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A Multigeneration Diffusion Model for IT-Intensive Game Consoles*

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Abstract

The video game industry has attracted more and more attention not only from technology giants such as Microsoft but also from software developers and private investors. Information technology dictates how game console producers compete in the marketplace. Intensive IT competition in each console generation has shifted the market balance. Competitors jockey to position themselves as the first-mover within a generation or to wait and enter the market with cheaper and more advanced technologies. To capture the characteristics of IT-intensive products, we propose a multigeneration diffusion model that captures both cannibalization and competition effects. We apply the model to analyze game console diffusion with real shipment data for three game consoles from two companies: Sony and Microsoft. We analyze two scenarios: one with only Sony's products, and one with both companies' products. We find that the cannibalization between Sony's products is minimal, and Microsoft maintains a strong competitive edge that has challenged Sony's market position. The results also explain how Sony has maintained its position as the market leader over the last two generations. This research sheds light on the nature of an IT-intensive game console competition between companies and generations.

Keywords: *Cannibalization, computer games, consumer electronics, diffusion, economic analysis, multigeneration diffusion model, technology management*

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1. Introduction

The video game industry has gained more and more attention recently. With Microsoft's launch of the Xbox in 2001, the console wars entered a new phase, shifting the balance in an industry whose total sales top Hollywood's domestic box office revenues. Colin Sebastian, an analyst with Lazard Capital Markets, was particularly impressed with the inroads Microsoft made in an industry Sony dominated with its PlayStation 2 (PS2). He predicted that Microsoft and Sony would each take 40 percent of the next-generation market, with Nintendo keeping the remaining 20 percent (Slagle 2006). Doug Lowenstein, president of the Entertainment Software Association, believed that the video game business would only improve in the more distant future (Slagle 2006).

However, in spite of the promising future of the game industry predicted by the experts, firms engaged in this industry have faced challenges from the unexpectedly swift growth of the market and fast-paced IT development. One typical characteristic of high-tech products such as game consoles is their short technology development cycle, which enables companies to release a new generation within just a few months. With the frequent introduction of new generations, companies are competing with other companies in the development of new technologies and also with their own products in different generations. The marketing literature calls the latter effect as *cannibalization* (Desai 2001, Mason and Milne 1994, Moorthy and Png 1992), a common phenomenon in the game console industry. The two leading producers, Sony and Microsoft, have had to be cautious when introducing new generations, since cannibalization could negatively affect their older generations' sales.

In addition to pressures resulting from cannibalization, game console producers are facing heavy competition in terms of technology and their marketing strategies. Appendix A provides a list of the technological features and prices of the consoles launched by Sony and Microsoft prior to January 2006. Sony, as a first-mover in the last two generations, shipped more than 150 million PlayStation One (PS1) and PS2 units as of 2005 (ABIresearch 2006). In most respects, the PS2 did not outperform its biggest rival, the Xbox. Comparison points included the processor and hard drive, and the extent to which it was compatible with other entertainment-related capabilities, such as HDTV support. Although the Xbox was the better of the two products in terms of the quality of its underlying technology, it still experienced difficulty when launched in the U.S. in 2001. Its sales were far below the company's expectations. Advanced technology alone did not allow Microsoft to surpass Sony's market-leading position. In this context, Sony held a first-mover advantage in its investments in technology and marketing. By switching from PlayStation to Xbox, consumers would have had to incur a high switching cost and would have gained only small improvement in terms of the entertainment value. This allowed Sony to retain its market edge for that generation of technology.

However, with the presence of a strong competitor like Microsoft, Sony faced challenges to enlarge its market potential and compete for new players. In the next generation's competition, Microsoft gained first-mover advantage by introducing the Xbox360 in 2005, one year ahead of PlayStation 3 (PS3). "Clearly, Sony is playing catch-up at this point," said P. J. McNealy, an analyst at American Technology Research (Guth 2006). Sony bought time by waiting for the technology to mature, specifically the Blu-ray format. By doing so, though, the company lost its first-mover advantage. It only sold 490,700 PS3 units in December 2006, while 1.1 million Xbox360 consoles had been shipped by that time, according to the NPD Group, a marketing research company (McMaster 2007). Microsoft overwhelmingly won the battle for Christmas sales in 2006.

Going forward, Sony must formulate its marketing strategies carefully so as to sustain market share and early-mover advantages. Whether the PS3 will help Sony regain the market is yet to be determined. Meanwhile, jockeying continues among competitors to be the first-mover for the next generation, or to wait and enter the market with more technological advances.

Therefore, from both theoretical and practical perspectives, it is not clear how competition among companies and cannibalization between generations affect the diffusion of high-tech products such as

game consoles. In this study, we propose a multigenerational diffusion model to accommodate both intergeneration cannibalization and market competition effects in an IT-intensive industry. Using real shipment data for game consoles, this study examines two interesting scenarios: one with only Sony's products and the other with both Sony's and Microsoft's products. We find that the cannibalization between PS1 and PS2 is limited. Surprisingly, more than half of the PS2 adopters were existing users of PS1. In addition, the market competition between companies is concentrated within certain generations. We find little evidence of cross-competition between the Xbox and the PS1, whereas the competition between the Xbox and the PS2 is much more severe. Our results also indicate that Sony, as a long-time market leader, retains its first-mover advantage with the PS1 and PS2. However, in competing with a strong brand name such as Microsoft, Sony faces significant challenges in sustaining its competitive advantage in the next generation competition between the Xbox360 and the PS3.

To the best of our knowledge, this is the first study in the literature that considers both cannibalization and market competition effects in for the competition between high-tech products. Furthermore, our model is able to separately identify first-time adoption, repeat adoption, cannibalization, and switching among brand names. This study contributes to the IS literature by building new theory on the diffusion of high-tech products. In particular, we use real shipment data to study the diffusion of three game consoles from two competitors. Our results provide insights on competition in the game console market, and how different components – including first-time adopters, repeat purchasers, cannibalized sales, and switching sales – contribute to product sales. Our analysis helps firms and managers in this industry to better understand competition within their market and cannibalization between generations of their own products. Industry decision makers can use these results when planning technology development cycles and marketing strategies, such as selecting an appropriate launch date.

The rest of the paper is organized as follows. In the next section, we review the related literature. We propose our models in Section 3. Section 4 presents the empirical study and the data and methodology we use in the estimation process. We also discuss the implications of our results under different scenarios. To examine the robustness of the findings, we conduct a sensitivity analysis in Section 5 and conclude with the main contributions and interesting future research topics in the last section, followed by references.

2. Theoretical Background

This study is related to both diffusion theory of technology or high-tech products in the IS literature and cannibalization theory in the marketing literature. Diffusion theory indicates a time lag in the adoption process and separates adopters into categories according to the timing of adoption (Rogers 1962). The theory has been applied in the IS literature to study the adoption or diffusion process of technology or technology-related products (e.g., Akcura and Altinkemer 2002, Altinkemer and Yilmaz 2008, Kauffman and Techatassanasoontorn 2004 and 2005). Consistent with the definition in Bass (1969), we refer to adopters as either innovators or imitators. *Innovators* are the early adopters who are not affected by social pressures and adopt the product at its early stage. *Imitators* are the late adopters whose adoption decisions are influenced by social interaction and interpersonal communications (i.e., by word-of-mouth).

The Bass diffusion model is one of the most recognized models for explaining product diffusion patterns and predicting market demands. The model has been widely used in the IS literature to examine the adoption process of technologies (e.g. Akcura and Altinkemer, 2002, Altinkemer and Yilmaz 2008, Kauffman and Techatassanasoontorn 2004, Kim et al. 2000). For example, Akcura and Altinkemer (2002) extended the Norton and Bass (1987) model by incorporating the impact of switching in the adoption process for B2B, B2C, and P2P exchanges and e-Speak. They found that the imitation effect was much stronger than the innovation effect and predicted future demand for these electronic exchanges in different scenarios. Kim et al. (2000) modified the Norton and Bass (1987) model to study the inter-product category effect in addition to the technology substitution effect. They used wireless telecommunication data from two Asian markets and demonstrated there

was significant market competition between generations of the technology. The market potential was influenced by the overall structure of a geographic market. Different from their study, our model explains the *competition effect* between companies rather than across product categories. More importantly, it also captures the *cannibalization* effect between product generations.

Another interesting work by Kauffman and Techatassanasoontorn (2005) investigated the diffusion patterns of global digital wireless phone technologies. They proposed a *regional contagion theory of diffusion* and verified it through empirical analyses. While their study focused on explaining the regional diffusion patterns of technologies, we examine the diffusion patterns of different generations of high-tech products and identify various components of the demand.

In the marketing literature, *cannibalization* is often referred to as the reduction in sales of a firm's current or high-quality product due to the introduction of its new or low-quality product (e.g., Desai 2001, Mason and Milne 1994, Moorthy and Png 1992). In most cases, cannibalization is not efficient for firms, since that portion of sales is a shift from their other revenue streams. Many studies in this field have focused on low-quality products cannibalizing sales from high-quality products (e.g., paperback versus hardback books) in different market structures. For example, Moorthy and Png (1992) considered a monopoly case where one seller determined whether to introduce both low-end and high-end products simultaneously or sequentially. They found that sequential introduction is better than simultaneous introduction for reducing cannibalization when consumers are relatively more impatient than the seller. In another study, Desai (2001) modeled a duopoly case and found that under some conditions the problem of cannibalization does not affect the firms' price and quality choices. However, when those conditions do not hold, only the high-valuation consumers can get their preferred products.

We study cannibalization between generations rather than between different quality levels of the same product. Since consumers receive early notice of the launch for a new generation, some portion of the potential buyers for the current generation may prefer to wait for the new generation. For example, Sony announced the launch of PS3 almost one year prior to its actual introduction. As a result, we expected that the new generation would cannibalize sales from the old generation. Our model identifies cannibalization between generations, which can help companies strategize about the introduction of a new generation. Since the cost for upgrading high-tech products is not low, usually the shorter the development period, the higher the cost will be. Therefore, introducing a new generation too early may not only increase R&D costs to the firm but also increase the magnitude of cannibalization. Although finding an optimal introduction time is not the focus of this paper, our analysis sheds light on how Sony successfully chose the launch time for PS2 by introducing it at a late stage in PS1's life cycle.

3. Model

The adoption diffusion models stem from Bass (1969) and have been further extended in the marketing and IS literature (Norton and Bass 1987, Mahajan et al. 1995, Hu et al. 1997, Kim et al. 2000, Bass and Bass 2001, Bass and Bass 2004, Danaher et al. 2001, Akcura and Altinkemer 2002, Kauffman and Techatassanasoontorn 2005). Norton and Bass (1987) first considered products with successive generations, but their model did not allow backward switching and could not separately identify first-time purchases and repeat purchases. These problems were solved by Bass and Bass (2001), who introduced a more sophisticated diffusion model through which first-time sales and repeat sales could be estimated separately. They also showed methods for estimating an installed base at each time period. However, their model considered only the monopoly case or the industry as a whole where no competition effect influences the diffusion process of the product. We extend the Bass and Bass (2001) model by incorporating the competition factor, which allows us to examine the competitive power of each player in the market.

A multi-category diffusion model was first introduced in Kim et al. (2000), who extended Norton and Bass (1987) by defining the market potential as a function of sales revenue from other categories. However, their model focused mainly on the comparison between product categories rather than the

competition between companies in the same industry.

Danaher et al. (2001) presented a model for first-time sales and subscriptions using a multiplier approach. Two different multipliers represent intergenerational impacts and competitive impacts. One is for *leapfrogging* and another is for *switching*. However, the subscription service they studied is different from the game console market where consumers do not pay for using the console after purchasing: no fees are incurred after the initial purchase.

Different from these approaches, our model integrates both cannibalization and IT competition effects. We focus on the adoption processes for multigeneration game consoles. First, potential adopters will decide whether to buy existing consoles or to wait for the newer generation. According to the NPD Group, overall video game sales dropped five percent to $7 billion in the U.S. in 2005 as gamers waited for the new systems (Slagle 2006). The same phenomenon is true for the console market.

To simplify the estimation process, we assume that customers will be notified of the launch of a new generation one year prior to its actual launch time, consistent with the real market situation. Thus, the influence of the new generation will begin to take place one year in advance.

Second, those who decide to purchase current consoles will face two choices: selecting from among brand names and from among various generations. For example, in the game console market, PS1, PS2, Xbox, and Xbox360 coexist and compete with each other. We assume that there are two producers, $n = 1, 2,$ producing multigenerational game consoles in the market, $g = 1, 2, 3, \ldots, G$. (For a notation table, see Appendix B. Although we discuss a duopoly case here, our model can be expanded to include more companies competing concurrently.)

We follow the adoption-time distribution function $f(t)$ in Bass (1969):

$$f(t) = \frac{\frac{(p+q)^2}{p} e^{-(p+q)t}}{\left(1+\left(\frac{q}{p}\right)e^{-(p+q)t}\right)^2}, \qquad (1)$$

where p is the *coefficient of innovation* and q is the *coefficient of imitation*. Consumers are not allowed to make multiple purchases of the same product. Hence, the number of units sold can represent the number of adopters in the market. p and q also capture the various product characteristics at the same time. Although there are no product-level variables in the model, we do consider the influence of product attributes on attracting consumers when estimating the adoption parameters p and q. The micro-level impacts should also be reflected in the macro-level adoption process, which is our focus.

3.1. General Adoption Model

The general adoption model contains two parts, first-time sales and repeat sales (Bass and Bass 2001). $s_{n,g}(t)$ is the total adoption of company n's generation g at time t, and $a_{n,g}(t)$ and $r_{n,g}(t)$ are its first-time adopters and repeat adopters. Thus, the general adoptions of generation g produced by company n at time t are defined as:

$$Adopters_{n,g}(t) = firstAdopt_{n,g}(t) + repeatAdopt_{n,g}(t)$$

or $$s_{n,g}(t) = a_{n,g}(t) + r_{n,g}(t)$$

$$n = 1, 2 \quad g = 1, 2, \ldots G \qquad (2)$$

where $firstAdopt(t)/a_{n,g}(t)$ captures the number of first-time buyers and $repeat\ Adopt(t)/r_{n,g}(t)$ measures the number of adopters who have bought at least one product from a prior generation.

3.2. First-Time Adoption Function

Similar to Bass and Bass (2001), m is the market potential of each generation. We express $a_{n,g}(t)$ as a function of three basic components:

$$a_{n,g}(t) = m_{n,g} f_{n,g}(t) - ag_{n,g}(t) + ag_{n,g-1}(t). \quad (3)$$

The first part is the adopters who materialize, given no impacts from other generations. The second term $ag_{n,g}(t)$ is the lost buyers due to customers' expectations or the presence of the new generation, *g+1*. The last term $ag_{n,g-1}(t)$ is the number of adopters that generation *g* gains from the previous generation, *g-1*. The *cannibalization* effect is captured by $ag_{n,g}(t)$ and $ag_{n,g-1}(t)$.

$$ag_{n,g}(t) = m_{n,g} f_{n,g}(t) f_{n,g+1}(t) \quad (4)$$

$$ag_{n,g-1}(t) = m_{n,g-1} f_{n,g-1}(t) f_{n,g}(t) \quad (5)$$

Substituting (4) and (5) into (3) we have:

$$a_{n,g}(t) = m_{n,g} f_{n,g}(t) - m_{n,g} f_{n,g}(t) f_{n,g+1}(t) + m_{n,g-1} f_{n,g-1}(t) f_{n,g}(t). \quad (6)$$

Different from Bass and Bass (2001), we further define the market potential $m_{n,g}$, to be a function of a company's competitor's market share. Since both companies 1 and 2 are competing in the same market, not only do the company's own generations affect its sales, but its competitor's performance will either spur or diminish its sales. So the market potential equation should consider the *competition* impact in the market:

$$m_{n,g} = m_{n,g0}(m_{n',g})^{\varepsilon_{n',g\sim n,g}} (m_{n',g-1})^{\varepsilon_{n',g-1\sim n,g}} (m_{n',g+1})^{\varepsilon_{n',g+1\sim n,g}}$$

$$\text{where } n,\ n' = 1,\ 2, \text{ and } n \neq n'. \quad (7)$$

$\varepsilon_{n',g\sim n,g}$ is the competition effect of generation *g* of company *n'* on generation *g* of company *n*. The model captures the bidirectional interaction between two competitors' generations through $\varepsilon_{n',g\sim n,g}$. Both positive and negative effects are considered.

3.3. Repeat Adoption Function

We define the general repeat adoption function as follows:

$$r_{n,g} = rm_{n,g} f_{n,g}(t) - rg_{n,g}(t) + rg_{n,g-1}(t). \quad (8)$$

The first term stands for the repeat adopters given no other generations. The second term is the lost repeat adopters due to the introduction of the new generation, while the last term is the gaining repeat adopters purchasers that *g* usurps from *g-1*.

Similarly we derive the *cannibalization* effect for repeat sales functions:

$$rg_{n,g}(t) = rm_{n,g} f_{n,g}(t) f_{n,g+1}(t) \quad (9)$$

$$rg_{n,g-1}(t) = rm_{n,g-1} f_{n,g-1}(t) f_{n,g}(t). \quad (10)$$

Substituting (9) and (10) into (8), we have:

$$r_{n,g}(t) = rm_{n,g} f_{n,g}(t) - rm_{n,g} f_{n,g}(t) f_{n,g+1}(t) + rm_{n,g-1} f_{n,g-1}(t) f_{n,g}(t) \quad (11)$$

The repeat sales market potential is defined as the sum of the sales from all prior generations up to time *t*:

$$rm_{n,g}(t) = \sum_{i=1}^{i=g-1} \sum_{j=1}^{j=t-1} a_{n,i}(j). \quad (12)$$

4. Empirical Study

4.1. Data

In this section, we apply the proposed model to study cannibalization and competition between game consoles. We collected data on the number of consoles shipped globally for Sony and Microsoft in a 10-year period from 1996 to 2005. Our focus is on the diffusion of the PS1, the PS2, and the Xbox, as they obtained the largest market share in 2005. Since the Xbox360 was only released in November

2005, we do not have enough data points to estimate its diffusion curve. So the competitive power of Microsoft could be underestimated, as it has one less generation to compete in the market. The yearly shipment data considered is the number of adopters, since consumers usually do not purchase the same console multiple times. Data for the PS1 were collected from Sony's annual reports while shipment figures for the PS2 and the Xbox were provided to us by a market research company, ABIresearch. Table 1 summarizes the descriptive statistics of the data set.

Table 1. Descriptive Statistics

Variable	Description	Mean	Std Dev	Min.	Max.
$s_{s,1}$	Shipment of PS1 (units in millions)	10.25	7.01	2.77	21.60
$s_{s,2}$	Shipment of PS2 (units in millions)	14.58	7.88	1.41	22.52
$s_{m,x}$	Shipment of Xbox (units in millions)	4.79	2.14	1.40	7.30

To better understand how cannibalization and competition effects influence the adoption pattern, we first consider the scenario where only Sony's products exist, that is, where there is no competition effect. Next, we investigate the case where two brand names compete in the same market, in other words, a market with both PlayStations and the Xbox competing. We apply least squares regression to estimate the parameters and fit the diffusion curves (Kim et al. 2000, Bass and Bass 2001, Akcura and Altinkemer 2002). We estimate the system of equations in each scenario simultaneously to account for the interactions between generations and between competitors (The details of the system of equations in each scenario can be found in Appendix C.).

4.2. Results and Discussion

Scenario 1: PS1 vs. PS2

In this scenario, we assume that only Sony exists in the market selling its two generation game consoles: PS1 and PS2. Data for PS1 is from 1996 to 2005, while that for PS2 is from its launch time in 2000 to 2005.

Figure 1 shows the diffusion pattern of PS1 and PS2. As stated above, we take the cannibalization impact into account from 1999, one year prior to PS2's launch time. In this setting, since there are no other competitors stealing Sony's market share, each generation's adoption pattern is only affected by the other generation introduced by Sony. Apparently, after the introduction of the new generation PS2 in 2000, PS1's sales dropped significantly. However, we need to know if the decrease in PS1 sales is due to the cannibalization effect from its sibling PS2 or if it is just the nature of the product life cycle. If PS2's success is just a result of cannibalizing from PS1, the launch of PS2 would not be efficient for Sony. On the other hand, if the major portion of PS2's sales comes from new customers or repeat purchases, the success of PS2 would indeed be profitable to Sony. By looking at the cannibalization term of the model, $ag_{n,g}(t)$, we can easily answer this question.

Our results suggest that the cannibalization between PS1 and PS2 is extremely low (see Figure 2), less than 10 percent of PS2's sales on average. This indicates that Sony chose an ideal time to launch its PS2 to keep dominating the market without sacrificing much of the potential sales of the PS1. PS2's adoption quickly makes up for the declining sales of PS1 due to the nature of a mature product. In addition, we show the predicted sales up to 2010 for the market under this circumstance. As the graph indicates, Sony probably should have launched another new generation around 2005 to make up for the declining sales of the PS2 in order to sustain its position as market leader. However, because of the technology development cycle, Sony had to delay its launch time for PS3 to the end of 2006. Although the cannibalization effect between PS3 and PS2 at that time is likely to be low, Sony may have a hard time earning back the market share it lost when PS2's sales began decreasing and no successive generation could retain its customers. In fact, the Xbox360 outsold the PS3 by 2.06 million units in the U.S. market alone in 2007, according to the NPD Group (Brightman 2008, McWhertor 2008).

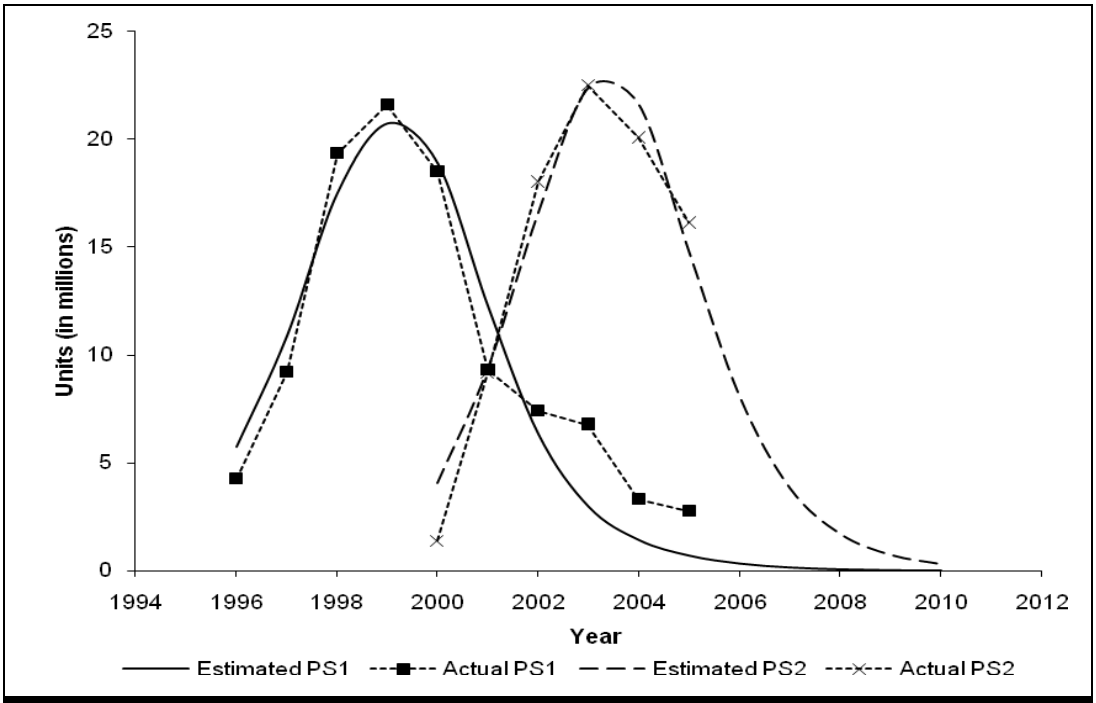

Figure 1. Diffusion of PS1 and PS2

Table 2 reports the estimated parameters. Our estimation produces good results in terms of model fitness (both R^2 are above 90 percent). The reason for the substantial difference between the market potential of PS1 and PS2 is explained in Figure 2.

Table 2. Estimated Parameters under Scenario 1

	PS1			PS2		
Parameter	**Estimate**	**Standard Error**	***t*-Stat**	**Estimate**	**Standard Error**	***t*-Stat**
***p* (coefficient of innovation)**	0.03	0.01	3.61***	0.02	0.00	4.90***
***q* (coefficient of imitation)**	0.78	0.09	8.28***	0.83	0.07	11.34***
***m* (market potential)**	105.58	8.20	12.87***	10.80	5.93	1.82
R^2		0.9059			0.9834	

Note: * = $p < .10$, ** = $p < .05$, *** = $p < .01$

Figure 2 separately identifies the total adoptions, repeats, and cannibalizations of the PS2. The graph shows that repeat purchasers contribute substantially to the total adoptions of the PS2, about 70 percent to 80 percent of the total adoptions. The repeat adopters are customers who have previously purchased a PS1 as in this scenario. The high number of repeats explains the relatively low estimated market potential of the PS2 compared with the PS1 (i.e., $m_{s,1}$ = 105.58; $m_{s,2}$ = 10.80). Although the market potential for the first-time adopters of the PS2 is not as high as the PS1, the PS2 still occupied a large market share and had shipped over 100 million units before 2006. One possible explanation for the high repeat purchases is the company's success in retaining Sony's loyal customers. This also helps to explain why Sony continues to dominate the game console market.

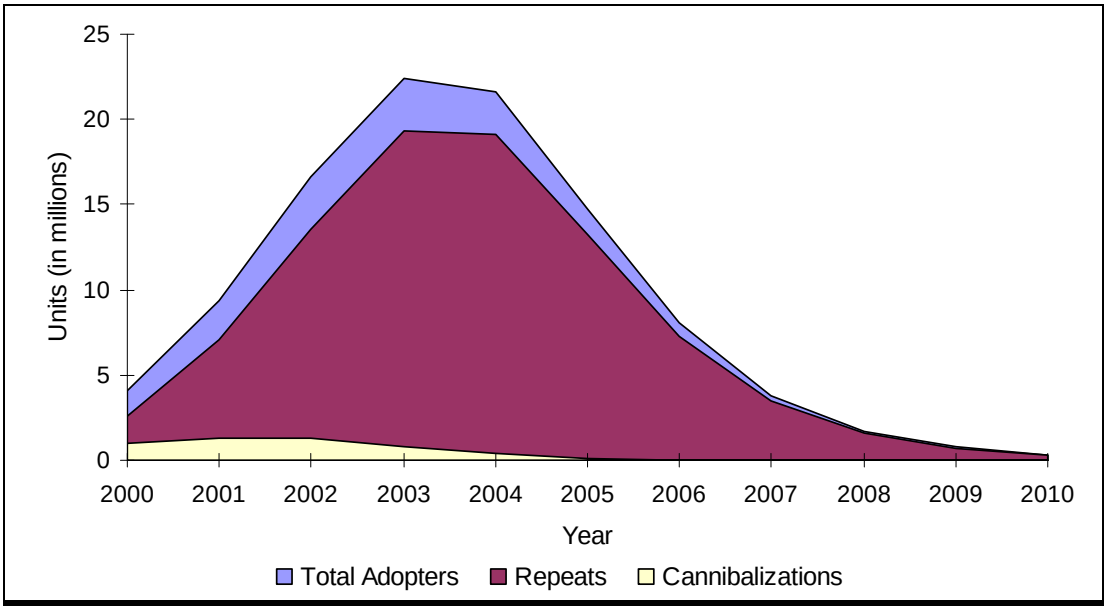

Figure 2. PS2 Diffusion with Adoptions, Repeats, and Cannibalization Separately Identified

After analyzing the simple case with only one company in the market, we next allow competition to play a role in the scenario. In the following section, we examine what happens when we add add Microsoft to the market.

Scenario 2: PS1 vs. PS2 vs. Xbox

Microsoft entered the game console market with its Xbox in 2001, one year after Sony introduced the PS2. In this case, we allow three products from these companies to compete in the market. Figure 3 shows the diffusion patterns for the PS1, the PS2, and the Xbox. With the introduction of the Xbox, both the PS1 and PS2 face a competition effect from this newcomer, as does Xbox.

Table 3a shows the estimation results of the parameters. Different from Scenario 1, since we now include the competition factor in the model, we do not estimate the market potential directly. Instead, we will estimate a market potential base m_0 for each generation, while the actual market potential will be affected by the competitive power of the competitor's products. Since there are not enough data points for an unbiased estimation, we fix the value for each market base m_0 and estimate the remaining parameters using SAS.

We take a two-step approach. First, to select a reasonable value of m_0, we use EXCEL to estimate the values for all parameters, including the market base m_0. Then, we fix the values of market base using the estimations from EXCEL, and estimate the rest of the parameters (i.e., the innovation and imitation coefficients and the competition parameters) in SAS. We conduct a sensitivity analysis to check the robustness of our results in the next section.

Table 3b reports the estimated competition parameter, $\varepsilon_{n',g\sim n,g}$. The negative impact of the Xbox on the PS1 and the PS2 ($\varepsilon_{m,x\sim s,1}$ = -0.09, $\varepsilon_{m,x\sim s,2}$ = -0.61) indicates the significant competitive power of the Xbox. Although Sony has been the market leader in this industry for years, the introduction of the Xbox is a considerable threat to Sony. Another interesting finding is that the competition is mainly between products in the same generation, especially between the Xbox and the PS2 rather than the PS1, as $\varepsilon_{m,x\sim s,1}$ is almost zero. Therefore, the rapid development of technology creates more challenges for firms in sustaining their competitive edge and marketing power. The launch of Xbox challenged the market balance of the console industry and usurped market shares from the PS2.

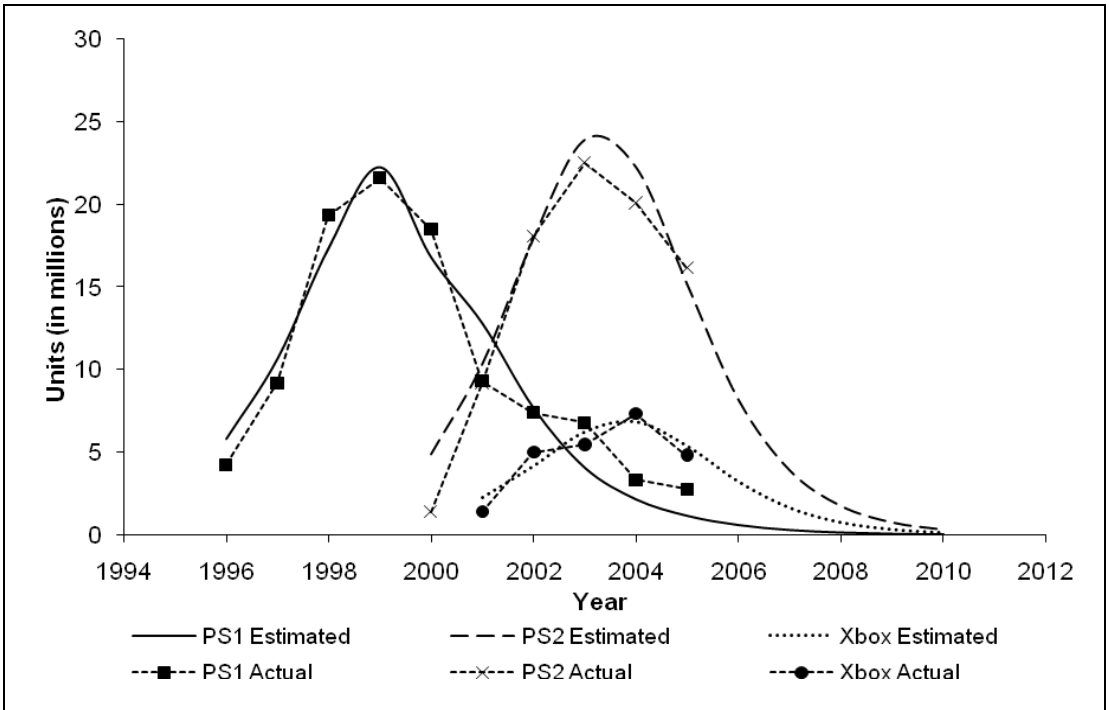

Figure 3. Diffusion of PS1, PS2 and Xbox ($m_{s,10}$ = 130, $m_{s,20}$ = 85, $m_{m,x0}$ = 5)

Table 3a. Estimated Parameters under Scenario 2 ($m_{s,10}$ = 130, $m_{s,20}$ = 85, $m_{m,x0}$ = 5)

	PS1			PS2			Xbox		
Parameter	**Estimate**	**Standard Error**	***t*-Stat**	**Estimate**	**Standard Error**	***t*-Stat**	**Estimate**	**Standard Error**	***t*-Stat**
***p* (coefficient of innovation)**	0.02	0.01	3.80***	0.02	0.00	5.41***	0.03	0.01	4.63***
***q* (coefficient of imitation)**	0.72	0.07	10.16***	0.82	0.07	12.40***	0.80	0.10	8.13***
R^2	0.9198			0.9845			0.9657		

Note: * = $p < .10$, ** = $p < .05$, *** = $p < .01$

Table 3b. Estimated Competition Parameters under Scenario 2

Competition Parameter	**Estimate**	**Standard Error**	***t*-Stat**
$\varepsilon_{s,1\sim m,x}$	-0.09	0.02	-4.06***
$\varepsilon_{s,2\sim m,x}$	-0.61	0.15	-4.00***

Note: * = $p < .10$, ** = $p < .05$, *** = $p < .01$

Companies can gain significant competitive advantage and higher market share by entering the market first (Robinson and Fornell 1985, Robinson 1988, Lambkin 1988, Parry and Bass 1990, Roger et al. 1992). As the first company to combine a DVD player with a game console, Sony obtained the first-mover advantage for two generations, the PS1 and the PS2, beating the second-mover, Microsoft. However, due to the intensive competition of new technologies, the PS2 and the Xbox would begin to lose profitability by 2007. Another new generation — the Xbox360 or the PS3 — could be introduced before 2007 to attract market attention and make up for the downward curve of PS2 and Xbox. In fact, consistent with our prediction, Microsoft stopped producing the Xbox in 2006, right

after the introduction of the Xbox360. With one less competitor, Sony adopted a different strategy, continuing to produce the PS2 in 2006 and 2007. Since the PS3 has already lost the first-mover advantage to Xbox360, Sony tried to enhance its competitive edge by having two generations competing in the market.

Although the market balance of the next generation is still unclear, Microsoft is already a first-mover through its introduction of the Xbox360 almost a full year prior to the PS3. The effects of Sony's decision to delay the launch of the PS3 may be twofold. On the one hand, introducing a new generation at a later stage of the PS2's life cycle may minimize the cannibalization effect. On the other hand, the longer Sony waits, the lower will be the competitive advantage and market share it might be able to obtain (Makadok 1998). Since the PS2 has already entered a mature stage and its sales have started declining, Sony's leading position might be challenged or even replaced by Microsoft with the Xbox360. To maintain its first-mover advantage and market leader position, Sony has to be more careful with its strategic planning and balance the trade-off between waiting for more mature technology and losing its first-mover advantage to Microsoft.

Our results also yield interesting findings for the characteristics of game consoles. The estimations suggest relatively high imitation ($q_{s,1}$ = 0.72, $q_{s,2}$ = 0.82, $q_{m,x}$ = 0.80), in contrast with the normal innovation ($p_{s,1}$ = 0.02, $p_{s,2}$ = 0.02, $p_{m,x}$ = 0.03) that has occurred for all three products. The fast imitation speed may be attributable to the unique nature of the product and its target segments. Game consoles are a typical IT-intensive product, and they tend to have much shorter generation-to-generation development cycles than traditional durable goods. Another argument is that the targeted market segments, usually teenagers and younger children, are not likely to put off their purchasing decisions once there are enough social pressures for them to adopt (Bass 1969). As a result, companies have to be more cautious in their production strategies, since faster adoption could easily result in product shortages during the peak seasons, which would hurt overall sales. For example, Sony and Microsoft have both experienced such problem when introducing PS2 and Xbox and, later, PS3 and Xbox360.

5. Sensitivity Analysis

In this section, we examine the impact of changing the value of the market base m_0 in Scenario 2 on the diffusion patterns of PS1, PS2, and Xbox. Since there are three parameters for analysis (i.e., $m_{s,10}$, $m_{s,20}$, and $m_{m,x0}$) that could generate hundreds of different combinations for changing their values, we report four representative cases in the paper.

In Case A, we increase all three parameters by five. Next, we reduce $m_{s,10}$, $m_{s,20}$ by five in Case B (since $m_{m,x0}$ = 5 is already very small, we will not reduce it). Then, we increase $m_{s,20}$ by five and reduce $m_{s,10}$ by five in Case C (again, we do not decrease the value of $m_{m,x0}$). In Case D, we increase $m_{s,10}$ and $m_{m,x0}$ while decreasing $m_{s,20}$ by five. The diffusion patterns for all four cases are illustrated in Figure 4. Table 4 summarizes the numerical results of the estimations.

The table indicates that both the coefficients and competition parameters are very close in all four cases (except for the imitation coefficient for the Xbox, $q_{m,x}$, in Case D). This suggests that either increasing or decreasing the market base for PS1 and PS2 will not affect the qualitative results, whereas increasing $m_{m,x0}$ alone might alter the diffusion pattern of the Xbox. Fortunately, we find that even with a slightly different estimation of $q_{m,x}$, both the signs and magnitudes of the competition parameters remain the same. Our analyses and predictions hold true even with different market base values, so our results are robust.

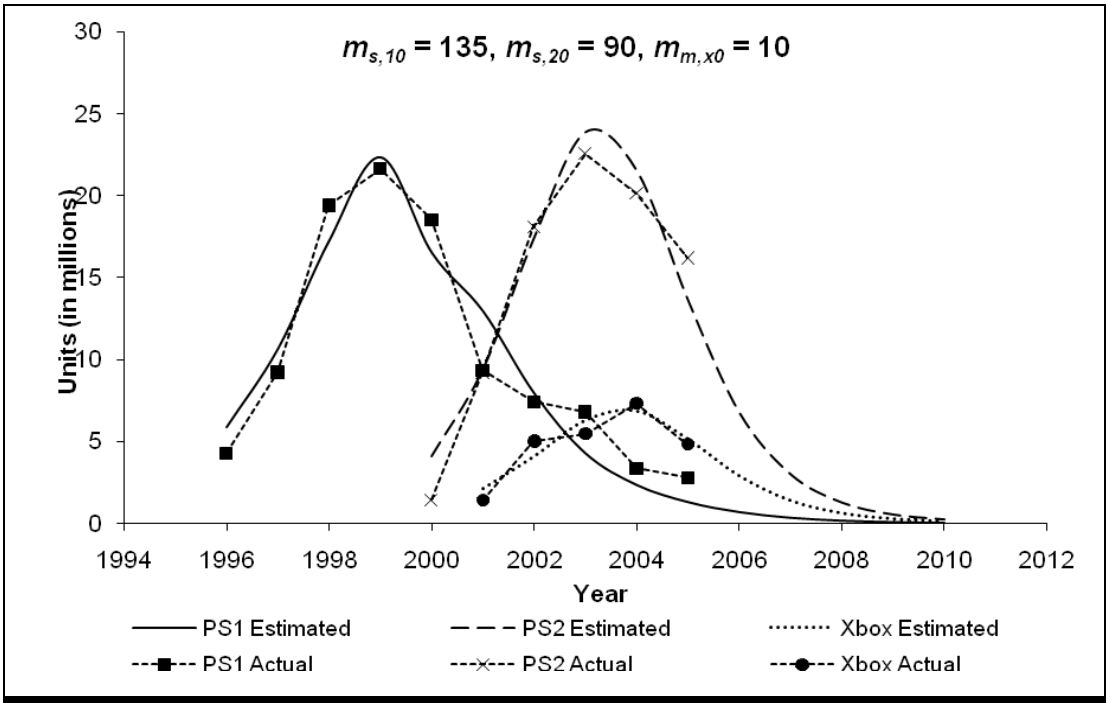

Figure 4. Case A: Diffusion of PS1, PS2 and Xbox

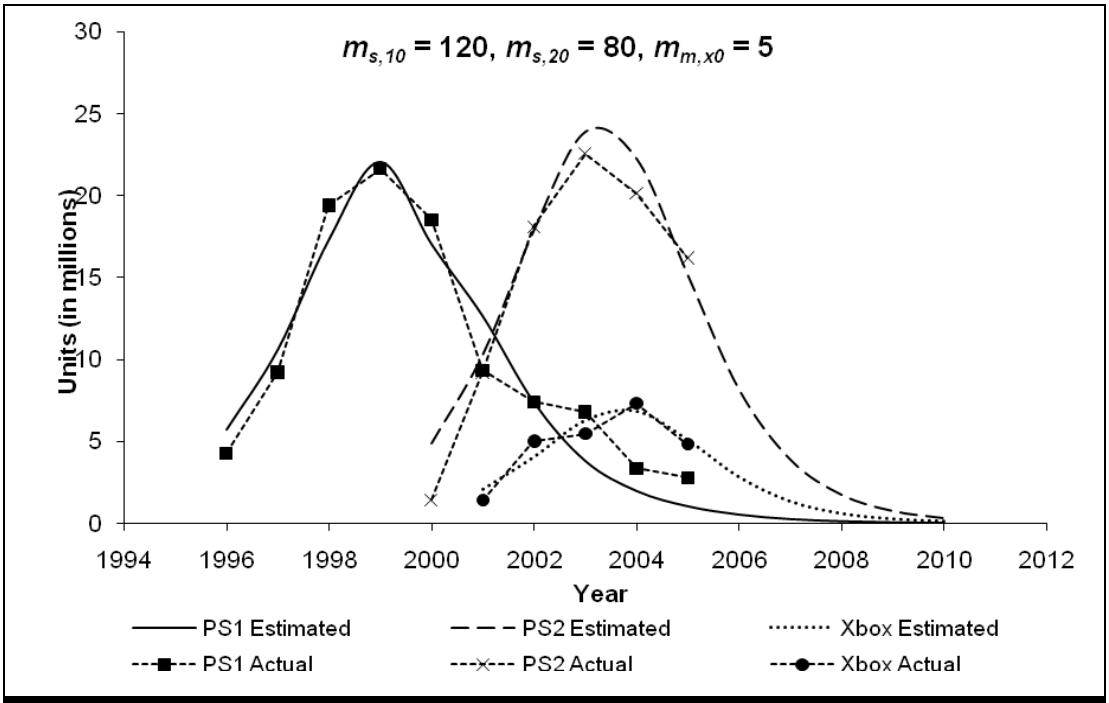

Figure 5. Case B: Diffusion of PS1, PS2 and Xbox

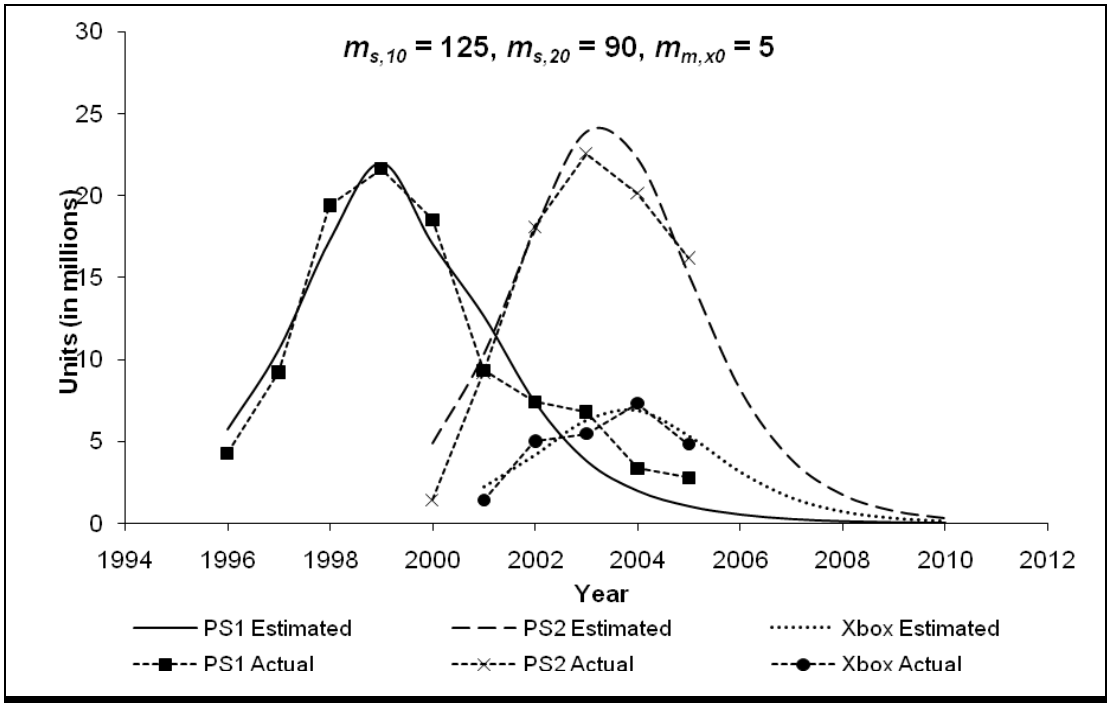

Figure 6. Case C: Diffusion of PS1, PS2 and Xbox

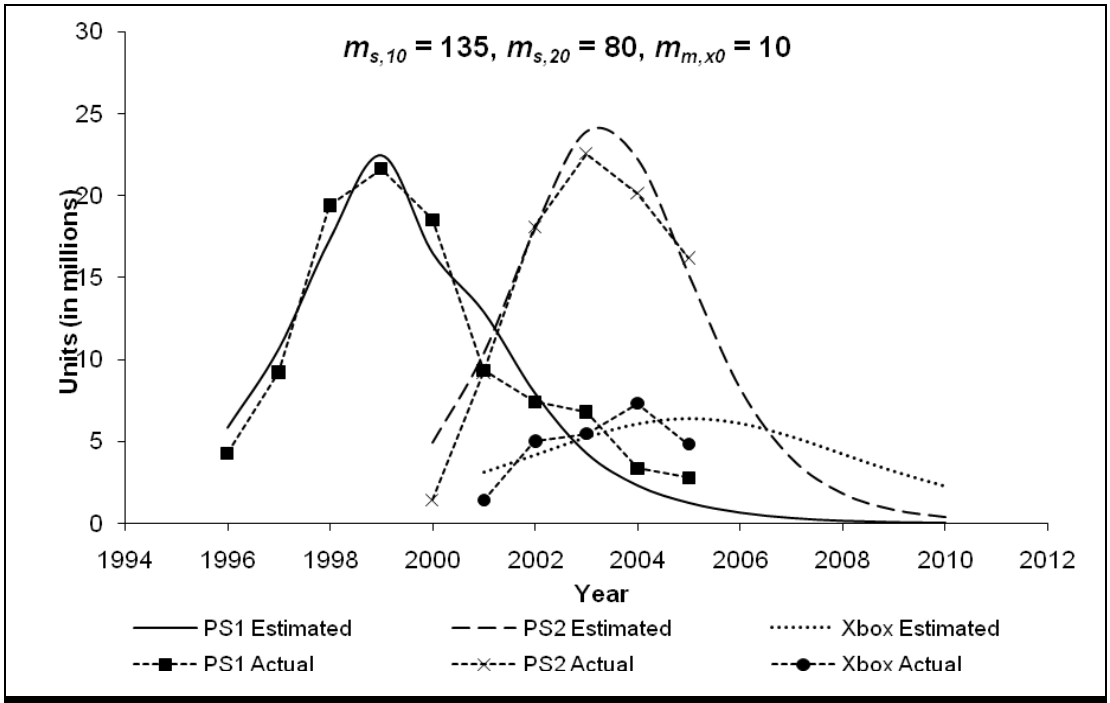

Figure 7. Case D: Diffusion of PS1, PS2 and Xbox

Table 4. Estimated Parameters for Case A – D

Parameter	Case A PS1	Case A PS2	Case A Xbox	Case B PS1	Case B PS2	Case B Xbox
***p* (coefficient of innovation)**	0.02***	0.02***	0.03***	0.02***	0.02***	0.03***
***q* (coefficient of imitation)**	0.70***	0.89***	0.85***	0.73***	0.82***	0.87***
$\varepsilon_{PS1\sim Xbox}$		-0.10**			-0.08***	
$\varepsilon_{PS2\sim Xbox}$		-1.16***			-0.60***	
	Case C PS1	**Case C PS2**	**Case C Xbox**	**Case D PS1**	**Case D PS2**	**Case D Xbox**
***p* (coefficient of innovation)**	0.02***	0.02***	0.03***	0.02***	0.02***	0.04**
***q* (coefficient of imitation)**	0.73***	0.82***	0.81***	0.71***	0.82***	0.41***
$\varepsilon_{PS1\sim Xbox}$		-0.08***			-0.09**	
$\varepsilon_{PS2\sim Xbox}$		-0.63***			-0.52***	

Note: * = $p < .10$, ** = $p < .05$, *** = $p < .01$

6. Conclusion

With the rapid development of new technologies, companies are able to introduce new generations of products faster than ever before. As a result, the level of competition among IT-intensive products has risen to a new level. Companies are facing challenges from both cannibalization of their own multi-generational products and severe competition in the market.

To capture the characteristics of IT-intensive industries, this study proposes a model that integrates both cannibalization and competition effects. The model distinguishes between first-time and repeat purchases, which helps firms to identify the different components of their revenue streams. We apply the model to one growing market, game consoles, by using real shipment data to study the competition between two leading companies, Sony and Microsoft. Our analyses indicate that the cannibalization effect between the PS1 and the PS2 is minimal, whereas a substantial portion of PS2's sales comes from the repeat business of consumers who have already bought PS1s.

In addition, the competitive power of the Xbox is shown to be strong. This may shift the balance of competition in the game console market, which has been dominated by Sony for years. Interestingly, we find that the competition has mainly been between products of the same generation rather than across generations. In other words, although Sony gained first-mover advantages by introducing two generations prior to Microsoft, it may not be able to sustain its leading position as game console technologies progress further.

This study adds to the growing literature on the diffusion of high-tech products and the interactions between and among generations and competitors. Although our analysis has focused on game consoles, the proposed model can be applied to other high-tech products, including digital cameras, personal computers, and mobile phones. The results enable us to identify various drivers of product sales, and to gauge how competitive the product is in the current market. As a result, managers can utilize these findings to devise better product development and introduction strategies so as to optimize the performance of their products.

Similar to other empirical studies, this paper is not without limitations. First, due to the lack of data, the scope of the study is limited to two companies and three products over two generations. However, since these products represented more than 70 percent of the market shares in 2005 (ABIresearch 2006), our results are, nevertheless, informative. Second, since the sales of game consoles could be indirectly affected by other products such as video games or PC games, considering competition within only one industry may overestimate the competitive power involved in the relationships between console producers. However, incorporating game developers and gamers into the model

would result in a setting that is beyond the scope of this paper. We believe that it is of great interest to further study the dynamic strategic actions between these players, especially game console producers, game developers, and gamers. Third, our study suggests that sales cannibalization between the PS1 and the PS2 is minimal, which implies that Sony should be careful to introduce new product generations at the appropriate times.

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Appendix A: Comparison of Game Consoles

	 **Sony PlayStation**	 **Sony PlayStation 2 Console**	 **Microsoft Xbox Console**	 **Microsoft Xbox360 Console**
Price	$71	$129 - $160	$199 - $299	$244 - $399
Processor	33 MHz	295 MHz 128-bit Emotion Engine	733 MHz Intel Pentium 3	3.2 GHz Triple Core IBM PowerPC
Processor Speed	33 MHz	295 MHz	733 MHz	3.2 GHz
Gaming Type	Optional Online Gaming	Optional Online Gaming Multiplayer Gaming	On-Line Gaming LAN Gaming Multiplayer Gaming	On-Line Gaming Multiplayer Gaming
Installed RAM	3.5 MB	32 MB	64 MB	512 MB
Hard Drive Size	Not available	Future Add-on	8 GB	20 GB
Display Max. Resolution	640 x 480	1280 x 1024	1920 x 1080	1280 x 720
Communication Type	Not available	Fast Ethernet	Fast Ethernet	IEEE 802.11a IEEE 802.11b IEEE 802.11g Fast Ethernet USB 2.0
DVD Movie Playback	Not available	DVD Movie Playback	Optional DVD Movie Playback	DVD Movie Playback
HDTV Compatibility	Not available	HDTV Movie support	HDTV Movie support HDTV Game support	HDTV Game support
Release Date	Dec, 1994	Mar, 2000	Nov, 2001	Dec, 2005

Appendix B: Notation Table

n: company index, *n = 1, 2*
g: generations index, *g = 1, 2, …, G*
p: coefficient of innovators
q: coefficient of imitators
m_0: market potential base
m: market potential
rm: repeat purchase market potential
f(t): adoption time distribution function
s(t): general adoption function
a(t): first time adoption function
ag(t): first time cannibalization effect
r(t): repeat adoption function
rg(t): repeat cannibalization effect
ε: competition parameter

Appendix C: Empirical Models

We first define the company index *n* as *s* for Sony and *m* for Microsoft. Next, let the generation index *g* represent different generations of the two companies, *g* = 1 for PS1, *g* = 2 for PS2, and *g* = *x* for Xbox.

Scenario 1: PS1 vs. PS2

In this scenario, since there is no competitor in the market, the potential market for Sony will not be impacted by the competition factor. In other words, we will not estimate the competition parameter, *ε*.

For PS1, since it is the first generation introduced by Sony, there would be no repeat purchases but only first adoptions. In addition, before consumers knew about the launch for PS2, there should be no cannibalization effect for its sales. Therefore, the equation before 1999 is simply: $s_{s,1}(t) = a_{s,1}(t) = m_{s,1} f_{s,1}(t)$. Starting from 1999, PS2 begins cannibalizing sales of PS1. Thus, the equation becomes: $s_{s,1}(t) = a_{s,1}(t) = m_{s,1} f_{s,1}(t) - m_{s,1} f_{s,1}(t) f_{s,2}(t)$.

For PS2, the sales will consist of both first adoptions and repeat adoptions. Moreover, it will enjoy the switching sales from PS1. The model should be:

$$s_{s,2}(t) = a_{s,2}(t) + r_{s,2}(t) = m_{s,2} f_{s,2}(t) + m_{s,1} f_{s,1}(t) f_{s,2}(t) + \left[\sum_{i=1}^{i=t-1} a_{s,1}(i)\right] f_{s,2}(t)$$

Scenario 2: PS1 vs. PS2 vs. Xbox

Since we consider a duopoly case in this scenario, the market potential should be affected by the competition between the two companies. In other words, we will estimate the market base, m_0, as well as the competition parameter, *ε*, for each generation of each company.

The functions for PS1 and PS2 are similar to those in Scenario 1 except that starting from 2000 the market potential becomes a function of other variables (i.e. m_0 and *ε*). Therefore, the equations for PS1 and PS2 are as follows:

Before 1999: $s_{s,1}(t) = a_{s,1}(t) = m_{s,1} f_{s,1}(t)$

1999 – 2000: $s_{s,1}(t) = a_{s,1}(t) = m_{s,1} f_{s,1}(t) - m_{s,1} f_{s,1}(t) f_{s,2}(t)$, and

$$s_{s,2}(t) = a_{s,2}(t) + r_{s,2}(t) = m_{s,2} f_{s,2}(t) + m_{s,1} f_{s,1}(t) f_{s,2}(t) + \left[\sum_{i=1}^{i=t-1} a_{s,1}(i)\right] f_{s,2}(t)$$

After 2000: $s_{s,1}(t) = a_{s,1}(t) = m_{s,1} f_{s,1}(t) - m_{s,1} f_{s,1}(t) f_{s,2}(t)$, and

$$s_{s,2}(t) = a_{s,2}(t) + r_{s,2}(t) = m_{s,2} f_{s,2}(t) + m_{s,1} f_{s,1}(t) f_{s,2}(t) + \left[\sum_{i=1}^{i=t-1} a_{s,1}(i)\right] f_{s,2}(t)$$

where $m_{s,1} = m_{s,10}(m_{m,x})^{\varepsilon_{s,1\sim m,x}}$, and $m_{s,2} = m_{s,20}(m_{m,x})^{\varepsilon_{s,2\sim m,x}}$

The equation for Xbox is derived in a similar manner. Again, since Xbox is the first generation introduced by Microsoft, there should be no repeat purchasing. Due to data availability, we do not consider Xbox360 in this case. Thus, there is no cannibalization effect for Xbox after 2004 (i.e. one year before the actual launch of Xbox360). Since Xbox360 was launched at the end of 2005 and our data analysis covers the period from 1996 to 2005, the impact of the lack of data points for Xbox360 should be minimal. However, it is worth noting that the competitive power of Microsoft could be underestimated due to the absence of Xbox360 in the model.

$s_{m,x}(t) = a_{m,x}(t) = m_{m,x} f_{m,x}(t)$

where $m_{m,x} = m_{m,x0}(m_{s,1})^{-\varepsilon_{s,1\sim m,x}}(m_{s,2})^{-\varepsilon_{s,2\sim m,x}}$.

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