according to their introduction date and operating performance.

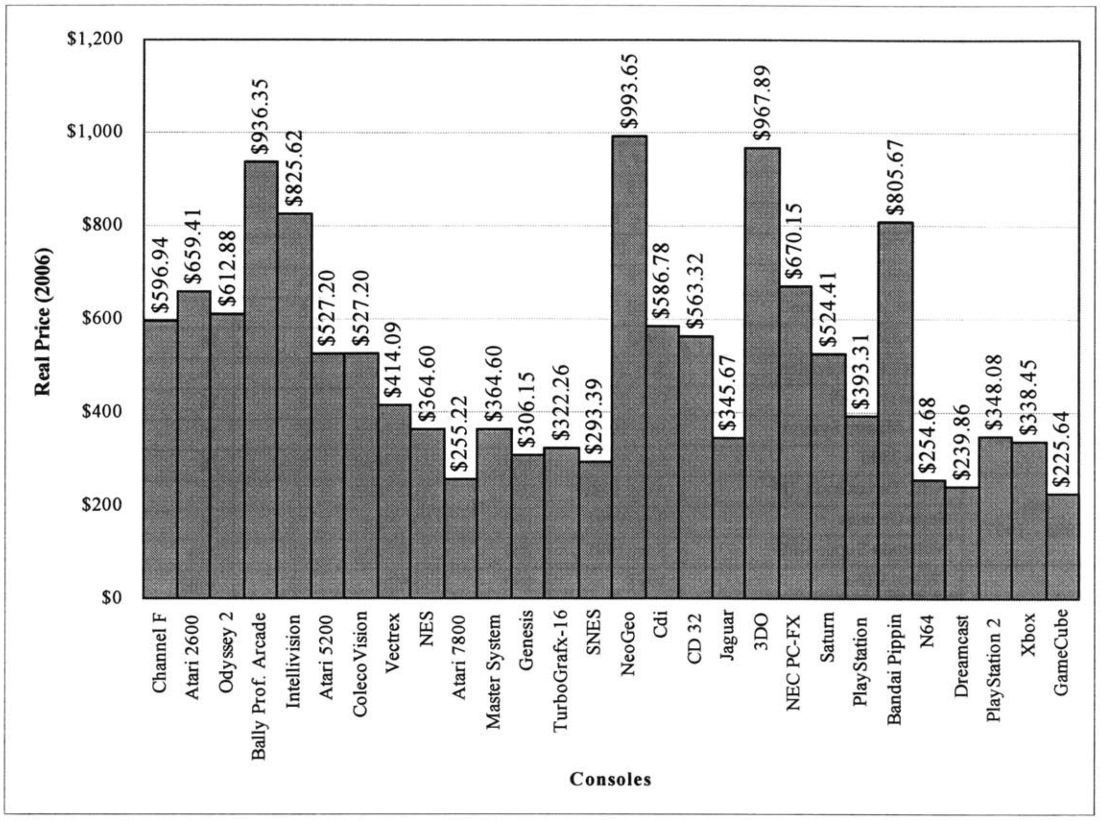

Figure 2 – The real retail price (adjusted for 2006 price) of various game consoles [3]

[3] Source: Compiled from: Curmudgeon Gamer. Retrieved April 2, 2007 from http://curmudgeongamer.com/2006/05/history-of-console-prices-or-500-aint.html; Leonard Herman. *Phoenix: The Fall & Rise of Video Games*. Rolenta Press, 1997; W. Forster. *Encyclopedia of Game.Machines: Consoles, Handhelds, and Home Computers 1972 – 2005*. Gameplan, Germany, 2005.

Generation (Time Period)	Platform	Release Date	Nominal Intro Price (US$)	Operating Performance			
				CPU		Graphics	Storage
				Clock Speed	Bit Rating	# Display Colors	
1st (1972 - 1979)	Magnavox Odyssey[4]	May 1972	100	N/A	N/A	N/A	N/A
	Atari PONG[5]	1975	-[6]	N/A	N/A	N/A	N/A
2nd (1976 - 1984)	Fairchild Channel F	Aug. 1976	170	1.78 Mhz	8	4	2K
	Atari 2600	Oct. 1977	200	1.2 Mhz	8	16	32K
	Magnavox Odyssey 2	1978	200	1.79 Mhz	8	16	8K
	Mattel Intellivision	1980	300	0.9 Mhz	8	16	16K
	Atari 5200	1982	250	1.79 Mhz	8	16	32K
	Coleco Colecovision	Sep. 1982	200	3.58 Mhz	8	16	8K
3rd (1984 - 1991)	Nintendo NES	Oct. 1985	200	1.79 Mhz	8	16	512K
	Sega Master System	Jun. 1986	200	3.58 Mhz	8	16	512K
	Atari 7800	Jun. 1986	140	1.79 Mhz	8	16	128K
4th (1988 - 1997)	NEC TurboGrafx-16[7]	Aug. 1989	200	7.16 Mhz	8	32	2.5M
	Sega Genesis	Sep. 1991	190	7.6 Mhz	16	64	4M
	Nintendo Super NES	Sep. 1991	200	3.58 Mhz	16	256	6M
5th (1993 - 2005)	Philips CD-i	1991	400	15Mhz	32	16M	660M
	3DO Interactive Multiplayer	Oct. 1993	700	12.5Mhz	32	16M	660M
	Atari Jaguar[8]	Oct. 1993	250	3.5Mhz	16	16M	6M
	Sega Saturn[9]	May 1995	400	28.6 Mhz	32	16M	660M
	Sony Playstation	Sep. 1995	300	33.8Mhz	32	16M	660M
	Nintendo N64	Oct. 1996	200	93.75Mhz	64	4B	64M
6th (1998 - Present)	Bandai Pippen	1996	620	66Mhz	64	256	660M
	Sega Dreamcast	Sep. 1999	200	200Mhz	128	4B	1.2G
	Sony Playstation 2	Oct. 2000	300	295Mhz	128	4B	4.7G
	Nintendo GameCube	Nov. 2001	200	485Mhz	128	4B	1.5G
	Microsoft Xbox	Nov. 2001	300	733Mhz	128	4B	4.7G

Table 1 – Summary of game consoles and their technical performance [10]

[4] The Magnavox Odyssey was powered Analog logic chips.
[5] The Atari PONG was powered by custom logic chip 3659-1C, which was technically not a microprocessor.
[6] Price was not available for the Atari PONG.
[7] While NEC TurboGrafx-16's CPU was 8-bit, its graphics processor was 16-bit.
[8] While Atari Jaguar's CPU was 16-bit, its digital signal processor (DSP) was 32-bit, and the animation processor (blitter) was 64-bit.
[9] Saturn had two CPUs.
[10] Source: Adapted from W. Forster. *Encyclopedia of Game.Machines: Consoles, Handhelds, and Home Computers 1972 – 2005*. Gameplan, Germany, 2005; S. Gallagher and S. Park. *Innovation and Competition in Standard-Based Industries: A Historical Analysis of the US Home Video Game Market*. IEEE Transactions on Engineering Management, Vol. 49, Issue 1, pp. 67-82, 2002.

2.3 Early Days

The game console industry had its humble beginning at Brookhaven Laboratories, Connecticut in 1958 when Willy Higinbotham, a physicist at the research institution, developed a simple interactive tennis game on an oscilloscope. Unfortunately, the machine that it ran on was exorbitantly expensive and ultimately limited the diffusion of the technology beyond the confines of the lab (Kent, 2001). The first true computer game was Space War where two players shoot missiles at each other's spacecraft. The game was programmed on a Digital Equipment Corporation PDP-1 by students, Steve Russell and Alan Kotok, at the Massachusetts Institute of Technology in 1961 (Kent, 2001). Even though the game was well received in the small community of computer scientists and hackers at that time, it never commercialized as a consumer game.

2.4 The First Generation (1972 – 1979)

Thus far games had been developed and played on expensive computer systems found only in corporate and academic labs. Video games were out of reach to consumers until 1970 when Ralph Baer, an engineer at the military contractor Sanders, developed a simple interactive game on consumer TV set, which ultimately paved the way for the commercialization of video games in the consumer market.

The first home video game console was the Magnavox Odyssey, which was released in the U.S. in 1972. The production and marketing of the game console began when

Magnavox, a subsidiary of electronic manufacturer Philips, bough the patents that Baer filed for his TV game invention. Only about 100,000 units of the Odyssey were sold in the first year (Forster, 2003). While the Magnavox Odyssey was a novel, innovative product at the time, it was retailed only through Magnavox dealers, which led to the perception amongst consumers that the game console only worked on Magnavox TVs (Winter, 2007). Even with a misleading marketing strategy, demand for the product was fairly well received. However, weak intellectual property protection and the advent of cheap Odyssey clones in the market further reduced the demand of the Odyssey. One of the clone manufacturers, Atari, would soon change the competitive landscape with the introduction of the most successful video game console in the 70's.

2.5 The Second (8-bit) Generation

In 1971, Bushnell, a young charismatic entrepreneur from Utah founded Atari to develop and market coin-operated arcade machines. The company's first order of business was to create a ball and paddle game, much like Higinbotham's and Baer's experimental game concepts. This new game named PONG was officially launched to the market in 1972. It was very successful and helped establish Atari as a serious game manufacturer in the early days of the industry.

As the industry evolved from its primordial stage, the need to make the game consoles programmable for a variety of exchangeable games became a pressing issue. Even though Atari was well positioned to debut a radical new product to address this need, it was semiconductor pioneer Fairchild Semiconductor that released the first microprocessor-based game console, named Channel F. The design of the console was a breakthrough because it offered the ability to play multiple plug-in games. More significantly, the new console established the dominant design of the home video game console on which all subsequent products are based. Despite innovative design, the Channel F failed to appeal early buyers. A year after the introduction of Channel F, Fairchild lost interest and eventually exited the market.

Even though the home segment of the video game market was small, it grew rapidly due to the novel concept of allowing people to play electronic games in the comfort of their own homes. After the initial success of PONG, Atari looked to the home video game market segment to expand its business. In late 1977, Atari officially entered the market with the launch of the Atari Video Computer System (VCS), which was later renamed to Atari 2600. At $200, over 25 million units of the Atari 2600 were sold in its first six years (Coughlan, 2001; Cohen, 1984). By 1980, Atari emerged as the clear market leader with a hard to beat brand name. Despite Atari not having the most advanced game console at the time, the company operated on sound business strategies that contributed to its success. Atari agreed to being acquired by Warner Communication to access the greater financial resources needed to grow the business. Furthermore, Atari, more than any other competitors, realized early the strategic advantage of software in differentiating its console from the competition. It formed and benefited enormously from strategic partnerships with arcade developers who converted popular arcade hits, like Pac-Man and Space Invaders, to the 2600. Through these partnerships, Atari successfully expanded the library of quality games on the Atari, further solidifying the Atari 2600 as the dominant game console of its time.

Two notable challengers to Atari's dominance in the video game console market emerged in the 70's and early 80's, Mattel and Coleco. Mattel entered the market with the launch of the Intellivision in 1980. While the audio and visual capabilities of Mattel Intellivision were ahead of those of the Atari 2600, it was no match to Atari's huge collection of arcade converted games. By the end of 1983, the Mattel sold fewer than 2 million units of the Intellivision and barely made a dent in Atari's market dominance (Forster, 2005). The other challenger, Coleco, introduced the Colecovision in 1982. The Colecovision's technical performance was convincingly better than the Atari 2600. Moreover, the console was positively well-received in the market. In the beginning of 1983, the Colecovision even outsold the 2600 (Schilling, 2003). Unfortunately, Coleco's market success would be denied later that year when the entire U.S. video game industry collapsed on itself.

2.6 Game Over: The Crash of 1983

In 1981 the video game industry peaked. At the same time, the market was getting overcrowded with more than fifty firms competing. Furthermore, competition from personal computers intensified as they became less expensive and as more game titles were converted to personal computers. Yet there was no slowing down from game suppliers as hardware manufacturers continued to produce more consoles and game developers more game titles. By the middle of 1983, there was simply an oversupply of game titles. In fact, in 1983 game manufacturers doubled the number of new game titles from all previous years combined (Forster 2000). Worse, many of these games were of poor quality, which did not help to drive demand. Huge inventory backlogs made companies resort to dumping their inventory at rock-bottom prices. Despite lower prices, games still suffered from the dearth of creativity.[11] The oversupply of bad games eroded consumer confidence and retailers to experience losses, eventually leading to the game industry collapsing on itself at the end of 1983.

The crash of 1983 decimated the market and many companies left it. Many software developers migrated to the personal computer market where they continued developing games. Most console manufacturers could not make that market transition as easily as their software counterparts and remained in the video game console market. The few that remained, including Atari, struggled to survive. However, game manufacturers (both hardware and software) were not the only companies that fell victim to the crash of 1983; distributors were left holding huge unsold inventories after the crash.

2.7 The Third Generation (1984 – 1991)

Despite poor demand and market conditions, Japanese firm Nintendo made a surprising entry to the U.S. video game console market in 1985 with the introduction of the Nintendo Entertainment System (NES). While the NES was an 8-bit game console with

[11] E.T. the Extra Terrestrial was the most notable example. It developed and was completed in five weeks with poor quality.

marginal speed performance over its competition, the sound and graphics capabilities of the machine far exceeded those of its predecessors.

Against the backdrop of a declining market, Nintendo convinced two key determinants in the market to make the launch of the NES a successful one: the distributors and consumers. The distributors, badly affected by the market crash two years earlier were reluctant to stock anything relating to video games (Sheff, 1993). The consumers who had lost confidence in game console or had moved to personal computers, needed to be persuaded to return to the video game console market. To overcome these challenges, Nintendo first adopted a strategy to woo the distributors. They formed attractive incentives to retailers who agree to stock their merchandise by offering to buy back any unsold consoles. Seeing this as a no-lose situation, the retailers accepted Nintendo's proposal. On the consumer front, Nintendo launched an aggressive marketing campaign to win back consumers to the market. Nintendo's plan worked and over a million units were sold by the first year (Herman, 1997).

Nintendo learned from Atari's mistake and formulated a strategy to win and maintain consumer confidence by indirectly controlling the quantity and quality of games through licensing. Under Nintendo's licensing agreement, third-party developers were subjected to content regulation, restricted from making games on other platforms, and required to preorder minimum quantity of cartridges from Nintendo.[12] While the licensing policies improved the overall quality of games and restore consumer confidence, its draconian tone frustrated many developers. But with the NES selling like hotcakes, most game

[12] Nintendo manufactured all cartridges for the NES.

developers were willing to comply with Nintendo's terms. From a strategic viewpoint, such maneuvers allowed Nintendo to exert tight control of complementary goods, which in the presence of network effects enable early business growth. Apart from third-party developers, Nintendo also relied on its internal software teams to produce first-party games, such as Super Mario Brothers, for building its library of software. By the end of 1988, Nintendo's new business model not only revived the home video game console market but also propelled the company to become the undisputed leader of this era.

In the third generation, we also witnessed the U.S. market entry of another Japanese console manufacturer Sega. The company marked its market debut as a home video game console with the introduction of its 8-bit console, the Sega Master System in 1987. The console sold fairly well, but compared to Nintendo, it never gained any significant presence in the market. By the end of the era, Sega managed to sell two million units of Sega Master System in the U.S. In contrast, Nintendo sold 20 million units of the NES (Schilling, 2003).

2.8 The Fourth Generation (1988 – 1997)

In 1989, semiconductor manufacturer NEC brought the TurboGrafx-16, that was selling very well in Japan, to America. Even though its CPU was technically an 8-bit microprocessor, its 16-bit multimedia chips were vastly superior to those found in competing products. Although the product was well received in the Japanese market due to the existence of good Japanese third party support, poor marketing and the lack of software titles designed specifically for American gamers inhibited the product from capturing any significant market share in America (Stahl, 2007).

The release of the NEC TurboGrafx-16 in 1987 heralded the arrival of 16-bit generation game consoles. In contrast to the flat graphics of the previous generation, 16-bit games offered a fast scrollable 2D playing field. Fundamentally, a 16-bit CPU featured data word length that was twice that of the CPU from the preceding era. This new improvement in word size expanded the addressable memory space and color palette of a game console. Apart from increased bit ratings, the video game consoles of this generation were also enhanced by more sophisticated multimedia chips capable of faster 2D animation and scrolling.

In 1990, a year after the release of the TurboGrafx-16, Sega leapfrogged Nintendo with the release the Sega Genesis, a 16-bit game console with good multimedia capabilities. Sega utilized its experience in the arcade business by converting many arcade games to the Sega Genesis, which was welcomed by gamers and developers as a serious alternative to the NES. Sega also targeted the Genesis to mature gamers with a large collection of sport games. For the first two years, the sales of the Sega Genesis were brisk while Nintendo was still firmly invested in the 8-bit game business. For a brief moment in 1993, Sega achieved a market share of 45% toppling rival Nintendo's 44% (Forster, 2005). This feat was short-lived as Nintendo eventually responded to its eroded market share with the launch of its next-generation console called the Super Nintendo Entertainment System (SNES).

At the end of 1990, three years after the release of the TurboGrafx-16, Nintendo finally countered the competition with the release of the SNES. Despite a late start, Nintendo easily overtook the Genesis regaining the top spot of game consoles in the market. Software sells hardware; Nintendo made up for the loss of market share with a series of hit game titles from first and third parties, drawing many consumers to purchase the SNES. The arrival of Sega as a serious competitor brought new threats and problems to Nintendo, Nintendo's bargaining power diminished as it came under pressure from third-party developers to loosen restrictions of its licensing agreements (Gallagher and Park, 2002). In addition, the company also came under increasing scrutiny by the government over alleged antitrust practices forbidding third-developers from developing games on other platforms (Kent, 2001). Under these developments, Nintendo had to revise its licensing policies and allowed third-party developers greater autonomy in how they wanted to develop and market their software. Despite reduced market power, Nintendo still managed to sell 50 million units of SNES worldwide while Sega finished with only 30 million units at the end of the era (Forster, 2005).

2.9 The Fifth Generation (1993 – 2005)

The generation that succeeded the 16-bit generation was made up of both 32- and 64-bit consoles. The technological shift from 16-bit to 32/64-bit era was huge in contrast with previous technological change. Game consoles in this generation were enhanced by two key technological innovations: three-dimensional (3D) graphics and compact disc (CD) technology. Together, these two innovations paved the way for new, improved game experiences.

Although Philips was the company that introduced the first game console, the Odyssey, to the market in the early 70's, the company disappeared from the market soon after the collapse of market. In 1991, in true pioneering spirit, Philips released the first 32-bit game console called the Philips CD-i. The product, featuring a CD drive, functioned not only as a game console but as a music player, a movie player, and an interactive educational tool. Poor third party support, failed marketing campaign, high introductory price, and uncertain market positioning doomed the console. By the end of the era, the machine garnered no more than 2% market share in the U.S. (Trachtenberg, 1996).

In the same year Philips CD-i was launched, Trip Hawkins, the flamboyant founder and CEO of Electronic Arts, one of the largest game developers in the world, stepped down from his position and founded 3DO. Hawkins had envisioned 3DO as the imminent developer of a superior 32-bit game console as well as the first platform manufacturer that operated on a business model providing the licensing of manufacturing rights of hardware and software to partners. After almost two years of development, the 3DO Interactive Multiplayer (IM) console was manufactured and released by 3DO partner Matsushita in 1993. Like the Philips CD-i, the 3DO IM was promoted as an entertainment system and used CD-ROM as a primary storage medium. The 3DO IM also suffered from introductory high price – almost three times more expensive than a competing console – which turned many potential adopters away. Some scholars like

Gallagher and Park (2002), and Schilling (2003) argued that the demise of 3DO was rooted in its business model. Even before the product was developed, a large number of software and hardware developers had signed the licensing agreement, but the proliferation of consoles and games never materialized after product launch due to weak sales of the console. Traditionally, platform providers like Sega and Nintendo would use game licensing fees to subsidize production cost of hardware, which enabled the manufacturers to sell their products at cost or even at loss. The problem with 3DO hardware partners was that they did not sell games and consequently were unwilling to price the 3DO console at a much lower price for market penetration at the expense of profit margin. High price diminished the appeal of the console and led to poor sales. Without a large installed base, software developers had no incentive to produce games, which ultimately led to the demise of the machine.

The Atari Jaguar was Atari's last attempt to regain the dominance that it once held. While the Jaguar used a 16-bit CPU, its custom audio and visual chipset was 64-bit based. In fact, Atari marketed the console as a 64-bit machine, hoping that the additional 32-bit would differentiate the console from their competitors (Forster, 2005). Even though the new chipset offered better performance than anything else on the market, developers shunned the platform due to its complex architecture and poor support from Atari (Forster, 2005). Despite a low price of $250, the console suffered a lackluster debut to the market. Unable to regain market share, Atari finally exited the market in 1997.

Sega officially entered the 32-bit generation with the introduction of the Sega Saturn in 1994, four months prior to the Sony Playstation and sixteen months prior to the Nintendo 64 (N64). Sega had hoped that with features such as 3D graphics and CD capabilities, which were well-aligned with the industry needs at that time, the Sega Saturn could compete directly with upcoming products by rivals Nintendo and Sony. Sega shipped the product four months earlier than the Sony Playstation, yet the company faced an uphill battle when the Playstation was finally released to the market. The problem was that Sega, in an effort to beat Sony in product release, problematically launched the Saturn without coordinating with their developers who were caught off guard. The result was few launch titles for the Sega Saturn (Stahl, 2007). Saturn eventually recovered from the debacle, but the platform never garnered the size and variety of hit titles that Sony Playstation and N64 did with their game library.

Sony launched the Sony Playstation four month later than the Sega Saturn and Sony eventually outsold Sega two to one by 1996 (Gallagher and Park, 2002). The Playstation was well positioned in the market. It functioned as most gamers expected: a top-performing console capable of bringing the best game experience to the gamer. Sony, learning from the Betamax debacle, realized the critical role complementary products play in raising the value of owning a Sony Playstation (Coughlan, 2001). As a result, Sony aggressively convinced third-party developers to produce games for the Playstation. More importantly, Sony fine-tuned the development kit and made it easy for third-party developers to maximize the 3D graphics capability of the hardware. By the end of 1996, the installed bases of Saturn, Playstation, and N64 were 1.2 million, 2.9 million, and 1.7 million respectively (Rigdon, 1997).

Sony's rapid gain of market share is remarkable because the Playstation marked Sony's first foray into the video game industry, after Nintendo abandoned them in a joint project to develop an add-on for the NES. The success of the Sony Playstation was largely attributed to Sony's extensive distribution channel, expertise in consumer electronics and entertainment makers, and broad value network of key partners and complementary products.

The Nintendo 64 (N64) was the fruition of a collaboration between Nintendo and Silicon Graphics, a company at that time considered the undisputed leader in 3D graphics technology (Forster, 2005). The industry leader Nintendo attempted to repeat market success with the Nintendo 64; but it stumbled when faced with the emergent technologies of 3D and CD as well as the threat of the new entrant Sony. In the 32/64-bit generation, only the Nintendo 64 (N64) and Atari Jaguar stuck with solid-state cartridge while the rest of the industry migrated to CD. Nintendo justified the technical decision of not migrating to CD by citing that the CD has slower access speed than the cartridge. But Nintendo's real desire to stay with cartridge may have been motivated by higher licensing revenue from the more expensive solid-state format (Kent, 2001). Despite partial adoption of the new dominant design and few game titles, the console did reasonably well in the first two years following its release.

2.10 The Sixth Generation (1998 – Present)

In the sixth generation, console manufacturers fine-tuned their hardware and improved 3D performance to further enhance game play and allow for the development of more realistic games. The competitive landscape in the sixth generation is about the same as that of the previous generation with Sony, Sega, and Nintendo, once again, competing as bitter rivals. However, we also witness Microsoft's surprising entry to the market with the Xbox. The first console released in this generation was the Pippen, a console jointly developed by Apple and Bandai, a Japanese toy manufacturer. Unfortunately, due to mediocre technical performance and worse, the lack of software, fewer than 200,000 units of the Bandai Pippen were sold (Forster, 2005). Before long, that game console slid to obscurity. On the other hand, Nintendo struggled to regain the market position that it enjoyed in the 1980's and early 1990's. The incumbent leader, Sony, maintained its leadership position with the highly successful Sony Playstation 2.

Reeling from lackluster market performance with the Saturn, Sega attempted a rebound with the Dreamcast. Released in 1998, the Sega Dreamcast featured impressive hardware specifications. For medium storage, Sega opted for a proprietary format called GD-ROM, which has the ability to prevent piracy and to store up to 1.2 GB of content. Despite an early lead, Sega was unable to attain a majority in market share. The reasons: the small library of game titles and poor developer relationship. Just as Sega hastily released the Saturn, the company abruptly retired it when it released the Dreamcast, angering many game developers who had already invested money in developing Saturn games. Game developers responded by abandoning the Dreamcast and went on to develop games on the

Playstation 2 which had a much larger installed base (Stahl, 2007). Even though initial sales of the console were strong, the Sega Dreamcast was eventually supplanted by the Sony Playstation 2. The successor to the Sega Saturn, the Sega Dreamcast, achieved little success despite remarkable hardware performance and early market entry. In the end, Sega only achieved a meager market share of less than 5%. Sega, with its last hope of restoring its former glory diminished, exited the home video game industry in 2001 and focused solely on software game development (Schilling, 2003).

Sony maintained its market leadership in the sixth generation with the SonyPlaystation 2. The game console sported not only 3D graphics acceleration but also DVD movie playback and backward compatibility to older Playstation games. Consumers reacted positively to the well-executed and prolonged market campaign and the game console itself, buying over 20 million units of Playstation in the first year alone. Furthermore, the Playstation 2 blurred the line between a game console and an entertainment center. Sony succeeded with the Playstation 2 where Philips CD-i and 3DO Interactive Multiplayer failed. What really differentiated the Sony Playstation 2 was 3D performance. At the core of the game console was a 128-bit microprocessor Cell, which was jointly developed by Sony, IBM, and Toshiba for optimized performance in floating calculations. Coupled with a graphics chip from nVidia, the Sony Playstation was capable of animating photorealistic 3D objects with accurate physical effects in real-time (Schilling, Chiu, and Chou, 2001). Additionally, excellent development tools and good developer relationships formed since the previous generation made game developers release hit titles that further drove sales of the console.

In 2001, Microsoft entered the game console market with the launch of the Xbox, a game console that was built almost entirely on PC components. Considering Microsoft was a new entrant to the market, it performed rather well by selling 20 million units of Xbox to date (Forster, 2005). Microsoft's entry success can be attributed to the firm's commitment to investing sufficient amount of capital to this new venture as well as leveraging its 3D programming toolkit called DirectX.

After three generations of manufacturing game consoles with cartridges, Nintendo finally embraced the optical medium with the launch of the Nintendo GameCube in 2002. Unlike rivals' consoles, the Nintendo GameCube was never intended to be marketed as a home entertainment systems and did not have DVD functionality. Instead, it used a proprietary 8 cm wide optical medium with copy protection and storage of up to 1.5 GB of information (Forster, 2005). The Playstation and Xbox primarily targeted the mature gamer market segment, Nintendo wooed the younger crowd with a compact, cubic game console. But underneath GameCube's cute appeal was a powerful PowerPC CPU and audio-visual chipset giving the console the power to compete head on with other rivaling consoles (Forster, 2005). Despite of the new direction in hardware design, Nintendo failed to capture the market dominance the company enjoyed in the past. By the end of 2002, Nintendo managed to sell fewer than 7 million units of the console worldwide (Schilling, 2003).

3 Historical Analysis

The history of the video game console industry provides not only cases of successful and failed business ventures but also insights into competition, technological innovations, installed base, and complementary goods. Against this background, this section assesses the industry of video game console from a historical perspective using relevant theoretical frameworks.

3.1 Innovations and Dominant Design

Similar to the early phase of any industry, there was a great need for innovation in the market to push the technological boundary of the video game console to the next level. The need for innovation was driven by the need to address early design deficiencies with a still low domain knowledge.

3.1.1 Emergence of Dominant Design in the Industry

The technological progression of the video game console industry is driven by incremental innovations in two key areas of the hardware system: microprocessor and media storage. In the industry, we see two notable dominant designs that emerged from the market addressing user needs in these two areas. The first dominant design occurred in 1976 and the second one in 1992.

During the early days of the industry, when products were not well refined, video game consoles suffered from three primary deficiencies. First, because most games were built directly into the hardware, there were few to no game variants that could be exchanged among console owners. Second, only one game genre (the ball and paddle) was available to consumers. Third, almost all game at that time required two players to play against each other. All these factors limited the attractiveness of the game console to the mass market and hindered further market expansion.

There was incentive for companies to innovate and establish a dominant design for the industry especially in the early phase of a technological progression. By 1976, advances in semiconductor technology enabled programmability in electronic circuits through the use of a microprocessor. Cost reduction in the manufacture of solid-state chips, further pushed the use of memory in electronic circuits. Console manufacturers traditionally depended on chip manufacturers for the supply of electronic components and knowledge. Thus, it is not surprising that a semiconductor company, Fairchild Semiconductors, released the game console that established the first dominant design in the video game console industry. The release of Channel F addressed those early deficiencies adequately with two important features:

- Its use of a general purpose microprocessor and certain specialized multimedia chips in the console.
- Its games are stored on electronic media (cartridge) as add-ons to the system.[13]

[13] A game cartridge is made of solid-state memory chips.

This new design, the game logic and system execution, two critical functions of the game console system, are now separated as software and hardware respectively. This new approach to a video game system design enabled programmability and modularity in the product design domain, and also allowed for the specialization of economic activities where software studios focus on producing games while console manufacturers specialize on the development and production of game consoles.

While the first dominant design was based on microprocessors and solid-state cartridges, the second dominant design was based on:

- The use of highly-advanced 3D graphics processors.
- The storage of games on optical media.

The emergence of the second dominant design occurred sometime in the beginning of the fifth generation. The integration of a powerful 3D graphics processor in most game consoles in that generation allowed the creation of new game genres, such as first-person shooter and 3D car racing. Gamers enticed by stunning 3D graphics began to favor consoles that offered superior 3D capabilities and performance. However, 3D on its own may not have enough added value for consumers to switch to the new generation of consoles. Complementing the 3D graphics was the Compact Disc (CD), emerging as a solution to increased storage needs. The biggest advantages of using CDs include lower production cost and the ability to store massive amount of information. On the downside, these CDs were not writeable, prone to piracy, and suffered from low access speed.

Interestingly, both 3D and CD technologies benefited from each other's presence in the market. As 3D games become more common, larger storage is needed to store the increased graphical content, for which the CD was aptly suited. On the other hand, CD enabled the creation of more complex games, which further drove demand for 3D games.

3.1.2 Adoption of Dominant Design and Competitiveness

Even though Fairchild Semiconductors was the first to adopt the first perceived dominant design (microprocessor and cartridge), it did not benefit. Other competitors, notably Atari, quickly adopted the dominant design and marketed their product more successfully than Fairchild Semiconductors. Likewise, 3DO and Sega were the first in the market to adopt the second dominant design (3D graphics processor and CD); but they too failed to capitalize on the emergent product attributes. Why did an early lead in technological leadership or even ownership of a dominant design fail to translate to market advantage? In retrospect, one explanation offered is that most new markets are characterized by a period of experimentation in establishing dominant design. From a system architecture point of view, the arrangement of linkages between components, the design of individual components, and the definition of product attributes can make or break a pioneer's product design. The risk lies in defining a product attribute that may not meet the needs of the customer. Moreover, once a firm commits to a design, the redesign may be exorbitantly expensive. This presents an opportunity for later entrants to address design issues by designing products that enhance "ideal" product attributes (Kerin, Varadarajan, and Peterson; 1992).

3.2 First-Mover Advantage

The microprocessor exerts a strong influence on the technological progression of the video game console industry. Indeed, each time a new generation of microprocessor is introduced, firms seize the opportunity to utilize the technology by releasing new products and in doing so create market ecosystems that are distinct from those of previous generations. The video game console industry, because of its short product lifecycle, is divided into eras that correspond to their underlying microprocessor architecture. A summary of market pioneers and leaders of each generation are presented in the table below:

Generation	Market Pioneers	Market Leaders
1st	Magnavox Odyssey (1972)	Magnavox Odyssey (1972)
2nd	Fairchild Channel F (1976)	Atari 2600 (1977)
3rd	Nintendo NES (1983)	Nintendo NES (1983)
4th	NEC TurboGrafx-16 (1987)	Nintendo SNES (1989)
5th	Philips CD-i (1991)	Sony Playstation (1994)
6th	Bandai Pippin (1996)	Sony Playstation 2 (2000)

Table 2 – Market Pioneers and Leaders

Table 2 illustrates how in the video game console industry, being first in the market does not guarantee high market share. From the table, the market pioneer in the second, fourth, fifth, and sixth generations, did not end up as the market leader. If theories for first-mover advantage are right, why did the market pioneers not benefit from first-mover advantage?

3.3 Complementary Assets

We have seen that even firms with strong technological knowledge and products, cannot compete effectively without the rudimentary support of resources. Thus, companies wishing to exploit innovations need to utilize complementary assets. Strength of resources has little relevance if they are not complementary to technological innovation. In terms of market competition, incumbent companies can use their existing proprietary complementary assets to their advantage (Tripsas, 1997; Klepper and Simons, 2000). The cost of reconfiguring their resource base may be another reason why incumbents resist embracing new innovations. Conversely, later entrants, not handicapped by inertia, are more likely to embrace technology. Successful entrants are the ones who preemptively use complementary assets to their advantage to yield better than average performance.

Fundamentally, complementary assets support innovation from two fronts: technology and commercialization (Teece, 1986). First, complementary assets, categorized as process or technological, are assets that help to transform designs to products. Examples of technological assets are manufacturing process, system integration knowledge, and possession of key intellectual properties. Second, commercialization complementary assets are resources of a firm that support the commercialization of innovations. Examples of commercialization assets are brand name, reputation, value network, and marketing capabilities.

Technological Complementary Assets	Commercialization Complementary Assets
• Manufacturing process • Knowledge base • Patents	• Brand name • Reputation • Marketing capabilities

Table 3 – Examples of technological and commercialization complementary assets

The table below illustrates how various successful and less successful companies throughout the history of the industry utilize technological and commercialization complementary assets.

Generation (Time Period)	Platform	Technological Complementary Assets	Commercialization Complementary Assets
1st (1972 - 1979)	Magnavox Odyssey	•Acquired patent to the first TV game	•Distribution channel in consumer electronics •Subsidiary of a giant electronic manufacturer •Poor marketing
	Atari PONG	•Arcade expertise	•Distribution channels to the arcade market
2nd (1976 - 1984)	Fairchild Channel F	•Experience in electronic design •Established as dominant design	•Direct access to manufacturing of microprocessors and other electronic components •Image as a chip manufacturer
	Atari 2600	•Killer applications in arcade converts like Space Invaders and Pac-man	•Access to distribution channel to the entertainment market •Financial backing from parent company, Warner Communications
	Mattel Intellivision	•Delayed shipments of key add-ons	•Distribution to the toy market •Established brand name in children's market
	Atari 5200	•Backward compatibility with Atari 2600 games •Console design did not utilize new chips and technology not as sophisticated as competitors	•Household brand name
	Coleco Colecovision	•Use of advanced chips to push the performance of product	•New entrant to the video game industry, little experience in electronics

3rd (1984 - 1991)	Nintendo NES	•Lock-in chip •Bundling of killer application Super Mario Brothers	•Excellent distribution channels •Solid franchise with storyline and characters, e.g. Donkey Kong and Super Mario Brothers
	Sega Master System	•Arcade expertise	•Poor marketing campaign
	Atari 7800	•Late market release •Console was designed with dated technologies	•Low marketing budget, which led to poor marketing
4th (1988 - 1997)	NEC TurboGrafx-16	•Vastly superior graphic processor •Early market release •Excellent software support in Japan but games had little relevance to the American gamers	•Lack of brand name •Direct access to manufacturing of microprocessors and other electronic components
	Sega Genesis	•Applications that push the limits of the console	•Good franchise, e.g. Sonic •Appeal to mature gamers due to the availability of sports games
	Nintendo Super NES	•Use of advanced graphics and sound chips	•Excellent distribution channels •Franchise
5th (1993 - 2005)	Philips CD-i	•Maintain intellectual properties to CD technology [14]	•Strong brand recognition •Poor market positioning of the product
	3DO Interactive Multiplayer	•Good design	•Large number of partners •Lack of subsidy for hardware manufacturers
	Atari Jaguar	•Use of sophisticated technology in console	•Loss of confidence by consumers in Atari products
	Sega Saturn	•Poor logistical coordination and relationship with third-party developers •Software did not push the limits of the hardware	•Suffered from weak brand after the Playstation was released
	Sony Playstation	•Maintain intellectual properties to CD technology [14] •Experience in chip design	•Excellent distribution channels in entertainment and consumer electronics •Appeal to adult gamers
	Nintendo N64	•Lock-in to cartridge technology •Joint venture with Silicon Graphics on the development of graphics chips	•Recognized as a children game machine •Weak distribution channel to adult gamers
6th (1998 - Present)	Bandai Pippen	•Poor design	•Bought manufacturing license from Apple
	Sega Dreamcast	•Poor relationship with third developers	•Brand name has been weaken by Playstation
	Sony Playstation 2	•Joint venture with IBM and Toshiba in the development processors •Well-designed console	•Excellent brand name carried over from the previous generation
	Nintendo GameCube	•Late release to the market •Use of a closed propriety optical medium	•Brand name has been weaken by Playstation
	Microsoft Xbox	•Experience in operating system •Offer good development kits	•Image as a monopolistic PC software supplier •Excellent distribution channels in the PC game market

Table 4 – Summary of firms and their technological and commercialization complementary assets [15]

[14] The prominent CD was the result of a joint venture between Philips and Sony in the 1970's.

As Table 4 shows, there are numerous cases where possession of a similar complementary asset by different firms in different periods of history resulted in different outcomes. Both Atari and Sony used sophisticated chips in the design of their respective products, the Jaguar and the Playstation 2 respectively. Yet, it was Sony that reaped the benefit of applying a superior technology to its product. In terms of technological complementary assets (resources that transform designs to products), Sony made substantial efforts to make the Playstation 2 easy for developers to program by investing time and money to create a resource base to support third-party development (e.g. development kit and developers outreach programs). As a result, developers were attracted to the platform and created not only more variety but higher-quality games that pushed the limits of the hardware. Atari, on the other hand, did not offer the same level of support to its developers. Clearly, the implication of such a case demonstrates simply possessing a complementary asset is not enough to translate to strategic advantage; proper alignment of assets to technology, product, and market conditions is required by the firm to succeed.

[15] Source: Adapted from: W. Forster. *Encyclopedia of Game.Machines: Consoles, Handhelds, and Home Computers 1972 – 2005*. Gameplan, Germany, 2005; A. Afuah and R. Grimaldi. *Architectural Innovation and the Attacker's Advantage from Complementary Assets: The Case of the Video Game Console Industry*. Social Science Research Network (SSRN) Working Paper Series, 2005.

3.3.1 New Entrants Microsoft and Sony

In the business of video game consoles, Microsoft and Sony's debut in the market demonstrated how both companies leveraged their existing complementary assets to compete successfully in the new market. From a technological complementary assets viewpoint, Sony's successful debut in the game console is attributed to its experience in the design and development of consumer electronics (Schilling, 2005). Furthermore, as a pioneer in the joint development of CD with Philips, not only did Sony have years of expertise in this technology but the manufacturing capabilities to produce CD-ROM drives at better economies of scope and scale than its competitors. When it came to commercializing its first game console, the Playstation, Sony relied on its strongly established distribution channels in the electronic and entertainment markets. Like Sony, Microsoft was already an established-giant in another industrial sector when it entered the market. The company also recognized the value of leveraging its complementary assets early in the game. Microsoft leveraged its industry-winning 3D development suite (DirectX) and value network with software developers, software retailers, and other partners to enhance the market position of the firm. Particularly, by releasing a game console that had architecture similar to the dominant Wintel-based personal computers, game developers were able to convert PC games quickly and easily over to the Xbox. While these initial complementary assets may not have been the only factors influencing the two companies' successes, they certainly helped them to overcome initial entry to market barriers.

3.4 Network Effects

Since consoles contribute no value as a stand alone device, the sales of game consoles depend heavily on the variety of games available (Clements and Ohashi, 2004). We observed from the history of the industry that console manufacturers with a wider variety of games and better game quality often have higher market share (Gallagher and Park, 2002; Schilling, 2003; Clements and Ohashi, 2004). Figure 3 illustrates this assertion.

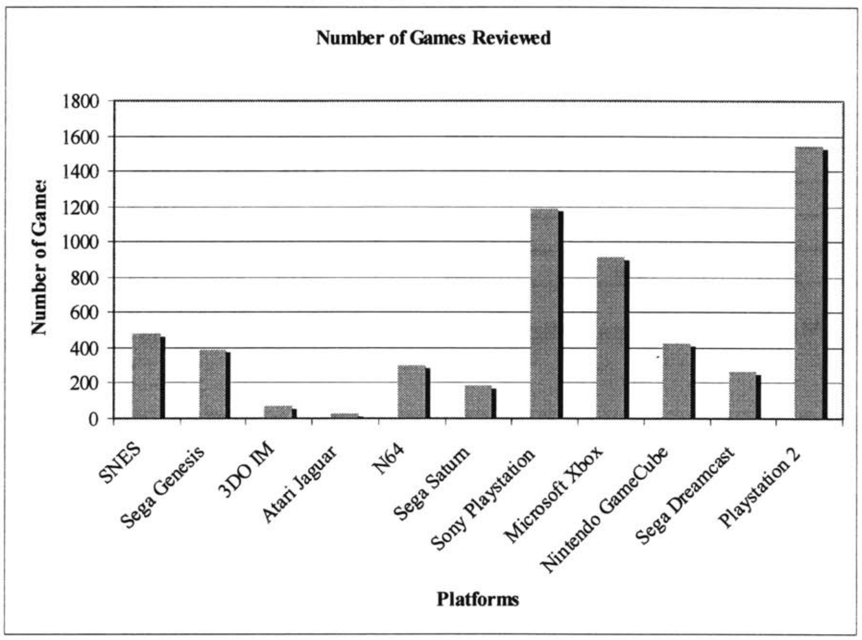

Figure 3 – Number of games reviewed based on the aggregate data of all game review websites via Gamerankings.com [16]

In the chart above, consoles with the largest installed base in their respective generation, the Sony Playstation and the Sony Playstation 2, had the most variety of games. At the

[16] Source: Gamerankings.com. Retrieved on March 18 to April 17 from http://www.gamerankings.com/. Note: Gamerankings.com provide a database of aggregate game reviews obtained from over 50 game review websites. The number of games shown here does not reflect the actual number of games released to the market. The figures merely illustrate the number of games that were reviewed.

same time, these platforms also captured the highest market share. The Sony Playstation led with up to four times the game variety than its closest competitor and the Playstation 2 had almost twice the amount. In the fourth generation, both the SNES and the Sega Genesis have about the same number of available game titles. These figures correspond to the market share of the platforms, which the SNES garnered about 60% and the Sega Genesis about 40%.

	Generation of Video Console					
Firm	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
Magnavox	38%	5%				
Coleco		10%	<1%			
Atari	28%	77%	1%	<1%	<1%	
Sega			14%	34%	7%	8%
Nintendo			85%	57%	24%	15%
Sony					68%	62%
Microsoft						15%
Others	34%	8%	<1%	<9%	<1%	<1%

Table 5 – Market shares of major firms that competed in the video game console industry

The overall value of a game console increases with increasing game variety, console manufacturers apply various strategies to maximize this phenomenon. Strategies that directly control the distribution of software include:

- **Internal game development** – The consumption of a game console requires the consumption of a game and a game console often comes bundled with at least one game. As a result, many hardware companies built up and relied on their internal software development group to produce games for bundling with the hardware at product launch.

- **Franchising** – Successful console manufacturers create lasting franchise to appeal to targeted demographics of the market. For example, Nintendo was the first to use rich storyline and characters in their early games. For example, the plot in the Nintendo game Super Mario Bros., revolves around the player-controlled character Mario who races through the Mushroom kingdom to save Princess Peach. Since the mid 90's, licensing from entertainment and sports franchises are used extensively by game developers. Licensing content from entertainment and sports franchises have the complementary effect of benefiting the game publishers by differentiating their products in the market while games featuring captive content stimulate demand for these franchises (Coughlan, 2000; Crandall and Sidak, 2006).
- **Exclusive titles** – Securing exclusive rights to games, especially ones that are are well received by the market (e.g. Final Fantasy) can greatly enhance indirect network effects.
- **Game development** – Availability of good development tools and software libraries greatly enhances development productivity, in turn can leading to less costly and faster game development.

There are other strategies to enhance network effects without direct control of the software and these are:

- **Penetration pricing** – The platform provider offers a low introductory price, which allows for the build up of an installed base. As market share grows, software sales increase, making the platform more attractive for developers to create more variety of games. Console manufacturers derive their revenues from license contracts in addition to revenues generated from the sales of consoles. In the game console business, most console manufacturers derived much higher revenue from licensing than from the sale of consoles. In fact, console manufacturers have known to actually sell consoles at a loss, in order to penetrate the market (Becker and Wilcox, 2001; Wildstrom, 2001). Console manufacturers make up for such losses with revenues from licensing, which typically has higher profit margin.

- **Early mover in the market** – Early move in the market helps the firm to grow the installed base early. However, first mover in this industry as explained previously does not guarantee success.

4 The System Dynamics Analysis

So far we have taken an inductive-driven approach to examining the determinants to competitive success in the video game console industry. The next step is to use a holistic-driven analysis to understand how determinants in the industry interact with one another. In particular, a system dynamics model created to allow us to identify key determinants and understand the underlying dynamics using discussions from the previous chapter as well as information from reviewed literature. The purpose of a system dynamics model is not to predict future behavior of the system but rather to better allow us to examine the complex interrelationships that we may have missed in our earlier analysis.

Readers who are unfamiliar with the concepts of system dynamics can refer to Appendix A for an overview of system dynamics.

4.1 The Self-Reinforcing Indirect Network Effects

Before we delve into the discussion of the model, let us first use the principles of system dynamics to explain the self-reinforcing effect of indirect network effects in the video game console industry. In the industry, where the base good relies on the availability of complementary goods, the installed base of complementary goods is a factor that cannot be ignored. As the market grows, it becomes more important to have a consistent strategy to grow the installed user base. Figure 4 highlights the linkages of indirect network effect in the game console market. All causal links in the network effect loop are positive.

Consequently, the direction of any change in the system is reinforced. If one of the causal links in the self-reinforcing loop exhibits some form of amplification, a small change anywhere along the loop gets amplified over and over again. Companies that exploit these positive feedback loops (virtuous cycle) early can stand to yield better than average performance in growth and market share.[17] As more people become users of a product, the appeal of the product grows, which attracts more people to purchase the product. Simultaneously, a wide adoption of the product catches the attention of third-party developers who see a market potential in developing games for that platform. As more software developers enter the market, a wider variety of software for the platform is produced. Furthermore, other determinants such as a higher proportion of quality games attracts more people to adopt the console (Katz and Shapiro, 1985; Clements and Ohashi, 2005). As the installed base grows, the cost of switching to a substitute product becomes prohibitively expensive, further reinforcing lock-in. Under this scenario, the effects of early decisions are substantially amplified. This is why many platform providers exploit network effects as they release their game console to the market.[18]

[17] Self-reinforcing positive feedback loops can also amplify the effects of bad decisions early (vicious cycle) that eventually lead to worse than average market performance for a firm.
[18] See Section Network Effects in Chapter Three for a detailed analysis of the strategies used by companies to exploit indirect network effects.

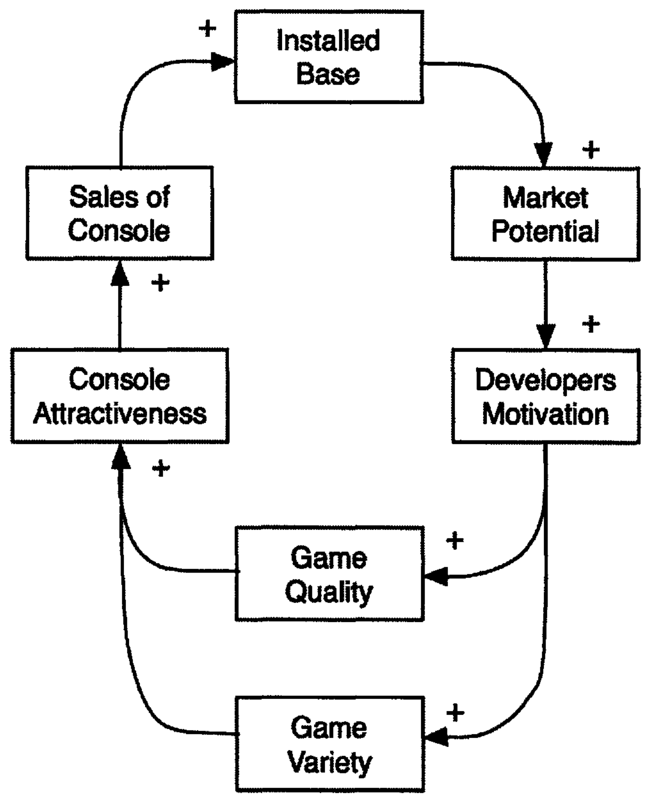

Figure 4 – The self-reinforcing indirect network effect loop

4.2 Methodology

The model created for this thesis is adapted from the system dynamics model on learning effects of a firm, as described in the paper by Sterman, Henderson, Beinhocker, and Newman (2002). The model was modified by removing most of the original feedback loops describing the production of a firm, as they have little relevance in our investigation. The model was then extended on Vensim DSS[19] by including endogenous and exogenous competitive factors of the video game console industry.

[19] A software application program used for the creation and simulation of system dynamics simulation models. Information available at http://www.vensim.com/.

4.3 Model Structure

The system dynamics model represents a generation of the video game console industry.[20] [21] It captures the following feedback loops, identified as the most critical drivers to business growth in a video game console manufacturer:

- Diffusion of video game consoles.
- Attractiveness of video game console.
- Drivers to the attractiveness of video game console.
    - Price and price elasticity of demand.
    - Perception of technology.
    - Indirect network effects (variety of games).
    - Random events and noise.

We simulate the model against the fifth generation of the video game console market by using empirical data of price, price elasticity, and technology perception of consoles competing in that market.

[20] The diagrams shown in this chapter may be modified cosmetically from the actual model by excluding certain variables that are used solely for calibration purposes.

[21] The actual Vensim model uses a feature of Vensim DSS called subscripts. According to Vensim manual: "Subscripts allow a single variable to represent more than one thing … Subscripts do not appear in sketches. Sketches represent structure, and subscripts are a convenient way of replicating structure. The sketch maintains a simpler and less cluttered view of a model by not distinguishing subscripted and unsubscripted variables." (Ventana, 2006) The application of subscripts allows a group of companies competing in a generation to be represented as an array in Vensim.

4.3.1 Key Assumptions

The following assumptions were made in the construction of the model:

- Owners who discard their older consoles will migrate to newer consoles.
- All drivers to console attractiveness have equally weighted influences on the overall console attractiveness.
- The demand curve of game console is linear.

4.3.2 Diffusion of Video Game Consoles

The standard supply and demand model in microeconomics describes the commercial interactions between the supplier and the consumer. When the price of a good falls, the demand by consumers for that good increases. These fundamental market interactions are described in the top left section of the model. The variables *Lowest Price* (minimum price among the three consoles) and *Demand Curve Slope* are used to determine the consumers demand. The stock and flow on the right section of the diagram describes the adoption of fifth generation consoles. The adoption rate is controlled by the feedback information originating from stocks *Non Adopters* and *Cumulative Adopters*. As more people adopt the game console, the rate of adoption slows. Moreover, the adoption rate is also driven by other factors, such as word of mouth (*Word of Mouth Strength*) and natural rate adoption of the product (*Innovator Adoption Fraction*). Not all owners of previous consoles are willing to adopt the newer consoles immediately and the adoption rate of newer consoles is low during the early phase of the industry. A stock, represented by variables *Adopters of Previous Generation Console* and *Adopters of Previous Generation Console Discard Rate*, captures the influences of the previous generation on the adoption of newer consoles.

The dynamics of adoption and demand for a game console are captured in the causal loop diagram below:

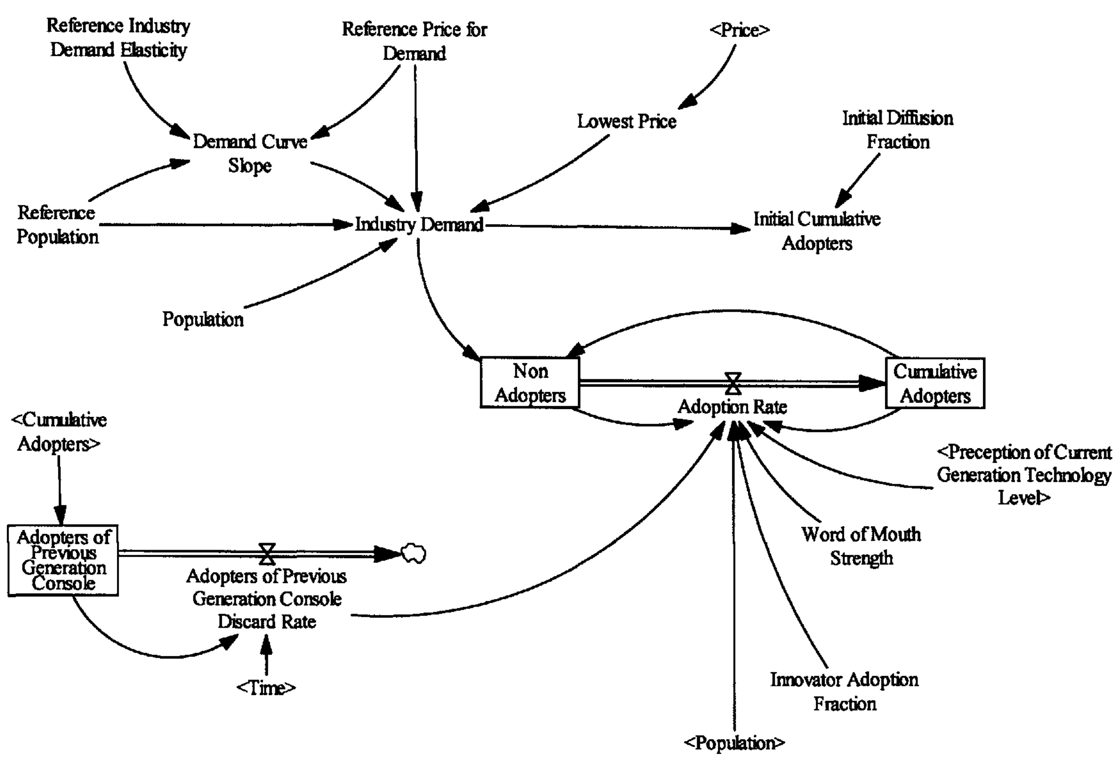

Figure 5 – Diffusion of video game consoles

A portion of this sub-model is based on Sterman, Henderson, Beinhocker, and Newman's (2002) model on product adoption and demand. The definitions of key variables are presented in the table below:

Variables	Description
Cumulative Adopters	Cumulative number of adopters of the console.
Adoption Rate	The rate at which consumers adopt the console.
Innovator Adoption Fraction	The fractional rate per year that non-adopters will adopt the product.
Non Adopters	Consumers who have not adopted the console.
Industry Demand	The number of consumers in the population who will in equilibrium choose to purchase the product as a function of the minimum price available in the market.
Population	Total population of potential adopters.
Demand Curve Slope	The slope of the demand curve as a function of the price elasticity at the reference price level.
Reference Population	Potential number of consumers willing to purchase the product at reference price.
Reference Price for Demand	Price at which the potential adopter population equates the reference population.
Adopters of Previous Generation	The number of people who adopt a console from the previous generation.
Adopters of Previous Generation Discard Rate	The rate at which people discard their older consoles.

Table 6 – Descriptions of variables represented in the diffusion of video game console causal loop diagram [22]

[22] Some descriptions were taken directly from Sterman, Henderson, Beinhocker, and Newman's (2002) model.

4.3.3 Attractiveness of video game console

The dynamics of the attractiveness and the installed base of a video game console are captured in the causal loop diagram below:

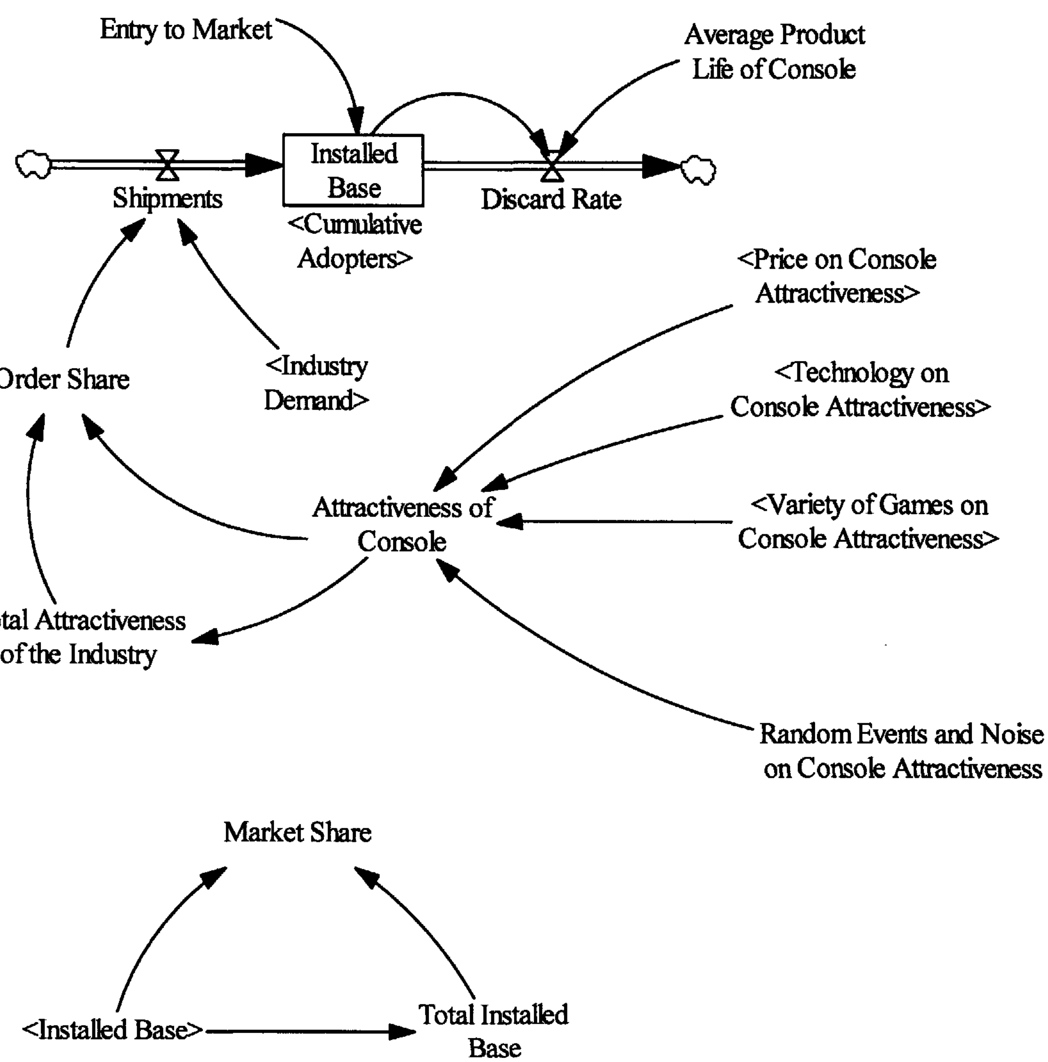

Figure 6 – The video game console market

The variable *Attractiveness of Console* represents the attractiveness of a game console to non-adopters. In our model, the attractiveness of a console depends on four other attributes, which are collectively known as the drivers of console attractiveness. These four attributes are:

- Price.
- Perceived technology.
- Variety of games.
- Random noise – "the luck factor."

The mathematical relationship between the attractiveness of a console and its determinants is shown as:

$$\text{Attractiveness of Console}_i = \text{Price Attractiveness}_i \times \text{Technology Attractiveness}_i \times \text{Game Attractiveness}_i \times \text{Random Noise}_i \qquad (1)$$

All drivers of console attractiveness are normalized with a relevant reference value ensuring that the values reflect meaningful relative strength with respect to the standard or an acceptable reference value. The descriptions of other drivers of console attractiveness are provided in subsequent causal loop diagrams. The parameter *Random Events and Noise* is simulated with a random generator function in Vensim where each firm receives an unique random seed value.

The definitions of key variables are presented in the following table:

Variables	Description
Entry to Market	Firm's entry to market.
Installed Base	Cumulative number of consoles currently in the market.
Discard Rate	Rate at which consoles are discarded by users.
Shipments	Rate at which consoles are sold by a company.
Order Share	The attractiveness of a console relative to other firms' consoles.
Total Attractiveness of the Industry	The total attractiveness of all consoles.
Attractiveness of Console	The attractiveness of a game console to the non-adopter.
Price on Console Attractiveness	Effects of price on the overall console attractiveness.
Technology on Console Attractiveness	Effects of perceived technology on the overall console attractiveness.
Games on Console Attractiveness	Indirect network effects of games on the overall console attractiveness.
Random Events and Noise on Console Attractiveness	Effects of random events and exogenous noise on the overall console attractiveness. The luck factor.

Table 7 – Descriptions of variables represented in the diffusion of video game console causal loop diagram

The order share of a firm, which is defined as the fraction of the industry order going to that firm, is determined by the strength of attractiveness of a game console relative to the rest of the competition. The following expression shows the relationship:

$$Order \quad Share_i = \frac{Attractiveness \quad of \quad a \quad Console}{\sum_{i=0}^{n} Attractiveness \quad of \quad a \quad Console_i} \tag{2}$$

The rationale for this relationship is that the stronger the console attractiveness relative to the competition the larger portion of sales of that console.

4.3.4 Indirect Network Effects

The dynamics of indirect network effects on attractiveness of a console are captured in the causal loop diagram below:

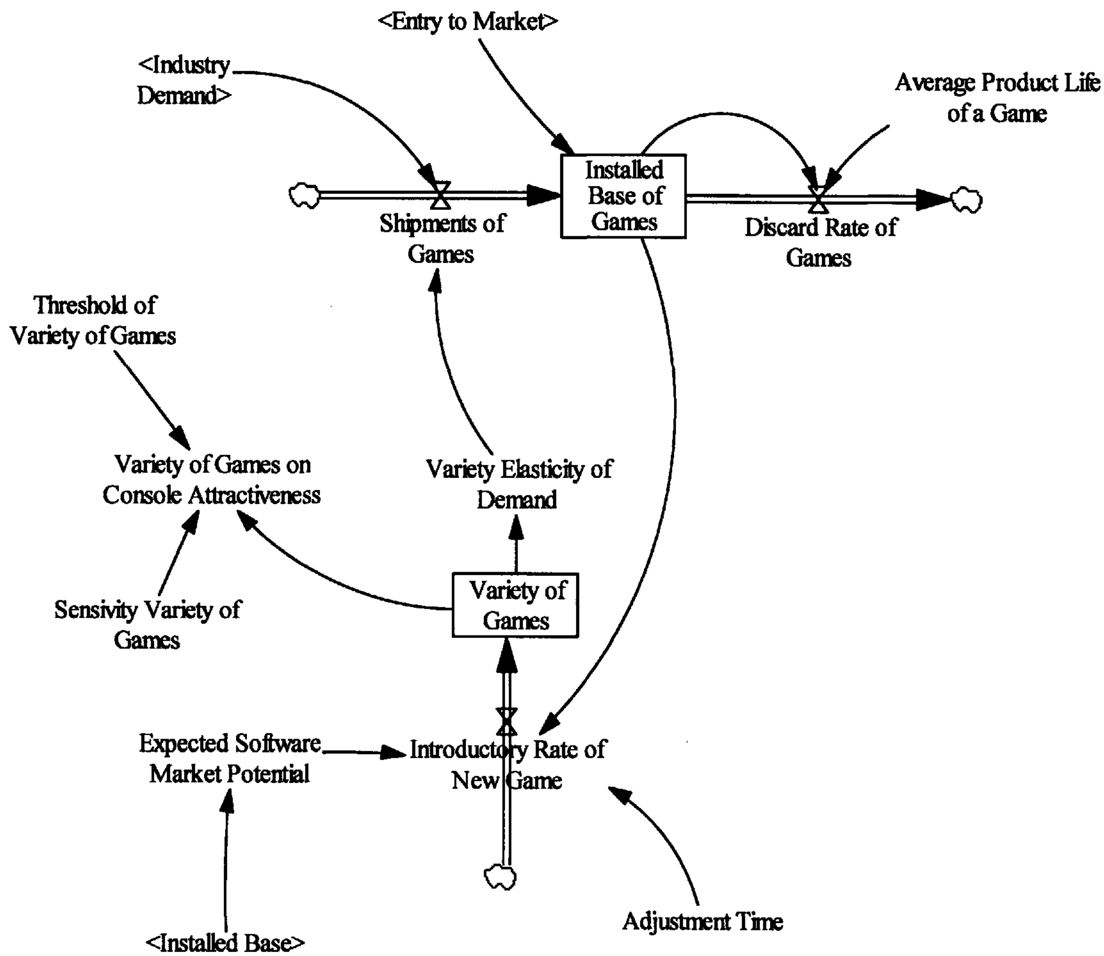

Figure 7 – The effect of software (Games) on sales of consoles

The definitions of key variables are presented in the following table:

Variables	Description
Games on Console Attractiveness	Effects of games on the overall console attractiveness.
Threshold of Installed Base on Variety of Games	Reference size of installed base to cause significant network effect.
Sensitivity Variety of Games	Strength of the effect.
Variety of Games	The cumulative number of games title in the market.
Introductory Rate of New Games	The rate at which new games and released to the market.
Expected Software Market Potential	Developers' perception of the market potential as a motivating factor for developers to produce games.
Variety Elasticity of Demand	Responsiveness of demand with respect to game variety.
Installed Base of Games	Cumulative number of games currently in the market.
Shipments of Games	Rate at which games are sold by all software companies.
Discard Rate of Games	Rate at which games are discarded by all software companies.
Game Quality	The perceived quality of games.

Table 8 – Descriptions of variables represented in the indirect network effects console causal loop diagram

Our indirect network effect (*Games on Console Attractiveness*) uses an adapted version of a similar mathematical function found in Chapter 10 of Sterman's book Business Dynamics (2000). The mathematical relationship is expressed as:

$$Games\ \ Attractiveness_i = \exp\left[\frac{\begin{matrix}Sensitivity\ \ Variety\\ of\ \ Games \times Game\ \ Variety_i\end{matrix}}{\begin{matrix}Threshold\ \ of\ \ Variety\\ of\ \ Games\end{matrix}}\right] \times Game\ \ Quality \qquad (3)$$

In markets that exhibit strong indirect network effects, the adoption of complementary products by other users can benefit the base product directly. The network effects influencing console attractiveness can be approximated as an exponential function (3). The mathematical relationship is by no means complete. In fact, for a more detailed analysis, Sterman (2000) recommends constructing a set of "nonlinear functions that would saturate for high levels of installed base, representing the eventual dominance of diminishing returns as the installed base becomes very large." For now, this crude expression gives a reasonable estimation of the system response. The relationship above also incorporates the variable *Game Quality* to simulate the effect of game quality on game attractiveness. The data for *Game Quality* (Figure 8) are taken from the website www.gamerankings.com, which aggregates game ratings from over fifty game review websites. Unfortunately, it was not possible to retrieve game ratings by year as the website does not facilitate data query for games reviewed before the year 2000. As a result, *Game Quality* is represented only as a constant.

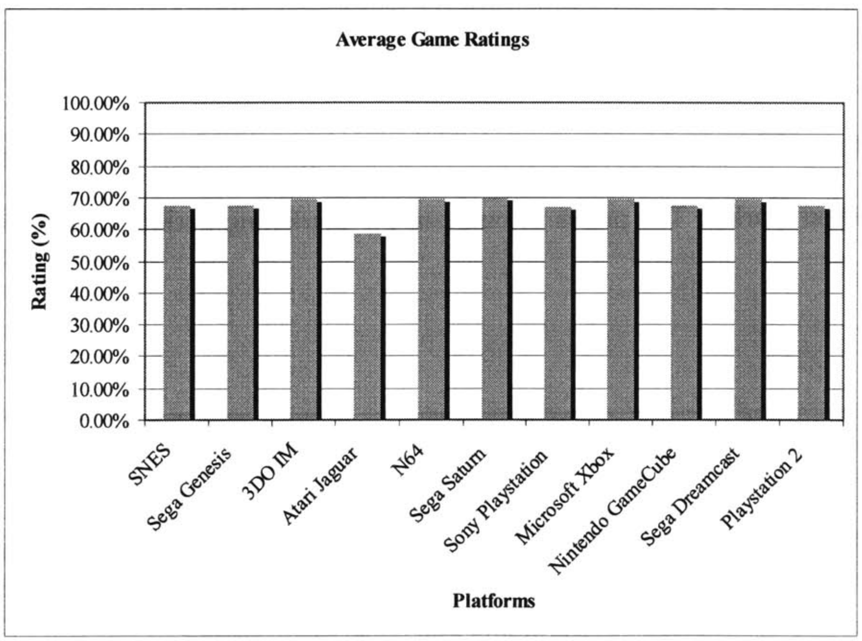

Figure 8 – The average game ratings of games aggregated from various game review websites via Gamerankings.com[23]

[23] See Appendix B for detailed presentation of distribution of game ratings by platform.

4.3.5 Price and Price Elasticity of Demand

The dynamics of price and its affect on the attractiveness of a console is captured in the causal loop diagram overleaf:

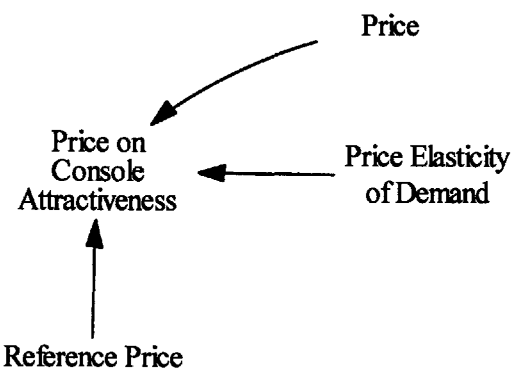

Figure 9 – Price on the attractiveness of console

The input to variable *Price* uses the dynamic price of three consoles competing in the fifth generation market. The prices throughout the marketing period are summarized in Table 9.

Platform	Price (US$)								
	1994	1995	1996	1997	1998	1999	2000	2001	2002
Nintendo 64 (N64)			199.61	159.33	138.06	121.92	105.23	90.09	84.42
Sony Playstation		301.67	235.15	158.03	138.79	117.84	99.59	99.63	109.31
Sega Saturn		369.58	233.98	172.71	77.86	40.3	31.65	36.14	

Table 9 – Prices of fifth generation game consoles [24]

Price elasticity of demand is included in the model to represent the magnitude of demand change in response to a unit change in price. We model price elasticity as the variable

[24] Source: M. Clements and H. Ohashi. *Indirect Network Effects and the Product Cycle: Video Games in the U.S.*, 1994-2002. The Journal of Industrial Economics, Vol. 53, Issue 4, pp. 515-542, 2005.

Price Elasticity of Demand.[25] More importantly, price elasticity of demand in each console is known to vary with time. In the seminal work by Clements and Ohashi, the authors found that price elasticity of demand in the fifth generation of the video game console industry was known to be dynamic. They explain: "We find that lowering price is particularly effective near the beginning of the product cycle: Demand for hardware is particularly elastic with respect to price at the beginning of the cycle ... At the end of the cycle, when a hardware standard is becoming out-of-date relative to newer competitors, the elasticity of hardware demand with respect to both price and software variety is low" (Clements and Ohashi, 2004). Dynamic price elasticity proves to be useful as we can now model the dynamics of consumers' response to price change at any given time.

Platform	Elasticities	1994	1995	1996	1997	1998	1999	2000	2001	2002	Average
N64	Price (E_p)			-4.38	-3.45	-2.95	-2.55	-2.13	-1.77	-1.65	-2.10
	Software Variety (E_s)			0.02	0.11	0.40	0.90	1.34	1.55	1.44	0.64
	Share ($-E_s/E_p$)			0.01	0.03	0.14	0.35	0.63	0.88	0.87	0.32
Saturn	Price (E_p)		-8.40	-5.19	-3.74	-1.66	-0.84	-0.64	-0.71	0.00	-2.35
	Software Variety (E_s)		0.09	0.53	1.08	1.19	0.90	0.47	0.24	0.00	0.50
	Share ($-E_s/E_p$)		0.01	0.10	0.29	0.72	1.07	0.73	0.34	0.00	0.36
Playstation	Price (E_p)		-6.83	-5.22	-3.43	-2.96	-2.46	-2.01	-1.96	-2.14	-3.00
	Software Variety (E_s)		0.16	0.65	1.59	2.47	3.40	4.49	5.42	5.09	2.59
	Share ($-E_s/E_p$)		0.02	0.12	0.46	0.83	1.38	2.23	2.77	2.38	1.13

Table 10 – Price and Software Variety Elasticities of Game Consoles [26]

[25] Price elasticity of demand was hastily implemented in the model. Although it offers a reasonable estimation of the system, a better way is to incorporate price elasticity of demand directly to the variable *Demand Curve Slope*. This modification would have been cleaner and more accurate.
[26] Source: M. Clements and H. Ohashi. *Indirect Network Effects and the Product Cycle: Video Games in the U.S.*, 1994-2002. The Journal of Industrial Economics, Vol. 53, Issue 4, pp. 515-542, 2005.

4.4 Perception of Technology

The dynamics of the perception of technology and its affect on the attractiveness of a console are captured in the causal loop diagram overleaf:

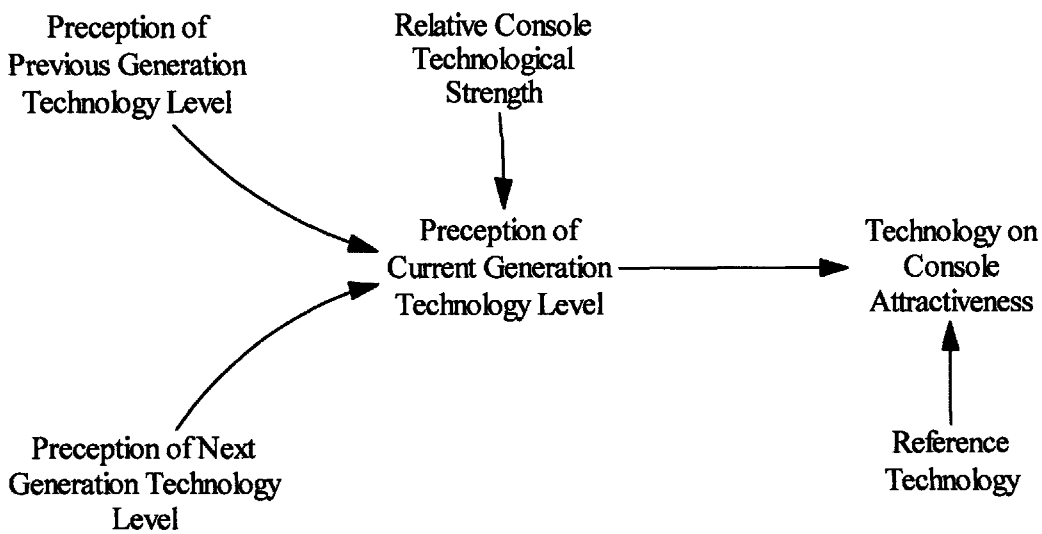

Figure 10 – Perception of technology

We approximate the *Relative Console Technological Strengths* by performing a comparative analysis of technical strengths and weaknesses of all three consoles (Table 11).

Model	Sega Saturn	Sony Playstation	Nintendo 64
Acronym	SAT	PS	N64
Year Released	1994	1995	1996
		CPU	
Model	2x Hitachi SH2	LSI/MIPS R3000A	NEC/MIPS R4300i
Type	32-bit RISC	32-bit RISC	32/64-bit RISC
Clock Speed	28.6 Mhz each	33.8 Mhz	93.75 Mhz
Benchmark	25 MIPS each	33.8 MIPS	100 MIPS
		Memory	
Type	SDRAM/DRAM	SDRAM/DRAM	Rambus DRAM
Main RAM	2 MB	2 MB	4.5 MB
Video RAM	1.5 MB	1 MB	0[27]
		Storage	
Type	CD	CD	ROM (cartridge)
Size	600 MB	600 MB	64 MB
		Graphics	
GPU	VDP1, VDP2	GPU	SGI/Nintendo RCP
Clock Speed	7.2 Mhz		62.5 Mhz
Normal Resolution	320 x 224	256 x 240	320 x 240
Highest Resolution	704 x 480	640 x 480 (interlaced)	640 x 480 (interlaced)
Color Depth	24-bit	24-bit	32-bit
Pixel Transfer			0.02 G/s
		3D Graphics	
Geometry Processor	SCU, DSP	GTE	RCP
Speed		66 Mhz	
		Sound	
Processor	SCSP, 68EC000	CPU, DSP	SPDP (part of CPU)
Channels	32 PCM and FM	24 ADPCM	up to 24 ADPCM[28]
		Others	
Readers' Rating (out of 10)	4	4.5	5

Table 11 – Technical specifications of fifth generation game consoles [29]

[27] Unified memory architecture - no dedicated memory for video or sound.

[28] Each channel takes up 1% of coprocessor rendering time.

[29] Source: W. Forster. *Encyclopedia of Game.Machines: Consoles, Handhelds, and Home Computers 1972 – 2005*. Gameplan, Germany, 2005.

The *Relative Console Technological Strengths* are finalized using data from Table 11.

Model	Sega Saturn	Sony Playstation	Nintendo 64
Relative Console Technological Strength	0.75	0.90	1.00

Table 12 – Relative Console Technological Strengths of fifth generation game consoles

4.5 Model Inputs

The market release dates of consoles are programmed into the model. The first console that appeared in the market, Sega Saturn, is assigned with time t = 0 years. The Sony Playstation and the Nintendo 64 entered the market at t = 0.25 year and t = 1.25 years respectively. Finally, in approximate terms, other hypothetical inputs supplied to the model are summarized as follow:

Variables	Values
Average Product Life of Console	4
Average Product Life of a Game	2
Reference Price for Demand (price equilibrium)	$300
Population	200 million
Time Period	8 years

Table 13 – Hypothetical inputs to the model

4.6 Simulation Results

We simulated the model for 8 years corresponding to the duration of the fifth generation. This section highlights some of the results from our simulation runs. Figure 11 shows the simulated installed base of various consoles competing in the market.

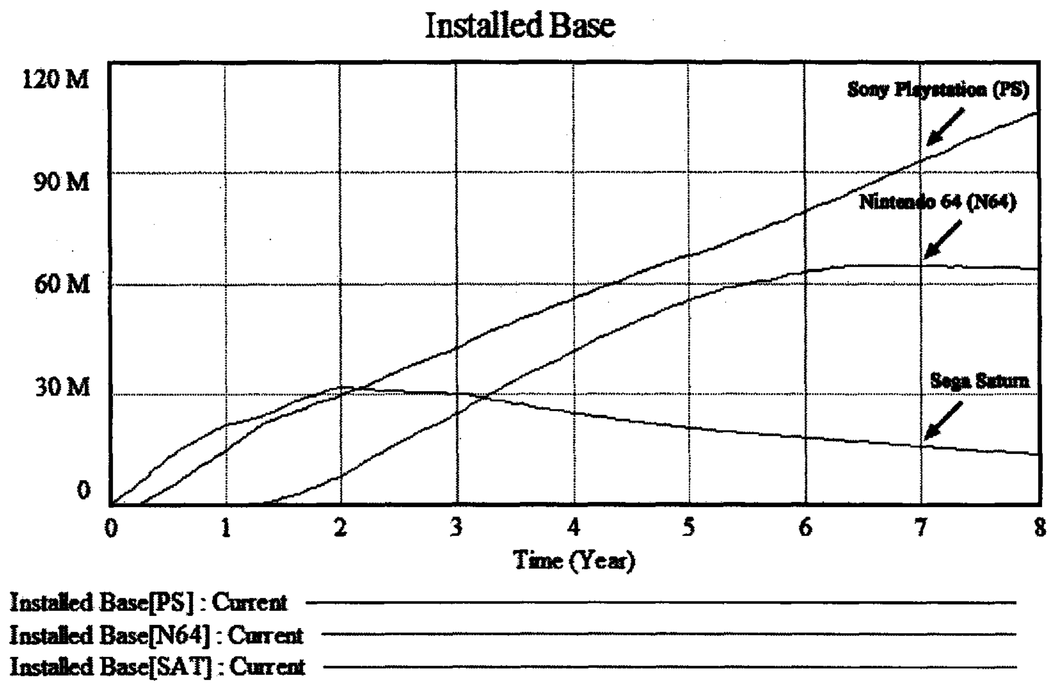

Figure 11 – Simulated results showing installed Bases of fifth generation game consoles

While the absolute values of market size obtained from the simulation runs differ considerably from real world values, the simulated relative market shares and trends (Figure 11) are positively correlated to the real world values and trends (Figure 12).

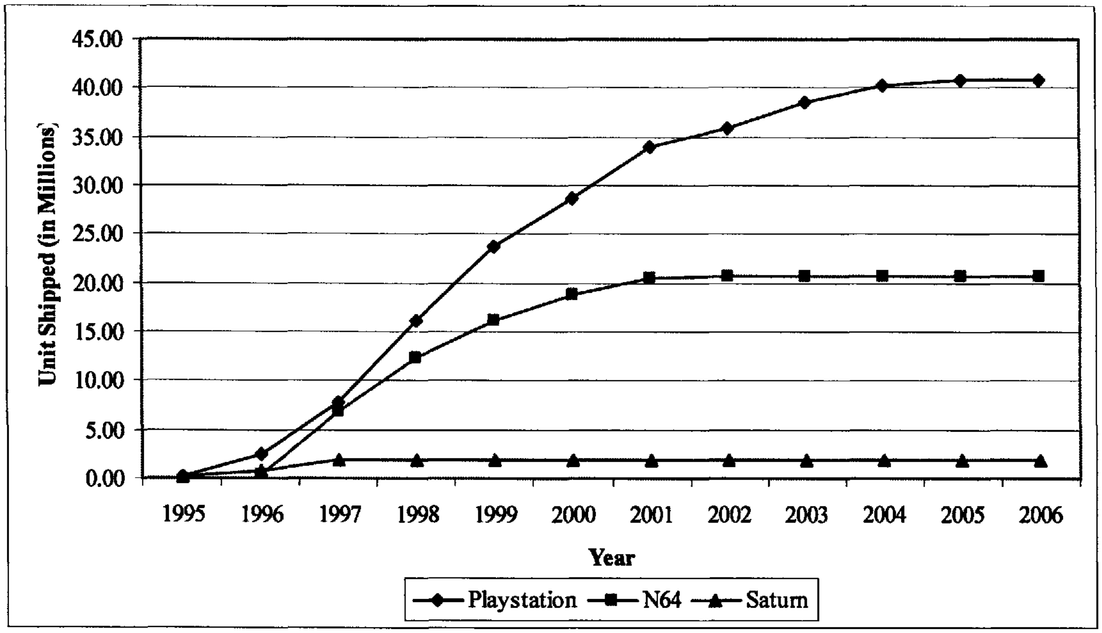

Figure 12 – Actual cumulative shipments of 5th generation consoles

The drivers of console attractiveness are plotted in Figure 13.

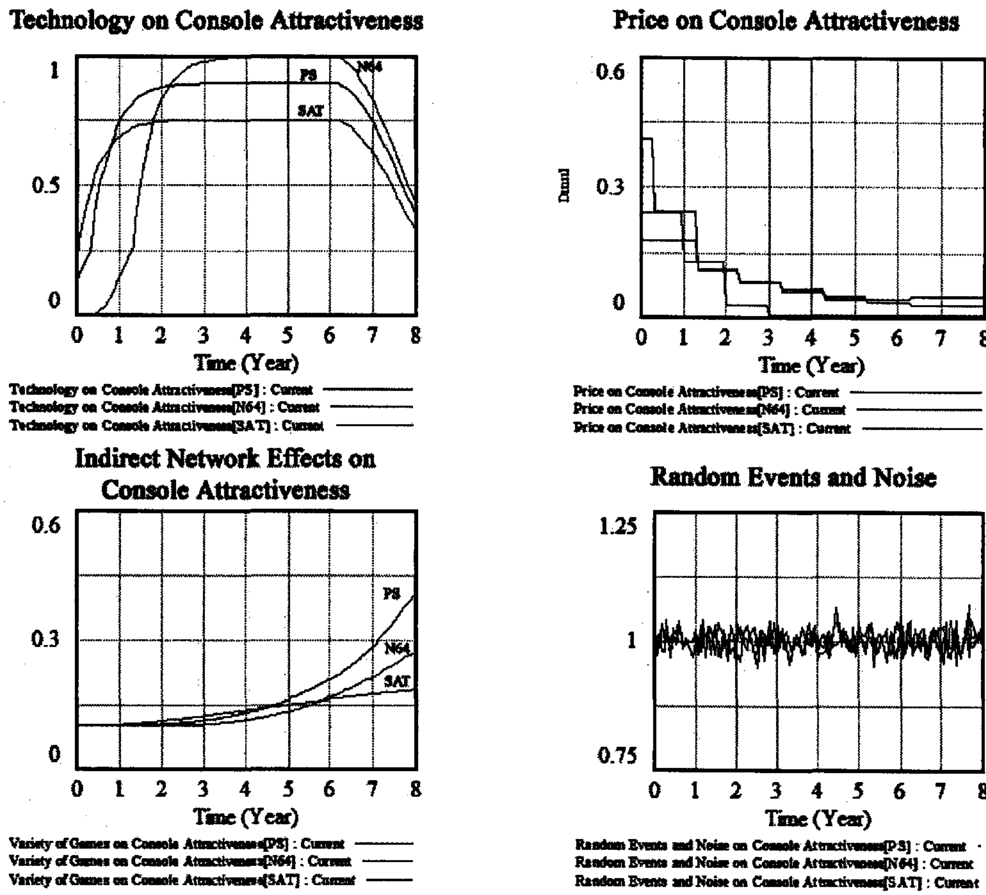

Figure 13 – Dynamic responses of individual components of console attractiveness

The curve depicting *Technology on Console Attractiveness* shows the attractiveness of console in terms of its technological attributes. The shape of the curve is attributed to he initial ramp-up of favorable perception of console due to preannouncements and marketing leading to product release. The curve then levels off at a level that corresponds to the console's relative technical performance. Towards the end of the duration, the curve declines as consoles begin to lose their technical appeal to newer consoles. Indirect network effects curve shows an exponential type of growth in attractiveness. The chart clearly shows that as the installed base grows, the attractiveness of consoles due to network effects grows more than proportionately. The curve on Price on Console Attractiveness is a direct reflection of the actual prices of the consoles.[30] Combining the effects of all individual components, we get the overall console attractiveness (*Attractiveness of Console*), which can be seen in Figure 14.

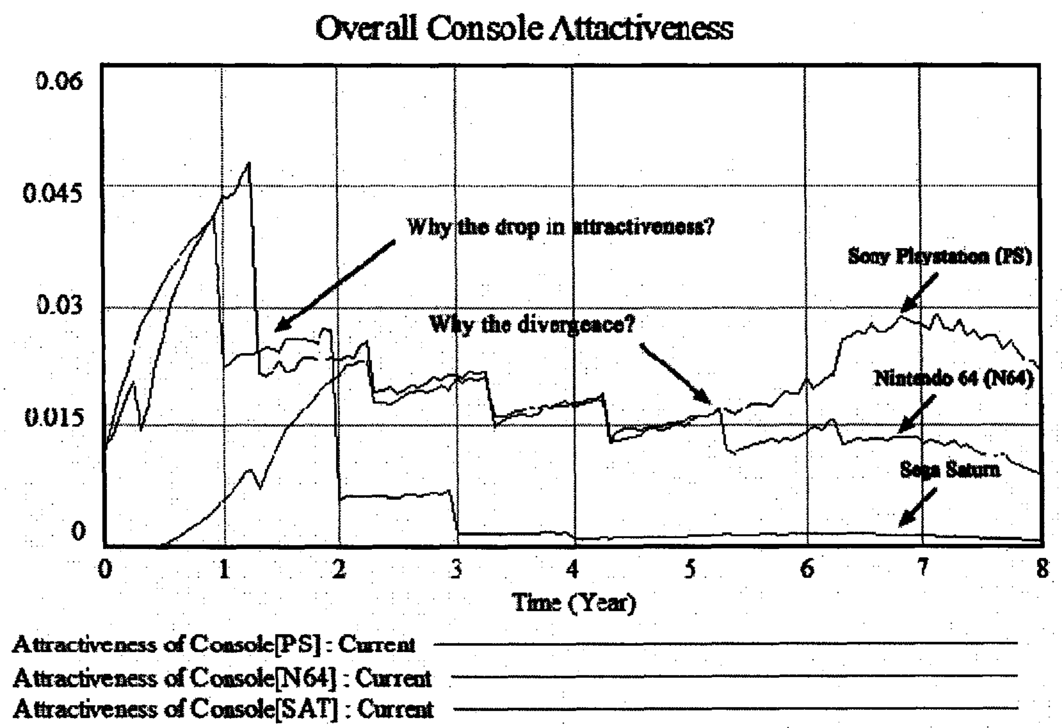

Figure 14 – The overall console attractiveness

4.7 New Questions

The simulation runs have produced some interesting results. The simple system model provided a reasonable approximation of the actual case of the competitive market

[30] Actual prices are found in Table 9.

operating in the fifth generation of video game console by comparing Figure 11 and Figure 12. However, it also raises two new questions:

- Why did Sega Saturn despite being the first mover, not yield satisfactory market performance?
- Soon after Nintendo 64 was released, the product caught up to the Sony Playstation in terms of console attractiveness, but by the fifth year Nintendo 64's appeal to consumers faltered. Why?

The following sections address these questions.

4.7.1 Perception of Technology and Pricing

1. Why did Sega despite being the first mover, did not yield satisfactory market performance?

Even though Sega enjoyed a ten month lead over Sony on product release, the market perception of the Sony Playstation was more favorable because the product had stronger perceived technical performance relative to the Sega Saturn. The Playstation's perceived technological attractiveness is boosted by performance while the Saturn's perceived technological attractiveness by early lead-time. Taken together the two effects roughly balance each other out. Therefore, for the first year, both machines have similar technological appeal to consumers. The technological attractiveness of the current products did not reach saturation till the second year (Figure 13). Furthermore, because of marginal perceived performance gain, uncertain technological standard, or high switching cost. Consumers may choose to defer purchase until the Sony Playstation console is released to the market, especially if the product is seen to offer more value.

When the Sega Saturn was launched, it had a price tag of $369.58. In contrast, the Sony Playstation was introduced with a price of $301.67 (Table 9Table 14). The price elasticity for Sega Saturn and Sony Playstation in the first year were -6.83 and -8.40 respectively (Table 10), making the Sega Saturn more price elastic than the Sony Playstation. As with any highly elastic good, consumers are likely to find substitute goods when the price is deemed high. So despite early lead, Sega was unable to exploit early lock-in associated with indirect network effects as demand for its product lowered due to weaker perceived technological performance, high price, and high price elasticity relative to those of the Sony Playstation. As the market expanded, the sales of Sony Playstation surged. By 1996, Playstation's installed base outgrew Saturn's installed base. The rate of installed base growth of Sony Playstation is higher than the Sega Saturn, the indirect network effects for the Sony Playstation became significant early enough to cause even further lead in market share over Sega.

4.7.2 Sensitivity to Strategic Decisions

2. Soon after Nintendo 64 was released, the product caught up to the Sony Playstation in terms of console attractiveness, but by the fifth year Nintendo 64's appeal to consumers faltered. Why?

In terms of technical attractiveness, the Nintendo 64 has a slight edge over the Sony Playstation (N64 was rated at 1.0 and Sony Playstation at 0.9). Sony, on the other hand, has a large installed base and led Nintendo by a year early in product (Figure 11). When the Nintendo 64 was finally released, it was priced $35.54 lower than the Sony Playstation. Despite having a lower price elasticity (Figure 15), the lower introductory price and the apparent technological strength of the N64 beget strong demand for the product by consumers. As competition between Sony and Nintendo intensifies, the two rivals locked in a price war. For the next two years, there were no significant differences in the prices between the two consoles (Table 14).

Platform	Price (US$)							
	1995	1996	1997	1998	1999	2000	2001	2002
Nintendo 64 (N64)		199.61	159.33	138.06	121.92	105.23	90.09	84.42
Sony Playstation	301.67	235.15	158.03	138.79	117.84	99.59	99.63	109.31
Price Difference	N/A	-35.54	1.3	-0.73	4.08	5.64	-9.54	-24.89

Table 14 – Price Differences between N64 and Playstation

However, in 1999, we see a slight dip in price elasticity for Nintendo 64 (Figure 15). That same year Sony dropped the price of the Playstation $4.08 below that of the Nintendo 64. While these changes may seem small, the virtuous cycles (as described in section The

Self-Reinforcing Indirect Network Effects) in the system can amplify the effects of these changes substantially to cause a very different outcome. By the following year, the attractiveness of both consoles began to diverge. This may explain the drop in the variable *Attractiveness of Console* at t = 5.25 years. Nintendo finally reacted in 2001 by aggressively lowering prices, but it was already too late to reverse the self-reinforcing effects.

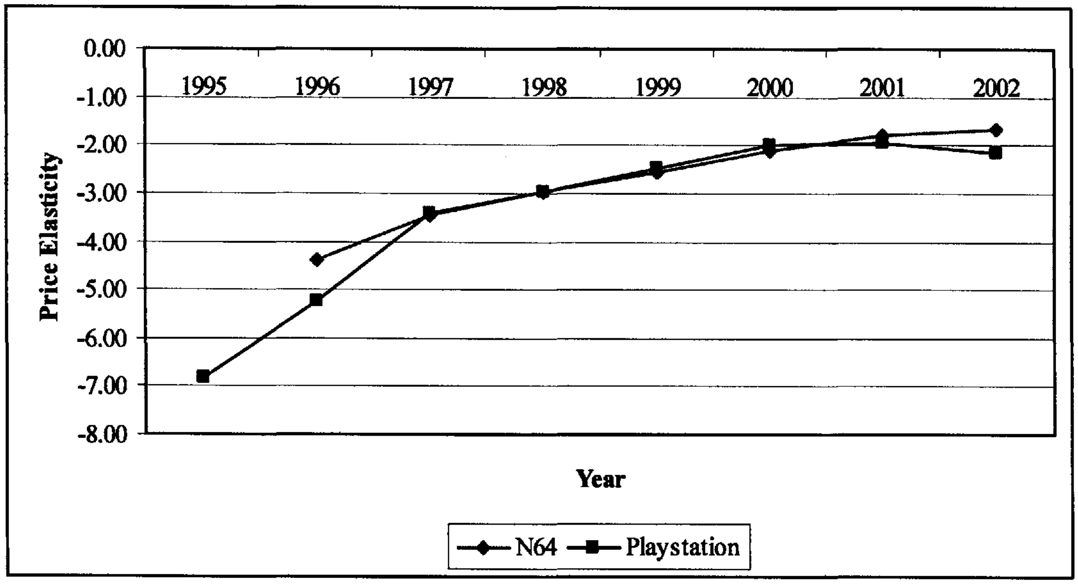

Figure 15 – Changing price elasticities of N64 and Playstation

People's response to price changes differ over time even though other factors stay the same. In retrospect, it is easy to spot the change in price elasticity. In the real scenario, consumers' preferences and market conditions may go unnoticed. Indeed, it may be difficult even to define the predictors of shifting price elasticity in the game console market.

5 Conclusions and Implications

This chapter summarizes the findings from the thesis and concludes with implications and suggestions for companies wishing to achieve competitive success in the video game console industry.

5.1 Policy Implications

The U.S. antitrust law under the Sherman Antitrust Act addresses firms that engage in practices that prevent or reduce competition in a market. Anti-competitive practices relevant to the video game console industry include dumping, barriers to entry, price fixing, and product tying. The discussion on the video game console industry so far has been done through the lens of microeconomics and strategic management. What are the policy implications from this study? After all, the video game console industry is a highly competitive market system with competing firms driven to building and sustaining large market share. Can we expect firms competing in the video game console industry to behave in manners that are culpable of reducing competition in the market? In various ways, many of the firms that compete in the video game console industry fit into the traditional definition of a monopolist. Most firms in the industry have market power in some form or another. All hardware products in the industry are differentiated, sold below marginal cost, and may have exclusive game titles. These characteristics appear to violate the behavioral standards of Section 2 of the Sherman Act (Schmalensee, 2000). However, in a Schumpeterian-based industry, incumbent products face constant threats of newer products that arise from rapid technological change. The case of the video game console industry illustrates that firms with market power are vulnerable to competitive threats since market leaders are not known to last more than two market generations. Indeed, many economists suggest factoring rapid technological innovation into the existing antitrust laws in the U.S. to better reflect the competitive landscape in today's market (Ordover and Willig, 1985; Schmalensee, 2000; Lipsky, 2001). In terms of price fixing, studies examining the lag effects of platform providers' pricing and advertising decisions indicate there are no significant signs of concerted efforts of price coordination (Shankar and Bayus, 2002). According to Shankar and Bayus (2002) "industry analysts and government antitrust documents indicate that firms in the video game industry do indeed have short planning horizons and do not usually consider any inter-temporal effects of price and advertising in their decisions."

5.2 Further Research

The rapid, dramatic turnover of market leadership and technological standards in the video game console industry offers plenty of opportunities for future work by applying different theoretical frameworks. In particular, does an industry characterized by the overlapping of two or more generations of differing technological standards overturn a traditional theoretical model of innovation? On the other hand, more thorough and in-depth analyses of the investigated areas would greatly contribute to the understanding of market competition, innovation diffusion, and the dynamics operating in the industry. There is no denying that this thesis benefited from previous research in this industry

(Gallagher and Park, 2002; Schillings, 2003; Clements and Ohashi, 2005). Insights into how Sony beat Sega despite being four months late in product launch and how a small price drop by Sony in crucial moments resulted in significant market share growth, would not had been possible without the data provided by Clements and Ohashi (2005). Therefore, further research in extending previous studies would be most beneficial in the near future in order to bring further clarity and coherence to the subject.

5.3 The Evolution of the Industry

One area that requires further accuracy and consistency is the market evolution of the video game console industry. While our findings in this area are startling, they are also inconclusive due to limited data. Nonetheless, the findings are significant enough to warrant a brief explanation.

The Abernathy-Utterback model (Abernathy and Utterback, 1978) was developed in 1978 to describe the evolution of an innovative industry. The authors observed the survival of firms and the final structure of an industry are profoundly influenced by business cycles and technological standards. The period following the market's inception is characterized by market turbulence and a high level of uncertainty in technology. In this period, the rate of innovation is highest as firms experiment with new technological ideas and designs. As the industry evolves, it transitions into a period of firms racing to devise new designs to differentiate their products from those of their competitors. Also during this period the number of firms entering the market increases substantially. As technological innovations converge towards a dominant design, a well-defined market will begin to take shape (Anderson and Tushman, 1990). Once a design becomes dominant, firms shift focus from product differentiation to product performance and process efficiency. At this point in the evolution, the creation and acquisition of complementary assets becomes critical for firms to compete in the market (Suárez and Utterback, 1995).

The video game industry shows a noteworthy account of rapid growth and industrial chaos. While portions of the industrial evolution of the video game console industry are consistent with the Abernathy-Utterback model, certain instances observed in the industry history deviate from the theoretical model.

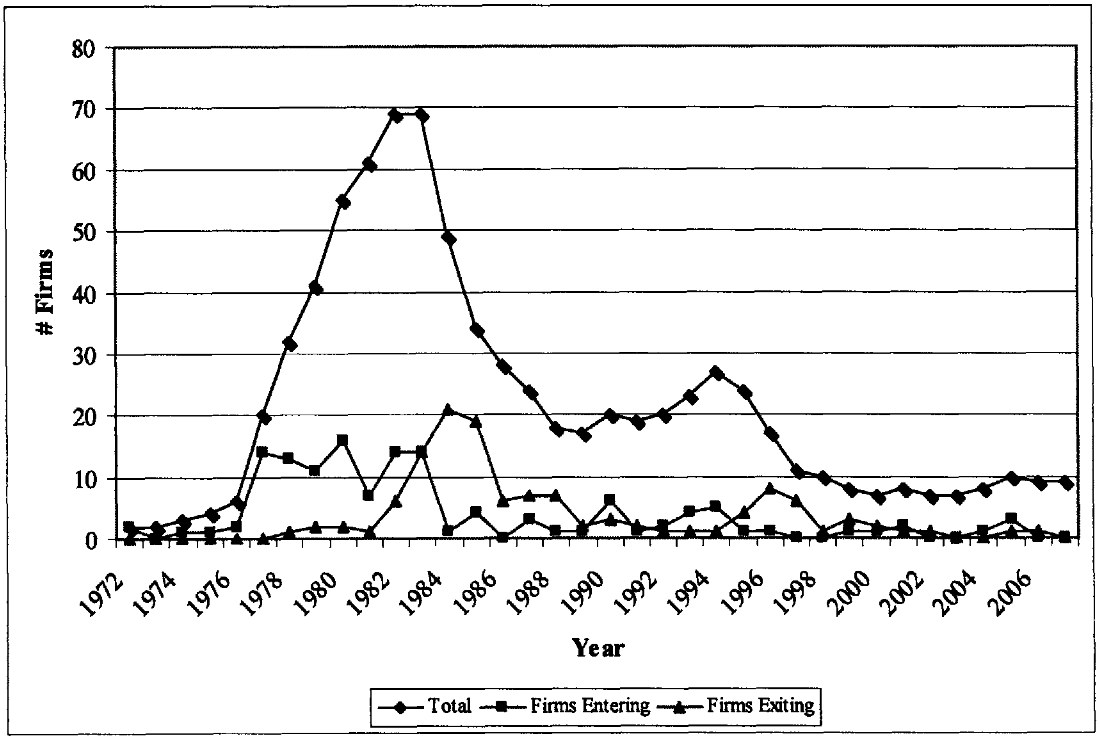

Figure 16 – Number of firms (including clone makers) competing in the world video game console market[31]

Between 1972 and 1976, several companies entered the market and experimented with different designs. Most games developed during this phase of the industry were of the ball-and-paddle game genre, though some companies engaged in product differentiation. For instance, Atari differentiated its game PONG with improved animation and sound while retaining its less complicated game rules. As company founder Bushnell later explained, PONG is "something so simple that any drunk in a bar could play" (Kent, 2001). Consistent with Abernathy-Utterback model, a period of firms entering the market in the early phases are followed by a period of firm exits. However, the video game industry deviates from the model in the timing of the dominant design, and the timing of

[31] Source: Number of companies compiled and estimated from: Classic Consoles Center, http://www.dieterkoenig.at/ccc; Console Database – http://www.consoledatabase.com/; Ultimate Console Database – http://www.ultimateconsoledatabase.com/.

firm entries and exits. Unlike the pattern of firm participation found in other industries (Suárez and Utterback, 1995; Christensen, Suárez, and Utterback, 1998), the emergence of dominant designs in the video game industry in 1976 and 1992 (Gallagher and Park, 2002; Schilling, 2003) did not trigger a wave of firms exiting the industry but instead stimulated a surge of companies entering the market. This deviation may be attributed to the fact that video game consoles are a complex system made up of different technological subsystems. At some level, innovations in video game consoles require strong coordination and compatibility with other products such as semiconductor components and software (Suárez, 2003). Lastly, the weak regime of appropriability present in the industry could effectively reduce the technological advantage of the intellectual properties certain firms held and lead to imitators releasing clones into the market. Together these factors reduced the rate of technological and market growth. Unfortunately, the study of the video game console market evolution is inconclusive as about a third of the data are missing the exit dates for firms participating in the market. For these firms with missing exit dates, we determine their values with a date that is five years after market entry. The five year value is averaged and approximated from known values.

Another anomaly in the growth of the video game market is the occurrence of a market crash in 1983. Unfortunately, due to the lack of adequate evidence, no conclusive link between the event, which effectively wiped out almost all companies competing in the market, and theories of dominant design can be established. The evolution of the video game console industry makes an intriguing case for broadening our understanding of dominant design and firm survivability in the competitive environment of an industry. Unfortunately, due to time constraints and limitation of data in the public domain,[32] further work is needed to obtain and apply a more complete, coherent picture and further shed light on this subject.

5.3.1 Model Limitations and Extensions

The system dynamic model would greatly benefit from more refinements and extensions. The model offers a reasonable approximate of the market system, but it is limited in what it can provide. The model structure needs further improvements and the application of additional empirical data. The following suggestions are offered to improve the system dynamics model:

- Many mathematical relationships in the system dynamic model are used conveniently. While they offer reasonable approximation, they are not robust enough for an in-depth analysis.
- Dynamics involving the co-existence of two of more generations of technology are complex. The model offers only the effects of migrating users and declining technology of the previous generation. These effects are not the only factors contributing to the inertia of the previous generation. The model should be extended with a few more effects of generation transition.

[32] Data for this thesis were obtained from public domain sources.

- More simulation runs involving the fluctuation of different variables should be performed to provide further insights to the sensitivity of the system.
- The supply and demand model used should be made nonlinear as quantity of demanded goods and quantity of supplied goods changes considerably across a range of prices.
- The stock and flow depicting the adoption of newer consoles needs further refinement.
- Models should include the demand of various customer segments (e.g. children and mature games).
- The equilibria of strategic decisions made by competing firms (game theory concepts) should be incorporated into the system dynamics model.

Also, many assumptions made in the modeling need to be validated with empirical findings from the industry. Some key concerns include:

- How game quality affects user decision to adopt a game console?
- Do consumers value all drivers of console attractiveness (price, game variety, and technological performance) equally?

5.4 Architectural Innovation and Market Transitions

In a paper published by Henderson and Clark (1995), the authors conclude that architectural innovation, defined as innovation that changes the way components of a product are linked together, brings new rules to the industry. So it is not surprising the advent of architectural innovations coincides with the emergence of dominant designs. In the history of the video game console, there are two instances when architectural innovation took place (Table 15).

	Changes	
Generation	**Technology**	**Critical Relationships between Components**
2nd	Use of microprocessor and memory	Instructions and data are stored in the memory awaiting for execution by the microprocessor.
5th	Use of 3D graphics processor and CD	Slow access speed of CD is justified by the ability to store massive amount of 3D textural graphics, which are needed to enhance the visual effects produced by the 3D graphics processor.

Table 15 – Summary of architectural innovation in the game console industry

A product is intrinsically linked to a firm's knowledge base, so architectural innovation potentially destroys the usefulness of existing knowledge for a firm. On the other hand, such disruptive innovation may enable other competitors to gain market share at the expense of the incumbent, which explains why a new entrant like Sony ended as the generation market leader. In terms of market implications, architectural innovations trigger not only changes in the linkages between components in the game console system but the interactions among competing firms in the market. A telling pattern emerges when we look at the turnover of market leadership, market transitions, and the emergence of architectural innovations taking place in the video game console industry. This observation is consistent with the findings of Afuah and Grimaldi (2005) in their forthcoming paper on the subject. In Table 16, we list all the transitions taking place in the industry, along with information about technological impact and whether the market leader was an incumbent or new entrant.

Transition	Technological Change	Market Incumbent	Market Leader[33]	Incumbent Displaced?
1st → 2nd	High	Magnavox	Atari	Yes
2nd → 3rd	High[34]	Atari	Nintendo	Yes
3rd → 4th	Low	Nintendo	Nintendo	No
4th → 5th	High	Nintendo	Sony	Yes
5th → 6th	Low	Sony	Sony	No

Table 16 – Market Incumbents and Entrants

Table 16 shows a tight correlation between technological change and the displacement of an incumbent company. When market transitions were low, incumbents like Nintendo and Sony in the 3rd → 4th and 5th → 6th transitions respectively maintained their leadership positions. Whereas in generations initiated by a disruptive technological shift, new entrants, like Atari, Nintendo, and Sony in the 1st → 2tnd, 2nd → 3rd, and 4th → 5th transitions, ended as market leader. This observation is interesting because the magnitude of impact from innovation between generations plays a critical role in determining successful market entry. Conversely, dominant companies often struggle when faced with disruptive technological change (Christensen and Overdorf, 2000). Shifts in technological innovation between generations are substantial enough that incumbents are likely to struggle as they adopt the new innovation with their high degree of incumbent inertia.

[33] The first firm to sell a product in a new generation of a market.

[34] The transition is listed as high not for technological reasons but for economic reasons. The market crash in 1983 (see Chapter 2 for more details) decimated the market, which effectively "reset" the competitive dynamics in the market.

There are unconcerned incumbent companies that often see new technology not unnecessarily as a threat but rather an occurrence that may not fit the paradigm of the firm (Anderson and Tushman, 1990).

5.5 Concerns of Market Competitiveness

In the beginning of this thesis, we asked the following questions:

1. How will technological discontinuities bring forth new dynamics that change the competitive rules on which companies operate?
2. How does timing of market entry affect the competitiveness of a firm?
3. What role do complementary assets play in the market?

In the context of the video game console industry, let us address these questions with the findings from our analyses.

1. How will technological discontinuities bring forth new dynamics that change the competitive rules on which companies operate?

The video game console industry has experienced six overlapping generations of technology. In each generation, we witness a different set of market leaders, technological standards, and even dominant designs. New competitive dynamics are introduced to the market as a new generation emerges, but prevailing dynamics from the previous generation do not disappear overnight. Such transitions between eras presents challenges to companies, especially market incumbents, competing in this market. When technological transition from generation to another is high, incumbent companies typically do not respond well due to their incumbent inertia. Conversely, new entrants stand to achieve a high level of success when they utilize compatible complementary assets to better meet market changes and exploit new technological innovations.

2. How does timing of market entry affect the competitiveness of a firm?

Once a company triggers the self-reinforcing feedback loops of network effects, a powerful phenomenon of rapid growth may arise leading to outcomes that diverge from those of other competitors. While early market entry is a good strategy for building and growing the installed base, it may not yield the best results in certain market conditions. A different strategy might be warranted for meeting a different set of market conditions. When one or more generations of technology overlap, new dynamics, such as uncertainty about new technological standards, high switching cost, and marginal technological performance, are invariably introduced into the market. These "spill-over" dynamics may diminish or even nullify first-mover advantage. A better approach seeks an optimal market entry time that maximizes competitive success by factoring in the conditions of the market as well as the "spill-over" dynamics. Indeed Christensen, Suárez, and Utterback (1998) suggest that firms stand the best chance of succeeding in the market when they enter during the period just before the emergence of a dominant design. They called this period of entry "the window of opportunity." Firms entering too early with respect to the window of opportunity are likely spending too much time learning and acquiring knowledge that may not be relevant later. On the other hand, firms entering too late face high barriers to entry brought forth by the effects of dominant design. Firms who fine-tune their market entry to the window of opportunity stand to have a higher chance of success (Christensen, Suárez, and Utterback, 1998).

3. What role do complementary assets play in the market?

Disruptive innovations potentially render linkages in an existing system ineffective and as a result requiring firms to reconfigure their organization structure, business processes, resources, and embedded knowledge in order to harmonize with adoption of the disruptive innovation (Afuah and Grimaldi, 2005). Complementary assets are critical factors in supporting the transformation from designs to manufactured goods and the commercialization of those goods. Success in commercializing disruptive innovations depends on how adept companies are in acquiring or building the optimal configuration of complementary assets.

5.6 Developed Framework for a Firm

At the firm level, a comprehensive conceptual model is constructed to illustrate the successes and failures of firms operating in the market.

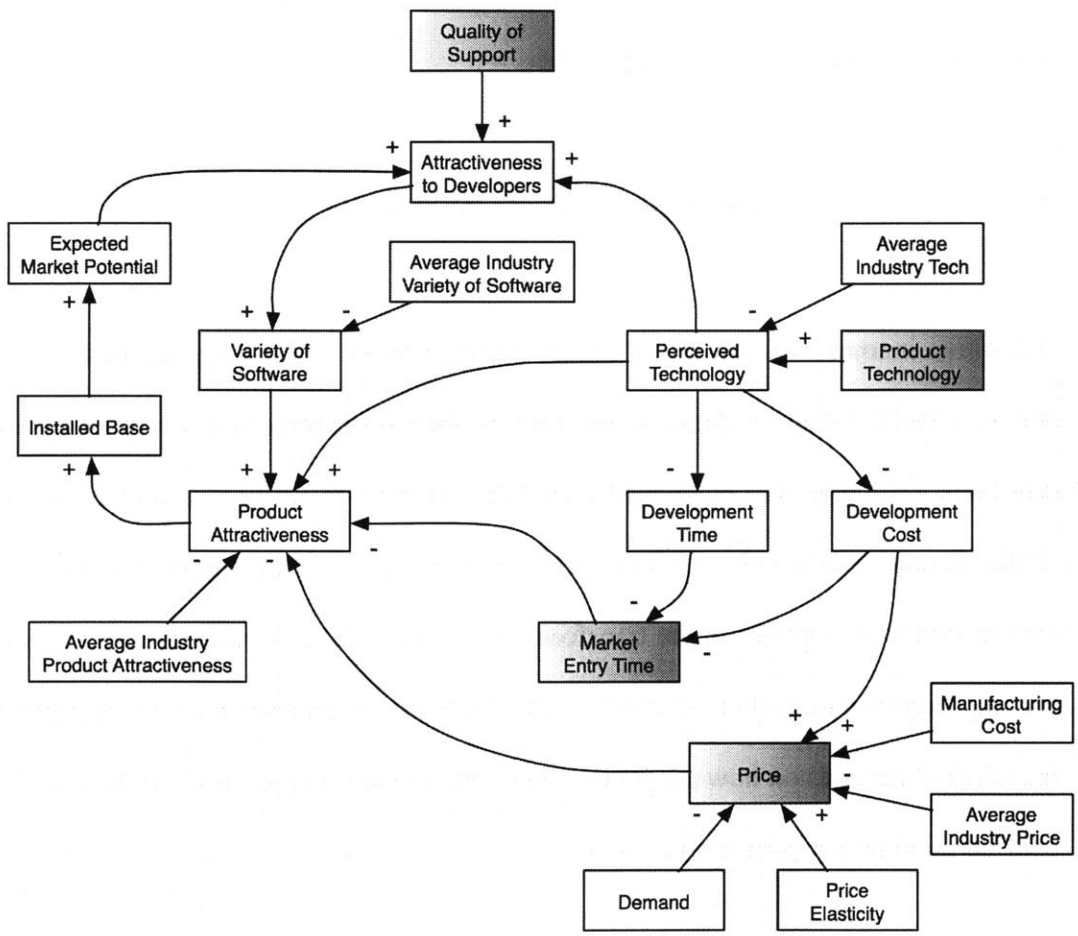

Figure 17 – A synthesized conceptual framework of determinants to successful competitiveness, firm controllable factors are shown in grey boxes

As we have learned from our discussions, a system consists of numerous cause-and-effect relationships. Figure 17 depicts these interactions operating in a video game console firm. A firm's performance depends on its ability to build a base of complementary assets and to accommodate for shifting dynamics. Today's complex market structure means a bewilderment of variables that companies need to be aware of. Through reinforcing feedback loops present in a network-based industry, early success in a process begets later success. Therefore, firms with a strategic goal of achieving long-lasting performance need to focus on elements that trigger the "virtuous" self-reinforcing cycles. Fortunately, most of these triggers are variables on which competing firms already have the direct control. In the context of the video game console industry, the four variables console manufacturers need to focus on are:

- Quality of Software Support.
- Product Technology.
- Market Entry Time.
- Price.

5.7 Conclusion

Our market view of the evolution of the video game console industry provides us with an understanding of the processes by which a firm achieves dominance when competing with other firms in the market. New technological trajectories may emerge through architectural innovations where the linkages among components of a product change without altering its constituents. Technological discontinuity often creates difficulties for established firms as embedded knowledge, business processes, and organizational structure prevent these companies from fully exploiting subtle architectural changes. At the same time, other competing companies utilizing newer architectural innovation offer better substitutes than products derived from prevailing designs. Our study corroborates Henderson and Clark's assertion that the best opportunity for competing companies to displace a market leader is through the application of architectural innovation. Historical analysis suggests that when technological shifts between generations are architectural, its impact on product design is great, and new entrants to the market displaced incumbent companies. Conversely, incumbent companies prevail when no significant shift in architectural design occured. Despite the central role that technology plays, it does not function in isolation. Successful firms in this industry benefit greatly from strategies that create and sustain complementary assets supporting the production and commercialization of an innovation.

From the system dynamics analysis, we learned how self-reinforcing cycles such as indirect network effects used to a firm's advantage increase the strength of determinants operating in the system. We also observed that the consequence of a seemingly small decision, good or bad, are amplified exponentially to the delight or chagrin of the decision maker. Any sound strategy with an objective of attaining lasting competitive advantage does not involve merely checking the precepts of strategic management. The decision-maker needs to understand the underlying forces of the industry are constantly changing and acting on them has consequences. It is through the understanding of the conditions and interactions in which the system components operate that we can effectively achieve competitive success.

The analysis provided by this thesis offers valuable insights into the dynamics of the video game console market. We have explored the cause-and-effect relationships underlying firms and product launches that both succeeded and failed. The battle of the next-generation consoles is currently underway, and the U.S. video game console market is starting to get interesting again. Already, Microsoft had launched the Xbox 360 ahead of its competitors. Meanwhile, incumbent Sony offers a compelling but expensive alternative console called the Playstation 3. Concurrently, Nintendo tempts consumers with the Wii, a low-cost, low-performing console featuring a novel motion sensor controller. So, the question remains: will Nintendo get its crown back?

6 Appendix A: An Overview of System Dynamics

This section offers an overview on system dynamics for readers who may not be familiar with its concepts. The essence of system dynamics stems from the acknowledgement that the structure of a system defines its behavior. System dynamics utilizes the notion of feedback loops to model complex interactions among different components in a system. The feedback loop is well established in the engineering domain where engineers have been using them to analyze and control engineered systems. A real world complex system is no different than that of engineering. Indeed, the structure of real-world institutional, social, and physical systems is defined by the decision-making processes from within these systems (Sterman 2000).

Decision-making processes in socio-economic systems is captured by causal loop diagrams, which are used by practitioners of system dynamics to represent the structure of a described system. In a system, a process or an interrelationship can be broadly categorized as either a feedback process or an accumulation process, which is modeled as a feedback loop and a stock respectively in a causal loop diagram.

6.1 Feedback Process

We represent the "cause-and-effect" relationship of two variables with a causal link, denoted by an arrow in causal loop diagrams. When multiple variables are chained together by causal links to form a closed loop, we establish a feedback loop identified either as positive or negative. The definitions of positive and negative feedback loops are as follow:

- A positive feedback loop represents a feedback loop "in which an initial change in one variable affects other variables in the loop in such a way as to reinforce the direction of the initial change." (Lyneis, 2005)
- A negative feedback loop, on the other hand, has the opposite effect, "in which initial change in one variable affects other variables in the loop in such a way as to reverse the direction of initial change." (Lynesis, 2005)

A positive feedback loop and a negative feedback loop are also known as reinforcing loop and balancing loop respectively. The following diagram shows an example of a heater thermostat that illustrates the concepts that were discussed.

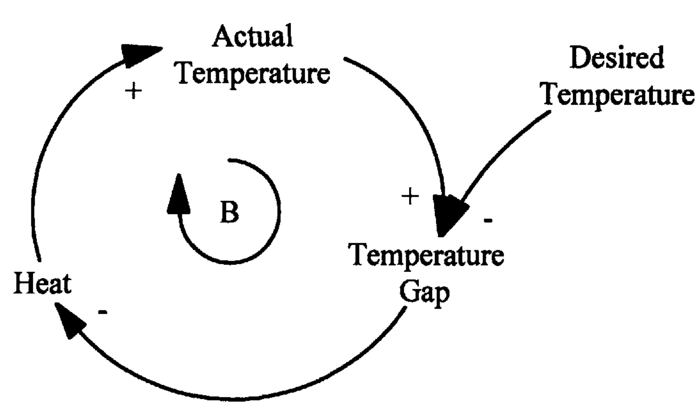

Figure 18 – A feedback loop of a thermostat system

In a heater, a thermostat controls the regulation of heat. The thermostat monitors the difference between the actual and desired temperature. When the actual temperature is greater than the desired temperature, the temperature gap will be positive. Since a positive temperature gap means the actual temperature has warmed up above the desired temperature, the heat supplied by the heater needs to be lowered. The negative causal link between the temperature gap and heat suggests the heat will be lowered with a rising temperature gap. A lower heat eventually allows the actual temperature to drop below the desired temperature. When the actual temperature falls below the desired temperature, the negative temperature gap will cause the heat rise up (as denoted by the negative causal link). We call the closed feedback loop of this system a balancing loop. When it is too hot, the system structure causes the temperature to fall and vice versa. The overall effect of the system is balancing.

6.2 Accumulation Process

While feedbacks are appropriate for representing many interrelationships in a system, they are inadequate in capturing another central concept of system dynamics: accumulation process. A stock captures the accumulation of variables operating in a system. The inflow and outflow (collectively known as flow) represent the addition and subtraction of variables to and from the stock. A good real life example of stock and flow is one's bank account. The bank balance represents the stock while deposit and withdraw represent the flow.

Figure 19 – The stock and flow of a bank balance

6.3 Path Dependence

In system dynamics, a path-dependent system produces an end state that diverges from its initial state. John Sterman in his book Business Dynamics (2000) defined path-dependence as "a pattern of behavior in which ultimate equilibrium depends on the initial conditions and random shocks as the system evolves." He uses the example of a bowl and a marble to illustrate path-dependence and describe how the placement of the bowl determines the behavior of the ball. The following is a summary of Sterman's explanation of path-dependence.

Imagine you have a bowl and you drop a marble anywhere within the bowl (Figure 20). No matter what the initial conditions are (velocity, height, etc), the marble will always roll to a stop at the same spot at the bottom of the bowl. Such a system is a locally stable equilibrium. The structure of this system is governed by a negative feedback loop as shown Figure 21. The marble is not affected by perturbations and does not follow a path to reach equilibrium. When a system is in stable equilibrium, Sterman observes that "pushing the marble off the equilibrium creates a force opposing the displacement." (Sterman 2000) This observation is indicated by the negative feedback loop in the causal loop diagram (Figure 21).

Figure 20 – The marble ends up in the same location [35]

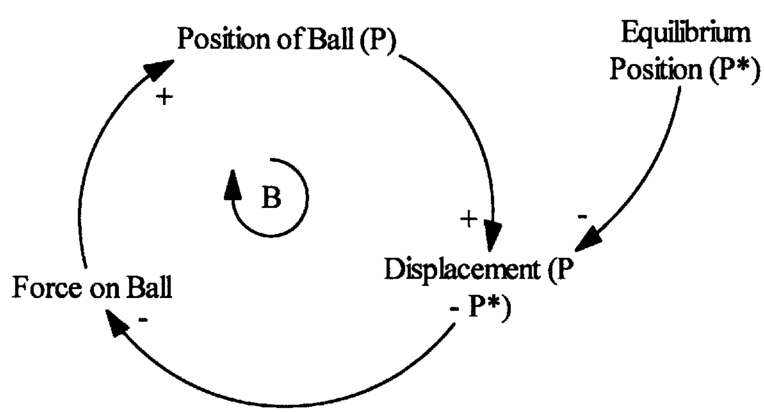

Figure 21 – Locally stable equilibrium is governed by negative feedback [35]

[35] Source: J. Sterman. Business Dynamics: System Thinking and Modeling for a Complex World. Irwin McGraw-Hill, 2000. pp. 351.

Let us now invert the bowl and place the marble on the top enough to make it stay in the location as long as there is no outside disturbance (Figure 22). In this state, the slightest disturbance will cause the marble to move away from its initial location. However, for the inverted bowl, positive feedback now dominates this system. As the marble moves farther away from its initial location, it experiences increasing force pulling it even farther away from its initial location (Figure 23). The final location, when the marble eventually comes to a rest, depends on the initial disturbance. The path which the marble travels depends on the initial disturbance, such as the direction and force of the push as well as initial the conditions like as weight of the marble and the surface condition of the bowl. Such a system is a locally unstable equilibrium.

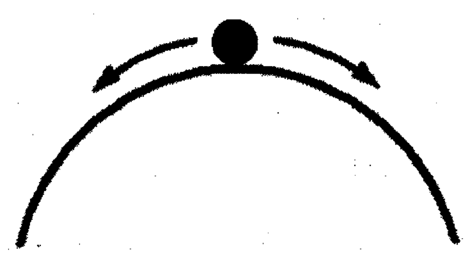

Figure 22 – A system in locally unstable equilibrium, the marble ends up in the same location [36]

[36] Source: J. Sterman. Business Dynamics: System Thinking and Modeling for a Complex World. Irwin McGraw-Hill, 2000. pp 351.

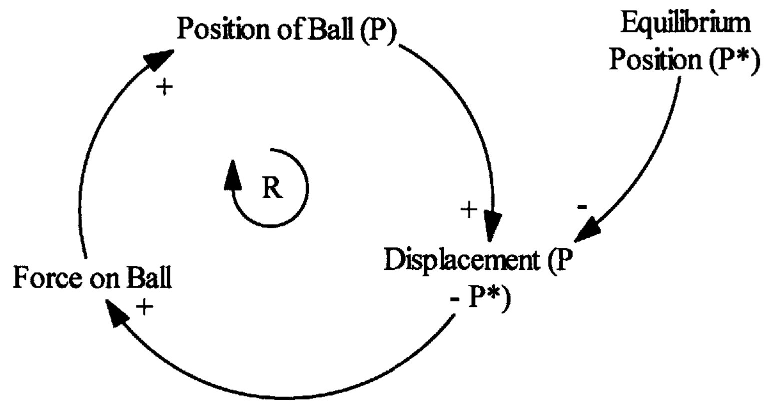

Figure 23 – Locally unstable equilibrium is governed by positive feedback [36]

6.4 Implications of Nonlinear Systems

Many nonlinear systems are dominated by positive feedbacks. In these systems, there exist multiple paths leading to different end states. In some cases, these paths may diverge significantly from their initial conditions. In addition, small noises and external disturbances, mirroring random events in the real world, influence the evolutionary path. These factors become significant as they are amplified by positive feedback processes in the system. This explains why the emergence of standards early in the history of the system can lead to system lock-in. In most cases, random events are unpredictable and uncontrollable, but decision makers set strong initial conditions conducive for success through sound policies early in the history of the system. Consequently, this effect eventually leads to long-term decisive outcomes. On the other hand, the positive feedbacks amplify bad decisions early, ultimately leading to an undesirable outcome.

In formulating strategies in a competitive market, the decision-maker needs to be aware of the feedback loops in the system. Let us suppose that a firm lowers the price of a good. The feedback loops in a market that is governed by negative feedbacks will balance the firm's competitive advantage gained from the lower price. The greater advantage one firm has over the other, the more likely the other competitor responds with a price cut to balance the relative advantage. However, for markets dominated by positive feedbacks, the consequence of price cut is different from the prior case. Let suppose one firm lowers price early to stimulate demand while another firm engages in a conservative policy that reduces price as volume expands. In the end, the positive feedbacks in the system reinforce both firms' strategies – an example of self-fulfilling prophecy as Sterman (2000) characterizes it. As the aggressive company lowers price, demand will pick up. Eventually, through economies of scale, the higher volume allows the company to lower price even more. On the other hand, the conservative company never achieved the volume increase and as a result, the inability to lower its price it is against its decision policy, ultimately leads to further market loss.

7 Appendix B: Additional Exhibits

Here are some charts showing the distribution of game ratings (on scale of 0 to 100) of various game platforms.

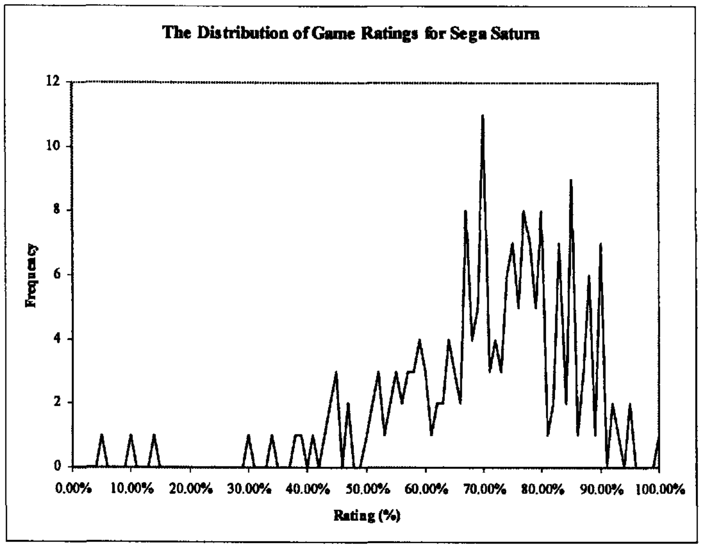

Figure 24 – Distribution of game ratings (Sega Saturn)[37]

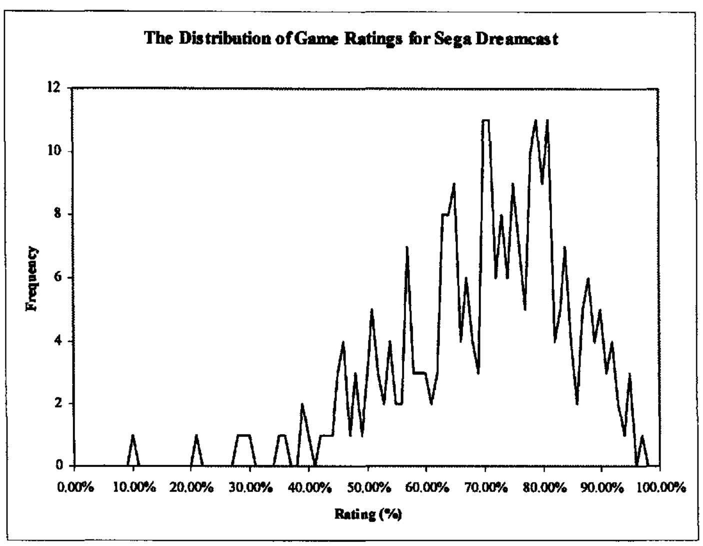

Figure 25 – Distribution of game ratings (Sega Dreamcast)[37]

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[37] Source: Gamerankings.com. Retrieved from http://www.gamerankings.com/.

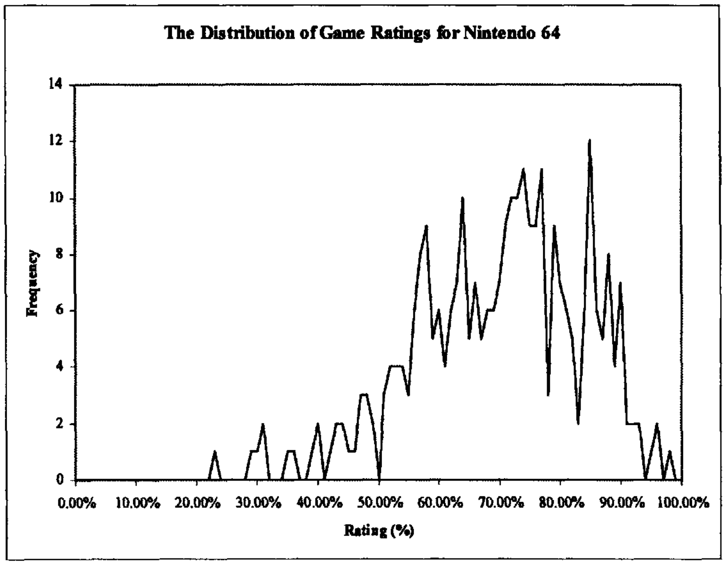

Figure 26 – Distribution of game ratings (Nintendo 64)[38]

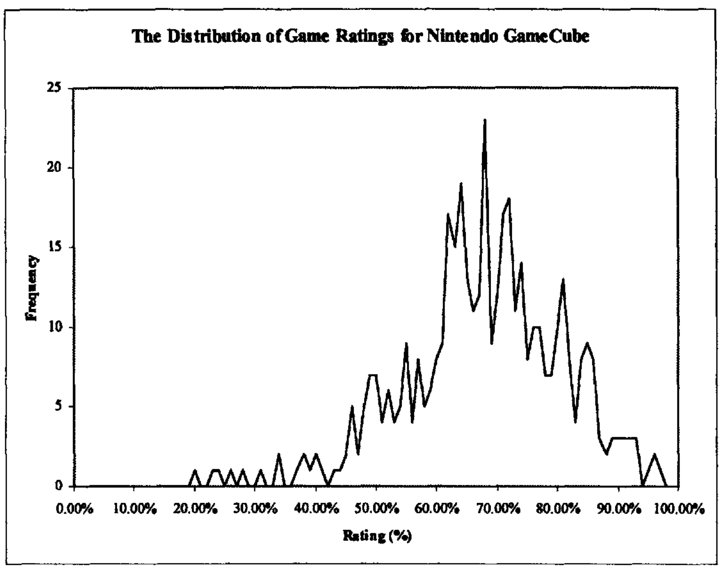

Figure 27 – Distribution of game ratings (Nintendo GameCube)[38]

[38] Source: Gamerankings.com. Retrieved from http://www.gamerankings.com/.

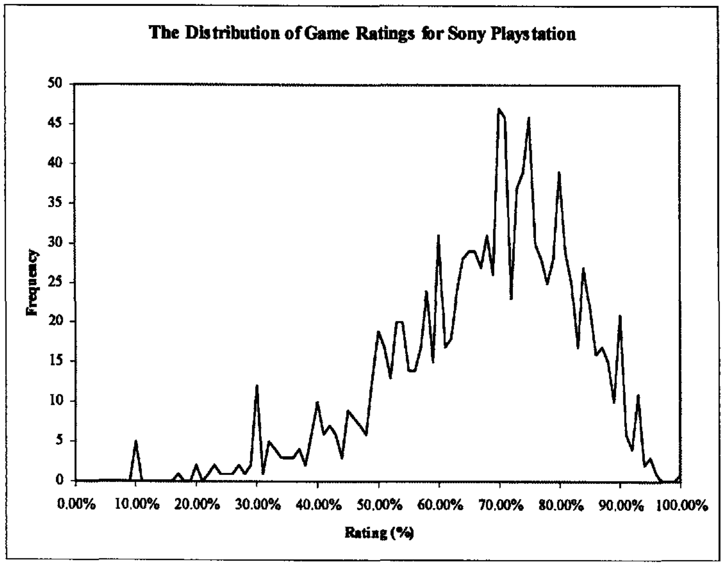

Figure 28 – Distribution of game ratings (Sony Playstation)[39]

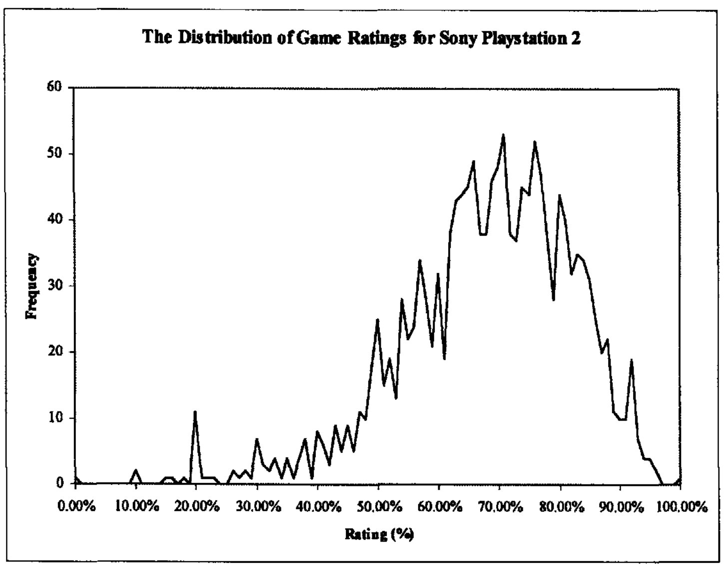

Figure 29 – Distribution of game ratings (Sony Playstation 2)[39]

[39] Source: Gamerankings.com. Retrieved from http://www.gamerankings.com/.

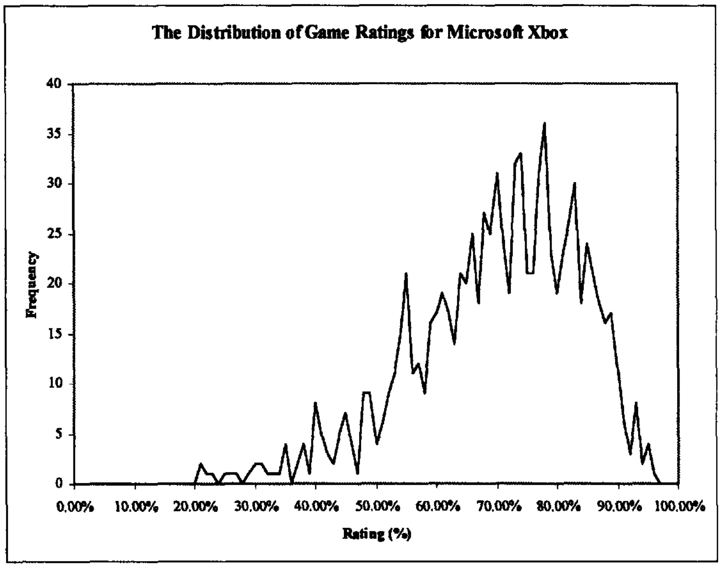

Figure 30 – Distribution of game ratings (Microsoft Xbox)[40]

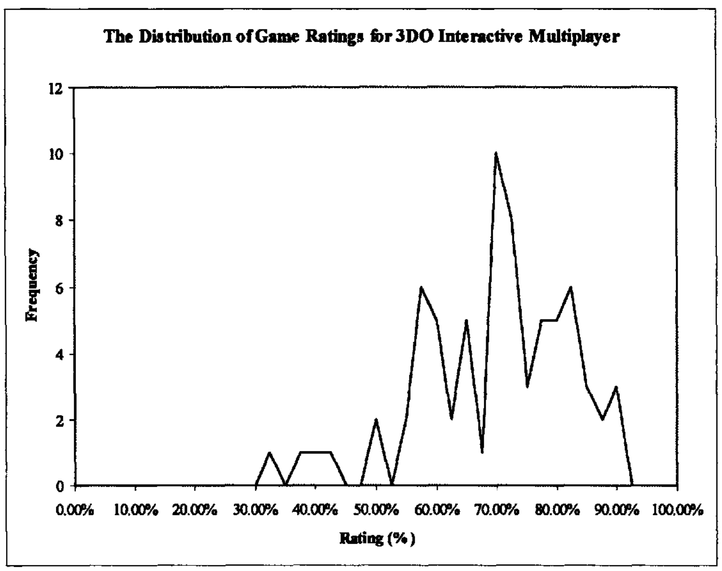

Figure 31 – Distribution of game ratings (3DO Interactive Multiplayer)[40]

[40] Source: Gamerankings.com. Retrieved from http://www.gamerankings.com/.

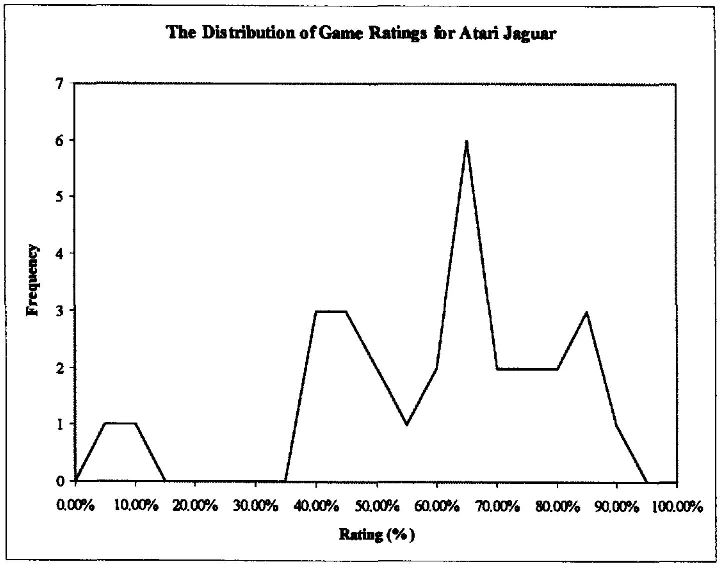

Figure 32 – Distribution of game ratings (Atari Jaguar)[41]

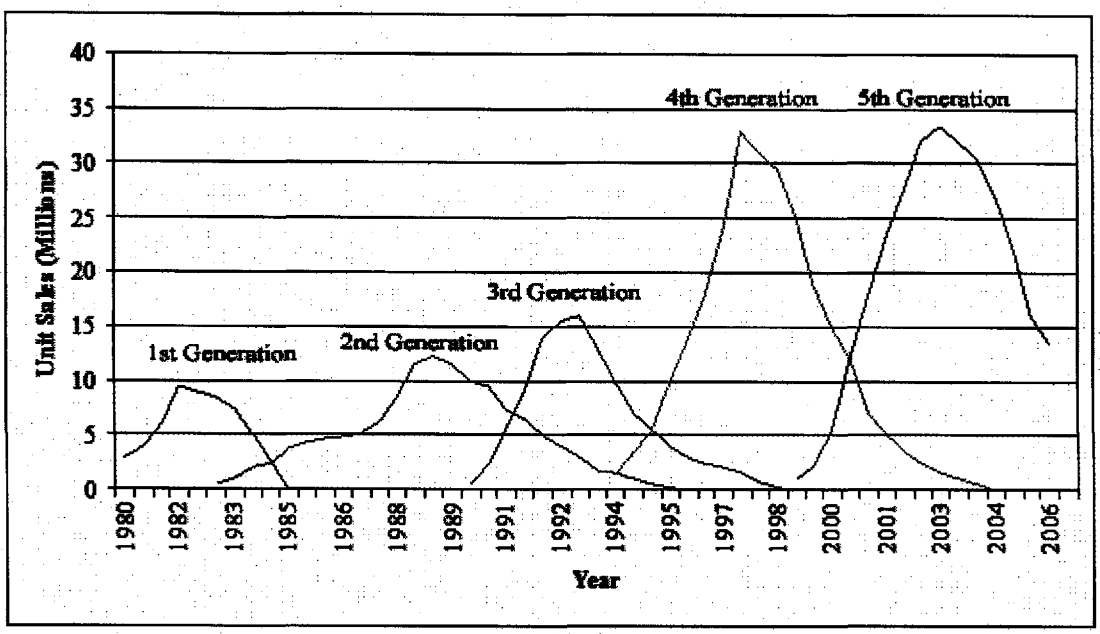

Figure 33 – Unit Sales of Game Consoles[42]

[41] Source: Gamerankings.com. Retrieved from http://www.gamerankings.com/.
[42] Source: Compiled and estimated from: Games Investor Consulting Ltd. *2001 to Present*. 2007. Retrieved on April 26, 2007 from http://www.gamesinvestor.com/Research/History/2001_/2001_.htm; Sony, *Playstation Milestones*. Retrieved on April 26, 2007 from http://www.us.playstation.com/Corporate/About/ThePlayStationStory/Milestones/default.html; Nintendo Annual Reports. Retrieved on April 27, 2007 from http://www.nintendo.com/corp/annual_report.jsp.

	Platform	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
4th Gen	Genesis	4.5	3.0	22.7	35.5	48.1	57.9	34.9	12.1	3.0	4.0	3.0	0.5					
	SNES			43.2	52.1	51.9	36.4	42.9	17.7	7.5	6.9	2.5						
5th Gen	Saturn							5.3	11.4	2.1	0.4							
	Playstation							11.1	28.2	45.9	55.5	50.8	39.4	16.6	13.6	8.3		
	N64								27.9	40.7	32.2	30.9	30.9	8.6	1.0			
6th Gen	Dreamcast											12.8	29.2	25.9	13.1	8.7	7.8	6.3
	PS2													48.9	51.3	51.7	51.4	52.8
	GameCube														9.2	17.7	21.4	20.2
	Xbox														11.9	13.6	19.4	20.7

Table 17 – Evolution of market shares [43]

Company	Enter Year	Exit Year
3DO	1993	1996
Aaronix	1981	1986
Apollo	1976	1981
Acetronic	1979	1984
Adam	1974	1979
Advision	1982	1987
Akor	1992	1997
Al Sagar	1980	1985
Amstrad	1990	1992
Atari	1972	1996
Audiosonic	1977	1982
Awia	2001	2006
Bally	1977	1985
Bandai	1982	1996
Binatone	1980	1985
Bingo	1980	1985
Bit Corp	1983	1988
Brandt	1983	1985
Cabel	1987	1989
Capcom	1994	1999
Casio	1983	1999
CCE	1985	1990
Coleco	1975	1984
Columbia	1980	1985
Commodore	1977	1994
Conic	1979	1984
Continental Edison	1983	1986
Daewood	1983	1995
Dick Smith	1982	1987
Digiplay	1981	1997

[43] Source: Compiled from: A. Afuah and R. Grimaldi. *Architectural Innovation and the Attacker's Advantage from Complementary Assets: The Case of the Video Game Console Industry*. Social Science Research Network (SSRN) Working Paper Series, 2005.

Dynavision	1983	1988
Edu Juegos	1982	1987
Eduscho	1980	1985
Emerson	1982	1987
Epoch	1978	1984
Fairchild	1976	1978
Fountain	1980	1985
Fujitsu	1991	1996
Fullwis	1983	1988
Funtech	1995	2000
Gakken	1983	1984
Goldstar	1994	1996
Grandstand	1977	1982
GiG Electronics Leonardo	1980	1985
Grundig	1979	1983
Guangdong	2005	2008
H.G.S. Electronic	1977	1984
Hae Tae	1990	1995
Hanimex	1977	1984
Industria Argentina	1981	1986
Interstellar	1988	1993
Intercord	1980	1985
Interton	1977	1983
Intervision	1982	1987
Intv	1985	1991
ITMC	1978	1983
ITT	1977	1982
Jopac	1980	1985
Jove Club	1983	1988
JVC	1994	1999
Katz	1996	1997
Korting	1983	1988
Lansay	1981	1986
Leisure-Dynamics	1982	1984
Luxor	1980	1985
Magnavox	1972	1984
Mattel	1979	1984
MBO	1978	1983
Memorex	1992	1997
MiRai Media	1990	1995
Microdigital	1982	1987
Microsoft	2001	2008
Milton Bradley	1982	1984
Mustang	1978	1983
NEC	1987	1996
Nichibutsu	1983	1988
Nintendo	1983	2008
Nordmende	1978	1983

OC	1980	1985
Ormatu Electric BV	1982	1987
Palson	1978	1983
Palladium	1977	1982
Panasonic	1993	1997
Palson	1979	1984
Philips	1977	1996
Pioneer	1993	1998
Polybrain	1982	1986
Polycon	1980	1985
Poppy	1978	1983
Prinztronic	1978	1983
Promotors	1980	1980
Radiola	1980	1985
Radofin	1979	1986
RCA	1977	1979
RDI	1985	1990
Rollet	1983	1985
Rowtron	1981	1985
S.H.G.	1982	1984
Saba	1977	1980
Sanwa	1978	1982
Sanyo	1994	1996
Schmid	1982	1984
Sears	1977	1983
Sega	1985	2001
Sheen	1978	1982
Shinco	2000	2005
Siera	1979	1984
SNK	1990	1997
Societe Occitane D'Electronique	1979	1984
Sony	1994	2008
Soundic	1980	1985
SSD	2005	2010
Tchibo	1982	1985
Tec Toy	1990	2008
Tomy	1981	2002
T.R.Q.	1979	1983
Teleng	1979	1984
Telepartner	1977	1984
Toy Quest	2005	2010
Unimex	1978	1983
Unitech	1999	2000
Universum	1981	1984
Videojet	1990	1995
Videomaster	1979	1983
VideoStellar	1978	1984
Voltmace	1978	1983

Vtech	1983	1988
Waddington	1980	1984
World Book	1989	1990
Worlds of Wonder	1987	1991
Xinga Technologies	2004	2009
Yeno	1984	1989
Zap-It Games	2006	2011

Table 18 – Firms (including clone manufacturers) entering and exiting the world video game console market[44] [45]

[44] Source: Number of companies compiled and estimated from: Classic Consoles Center, http://www.dieterkoenig.at/ccc; Console Database – http://www.consoledatabase.com/; Ultimate Console Database – http://www.ultimateconsoledatabase.com/.

[45] About a third of the data are missing the exit dates for firms participating in the market. For these firms with missing exit dates, we determine their values with a date that is five years after market entry. The five year value is averaged and approximated from known values.

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