The Launch Timing of New and Dominant Multigeneration Technologies

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The Launch Timing of New and Dominant Multi-Generation Technologies
An Application to the Video-Game Systems Market

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Abstract

In this paper we introduce a model that is suitable to study the diffusion of new and dominant multi-generation technologies. Examples are computer operating systems, mobile phone standards, video game consoles. Our model incorporates three new features that are not included in related models. First, we add the ability of a firm to transfer users of its old technologies to the new generations, what we call *firms' alpha*. Second, we add competitive relations between market technologies. Third, the launch strategies diagnosed by our model cover, as special cases, the *now or never* strategies and hence it is suitable to study intermediate launch strategies.

We state the relationship of our model to previous research both in terms of the model formulation and in terms of some of its analytical solutions. Specifically, the model may reduce to the Bass or the Norton and Bass models. Regarding the analytical solutions, we find that the *launch never* strategy arise when there are late product introductions by competitors, when a *firm's alpha* is very low, or when the competition is intense while the *launch now* strategy arise only when a *firm's alpha* is zero.

In addition, we evaluate different launch strategies and the optimality of launch timings in two detailed case studies on the video game systems market. We study the portable systems (PS) and the video game consoles (VGC) industry. Hence, we formulate our model for two market contexts, the duopolistic structure of the PS case and the triopolistic market of the VGC case. We present several insights from our analysis and we find interesting explanations for the pacing strategy in this market, for which we also provide a historical perspective.

Finally, we find that the appropriate timing of a new technology depends heavily on both the *firms' alphas* and on the competitive positioning of their products. In addition, we argue that the strategic interaction of firms may lead to very different sales outcomes depending on the competitive positioning of their products. In the VGC case we find that the Nintendo Wii was launched at an appropriate moment while the Sony PS3 perhaps should have never been launched.

KEYWORDS: MULTI-GENERATION DIFFUSION MODELS, LAUNCH TIMING, VIDEO-GAME INDUSTRY

1 Introduction

In a well-known study on the behavior of chimpanzees Jane Goodall writes:

> "In 1963 Goliath, a powerful and aggressive male in his prime (perhaps about 25 years of age) was the alpha male. He had a spectacular charging display during which he covered the ground very fast indeed, dragging and occasionally hurling branches. Early in 1964, however, Goliath was displaced from his top-ranking position in the community by an older and much less robust male, Mike... Unlike Goliath, who had maintained a very high ranking position for several years after losing his alpha rank, Mike dropped rapidly to a low position in the hierarchy... In chimpanzee society, dominance is something of a conundrum. The usual interpretation of the phenomenon is that it enables a high-ranking individual to have prior access to desirable foods, females, or resting places." (van Lawick-Goodall, 1973)

We believe that Goodall's description of *dominance* in the chimpanzee society directly applies to new technologies and their markets. Specifically, markets of new technologies formed by a few firms and products and by a single or a few dominant *alpha* technologies are analogous to the few chimpanzee males that fight for the *alpha* rank. Examples of products in this type of industries are operating systems, mobile phone standards, video game consoles, smart phones, and so on.

Many technology firms, like Apple or Microsoft, launch several versions of their products, what we know as product generations. Each time a new generation product is introduced to the market some or many of the users of the old generations switch to the new one, at the same time new users may adopt the new generation product while other users may switch from one firms products to another firms products after a new introduction. That is, each product generation cannibalizes its previous generation and each firm has a different capacity of transferring the users of the old technology to the new one. For example, we know that Apple has been very successful transferring the users of its old technologies to the new ones. Linux, even though it is a smaller player, is a second example of a technology with a high *alpha*. In contrast, it was widely documented how Microsoft users were hesitant to switch from Windows XP to Windows Vista. Some Windows users stickied to Windows XP while others switched to alternative operating systems. In this paper we will refer to the firms capacity of cannibalizing and transferring users of old technologies to new ones as the *firm's alpha*. In our example, Apple would be the player with a high *alpha*.

In this paper we extend the Norton and Bass (1987) model by incorporating three new elements that have not been addressed simultaneously in previous literature. These are the firm's ability of transferring its users to new technologies (the *firm's alpha*), the competitive interaction between firms in the market, and a new solution to the timing of new technologies. Our model is suitable to study the timing of new generation products in industries that are characterized by a relatively slow pace of introductions and a few firms launching new technologies. In addition, we test our model empirically under different settings and based on the new model we provide insights into the launch-timing strategies and into the optimality of launch timings.

Previous empirical literature has addressed the diffusion of new multi-generation technologies, like Norton and Bass (1987), Kim and Lee (2005), Danaher et al. (2001) and Kim et al. (2000), but they do not cover the topic of introduction timing. Two exceptions are Norton and Bass (1987) and Mahajan and Muller (1996). These last authors introduce the timing of new products into their models and tested them empirically. However, both the Norton and Bass (1987) and the Mahajan and Muller (1996) models suggest to launch new technology either *now or never*. Other analytical studies have addressed specifically the timing of new technologies, like Wilson and Norton (1989), Joshi et al. (2009), Bayus et al. (1997), Souza et al. (2004) and Morgan et al. (2001), but these later authors models have not been tested empirically and in most cases their models are suitable for industries with a fast pace of technology introductions, an exception being Joshi et al. (2009). More importantly, these studies do not incorporate the three new elements we address simultaneously.

The plan of the paper is as follows. In Section 2 we present our literature review. In Section 3 we present our model for the duopoly and triopoly case (sections 3.1 and 3.2, respectively), we discuss its relationship to previous models (section 3.3) and the analytical properties that distinguish it from previous models (section 3.4). In Section 4 we introduce the market context and our data. In Section 5 we motivate the model assumptions and the estimation procedure. In Section 6 we discuss the estimation results. In the next two sections we use our model to study the industry. In Section 7 we study the portable system market and we give insights about different launch strategies. Next, in Section 8, we study the main video game console market, composed of Microsoft, Sony and Nintendo, and we focus our analysis in the latest console race. We further provide insights into how different introduction timings may be optimal. Finally, in Section 9 we present our discussion and conclusions.

2 Literature Review

To our knowledge, Wilson and Norton (1989) and Mahajan and Muller (1996) are the two key studies concerned with the question of when it is optimal for a monopoly to launch multi-generation products. According to Wilson and Norton (1989) there are three critical issues which affect the optimal introduction time of a new generation. These are the interrelationship of sales of the two products, their profit margins and the planning horizon. Surprisingly, their model provides two optimal solutions regardless of the relevance of these factors. They conclude that different generations of a product should be introduced either all at the same time or sequentially and not overlapping. In a similar vein, Mahajan and Muller (1996) conclude that a new generation should be introduced as soon as it is available (if its market potential is larger than the preceding one) or it should be delayed to a much later stage, that is, to the maturity of the previous generation. Their findings seem special cases of the solutions proposed by Kamien and Schwartz (1972). Kamien and Schwartz (1972) suggest to *never launch* a technology only under extreme competition and to *launch now* only if the firm needs to take advantage of a profit stream that would otherwise be smaller once competitors come in.

More recently, Joshi et al. (2009) study the problem of product launch timings across different markets. They characterize situations, depending on social influence, where it is optimal to launch before maturity or after the maturity of the first generation product. However, Joshi et al. (2009) do not incorporate competition and their model is only useful to study the interaction of products across markets (same product in two geographies, for example). Souza et al. (2004) study the new product introduction strategy and its relation to industry clock speed. They provide analytical evidence that a time-pacing strategy (launching products every n time periods) performs relatively well compared to the optimal strategy. Their model applies to settings with a high frequency of product introductions. The studies of Morgan et al. (2001) and Bayus et al. (1997) analyze how the trade-offs between quality or product performance (measured by development costs) interact with the introduction timing decision. In contrast, we study the relationship between cannibalization and competition with the introduction timing decisions.

The literature on multi-generation products is very extensive. Padmanabhan and Bass (1993) and Bayus (1992) propose models to price successive generations of products, Danaher et al. (2001) analyze the relation between the marketing mix and diffusion of multi-generation products, Bucklin and Sengupta (1993) examine the diffusion of complementary innovations, Kim et al. (2001), Chatterjee and Eliashberg (1990), Kim and Srinivasan (2001), Jun and Park (1999), Vakratsas et al. (2002) and Bayus (1991) study how and when consumers decide to upgrade to improved products' versions. Islam and Meade (2000), Islam and Meade (1997) and Olson and Joi (1985) propose models for diffusion and replacement of products, while Purohit (1994), Robertson et al. (1995) and Prasad et al. (2004) analyze the introduction strategies of multi-generations products or the release of single products in multiple channels. Finally, Kim et al. (2000), Kim and Lee (2005), Peterson and Mahajan (1978) and Islam and Meade (1997) present alternative diffusion models for successive generations of products.

Our contributions to this literature are as follows. First, we propose a model that incorporates competition and cannibalization (*firm's alpha*) based on a duopolistic and triopolistic market. Second, our model parameters are simple to estimate or to calibrate with secondary quantitative or qualitative information and it is possible to find intermediate solutions to the introduction timing problem. Third, we provide two detailed case studies about the timing of game systems that are not documented in the literature. Finally, we present new insights regarding different launch strategies and the optimality of timing decisions.

Next we briefly discuss the Norton and Bass Model (NBM) as it is our departing point and it is essential in our model development.

2.1 The Norton and Bass Model

In this paper we overcome three limitations of the NBM model that have not been jointly addressed in previous research. Denote $S_1(\tau_1, \tau_2)$ as the first generation sales, $S_2(\tau_1, \tau_2)$ as the second generation sales and denote τ_1 and τ_2 as the launch moment of these generations, respectively. The first limitation is that $\partial(S_1(\tau_1, \tau_2) + S_2(\tau_1, \tau_2))/\partial\tau_2 = 0$ is obtained when $\tau_2 = 0$ or when $\tau_2 = \infty$. $S_g(\tau_1, \tau_2)$ are the sales of generation g given the introduction timings of the first and second generation products, τ_1 and τ_2, respectively. Therefore, the basic Norton and Bass (1987) model is not helpful to derive an intermediate optimal introduction timing apart of these two solutions. The second limitation is that it assumes that all the sales of the previous generation are captured by the second generation. Finally, the NBM does not consider the diffusion of competing products.

In the NBM cumulative sales are proportional to the cumulative distribution function of the adoption rate $F(t)$ and the market potential m. When a second generation is introduced, substitution and adoption effects should be added to the previous equation. For the case of two generations, Norton and Bass posit that the first generation cumulative sales follow

$$S_1(\tau_1, \tau_2) = m_1 F_1(\tau_1)[1 - F_2(\tau_2)], \text{ for } t > 0, \tag{1}$$

and that the second generation follows

$$S_2(\tau_1, \tau_2) = F_2(\tau_2)[m_2 + F_1(\tau_1)m_1], \text{ for } t > \tau_2 \tag{2}$$

where we use $S_g(\tau_1, \tau_2)$ to refer to the vector $[S_g(\tau_1, \tau_2; t = 0), \ldots, S_g(\tau_1, \tau_2; t = T_p)]$ and $S_1(\tau_1, \tau_2; t)$ is equal to $m_1 F_1(\tau_1; t)[1 - F_2(\tau_2; t)]$ while $S_2(\tau_1, \tau_2; t)$ is equal to $F_2(\tau_2; t)[m_2 + F_1(\tau_1; t)m_1]$. The introduction date of the first generation ($g = 1$) is τ_1 and the introduction date of the second generation ($g = 2$) is τ_2. T_p is the planning horizon, which is set as ∞ in Norton and Bass (1987). $F_i(\tau_i; t)$ is the cumulative sales function of generation g defined as $F_g(\tau_g; t) = [1 - e^{-b_i(t-\tau_g)}/1 + a_i e^{-b_g(t-\tau_g)}]$ for $t > \tau_g$ and $a_g = q_g/p_g$ and $b_g = p_g + q_g$, $g = 1, 2$. We use $F_g(\tau_g)$ to refer to the vector $[F_g(\tau_g; t = 0), \ldots, F_g(\tau_g; t = Tp)]$. Slightly stricter notation would use $F_g(\tau_g; t, \theta)$ where $\theta = (p_g, q_g, m_g)$ but we use the former as we focus on the timing parameters in this study. Note that in the Norton and Bass (1987) τ_1 is assumed to be fixed at some value (possibly at $t = 0$) and they do not focus on its value.

The equations of the NBM posit that after the second generation is introduced at time τ_2, the first generation's cumulative sales $S_1(\tau_1, \tau_2)$ become proportional to its cumulative adoption function $F_1(\tau_1)$, its market potential m_1, and the sales not captured by the second generation $[1 - F_2(\tau_2)]$ after τ_2. The sales of the second generation $S_2(\tau_1, \tau_2)$ are proportional to their own market potential m_2 and to the cumulative sales of the first generation $F_1(\tau_1)m_1$ after τ_2.

If the NBM equation (1) would contain only the term $m_1 F_1(\tau_1)$, then the sales $S_1(\tau_1, \tau_2)$ will be equivalent to the model of Bass (1969). However, in the Norton and Bass (1987) model a fraction $F_2(\tau_2)$ of $m_1 F_1(\tau_1)$ is captured by the second generation. Consequently, there is a moment in time when $F_2(\tau_2)$ will become 1 and all of the first generation sales are transferred to the second generation and the last element of $S_1(\tau_1, \tau_2)$ becomes 0. At the same time $S_2(\tau_1, \tau_2) = m_2 F_2(\tau_2) + F_2(\tau_2)F_1(\tau_1)m_1$ and therefore, $m_1 + m_2$ is the last element of the vector $S_2(\tau_1, \tau_2)$, given in equation (2).

In the next section we present a model that is a generalized version of the NBM and we believe this new general model overcomes all the three limitations of the NBM.

3 A Multi-Product Diffusion Model with Competition

This section is divided in four subsections. In the first (subsection 3.1) we extend the NBM to the duopoly case and in the second (subsection 3.2) we extend the model to the triopoly case. Both extensions are based on the same assumptions and we present the duopoly case first for ease of exposition. In the third section we present the relationship of our model to previous models proposed in the literature (section 3.3). Finally, in the fourth (subsection 3.4) we present the intuition and the analytical properties that make our specification suitable to optimize and study the launch timing of new dominant technologies.

3.1 Duopoly Multi-Generation Model

In order to expand the Norton and Bass (1987) model and add a second firm or a second competing product, we should make assumptions about the relationship between the firms' products. Here we make the assumption that the relationship between the two generations products of a firm are related in a very similar but more flexible way than in the NBM, and that is where the *alpha* parameter comes in. Additionally, we will assume that the sales that go from one product to a competitor's version are proportional to the cumulative sales function of the competitor's products.

Formally, if the market is composed of *two* firms s and n, the cumulative sales of firm s are

$$S_1^s(\tau_1^s, \tau_2^s | \tau_1^n, \tau_2^n) = \tilde{S}_1^s(\tau_1^s, \tau_2^s)[1 - \phi_{11}^{sn} F_1^n(\tau_1^n)][1 - \phi_{12}^{sn} F_2^n(\tau_2^n)] \tag{3}$$

and

$$S_2^s(\tau_1^s, \tau_2^s | \tau_1^n, \tau_2^n) = \tilde{S}_2^s(\tau_1^s, \tau_2^s)[1 - \phi_{21}^{sn} F_1^n(\tau_1^n)][1 - \phi_{22}^{sn} F_2^n(\tau_2^n)] \tag{4}$$

The cumulative sales of firm n are

$$S_1^n(\tau_1^n, \tau_2^n | \tau_1^s, \tau_2^s) = \tilde{S_1^n}(\tau_1^n, \tau_2^n)[1 + \phi_{11}^{ns} F_1^s(\tau_1^s)][1 + \phi_{12}^{ns} F_2^s(\tau_2^s)] \tag{5}$$

and

$$S_2^n(\tau_1^n, \tau_2^n | \tau_1^s, \tau_2^s) = \tilde{S_2^n}(\tau_1^n, \tau_2^n)[1 + \phi_{21}^{ns} F_1^s(\tau_1^s)][1 + \phi_{22}^{ns} F_2^s(\tau_2^s)] \tag{6}$$

where $\tilde{S_1^i}$ and $\tilde{S_2^i}$ are defined as

$$\tilde{S_1^i}(\tau_1^i, \tau_2^i) = m_1^j F_1^i(\tau_1^i)[1 - \alpha_i F_2^i(\tau_2^i)] \text{ for } i = n \text{ or } s \tag{7}$$

and

$$\tilde{S_2^j}(\tau_1^i, \tau_2^i) = F_2^i(\tau_2^i)[m_2^i + \alpha_i F_1^i(\tau_1^i) m_1^i] \text{ for } i = n \text{ or } s \tag{8}$$

Finally we have that

$$F_g^i(\tau_g^i; t) = [1 - e^{-b_g^i(t-\tau_g^i)}/1 + a_g^i e^{-b_g^i(t-\tau_g^i)}] \times I(\tau_g^i \geq t) \text{ for } t > 0 \tag{9}$$

where $S_g^i(\tau_1^i, \tau_2^i | \tau_1^s, \tau_2^s)$ represent the sales of generation g of firm i achieved by launching its first and second generation products at τ_1^i and τ_2^i and given the competing firm s launched its products at τ_1^s and τ_2^s; $a_g^i = q_g^i/p_g^i$ and $b_g^i = p_g^i + q_g^i$ and $I(\tau_g^i > t)$ is an indicator function that equals 1 when the introduction time of generation g of firm i, τ_g^i, is larger than or equal to t and zero otherwise. The term ϕ_{gk}^{ij} refers to the substitution (or loyalty) parameter between the generation g of firm i and the generation k of firm j. We use $F_g^i(\tau_g^i)$ to represent the vector $[F_g^i(\tau_g^i; t = 0), \ldots, F_g^i(\tau_g^i; t = T_p)]$. Again, stricter notation would use $F_g^i(\tau_g^i; t, \theta)$ where θ is a vector that collects all other parameters in the model. The parameters p_g^i and q_g^i are the innovation and imitation parameters of generation g and firm i, respectively, $g = 1, 2$ and $i = n, s$.

We may refer occasionally to ϕ as the vector $(\phi_1, \ldots, \phi_N)$ where N is the number of products and to α as the vector $(\alpha_1, \ldots, \alpha_I)$ where I is the number of firms. Equations 3 to 9 allow for a wide variety of relationships given the sign and size of what we call the loyalty parameters or ϕ and the values of the the *alpha* cannibalization parameters (α). The role of the α parameter is to relax the assumption of the NBM that all the sales of the first generation of a firm are transferred to the second generation. Note that the last elements of the vector in $\tilde{S}_2^j(\tau_1^i, \tau_2^i)$ will be equal to $m_2^i + \alpha m_1^i$ and the last element of $\tilde{S}_1^i(\tau_1^i, \tau_2^i)$ is equal to $m_1^j - \alpha m_1^j$. Therefore α can be interpreted as the proportion of sales that the first generation transfers to the next when $t = T_p$ and T_p is of course sufficiently long.

In Figure 1 we sketch the relationship between product generations in the duopoly model. Basically, there is substitution between all products but substitution starts at different points in time. The first generation is launched at $t = 0$ and it is the only product in the market up to $t = T1$. At this moment the first generation of the second firm is launched and the substitution between these two products (represented by the blank continuous line) starts too. The rest of the products are launched at time $t = T2$ and $t = T3$ and the substitution between them and the products launched before them start at these times. Note that the model allows for the possibility of *never* launching a product if we set its launch date at $t = T_p$. This figure represents a hypothetical case of launch dates but we can evaluate any launch-timing in the model. For example, we could evaluate the result of launching the products in reverse order or in any order. In practice the second generation arrives after the first one, but any other combination is allowed. Finally, note that there is only one single arrow between the products in the figure. That is, we assume symmetric competitive parameters. If the relationship between products is not symmetric then we would need two arrows connecting any pair of products in Figure 1.

Next we present the triopoly model and at the end of next section we discuss how both the duopoly and the triopoly models are related to previous research.

3.2 Triopoly Multi-Generation Model

In this section we extend the duopoly model and set the sales equations for firms s, n and x and we hold the assumption that each firm sells two generations of the same product.

The cumulative sales equations for firm x are:

$$S_1^x(\tau_1^x, \tau_2^x|\tau_1^s, \tau_2^s, \tau_1^n, \tau_2^n) = \tilde{S}_1^x(\tau_1^x, \tau_2^x)[1 + \phi_{11}^{xs} F_1^s(\tau_1^s)] \\ \times [1 + \phi_{12}^{xs} F_2^s(\tau_2^s)][1 + \phi_{11}^{xn} F_1^n(\tau_1^n)][1 + \phi_{12}^{xn} F_2^n(\tau_2^n)] \quad (10)$$

and

$$S_2^x(\tau_1^x, \tau_2^x|\tau_1^s, \tau_2^s, \tau_1^n, \tau_2^n) = \tilde{S}_2^x(\tau_1^x, \tau_2^x)[1 + \phi_{21}^{xs} F_1^s(\tau_1^s)] \\ \times [1 + \phi_{22}^{xs} F_2^s(\tau_2^s)][1 + \phi_{21}^{xn} F_1^n(\tau_1^n)][1 + \phi_{22}^{xn} F_2^n(\tau_2^n)] \quad (11)$$

The cumulative sales equations for firm s are:

$$S_1^s(\tau_1^s, \tau_2^s|\tau_1^x, \tau_2^x, \tau_1^n, \tau_2^n) = \tilde{S}_1^s(\tau_1^s, \tau_2^s)[1 - \phi_{11}^{sx} F_1^x(\tau_1^x)] \\ \times [1 - \phi_{12}^{sx} F_2^x(\tau_2^x)][1 + \phi_{11}^{sn} F_1^n(\tau_1^n)][1 + \phi_{12}^{sn} F_2^n(\tau_2^n)] \quad (12)$$

and

$$S_2^s(\tau_1^s, \tau_2^s|\tau_1^x, \tau_2^x, \tau_1^n, \tau_2^n) = \tilde{S}_2^s(\tau_1^s, \tau_2^s)[1 - \phi_{21}^{sx} F_1^x(\tau_1^x)] \\ \times [1 - \phi_{22}^{sx} F_2^x(\tau_2^x)][1 + \phi_{21}^{sn} F_1^n(\tau_1^n)][1 + \phi_{22}^{sn} F_2^n(\tau_2^n)] \quad (13)$$

And, the cumulative sales equations for firm n are:

$$S_1^n(\tau_1^n, \tau_2^n|\tau_1^x, \tau_2^x, \tau_1^s, \tau_2^s) = \tilde{S}_1^n(\tau_1^n, \tau_2^n)[1 - \phi_{11}^{nx} F_1^x(t - \tau_1^x)] \\ \times [1 - \phi_{12}^{nx} F_2^x(\tau_2^x)][1 - \phi_{11}^{ns} F_1^s(\tau_1^s)][1 - \phi_{12}^{ns} F_2^s(t - \tau_2^s)] \quad (14)$$

and

$$S_2^n(\tau_1^n, \tau_2^n|\tau_1^x, \tau_2^x, \tau_1^s, \tau_2^s) = \tilde{S}_2^n(\tau_1^n, \tau_2^n)[1 - \phi_{21}^{nx} F_1^x(\tau_1^x)] \\ \times [1 - \phi_{22}^{nx} F_2^x(\tau_2^x)][1 - \phi_{21}^{ns} F_1^s(t - \tau_1^s)][1 - \phi_{22}^{ns} F_2^s(t - \tau_2^s)] \quad (15)$$

where $\tilde{S_1^i}$ and $\tilde{S_2^i}$ are defined as

$$\tilde{S_1^i}(\tau_1^i, \tau_2^i) = m_1^i F_1^i(\tau_1^i)[1 - \alpha_i F_2^i(\tau_2^i)] \text{ for } i = n \text{ or } s \text{ or } x \tag{16}$$

and

$$\tilde{S_2^i}((\tau_1^i, \tau_2^i) = F_2^i(\tau_2^i)[m_2^i + \alpha_i F_1^i(t - \tau_1^i)m_1^i] \text{ for } j = n \text{ or } s \text{ or } x \tag{17}$$

and

$$F_g^i(\tau_g^i) = [1 - e^{-b_g^i(t-\tau_g^i)}/1 + a_g^i e^{-b_g^i(t-\tau_g^i)}] \times I(\tau_g^i \geq t) \text{ for } t > 0 \tag{18}$$

where $a_g^i = q_g^i/p_g^i$ and $b_g^i = p_g^i + q_g^i$ and $I(\tau_g^i > t)$ is an indicator function that equals 1 when the introduction time of generation g of firm i, τ_g^i, is larger than or equal to t and zero otherwise. The term ϕ_{gk}^{ij} is the competitive parameter that relates the generation g of firm i with the generation k of firm j. The parameters p_g^i and q_g^i are the innovation and imitation parameters of generation g, respectively, $g = 1, 2$.

The specification of (10) to (18) is similar to the duopoly case but now we allow for substitution between three market players x, s, and n and each of their products. The duopoly model consists of four launch-timing parameters, eight ϕ parameters, two α parameters, four p and q parameters and four m parameters. That is in total 26 parameters in four equations. The triopoly model consists of 45 parameters (six τ, 24 ϕ, six p and q, three α and six m) in six equations. In the estimation section 5 we describe how we calibrate both models and the parameter restrictions and assumptions we use. Next we describe the relationship of our model with previous models.

3.3 Links with Other Models

In Figure 2 we summarize the relationship of this general NBM with previous models based on different parameter configurations. It is useful to see the nodes at the top of the figure as possible cases for each firm in our model. We start with the left node. If the α parameter, in one of the firm's equations, is equal to zero then there exists no cannibalization between a specific firm generations and the diffusion of each of its generations follows an independent Bass Model. However, in this case if some of the ϕ parameters are different from zero then we have independent Bass Models but we add inter-generation competition (or what is the same as between firms competition); otherwise they follow independent Bass models. On the right hand side of the figure we see the case when the α parameter is set to 1 and this means that the relationship of generations within firms follows the NBM specification. As in the previous node the ϕ parameters may add inter-generation competition between firms (note that is not within the same firm). Finally, in the central node we have the case when α is different from both 0 and 1. In this last case, the model allows cannibalization within a firm's generations but the cannibalization is different from the NBM. Therefore we call this a *second type of cannibalization.* As before, for this node the ϕ parameters may add inter-generation competition between firms.

At the bottom of Figure 2 we give three boxes representing firms and the arrows correspond to two hypothetical specifications (case 1 and 2) for each firm. In the first case, firm 1 products follow a NBM with *second type of cannibalization*, firm 2 products follow independent Bass Models while firm 3 products follow the NBM. That is, in this case the only firm facing the effects of competition is firm 2. In the second case we set a different combination and our intention is to illustrate that the model parameters allow a diverse set of diffusion patters among firms and products. A similar specification for the NBM is possible when either the p or q of any of the generations is equal to 0. Note that each firm launches two generations of products within the planning horizon but the triopoly model may reduce to the duopoly model in case a firm sets the launch date at the end of the planning horizon (what we refer as T_p) for its two generations. A different specification happens when each firm launches a single product by setting one of its generations launch-timing equal to T_p. Hence, our model is flexible enough to allow different substitution patterns between firms' products and within firm generations. At the same time the triopoly case might reduce to different number of firms or products depending on the parameter values.

3.4 Why Our Model Works

In this subsection we present the intuition of why our model is useful to find intermediates dates rather than $\tau = 0$ or $\tau = \infty$ solutions of the NBM. The intermediate solutions are possible due to the trade-off between competitive interaction between products and the cannibalization within a firm's generations. For example, if the firm n launches a product at time τ_c and this product might enhance/deter the sales of one of the products of firm s after this time. Then the firm s has the incentive to advance/postpone the launch of its product relative to the launch of the competing product. In this way, firm s could maximize/minimize the positive/negative effects of competition. That is, the timing decision depends on the sign and size of the effect of firm's n product on the sales of firm's s products. In addition, there is a trade-off between maximizing or minimizing the effect of competition and the effects on firm s previous generation product. Therefore, by launching the second generation sooner the previous generation might lose sales to the second generation earlier in time. In summary, the optimization of the competitive effects and the own cannibalization effects is possible in our specification while it is not possible to optimize them in the NBM.

Here we present a simplified version of the duopoly model and assume that one of the competing firms launches only one product at τ_c while the second firm s sells two products and these are launched at τ_1 and τ_2. We further assume that the competitive effects are measured by the coefficients ϕ_1 and ϕ_2. Formally, the equations of firm s are

$$S_1^s(\tau_1, \tau_2|\tau_c) = m_1 F_1^s(\tau_1)[1 - \alpha_s F_2^s(\tau_2)][1 - \phi_1 F_1^c(\tau_c)], \text{ for } t > 0, \tag{19}$$

and

$$S_2^s(\tau_1, \tau_2|\tau_c) = F_2^s(\tau_2)[m_2 + \alpha_s F_1^s(\tau_1) m_1][1 - \phi_2 F_1^c(\tau_c)], \text{ for } t > \tau_2 \tag{20}$$

That is, the first and second generation sales of firm s, $S_1^s(\tau_1, \tau_2|\tau_c)$ and $S_2^s(\tau_1, \tau_2|\tau_c)$, are now related to the competing product by the loyalty parameters ϕ_1 and ϕ_2. It is easy to show that the sales gained or lost by adding competition to the NBM (with cannibalization of type 2) are

$$\Delta_s = \big[\alpha_s(\phi_2 - \phi_1)m_1 F_1^s(\tau_1)F_2^s(\tau_2) + \phi_1 m_1 F_1^s(\tau_1) + \phi_2 m_2 F_2^s(\tau_2)\big] F_1^c(\tau_c), \ \text{for } t \geq \tau_c \quad (21)$$

Δ_s is the sales change due to the introduction of a competing product and it depends on the parameters α_s, ϕ_1 and ϕ_2 and on the introduction timings τ_1 and τ_2 relative to τ_c. The terms $\phi_1 m_1 F_1^s(\tau_1)$ and $\phi_2 m_2 F_2^s(\tau_2)$ measure the share of each product of firm s that might be transferred/received to/from a competing product and the shares are ϕ_1 and ϕ_2. The term $\alpha_s(\phi_2 - \phi_1)m_1 F_1^s(\tau_1)F_2^s(\tau_2)$ reflects the share of the cannibalized sales that might be transferred to a competing product and this share is $\alpha_s \times (\phi_2 - \phi_1)$. Note that α_s is the share transferred between generations of the firm s while $\alpha_s \times (\phi_2 - \phi_1)$ is the share that might be transfer to a competing product. If $\alpha_s = 0$ this implies no cannibalization and we are back to the NBM specification with competition. Finally, all terms belonging to firm s interact with the diffusion of the competing product $F_1^c(\tau_c)$ after τ_c. This last term exists only after $t > \tau_c$ and hence firm s decision should take into account that after time τ_c their products will gain or lose some share to the competing product. Note that equation (21) uses a simplified version of the duopoly model and that in our application below we use the complete duopoly and triopoly model.

The following lemmas cover a few interesting optimal timing scenarios. We include them because they illustrate some extreme cases where the *launch now or never* strategy may be valid and they illustrate the flexibility of our model specification.

Lemma 1 *The optimal introduction timing of both the first and second generation products is equal to zero when there is no cannibalization ($\alpha_s = 0$), when the $\phi_1 < 0$ and $\phi_2 < 0$ and there is one competitive introduction at τ_c.*

From (21) it follows that if $\alpha_s = 0$, one has $\Delta_s = -(\phi_1 m_1 F_1^s(\tau_1) + \phi_2 m_2 F_2^s(\tau_2))F_1^c(\tau_c)$. It is clear that both products should be introduced at $t = 0$ given that they face competition after τ_c, that is, the earlier they are both introduced, the better. Hence, in the case of no cannibalization with competition the option of *launch now* is the optimal solution. If there is no competition and cannibalization we are back to the solutions of the Norton and Bass model. This lemma is in line with Kamien and Schwartz (1972).

Lemma 2 *The optimal introduction timing of the first and second generation products (τ_1 and τ_2) are equal to τ_c when there is no cannibalization ($\alpha_s = 0$), when the $\phi_1 > 0$ or the $\phi_2 > 0$, respectively, and when a competitive introduction happens at τ_c.*

Introducing at time τ_c produces a positive Δ_s and it is clear that a firm should choose a time closer to τ_c. If both products are launched before τ_c the sales stream is smaller between τ_1 and τ_c for the first generation, and they are smaller between time τ_2 and τ_c for the second generation. On the other hand, if they are launched after τ_c they do not benefit from competition for $\tau_1 - \tau_c$ or $\tau_2 - \tau_c$ periods, respectively. This lemma implies that *imitation* may be optimal under certain conditions. As before, the strategy of *launch never* is discarded because there are positive returns to launch at dates closer to competitors. This lemma may be modified easily to the situation where imitation is optimal for only one generation, for example if $\phi_1 = 0$ and $\phi_2 > 0$. In our application below we will conduct a numerical exercise (in section 7.2) where this lemma is at work.

Lemma 3 *It is optimal to never launch the second generation when $S_2^s(\tau_1, \tau_2|\tau_c)$ $+\Delta_s < 0$.*

When the returns on introducing the new product Δ_s outweigh the unit sales of $S_2^s(\tau_1, \tau_2|\tau_c)$ then it is optimal not to introduce it. Hence, the *launch never* strategy arises when there is stiff competition as in Kamien and Schwartz (1972). In our case study (section 8.2) we evaluate the parameter space that leads to this lemma.

There are other interesting possibilities of intermediate launch-timings when there is cannibalization and competition either for the first or second generation given different values for the ϕ_1, ϕ_2 and α parameters. In our case studies we explore numerically other possibilities for the α parameter and the optimal timing of products and explore the parameter space that may lead to any of these lemmas or to the *launch now or never* strategy.

4 The Video Game Hardware Market

The hardware market for video games can be split in two sub-markets: hardware for portable systems (PS) and hardware for video game consoles (VGC). In this paper we treat these markets to be independent of each other. Indeed, most press articles indicate that the markets of PS and VGC are independent. See for example The Herald (2005), Financial Times (2004), The Economist (2004) and The Washington Post (2008). The reader may be familiar with the video game console wars between Microsoft, Sony and Nintendo (BusinessWeek, 2008b; The Washington Post, 2006). At the moment (September 2009) these three companies are the main market players in the hardware market. Microsoft does not sell any PS while the three companies sell competing video game consoles. Sega stopped producing game consoles in 2001 (San Francisco Chronicle, 2001) and Apple and Microsoft are seen as potential new competitors of Sony and Nintendo in the PS market. (BusinessWeek, 2008a; Wall Street Journal, 2006).

4.1 Some Basic Figures

In Table 1 we report the release dates of the main PS hardware since 1998 for three main markets: North America, Japan and Europe. The release dates for PS seem almost arbitrary and they occur in months that range from February to December for all three regions. However, when we look at the time between releases within companies we discover a different pattern. Table 2 shows an average of two-year intervals between releases.

In Table 3 we report the release dates on all major VGC since 1987. Clearly, the VGC market is quite different from the PS market. The release dates in North

America are mainly chosen to be close to November while in Japan and Europe most releases occur also in other months of the last quarter of the year. If we look at Table 4 we can see that there is an additional regularity around the VGC releases. They occur approximately every five years. Only the Sony PS3 took more than 6 years to be released and this was due to a delay in the development of the blu-ray technology added to the PS3. See The New York Times (2006) for more details on this story.

In Table 5 and Table 6 we report the estimates of single-generation Bass models for PS and VGC. Portable systems have very similar innovation parameters (p) but quite different imitation parameters (q). We computed simple statistics on the Bass models and in most cases they fit the data quite well. We discuss more details on our data next.

4.2 Data and Data Cleaning

Our data for the duopoly and triopoly NBM models consists of weekly time series of sales at the USA for the last two PS of Nintendo and Sony and the last two generations of consoles released by Microsoft, Sony and Nintendo. The portable systems are the Nintendo DS, the Nintendo DS Lite, the Sony PlayStation Portable (PSP) and the Sony PSP Slim. The video game consoles are the Microsoft Xbox, Microsoft Xbox 360, Sony PS2, Sony PS3, Nintendo GameCube and Nintendo Wii. In addition, we obtained the corresponding release dates for all products from different news sources and for all cases the release dates matched the date of the first week that we observed in our data. We used a script to download our data from www.vgchartz.com and the site admins authorized us to use their data. Our data for all systems cover the period since their release week up to January 2009. That is, our data covers a period of almost 9 years and 10 systems.

Before we plug our data into the estimation routines we control for indirect network effects, seasonality and price. It has been documented that indirect network effects might play a role in the video game market (see for example, Chintagunta et al. (2009), Clements and Ohashi (2005) or Shankar and Bayus (2003)). Furthermore, Binken and Stremersch (2009) show that it is mainly *super star software* what drives indirect network effects in the video game systems market. Therefore, in this paper we use a simplified version of the model proposed by Binken and Stremersch (2009) to clean our data from indirect network effects and price. We use the following equation

$$Y_t = \alpha Y_{t-1} + \sum_{j=1...52} \beta_j WD_j + \sum_{l=t...t-L} \lambda_l PCD_l + \sum_{k=t...t-K} \delta_k SSI_k + \epsilon_t \qquad (22)$$

where Y_t are the system sales at week t; WD_j refers to the week j dummies; PCD_l is the price cut dummies with L total lags and it indicates the week when prices were cut; SSI_k is the total number of *super star software* introduced at week k.

To create the independent variables in equation (22) we collected release dates and quality ratings on the most popular video games for the systems in our sample. For each system we found approximately 120 video games to construct the SSI variable. In total we collected data for 1200 video games. These data come from many different online sources. Furthermore, we use many different news services to find the price cut timing for all consoles in our sample. We estimated equation (22) for each console in our sample and then we subtracted the terms $\sum_{k=t...t-K} \delta_k SSI_k$ and $\sum_{l=t...t-L} \lambda_l PCD_l$ from the consoles sales Y_t only if they are significant. We report in Table 7 the sales percentage that indirect network effects represent for each console and the number of lags for the SSI_k variable that we used. We chose the number of lags in the same way as Binken and Stremersch (2009).

Interestingly, despite our model is a much simpler version of that of Binken and Stremersch (2009) we find that indirect network effects represent on average a 13% of the consoles sales while Binken and Stremersch (2009) found that percentage to be 14%. That is, our results confirm their findings. In contrast, we use weekly data, they use monthly, and we find that on average the number of lags correspond to approximately 7 weeks (that is less than 2 months) while they report significant lags up to 5 months. In terms of weeks 5 months represent 20 weeks. We tested lag numbers up to 20 weeks but we did not find significant effects further than 14 weeks (see Table 7). Note that the number of lags in the Table should be read with caution because not all lags were found significant and as Binken and Stremersch (2009) we include the last non significant lag to avoid bias. An additional difference is that we estimate the equation (22) separately for each system while they use a panel approach and that their SSI variable is monthly while we trace software introduction per week. Our guess is that they use a panel approach because they consider much shorter time series and the panel approach helped them to identify their model parameters. However, they warn about considerable heterogeneity of the network effects and their result of 14% is therefore close to an average of network effects across systems. Our long time series of weekly data allows us estimate the model for each system and the fit we achieve is very good for all systems (R^2 close to 0.80). A final difference in our approach is that we use the 120 most popular video games per system while they use on average the 10 superstar software video games per system. We estimated a second version of the system models by including only the highly rated video games (the superstars), as do Binken and Stremersch (2009), in the SSI variable. Binken and Stremersch (2009) do not report the percentile they use as a selection heuristic and we selected the video games with a quality rating in the top 25 percentile. In this case, the average network effects jumps up to 15%, while it is also close to their reported number. That is, higher quality video games might have higher network effects although the difference between 13% and 15% can hardly be considered as significant.

The resulting adjusted series without network and price effects still needs to be cleaned from seasonality and for this latter purpose we use the $TRAMO/SEATS$ methodology (Gomez and Maravall, 2001, chap. 8). We further control for all major holidays in the USA and for Easter.

In sum, the series we plug in our estimation routine are the seasonally adjusted series without indirect network and price effects. We use this series because the competitive parameters on our model could pick up the correlation caused by indirect network effects, price and seasonality if we do not control for them.

Our data covers 10 gaming systems and therefore we estimated 20 models (10 for the network effects and 10 for the seasonal adjustment). We do not report these results but they are available from the authors upon request. In addition, we estimate both the duopoly and triopoly models with the original data and the parameter estimates remain very similar. However, the fit is better when we use the clean data.

5 Estimation and Parameter Assumptions

We use the systems NLS estimator described in Cameron and Trivedi (2005, Chap. 6, page 217) to estimate the parameters.

The duopoly multi-generation model consists of 26 parameters and in our estimation routine we use 16 free parameters. This number reflects the assumptions that the innovation and imitation coefficient, p and q, vary across firms and products and that the loyalty effects are symmetric. That is, we assume that ϕ_{gk}^{ij} is equal to $-\phi_{kg}^{ji}$. The τ_g^i parameters are the introduction date of each product and we keep the real launch dates in our estimation routine.

The triopoly model consists of 45 parameters and in the estimation routine we have 21 free parameters. This number reflects the assumptions that the p and q parameters vary across firms, that the loyalty parameters are symmetric, and that α_i for $i = x, s, n$ are fixed at some value. The main reduction comes from the assumption that $\phi_{gk}^{ij} = -\phi_{kg}^{ji}$ as it reduces the number of free parameters by 12. Note this is the symmetry assumption we described earlier when we discussed Figure 1. Finally, we use the real introduction dates as values for the τ_g^i ($g = 1, 2$ and $i = x, s, n$) parameters.

An important assumption in the estimation routine is the value of the α parameters and we need an assumption on them. As we mentioned earlier, the α parameter is simply the share of the sales that the first generation transfers to the second generation. The reason why we need to make an assumption regarding α is that there is a direct relationship between the α and the m parameters with the realized cumulative sales. We know that the realized cumulative market sales are fixed at some value, call it M, and it depends on both α and m. Of course, the realized M depends on all other parameters but specially the α and the m are very closely related to it. If we increase α then we need a lower m to keep the realized sales at M or if we lower α we need a higher m. This means that we can not simultaneously identify both parameters. This is a limitation and at the same time an advantage of our model because we can obtain the α parameter easily from experts opinions, managers, store sales data, or surveys. All we need to know is what percentage of the first generation sales (of an specific firm) is transferred to its second generation and that is α. However, in case the α is not available then we could make assumptions on the market potentials and estimate the α together with all other free parameters in the model. We know that market potential assumptions are quite common in the new products diffusion literature and they are straightforward to construct.

In the estimation routine first we assume the $\alpha = 1$ for all firms in both the duopoly and triopoly model. Then, as an illustration, we ask an expert opinion on the size of α for each firm in our triopoly model. We contacted a local store manager and asked him about the α parameter of Microsoft, Sony and Nintendo according to his experience. His information is that the α of Microsoft is 0.3, the α of Sony is 0.1 and the α of Nintendo is 1.1. These numbers imply that Nintendo is able to get 1.1 sold unit of Wii for each sold unit of the GameCube, Sony achieves the lowest with a 0.1 of PS2 unit sales going into the PS3, while Microsoft is in between with an α of 0.3.

To estimate both models we use the systems NLS estimator but due to the large number of parameters we split estimation in three steps. First we estimate the six innovation and imitation coefficients p and q given all other parameters fixed. Next we estimate the loyalty coefficients ϕ given all other parameters are fixed at their most recent estimated values. We iterate these two steps until convergence and at the end of the routine we estimate the six market potentials given all other parameters. Chintagunta et al. (2009) apply a similar estimation approach. In the estimation routine we constrained the ϕ coefficients setting their lower and upper limits at -4 and $+4$, respectively. However, all parameter estimates are within these limits as we report in Section 6. All our routines are programmed in R (R Development Core Team, 2005).

6 Estimation Results

We report the parameter estimates for the duopoly model in Table 8. In this model we consider two companies, Nintendo and Sony, and their portable gaming systems. The systems are the Nintendo DS and DS Lite and the Sony PlayStation Portable (PSP) and PSP Slim. We notice that the parameter estimates for the innovation and imitation parameters, p and q, are lower in the multi-generation model than in the independent Bass model reported in Table 5. In addition, the market potentials are remarkably lower in the multi-generation model. Two factors explain the lower estimates. First, the multi-generation model allows the first generation to transfer a percentage α of its sales to the second generation. Hence, the second generation market potential has a lower m estimate but note that the realized market potential in the multi-generation model may be higher than the m estimate after adding the competition and cannibalization effects. These results are in line with the findings of Norton and Bass (1987) regarding the size of the market potentials of the second generation products; see (Norton and Bass, 1987, footnote 2, page 1074). Finally, we find significant ϕ parameters and this is evidence supporting the idea that the portable systems compete against each other. For example, we see that the Nintendo DS is losing share to the Sony PSP (see the -0.57 estimate) and it is losing more to the second generation of Sony, the PSP Slim (see the -2.39 estimate). On the other hand, the Nintendo DS Lite is receiving a share from the PSP Slim (see the 0.66 estimate). We report the model fit in Figure 3 and we can see the fit is reasonably good.

In Table 9 we report the triopoly model parameter estimates with the assumption that all firm's $\alpha = 1$. In Table 10 we present the parameter estimates when we use $0.3, 0.1$ and 1.1 as the α parameters for Microsoft, Sony and Nintendo, respectively. Finally, in Table 11 we present the ϕ and α parameters reported in Table 9 in a easy to read format.

For the triopoly case it is the q parameter estimates that are much lower than in the Bass model reported in Table 6 while the p parameters remain very similar. An interesting result is that the Microsoft Xbox market potential is around 19 million units while the Xbox 360 market potential is a much lower value of 813 thousand units. A similar drop in market potential occurs from the Sony PS2 to the Sony PS3. The exception is Nintendo. The market potentials for both the Nintendo GameCube and the Nintendo Wii stay around the same level (17 million units). This finding is in line with the results of Shankar and Bayus (2003). Shankar and Bayus (2003) analyze the video game market between 1993 and 1995 and the two main players at that time where Nintendo and Sega. Note that in Table 3 we report the history of console releases since 1985 and that they analyzed the last three years of the 4th generation systems. They argue that Nintendo had a higher network strength than Sega and consequently Nintendo sales overtook those of Sega. Recently, the Nintendo Wii is overtaking the sales of the largest player, Sony, and our parameter estimates seem to capture this overtake.

In Table 10 we report the model with our expert's values on the α parameters. As we anticipated, the parameter estimates of the market potential m are higher for the second generation of Microsoft and Sony because we assumed a much lower α for them (0.1 and 0.3, respectively). The market potential for the Xbox360 goes from 813 thousand units in the first model up to $2,685$ thousand units in the second, that is 3.3 times higher. The PS3 m in the second model is 2.14 times higher than in the first. Finally, the market potential of Nintendo's second generation, the Wii, is 1.161 million units lower in the second model relative to the first because of the higher α. Surprisingly, the market potential of both generations of Nintendo are still high relative to each other despite the fact that Nintendo can transfer more consumers from the GameCube to the Wii (it has the highest α among the three companies). The rest of the parameters in Table 10, with very few exceptions, remain very close to the model parameters of Table 9. We are certain that there are other ways to retrieve the α parameters from experts, surveys or data we stress that this estimation exercise is just an illustration.

In Table 11 we arrange the ϕ and α parameters in two six by six tables. We numbered the estimated ϕ parameters in the top table and in the bottom we report their estimates using bold face for parameters with t-values higher than 1. We can see that the Wii is getting some share from the Xbox console (see the 2.39 parameter of the phi[4]) and that is is not competing against the PS3 (see the -0.02 of the phi[12]). This confirms what has been argued in the press that these two consoles are not substitutes for each other. A surprising result is that the Wii has a positive influence on PS2 (see the -0.60 estimate of the phi[8]). The PS3 is losing some share to the Xbox 360 and the GameCube (see the phi[6] and phi[11] estimates) according to the sign of the parameters but they are not significant. At the same time, the PS2 received share from the Xbox 360 and the GameCube. Most parameter estimates are in line with our anecdotal evidence and what we read in the press.

Finally, we plot the observed and fitted values of the triopoly model in Figure 4 and again the model fits the data reasonably well. Note that the real cumulative sales of the first generation products, the graphs in the left of Figure 4, stabilize after they reach their maximum. However, our model forecasts a decline in their number of cumulative units after reaching the maximum and this is a consequence of the substitution that takes place after new generations are introduced. Hence, the fit after the maximum is not really the same as the fit before the maximum of the cumulative sales given that we do not have data on substitution or *un-adoption* of these products. An interesting feature of the left-hand graphs is that the foreseen decline is faster for the Xbox and the GameCube while it is very slow for the PS2.

7 Duopoly Case Study: The Portable System Race

In this section we use our model to analyze the portable system market. We take the duopoly model and its parameter estimates and with them we simulate four different strategies for both Nintendo and Sony. We use a planning horizon $T_p = 90$ months and this number is long enough relative to the average pace of two years we report in Table 2. Next we describe the strategies we simulate and afterwards we present the insights gained by our numerical exercises. At the end of the section we present the sensitivity analysis to different parameter estimates.

7.1 Simulating Plausible Strategies

A *strategy* is a complete contingent plan for all market players. (Watson, 2002, pg. 26). That is, we define the actions of Nintendo as a response to any of Sony's actions and viceversa. In all of the strategies, except the first, we let Nintendo be the *leader* and Sony the *follower.* We reversed their roles in our numerical exercises and our insights remain without significant changes. Furthermore, the *leader-follower* assumption is common in the literature, see for example Bayus et al. (1997, p. 56). Finally, we assume that the order of entry does not modify the competitive relationship between products, just as in Kamien and Schwartz (1972), but note that we will provide sensitivity analysis to different parameter values in the next section.

The four strategies we consider are:

1. **Random Date Selection**: In this strategy both Nintendo and Sony randomly select a launch date for their two product generations at the beginning of the planning horizon. That is, both firms ignore each other's actions and the interaction among their competing products.

2. **Imitation**: In this strategy Nintendo selects the launch-timing for its two generation products and Sony imitates Nintendo. That is, Sony launches its PS2 console at the same time as the GameCube and it launches the PS3 at the same time as the Nintendo Wii.

3. **Pre-commitment and Optimization**: In this strategy Nintendo pre-commits to the launch date of their two generation products while Sony, with perfect foresight, optimizes the launch dates of its two generation products based on Nintendo pre-commitment dates.

4. **Uncertain Dates and Stochastic Optimization**: In this strategy Nintendo does not pre-commit to a launch date for its two generation products.

However, Sony assigns a probability to each of the possible launch-timings of the GameCube and the Wii and based on this information it optimizes the launch-timing of the PS2 and the PS3.

We give the details of each strategy in the Appendix A. We simulate these four strategies and we compute the outcome in terms of the maximum cumulative sales of Sony, Nintendo and the sum of both firms' maximum cumulative sales. We repeat the simulation of each strategy until we cover all the combinations possible of the launch-timing selected by Sony and Nintendo that each strategy implies. In this way we recover the distribution of the sales that both players may achieve by following each of the four strategies. We summarize these distributions in Table 12 and Figure 5.

In Table 12 we report six quantiles of the distribution of the sales for Sony, Nintendo and their sum and for each of the four strategies while in Figure 5 we plot their percentiles. The purpose of Table 12 and Figure 5 is to help us rank the strategies in terms of the likelihood of their sales outcomes. For example, in Table 12 we see that for Sony the sales achieved by imitating are lower than the sales achieved by randomly selecting its dates, see the second and fourth lines in the table.

In the right-hand side of Figure 5 we see that the strategy that results in higher sales for Sony is the third and that is the strategy in which Sony knows the exact launch dates of Nintendo's products. Only at the very first percentiles (from 0 to around 20%) the stochastic optimization strategy is better. In the graph it is clear that the second best strategy results when Sony applies stochastic optimization. As we can notice, this strategy puts a lower and upper limit to the sales of Sony, see the flat areas of the *uncertain dates* line at the first and last percentiles. Surprisingly, imitation is the worst strategy Sony could follow and it performs slightly worse than when Sony randomly selects its dates.

In the left-hand side of Figure 5 we see the quantiles of the distribution of sales achieved by Nintendo. Note that Nintendo is the leader and the outcomes are therefore not a mirror of the results obtained by Sony. For Nintendo the results are mixed. We see that before the percentile 50 the best outcome is achieved when Sony is imitating (interestingly this is not a good option for Sony) and that after the 50 percentile the best outcome is achieved by not announcing its launch dates and by not precommiting to them (see the *uncertain dates* line). On the other hand, before the 50 percentile the lowest sales are achieved when Sony uses stochastic optimization and above the 50% the lowest sales are either random selection of dates or pre-commitment. Note that Nintendo does not behave strategically in our simulations. That is, Nintendo does not know that Sony is following one of the four strategies. Given that Nintendo knows which strategy Sony is playing then it is straightforward for Nintendo to strategically select its launch dates and achieve high sales. This implies that if Nintendo strategically chooses its launch dates then playing the *uncertain dates* strategy can result in high sales while if Nintendo acts not strategically then pre-commitment is a reasonable strategy. Of course, we are not using very strict criteria to rank Nintendo's strategies but it is straightforward to rank the strategies using different criteria given we know their corresponding outcomes in terms of sales distributions.

7.2 Sensitivity Analysis of the Launch Strategies

The above results are sensitive to the parameter values we plug in the duopoly model. In all previous exercises we used the values we obtained from our estimation routine. To know how the sales outcome may change we compute the expected value of the sales achieved by playing the second strategy (imitation) and the third strategy (optimization) when we plug in a different set of parameter values in the model. First we evaluate the strategy by simulating different combinations for the phi[1] and phi[2] parameters, the phi[3] and phi[4] parameters and finally for the phi[1] and the alpha parameter of Nintendo. The phi[1] and phi[2] are the ϕ parameters between the Nintendo DS and the PSP and the PSP Slim, respectively. The phi[3] and phi[4] are the ϕ parameters between the Nintendo DS Lite and the PSP and the PSP Slim, respectively.

In Figure 6 we report the log of the ratio of the expected sales of Nintendo and

Sony given all possible combinations of these parameters, take two at a time, for the imitation and pre-commitment strategies. In the ratio Nintendo's expected sales is the numerator. This is a numerical intensive exercise in the sense that for each parameter combination we compute all possible combinations of launch-timings implied by each strategy and based on the outcome (in terms of their maximum cumulative sales) we compute the expected value for the sales of both players. In the graphs we report the log of the ratio of the expected maximum cumulative sales between the two firms. Note that we apply the log transformation to the final values because the log of the expected value is not the same as the expected value of the logs.

The graphs in Figure 6 provide a unifying message. Both strategies might yield high sales if a firm's products are superior (in terms of the ϕ) parameters or if a firm's ability to transfer users of old technologies to new ones is high (that is equivalent to a high alpha). If both ϕ parameters tend to be positive the ratio goes up and therefore Nintendo sells more relative to Sony. The ratio increases in a similar way when the alpha of Nintendo is higher. Earlier we concluded that the imitation strategy is the worst among the four strategies we evaluated for Sony. However, if Sony had superior products the imitation strategy may yield high sales, see how the log ratio goes up to -3 and -2 in the left-most and center upper panel graphs. This is evidence supporting Lemma 2. However, we can easily notice that despite the unifying message the surfaces have different slopes. That is, achieving higher sales by raising or decreasing each of the ϕ parameters does not yield the same increase/decrease in expected sales. We conducted the same sensitivity analysis for the random dates and the stochastic optimization strategies and the results are very similar.

The main lesson of this sensitivity analysis is that the outcome of any launch-timing strategy varies radically and it depends heavily on the competitive positioning of the firms' products and on the firms' ability to transfer users of their old technologies to the new ones.

8 Triopoly Case Study: The Video Game Console Race

In this section we present a different set of numerical sensitivity analyses and we will focus on the launch-timing of the Sony PlayStation 3 and the Nintendo Wii relative to their previous generations and relative to their competitors. In this section we focus on answering *what if* questions rather than studying the strategic interaction of firms, like in the previous subsection. We use the parameters estimates we obtained from our estimation routine to answer the *what if* questions and we assume a planning horizon $T_p = 150$ months. That is we assume 12.5 years as planning horizon and this is in line with a recent interview statement of the President of Sony Computer Entertainment in America, see Fast Company Blog (2009). In addition, we illustrate the sensitivity of the optimal launch-timing to different competitive and cannibalization parameters.

In Table 3 we reported the release dates of all major video game systems. It easy to notice that historically the phenomena of *a launch race* in a single year is relatively a recent experience for system manufacturers. This is interesting given that the number of systems manufacturers has stayed relatively constant since the early nineties. We observed for example that the Nintendo Wii was launched at the same time as the PlayStation 3 in North America three years ago. The GameCube and the Xbox were launched simultaneously in 2001. The other close to simultaneous launch cases occurred between the Wii and PS3 in Japan and between the Xbox and GameCube in Europe in 2006 and 2002, respectively. The average timing between releases is approximately five years (5.09 years), and the standard deviation of this average is almost one year (0.90 years), see Table 4. Hence, we believe that there is a need for insights about whether these launch-timing were chosen optimally or what could make them optimal.

The optimization situations that we consider next are much simpler than the optimization situations that we encounter in practice. They are simpler because of mainly two reasons. First, we do not consider the strategic interaction between firms as in previous section. Second, we do not consider price as part of the optimization problem because we focus on analyzing the launch-timing decision relative to different cannibalization and competitive settings. However, the timing decision can be considered as a sub-game of the price and timing game. That is, our analysis has no assumption regarding the price of the consoles and we focus on the effects of timing dates on the unit sales of the systems. This assumption is in line with similar studies to ours, see for example Joshi et al. (2009) and the work cited by (Souza et al., 2004, p. 538) regarding pricing assumptions. However, we do not consider this a very strong assumption in terms of our model estimation because of the cleaning procedure of our data. Nonetheless, if we had a reasonable assumption about the price for all six systems in our triopoly or duopoly model, and how the prices of all systems are strategically related to each other, then it is straightforward to introduce it in the optimization problem. Still, our results will be valid as price would possibly work as a discounting factor in the optimization problem. Of course, the effect of price on demand is not a straightforward introduction into our diffusion model and we consider this an area of further research.

8.1 Simulating *What If* Questions

The first *what if* question we answer is: What would be the maximum cumulative sales of the Nintendo and Sony if they would have launched their consoles at different dates and leaving everything else constant? That is, we answer how either the sum of the maximum of equation (12) and (13) for Sony and the sum of the maximum of equation (14) and (15) for Nintendo are maximized. In Figure 7 we plot the total sales of Nintendo (summing up the maximum cumulative sales of the Wii and the GameCube) achieved by launching at different dates. The maximum cumulative sales are reached when the Wii is launched at the month 64 (that is April 2005) and the GameCube at month 1 (January 2000). That is 5.33 years between their releases. The real release time between these two consoles was 5.01 years in North America, 5.22 years in Japan and 4.60 in Europe. The real launch dates happened at November 2006 (month 83 in the graph) and November 2001 (month 23 in the graph). Surprisingly, Nintendo is not launching that far from the optimal dates and according to this surface the difference of sales between real and optimal dates is $3,858.62$ thousand units ($66,431.66$ thousand units at the optimal and $62,573.04$ at their real launch dates). The story is different for Sony. In Figure 8 the maximum is reached when the PS2 is launched at month 1 (January 2000) and with the PS3 not launched. Note that setting the month of launch equal to the end of the planning horizon is equivalent to not launching. This is a radical scenario but it is explained by the fact that the PS2 is receiving sales from both the Xbox 360 and the Nintendo Wii according to our model estimates while the PS3 competitive parameters are not very favorable, see Table 11. The real launch dates of the PS2 and PS3 are the months 10 (October, 2000) and 84 (December, 2006), respectively. The total sales of Sony at these last pair of dates is 59.988 million units, in Figure 8 all the sales surface is graphed for all possible launch dates. We know that up to the first week of August 2009 the PS2 has sold 50.767 million units (source vgchartz.com). Hence according to our model the realized sales of PS3 will be around 9.22 (± 2.14) million units while up to date the Sony PS3 has sold 9.018 million units. The 2.14 million units is the average derivative of the surface at the real launch dates, the point $(10, 84)$ in Figure 8. Therefore, our model is not very optimistic about the PS3.

The next questions we answer are: what is the optimal launch time of the Nintendo Wii given the launch times of the Sony PS3? and what is the optimal time of the Sony PS3 given the launch times of the Wii? We can answer these questions by looking at Figure 9. In this figure we present two contour graphs (or heat maps). The lighter (yellow) areas represent higher total sales and the darker (red) areas represent lower sales. We call these graphs *sales reaction surfaces* because we can derive the best reaction function of either Nintendo or Sony given each other introduction timings. A *reaction function* maps any launch-timing of a firm to the best launch-timing of a second firm. We use the same definition of *reaction functions* as in Section 7. For example, in the left-hand graph we see that the maximum of Nintendo's sales is on month 73 given Sony launched its PS3 in month 1. From Table 11 we know that the PS3 and the Wii are not close competitors and not surprisingly the optimal launch date of the Wii given any introduction date of the PS3 remains close to the month 73 (January 2006) for any introduction timing of the PS3. What is surprising is that Nintendo launched 11 months later than its optimal timing. In the right-hand graph we see that the optimal launch dates of Sony are not very sensitive to those of the Nintendo Wii. For example, if the Wii were launched from month 1 up to the month 60 (that is from January 2000 up to December 2004) then the optimal month for the PS3 remains very close to the month 126 (June 2010). However, if the Wii is launched after the month 80 then the optimal action for Sony is to set the introduction date of the PS3 at month 150, the end of the planning horizon. Hence, the best strategy for Sony if the Wii is launched after month 80, is not to launch the PS3.

8.2 Sensitivity Analysis of the Optimal Launch-Timing

In the previous subsection we answered *what if* questions assuming our model parameter values are the ones resulting from the estimation routine. However, the optimal timing is sensitive to the parameter values and in this subsection we present how sensitive it is to different competitive and cannibalization settings.

First we present the sensitivity of the optimal launch date of the Sony PS3 to the competitive parameters that relate this console to the Xbox 360 and the Wii, the phi[6] and phi[12] respectively, for six different scenarios. In each of these scenarios we assume an early, a late, and an intermediate introduction timing of the Xbox 360 and the Wii. That is, we present three scenarios for each last generation console that competes against the PS3. Second, we present the sensitivity of the optimal launch date of the Sony PS3 given different cannibalization and competitive parameters using these same six possible scenarios. We present these results in Figure 10 and Figure 11 respectively.

In Figure 10 we present the scenarios for early (month 40), intermediate (month 84) and late (month 120) introduction timings of the Microsoft Xbox 360 at the upper graphs. In the graphs at the bottom we present the scenarios with the Nintendo Wii launched at the same set of introduction timings. For all six scenarios we leave all other introduction timings and parameters at their real or estimated values, respectively. Note that we only use the ϕ parameters that relate the three systems in our scenarios and set the others at their estimated values.

The first lesson we derive from Figure 10 is that the optimal timing of the PS3 depends on how it is competitively related to its two main competitors and not to only one of them. The second insight is that there is a parameter space for which it is better not to launch the PS3 (that is the flat top area in all graphs). Therefore, we can visualize the parameter space where Lemma 3 holds, these are the flat top *don't launch areas* in Figure 10. Hence, the *launch never* might be optimal depending on the competitive positioning of the PS3. Similarly, there is a parameter space for which there are earlier optimal introduction timings for the PS3. The third insight is that, the parameter space that is suitable for an earlier introduction gets reduced when the competing consoles are launched at later stages. See how the flat surface (the *don't launch area*) is larger for the center and right graphs relative to the left most graph. The fourth insight is that even when the competitive parameters are very favorable for the Sony PS3, its earliest optimal introduction timing happens at the month 60 (December 2004) and that would imply a 4.16 years difference between the PS2 and the PS3. That is, the *launch now* solution is not part of a very favorable set of parameter values. Note that this time difference between consoles is on the low side of the time between actual releases for all the major video game systems reported in Table 4.

This last result may point that the 4 year time between releases could be a good introduction pacing strategy when the product is superior relative to its competitors. Interestingly, the time between releases are in the low side for third and fourth generation consoles and they are in the high side for the the six and seventh generation systems. We do not have data on the earlier systems but our intuition is that the fourth generation consoles were superior to the third generation consoles and they were better positioned relative to its competitors. This may be the case, for example, of the Sega Genesis and the Sega Dreamcast launched 4.33 and 3.25 years after their previous generation, respectively. According to our discussions with some hard-core gamers that seems to have been the case indeed. In contrast, we have read in the press that the relative positioning of the Sony PS3 and the Xbox 360, for example, is not very strong relative to each other and this coincides both with longer time between releases diagnosed by our model and with the longer time between releases we document in Table 4 for the latest product generations.

In Figure 11 we present the sensitivity analysis of the optimal launch-timing of the PS3 to different cannibalization and competitive parameters, that is concerning the α and ϕ parameters. The upper graphs show the optimal timing of the PS3 for three scenarios of the launch-timing of the Xbox 360, similar as previous graphs. In the bottom graphs we present the scenarios with different introduction timings of the Nintendo Wii. The main difference between this and the previous figure is that one of the axis is now replaced by Sony's *alpha*. In the upper graphs we consider the cannibalization parameter of Sony and the ϕ parameter (phi[6]) that relates the Xbox 360 and the PS3. In the bottom graphs we use the same cannibalization parameter of Sony and the ϕ parameter that relates the Wii and the PS3, the phi[12]. The range we use for the α cannibalization goes from 0 up to 3. A higher number than 1 would imply that Sony is able to get more than one unit sale of the PS3 for each PS2 sold.

The first insight we derive from Figure 11 is that the optimal introduction timing of the PS3 depends on both the relative positioning to its competitors and to the cannibalization between Sony's generations. The second insight is that, as before, there is a parameter space for which it is optimal not to launch the PS3 (the top flat *don't launch areas*) and this space seems larger when competitors launch their consoles at late introduction dates. The third new insight is that the larger Sony's α is, the sooner it is optimal to introduce the PS3. If there is little cannibalization, for example for α values between 0 and 0.5, then it is optimal for Sony to set the launch-timing of the PS3 closer to the end of the planning horizon. For example, in the leftmost bottom graph the optimal timing for a low α values ranges between the month 100 (April 2008) and 129 (January 2010), when the phi[12] value is equal to 2. However, if the α value is larger (near 3 in the same graph) the optimal timing stabilizes at 81 (September 2006). The middle bottom graph corresponds to the scenario that considers the real introduction date for the Wii and in this graph the optimal timing stabilizes at month 65 (May 2005) when both the phi[12] and the α parameter are very favorable to Sony. The optimal timing stabilizes in all graphs around the month 64 (April 2005) and this month implies 4.5 years between releases. Therefore, the *launch now* strategy is not a result of very favorable competitive and *alpha* parameters. The real launch of the PS3 occurred in month 84 and this month is optimal only when the α is much larger than 1 and with a phi[12] approximately near 1. This may indicate that Sony's management might have been very optimistic about the PS3 when they chose that month, at least according to our model.

Finally, the last insight is that when there is no cannibalization the optimal timing of the PS3 is at time 0, that is the *launch now* strategy is covered only as a special case when there is no cannibalization between generations, (Lemma 1). In all the graphs of Figure 11 we can see that the *don't launch* area does not reach the $\alpha = 0$ and at this parameter value the optimal timing drops rapidly to the very start of the planning horizon. See the little empty space between the *don't launch area* and the back wall in all graphs. Visually, it is easier to detect how the surface drops to zero in the upper graphs.

To summarize, the *launch now* strategy results only when there is no cannibalization between a firm's product while the *launch never* strategy results when there are late product introductions by competitors, when a *firm's alpha* is very low, or when the competition is intense in terms of the ϕ parameters. In addition, we find that very favorable competitive and alpha parameters do not imply the *launch now* strategy as we discovered that the optimal launch-timing seems to reach a limit of 4 years between generations. Finally, we find that the higher a firm's ability to transfer its old technologies users to the new ones, the earlier it is optimal for it to introduce new generation products.

9 Conclusions and Discussion

In this paper we presented a new model that is helpful to analyze different launch-timing strategies and optimal introduction timings. It is straightforward to estimate the model parameters and to analyze different interesting competitive and *firms' alpha* scenarios. Our model is suitable to study settings where there are just a few market players or products and when there are some dominant *alpha* technologies in the market.

The insights we gained is that the *launch now or never* strategies may arise depending on the competitive parameters and the relationship between the products in the market. Specifically, the *launch now or never* strategies arise when there are late product introductions by competitors, when a *firm's alpha* is very low, or when competition is intense.

For the first time in the academic literature we provide some insights into the introduction strategy of the main players in the studied industry and we document their introductions since the late eighties. We find that the launch strategy of each 4 years seems appropriate when there is a better product positioning or very high *alphas*. That seemed to be the case at the early stages of the game systems industry while it is not any more so now.

According to our model, Nintendo launched the Wii at an appropriate moment while the Sony PS3 perhaps should have never been launched. Moreover, we find that different strategic interactions between firms lead to different sales levels and we argue that the strategy should be chosen relative to the firms' *alpha* and relative to the competitive setting that its products face. For example, the imitation strategy returns are higher for certain competitive parameters, specifically when the product is superior.

The managerial implications are clear. According to our insights the managers in industries with *alpha* technologies should pay not only attention to the competition but also to the ability of their firms to transfer users of old technologies to new ones. In our case study we pointed out that the outlook for PS3 is not very promising, it may reach maximum a 12 million unit sales according to our estimates. However, if Sony's managers work in new ways to increase Sony's *alpha* or its competitive positioning the outlook for the PS3 could improve.

The higher a firm's ability to transfer its old technologies users to the new ones, the earlier it is optimal for it to introduce new generation products. Think of the situation where the first generation product of a firm may face stiff competition after a point in time while its second generation is better equipped to fight against the new entrant. In this scenario, the best and perhaps the only surviving strategy would be to transfer its users of old technologies to the new ones as soon as possible and before competitive entry. We speculate then that the ability to survive in such market depends partially but heavily on the *firm's alphas*.

In our view, the technology markets mimic some of the competitive behavior of the *alpha* chimpanzees. The *alpha* rank for a chimpanzee means access to desirable foods, females or resting places while for companies the *alpha* rank means access to the users of their own old technologies. However, note that in the paper we assumed non-cooperative behavior between firms while it has been documented that *alpha males* in the chimpanzee society may form temporal alliances to overcome the current dominant *alpha male* (Nishida, 1983). This is a situation we do not study and that we may encounter in the future of the game systems markets. For example, the recent search alliance between Yahoo and Microsoft and the alliance between Toshiba and Sony regarding the blu-ray standard seem to be in line with the cooperative behavior of chimpanzees reported by Nishida (1983). On the other hand, the potential entrance of Apple and Microsoft in the portable gaming systems market points towards the arrival of more *alpha technologies* and hence perhaps more competition. Finally, we left out other aspects of the marketing mix that may prove important in the timing of new dominant technologies. We consider all these extensions interesting avenues for further research.

10 Tables and Figures

Firm	Portable System	North America	Japan	Europe
Nintendo	**DS Lite**	June 11, 2006	March 2, 2006	June 23, 2006
	DS	November 21, 2004	December 2, 2004	March 11, 2005
	GameBoy Advance SP	February 15, 2003	February 14, 2003	March 28, 2003
	GameBoy Advance	June 11, 2001	March 21, 2001	June 22, 2001
	GameBoy Color	November 19, 1998	October 21, 1998	November 23, 1998
	GameBoy	August 15, 1989	April 21, 1989	1990
Sony	**PSP Slim Lite**	September 5, 2007	September 13, 2007	September 5, 2007
	PSP	March 24, 2005	December 12, 2004	September 1, 2005

Source: VGchartz, Wikipedia & online press articles. Notes: We report the year of introduction when the exact date is not available.

Table 1: Release Dates of Portable Systems

Firm	Transition to/from	North America	Japan	Europe
Nintendo	**DS - DSLite**	1.55	1.25	1.28
	GBA SP - DS	1.77	1.80	1.96
	GBA - GBA SP	1.68	1.90	1.76
	GBC - GBA	2.56	2.42	2.58
	GB - GBC	9.27	9.51	–
Sony	**PSP Slim - PSP**	2.45	2.75	2.01

Table 2: Release Time Between Portable Systems (in Years)

Generation	Firm	Console	North America	Japan	Europe
7th generation	**Nintendo**	**Wii**	November 19, 2006	December 2, 2006	December 8, 2006
	Sony	**PlayStation 3**	November 17, 2006	November 11, 2006	March 23, 2007
	Microsoft	**Xbox 360**	November 22, 2005	December 10, 2005	December 2, 2005
6th generation	**Nintendo**	**GameCube**	November 18, 2001	September 14, 2001	May 3, 2002
	Sony	**PlayStation 2**	October 26, 2000	March 4, 2000	November 24, 2000
	Microsoft	**Xbox**	November 15, 2001	February 22, 2002	March 14, 2002
	Sega	**Dreamcast**	September 9, 1999	November 27, 1998	October 14, 1999
5th generation	**Nintendo**	**N64**	September 29, 1996	June 29, 1996	March 1, 1997
	Sony	**PlayStation**	September 9, 1995	December 3, 1994	September 29, 1995
	Sega	**Saturn**	May 11, 1995	November 22, 1994	July 8, 1995
	Atari	**Jaguar**	November 18, 1993	–	–
4th generation	**Nintendo**	**Super Nintendo**	August 13, 1991	November 21, 1990	April 11, 1992
	Sega	**Genesis**	September 15, 1989	October 29, 1988	November 30, 1990
3rd generation	**Nintendo**	**Nintendo**	October 18, 1985	July 15, 1983	–
	Sega	**Master System**	June 15, 1986	1985	1987

Source: VGChartz, Wikipedia & online press articles. Notes: We report the year of introduction when the exact date is not available.

Table 3: Release Dates of Major Video Game Consoles

Firm	Transition to/from	North America	Japan	Europe
Nintendo	**Wii - GameCube**	5.01	5.22	4.60
	GameCube -N64	5.14	5.21	5.18
	N64 - SNES	5.13	5.61	4.89
	SNES - Nintendo	5.82	7.36	–
Sony	**PS3 - PS2**	6.06	6.69	6.33
	PS2 - PS1	5.13	5.25	5.16
Microsoft	**Xbox 360 - Xbox**	4.02	3.80	3.72
Sega	**Dreamcast - Saturn**	4.33	4.02	4.27
	Saturn - Genesis	5.65	6.07	4.61
	Genesis - Master Sys	3.25	–	–

Table 4: Time Between Major VGC Releases (in years).

Video Game Console	m (thousand units)	p	q	Sample
Nintendo DS	**6799.3447****	**0.0140****	**0.1789****	**Nov 2004 - June 08**
	(1975.3660)	(0.0056)	(0.0543)	
Nintendo DS Lite	**27972.9479****	**0.0403****	**1.9922****	**June 2006 - Jan 2009**
	(1130.8544)	(0.0146)	(0.2999)	
PSP	**9717.9772****	**0.0109****	**0.1500****	**Mar 2005 - Sep 2007**
	(1525.7210)	(0.0026)	(0.0389)	
PSP Slim Lite	**7068.5424****	**0.0184***	**0.2449***	**Sep 2007 - Jan 2009**
	(2579.1973)	(0.0091)	(0.1168)	

Note: standard error in parentheses; *,** mean that the coefficient is significant with 95% and 99% confidence respectively

Table 5: Bass Model Estimates for Portable Systems

Video Game Console	m	p	q	Sample
Xbox	**16157.4500****	**0.0058****	**0.0993****	**Nov 2001 - Aug 2007**
	(699.5485)	(0.0009)	(0.0132)	
Xbox 360	**16312.2600****	**0.0054****	**0.1272****	**Nov 2005 - Jan 2009**
	(2826.5520)	(0.0012)	(0.0304)	
PlayStation2	**47847.1300****	**0.0037****	**0.0619****	**Oct 2000 - Jan 2009**
	(4520.1510)	(0.0007)	(0.0149)	
PlayStation3	**8190.0120****	**0.0075****	**0.1789****	**Nov 2006 - Jan 2009**
	(1173.5730)	(0.0014)	(0.0333)	
GameCube	**12716.7600****	**0.0058****	**0.0959****	**Nov 2001 - Apr 2008**
	(527.1293)	(0.0009)	(0.0142)	
Wii	**23353.9300****	**0.0063****	**0.1672****	**Nov 2006 - Jan 2009**
	(4673.3370)	(0.0014)	(0.0340)	

Note: standard error in parentheses; ** mean that coefficients are significant with 99% confidence.

Table 6: Bass Model Estimates for Video Game Consoles

System	Model Lags	% Network Effects
Nintendo GameCube	4	15.77%
Nintendo Wii	11	23.33%
Sony PlayStation2	–	–
Sony PlayStation3	5	2.28%
Microsoft Xbox	3	3.60%
Microsoft Xbox 360	7	6.69%
Nintendo DS	14	37.24%
Sony PSP	9	2.28%
All Systems	**7.57**	**13.03%**

Table 7: Video Game Effects on Game Systems

Coefficient	System	Estimate	s.e.	t-value
p	**DS**	**0.01189**	(0.0018)	6.56
	DS Lite	**0.03243**	(0.0040)	8.12
	PSP	**0.05556**	(0.0106)	5.25
	PSP Slim	**0.02843**	(0.0076)	3.74
q	**DS**	**0.07897**	(0.0406)	1.94
	DS Lite	**0.08174**	(0.0353)	2.31
	PSP	**-0.08717**	(0.0918)	-0.95
	PSP Slim	**0.12453**	(0.0358)	3.48
phis	**(1)**	**-0.57882**	(0.6478)	-0.89
	(2)	**-2.39516**	(1.9112)	-1.25
	(3)	**-0.41831**	(0.2109)	-1.98
	(4)	**0.66457**	(0.2196)	3.03
m	**DS**	**15991.8**	(530.0378)	30.17
	DS Lite	**10980.7**	(486.4696)	22.57
	PSP	**10498.0**	(169.4519)	61.95
	PSP Slim	**1012.0**	(205.1027)	4.93

Note: phis (1) is the substitution coefficient between DS and PSP, phi(2) between DS and PSP Slim, phi(3) between DS Lite and PSP, and phi(4) between DS Lite and PSP Slim; s.e. stands for standard error.

Table 8: Multi-Generation Model for Portable Systems

Coefficient	Console	Estimate	s.e.	t-value
p	**Microsoft**	**0.00943**	(0.0025)	3.79
	Sony	**0.00980**	(0.0011)	8.56
	Nintendo	**0.01156**	(0.0021)	5.63
q	**Microsoft**	**0.06115**	(0.0143)	4.27
	Sony	**0.03881**	(0.0051)	7.55
	Nintendo	**0.05381**	(0.0144)	3.74
phis	[1]	**-0.00512**	(0.2087)	-0.02
	[2]	**-0.07195**	(0.8990)	-0.08
	[3]	**0.02003**	(0.2270)	0.09
	[4]	**-2.39045**	(1.0587)	-2.26
	[5]	**-0.28843**	(0.1261)	-2.29
	[6]	**0.31218**	(0.8135)	0.38
	[7]	**0.62241**	(0.2734)	2.28
	[8]	**-0.20223**	(0.6419)	-0.32
	[9]	**0.11293**	(0.2238)	0.50
	[10]	**0.60116**	(0.1576)	3.81
	[11]	**-0.42376**	(0.5037)	-0.84
	[12]	**0.02402**	(0.9240)	0.03
m	**Xbox**	**19135.29**	(1132.2)	16.90
	Xbox 360	**813.10**	(1884.7)	0.43
	PS2	**41135.91**	(848.8)	48.46
	PS3	**987.54**	(6416.3)	0.15
	GameCube	**16382.92**	(1194.1)	13.72
	Wii	**17385.63**	(2029.2)	8.57

Notes: m is in thousand units

Table 9: Multi-Generation Model for Video Game Consoles (Microsoft $\alpha = 1$, Sony $\alpha = 1$, Nintendo $\alpha = 1$)

Coefficient	Console	Estimate	s.e.	t-value
p	**Microsoft**	**0.01220**	(0.0043)	2.82
	Sony	**0.01142**	(0.0021)	5.49
	Nintendo	**0.00809**	(0.0016)	5.06
q	**Microsoft**	**0.05423**	(0.0201)	2.69
	Sony	**0.03216**	(0.0078)	4.13
	Nintendo	**0.06670**	(0.0151)	4.43
phis	[**1**]	**-0.09294**	(0.2166)	-0.43
	[**2**]	**-2.13156**	(1.5318)	-1.39
	[**3**]	**0.04654**	(0.2377)	0.20
	[**4**]	**-3.08154**	(1.6084)	-1.92
	[**5**]	**0.13089**	(0.1357)	0.96
	[**6**]	**0.40535**	(0.5606)	0.72
	[**7**]	**0.90676**	(0.2681)	3.38
	[**8**]	**0.37551**	(0.5191)	0.72
	[**9**]	**0.09675**	(0.2246)	0.43
	[**10**]	**0.43943**	(0.2651)	1.66
	[**11**]	**0.36342**	(0.7003)	0.52
	[**12**]	**0.15694**	(1.0118)	0.16
m	**Xbox**	**18908.97**	(1346.3)	14.05
	Xbox 360	**2685.35**	(874.9)	3.07
	PS2	**40409.41**	(1002.8)	40.30
	PS3	**2117.23**	(1142.5)	1.85
	GameCube	**17665.16**	(1570.8)	11.25
	Wii	**16224.15**	(2706.9)	5.99

Notes: m is in thousand units

Table 10: Multi-Generation Model for Video Game Consoles (Microsoft $\alpha = 0.3$, Sony $\alpha = 0.1$, Nintendo $\alpha = 1.1$)

	Xbox	**X360**	**PS2**	**PS3**	**GC**	**Wii**
Xbox	x	-1	[1]	[2]	[3]	[4]
X360	1	x	[5]	[6]	[7]	[8]
PS2	-[1]	-[5]	x	-1	[9]	[10]
PS3	-[2]	-[6]	1	x	[11]	[12]
GC	-[3]	-[7]	-[9]	-[11]	x	-1
Wii	-[4]	-[8]	-[10]	-[12]	1	x
Xbox	x	-1	-0.01	-0.07	0.02	**-2.39**
X360	1	x	**-0.29**	0.31	**0.62**	-0.20
PS2	0.01	**0.29**	x	-1	0.11	**0.60**
PS3	0.07	-0.31	1	x	-0.42	0.02
GC	-0.02	**-0.62**	-0.11	0.42	x	-1
Wii	**2.39**	0.20	**-0.60**	-0.02	1	x

Notes: the numbers between brackets represent the phi coefficients of the multi-generation model reported in table 9. The bold coefficients have t-values greater than 1.

Table 11: Competitive Parameters

Strategy	Player / Quantile	1%	5%	10%	50%	90%	95%	99%
[1] Random Selection of Dates	**Nintendo**	1681.4	6538.5	10933.5	26369.6	39146.8	42941.3	48084.3
	Sony	1550.5	2528.4	3890.3	10398.8	19962.5	23481.8	29284.3
	Total	13833.1	21187.1	26621.7	45590.7	57653.5	59676.6	62545.3
[2] Pre-commitment / Imitation	**Nintendo**	3769.5	9998.8	13288.1	28553.4	37470.9	39509.4	41273.4
	Sony	724.0	1431.3	2383.7	9415.3	18372.8	19513.3	20362.9
	Total	7324.8	15961.7	19174.6	38146.2	54316.4	57663.5	60415.2
[3] Pre-commitment / Optimization*	**Nintendo**	1543.9	4696.4	8540.6	28837.4	35805.5	36944.6	38842.0
	Sony	13890.7	15387.0	16973.4	21908.2	31948.0	33108.3	34149.6
	Total	17887.0	25253.3	30900.2	52132.8	60307.6	62785.7	65845.1
[5] Uncertain Launch Dates / Optimization**	**Nintendo**	1548.9	3834.1	6769.8	28615.2	36868.9	38215.9	39742.1
	Sony	13285.2	13873.2	14441.2	20579.3	30961.4	31846.6	32695.6
	Total	17335.7	24765.2	30434.0	48845.5	59968.6	62956.7	66081.8

Notes: * Nintendo pre-commits to a date while Sony optimizes its launch dates given Nintendo pre-commitment dates.** Nintendo does not pre-commits to any date and Sony optimize given the probability that Nintendo launch at any date.

Table 12: Evaluation of Four Launch Strategies

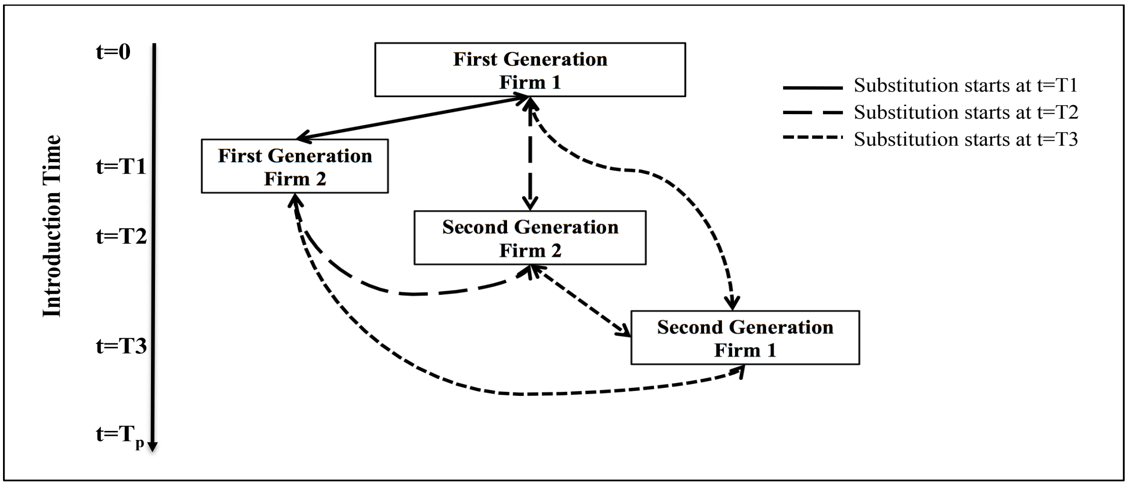

Figure 1: Interaction Between All Product Generations in Duopoly Model

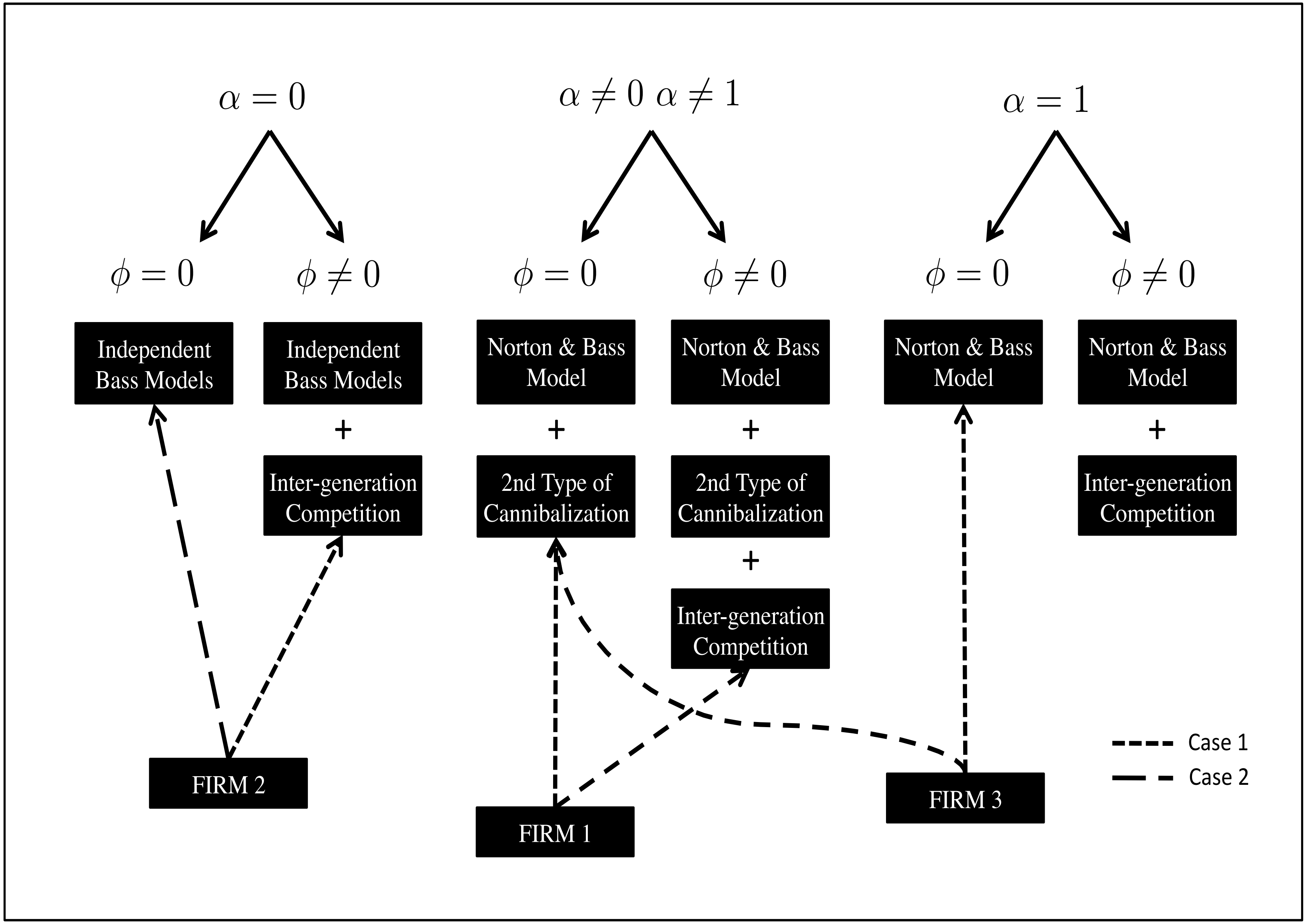

Figure 2: Model Relationship with Previous Research

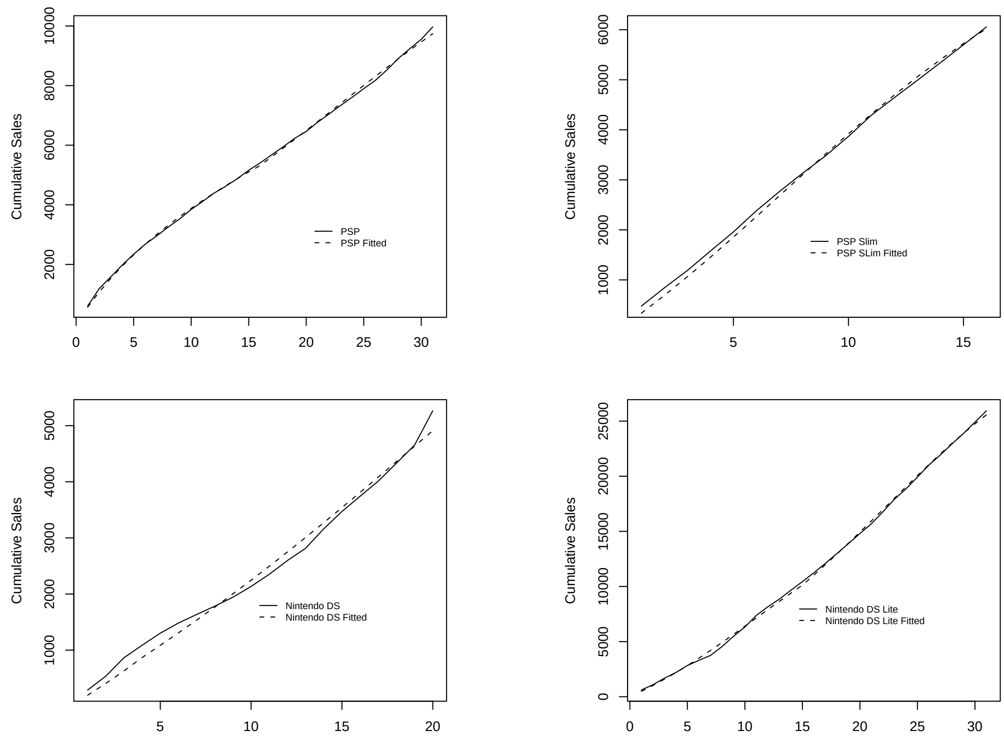

Figure 3: Multi-Generation Model Fit for Portable Systems

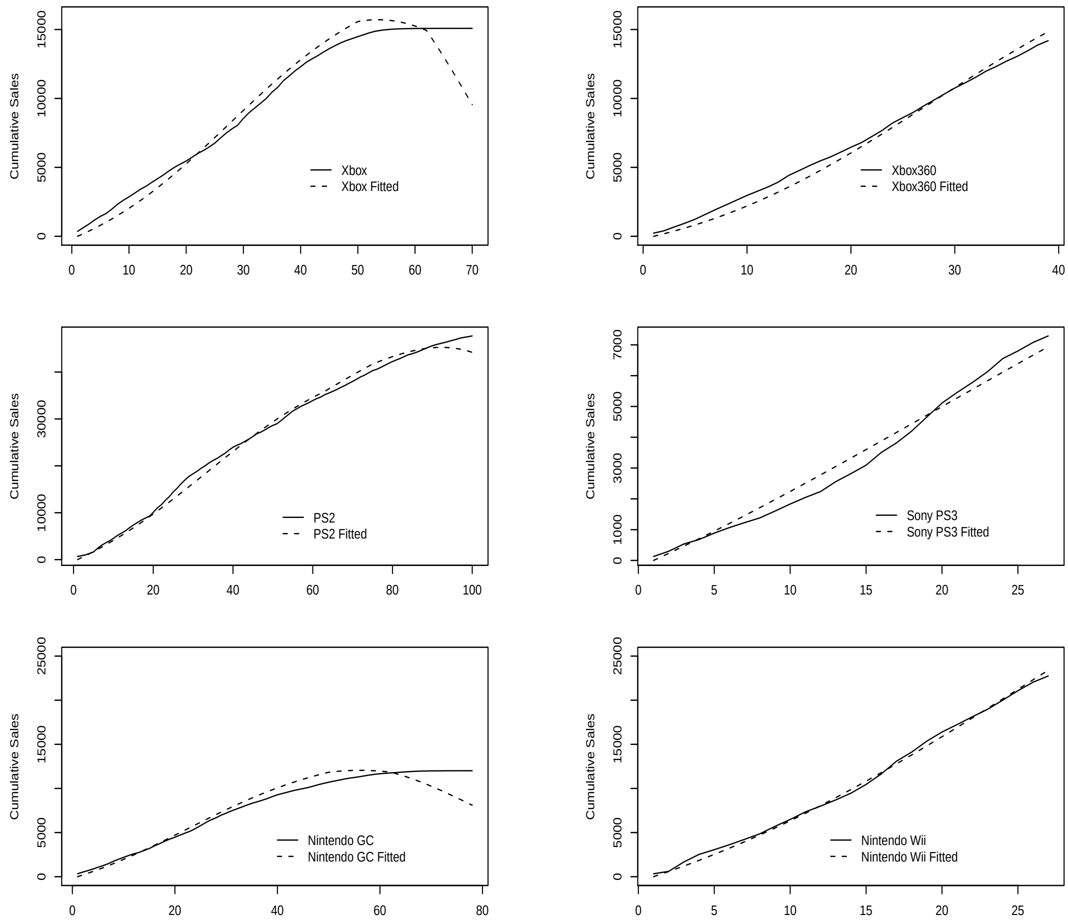

Figure 4: Multi-Generation Model Fit for Video Game Consoles

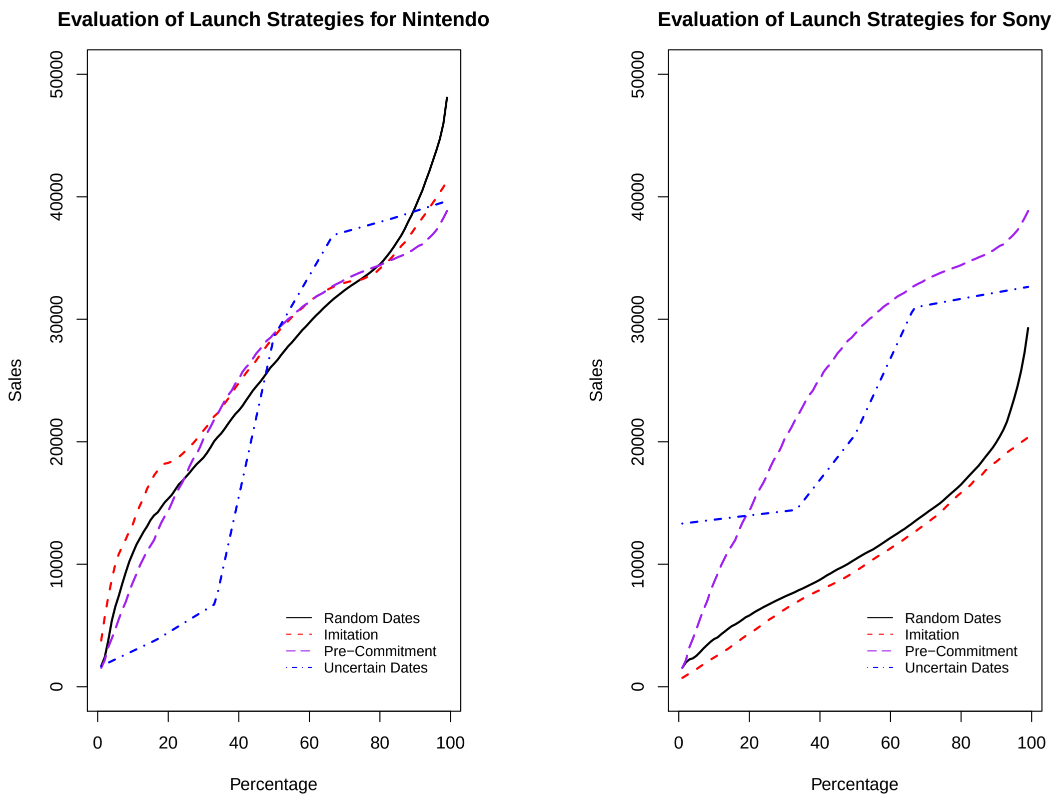

Figure 5: Cumulative Distribution Function of Sales given Different Strategies

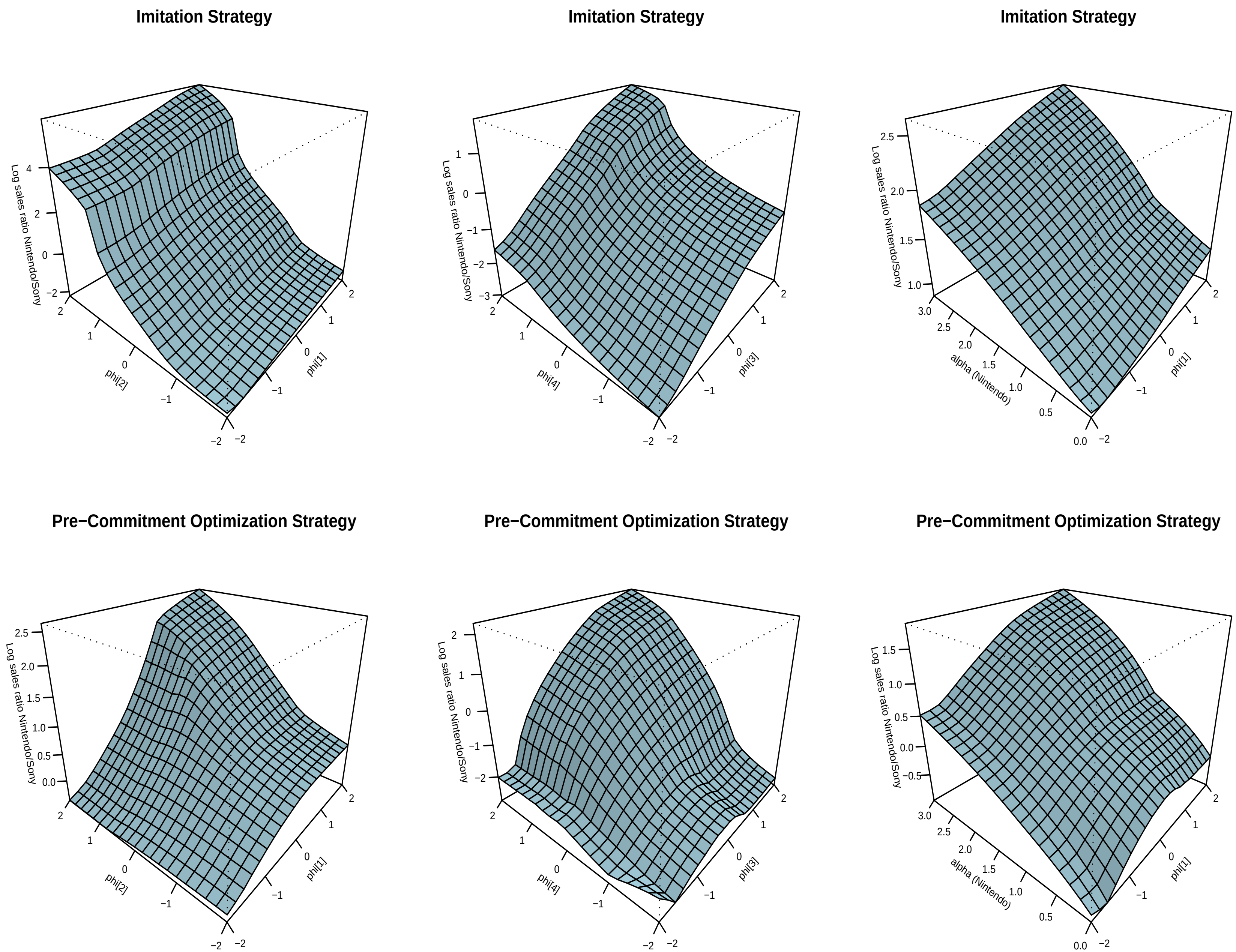

Figure 6: Strategy Sales Sensitivity to Competitive Parameters

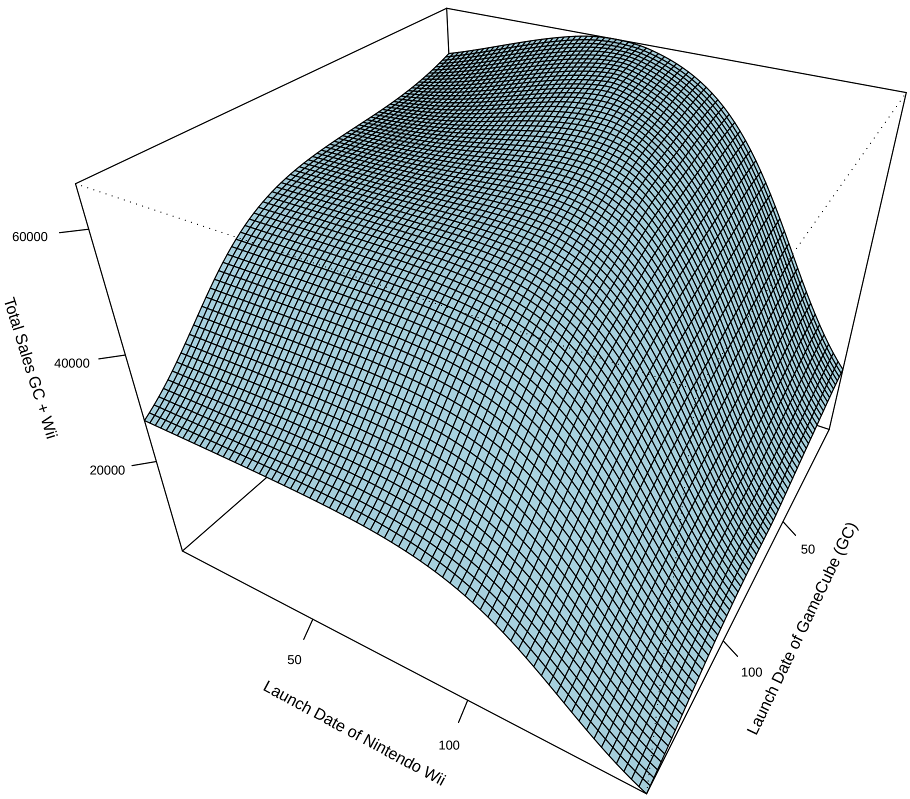

Figure 7: What if Scenarios for the Consoles of Nintendo

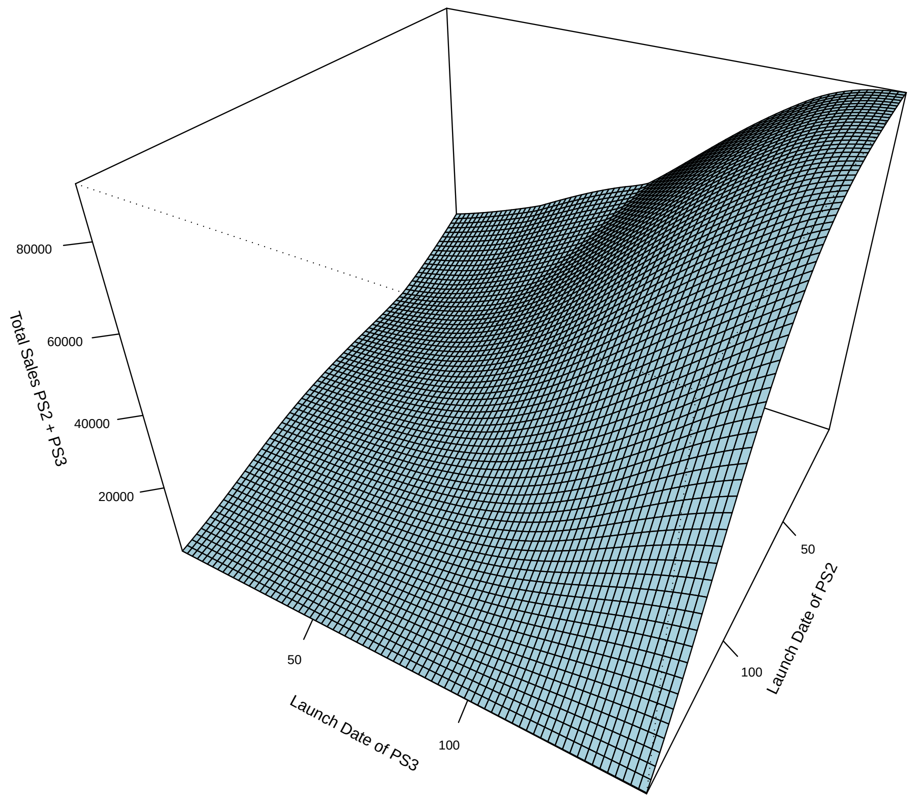

Figure 8: What If Scenarios for the Consoles of Sony

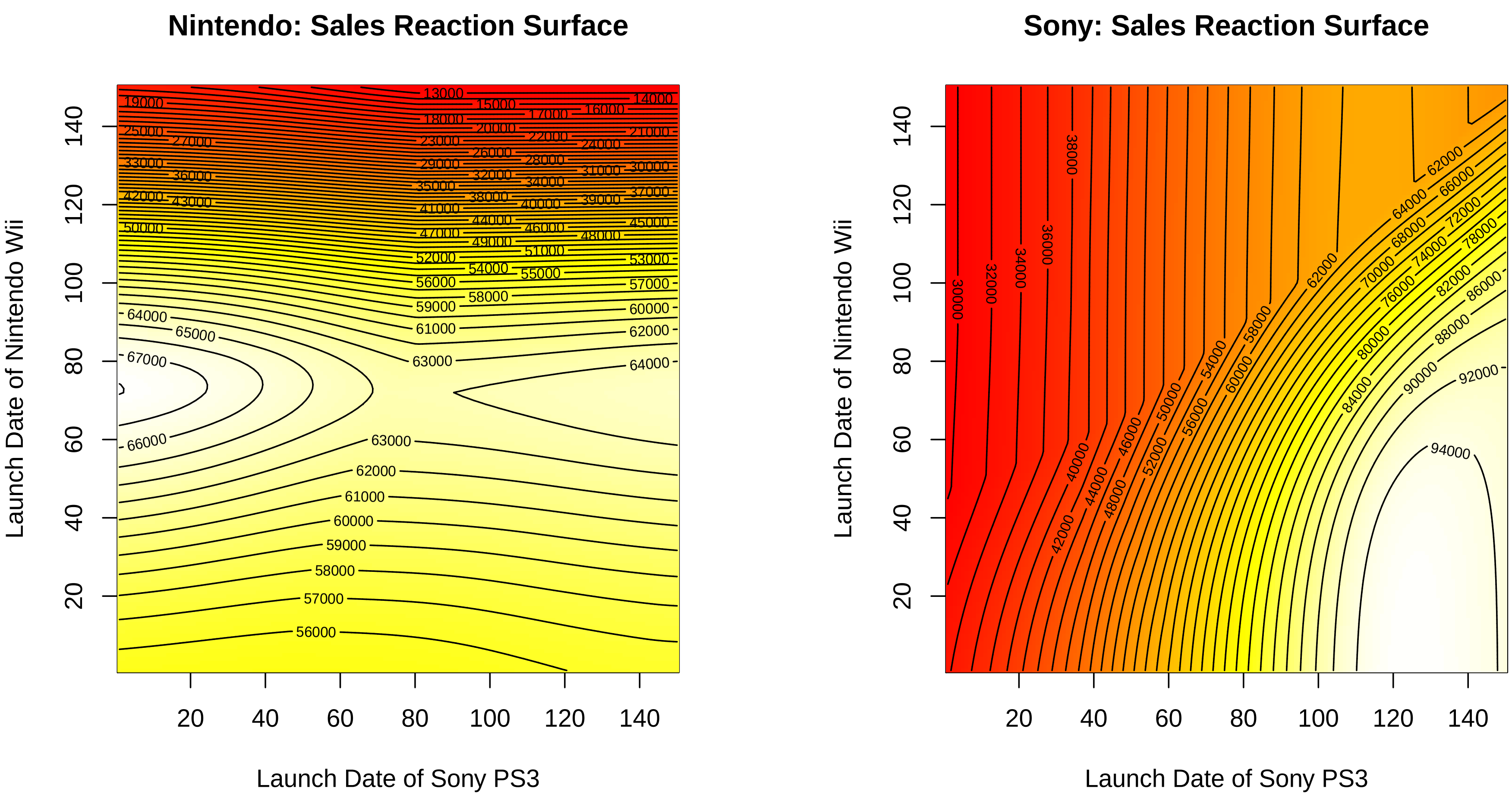

Figure 9: Sensitivity to Launch-Timing and Sales Reaction Surfaces

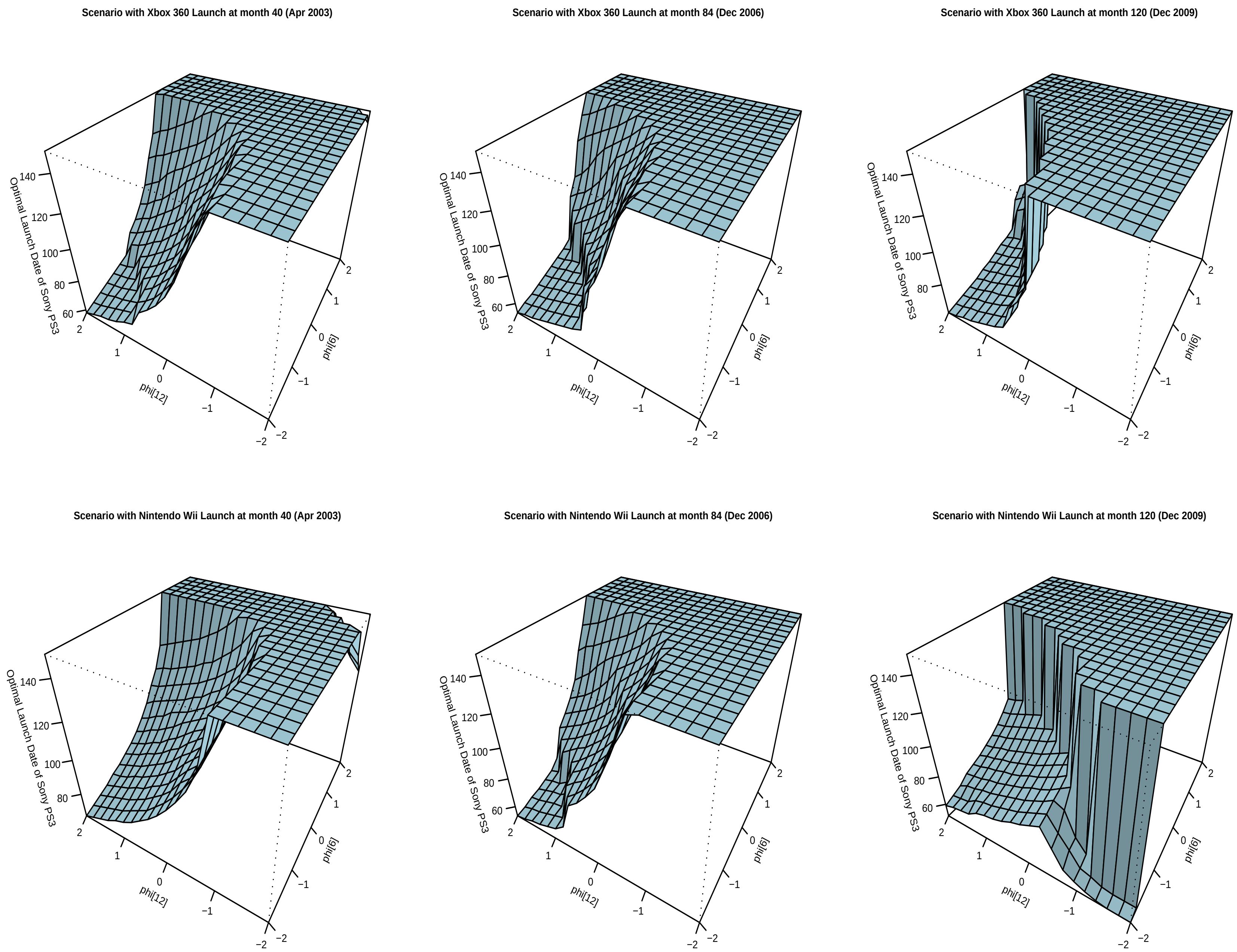

Figure 10: Sony PS3 Optimal Launch-Timing Sensitivity to Competitive Parameters

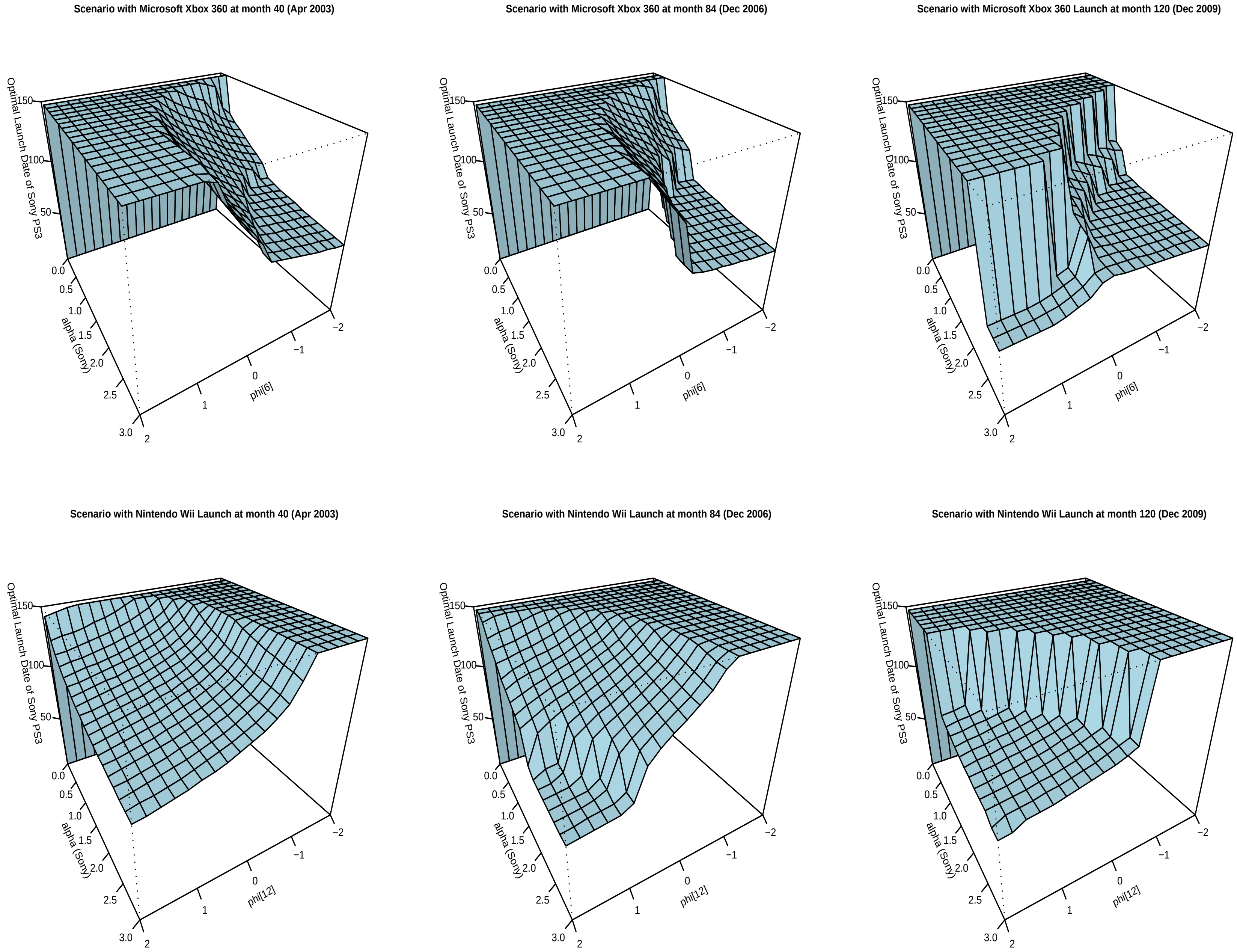

Figure 11: Sony PS3 Optimal Launch-Timing Sensitivity to Cannibalization and Competitive Parameters

A Strategy Evaluation

In this section we provide the details of each of the four strategies we use in our application.

A.1 Random Date Selection

In this strategy firm 1 selects τ_1^1 and τ_2^1 randomly and firm 2 selects τ_1^2 and τ_2^2 in the same way. We discretize the planning horizon in T_p periods. Hence the possible launch dates τ_i^g (where i stands for firm i while g stands for the system generation) might be at any t within $t = 1, \ldots, T_p$; we denote the length of the planning horizon p. We consider a 90 month planning horizon that is 7.5 years. This time frame is long enough given the average life-cycle of the portable systems is 2.5 years. With this planning horizon we evaluate the maximum of the cumulative sales for each system of both firms given all the feasible launch dates τ_i^g for $i = 1, 2$ and $g = 1, 2$. That is, firm 1 might select one out of the p^2 possible launch-timings but we restrict the combinations to the set where $\tau_i^2 \geq \tau_i^1$. This means that we restrict that the second generation product for both firms is launched at a date either at the same time or after the first generation. The feasible set reduces from p^2 to $(p+1) \times p/2$ feasible combinations for each player. Note that we use $T_p = 90$ and we set $p = 45$. In the duopoly case $i = 1$ refers to Nintendo and $i = 2$ refers to Sony.

We evaluate equations (3) to (6) with the feasible set of launch-timing and we compute the maximum cumulative sales achieved by each product generation for both firms. That is we compute $\max(S_g^{Sony}(\tau_1^{Sony}, \tau_2^{Sony} | \tau_1^{Nin}, \tau_2^{Nin}))$ for $g = 1, 2$ and $\max(S_g^{Nin}(\tau_1^{Nin}, \tau_2^{Nin} | \tau_1^{Sony}, \tau_2^{Sony}))$ for $g = 1, 2$. The $g = 1$ product of Sony is the Sony PSP and the $g = 2$ product of Sony is PSP Slim; for Nintendo the $g = 1$ product is the DS and the $g = 2$ product is the DS Lite. In table 12 we report the quantiles of the total sales of Sony achieved by this strategy, that is $\sum_g \max(S_g^{Sony}(\tau_1^{Sony}, \tau_2^{Sony} | \tau_1^{Nin}, \tau_2^{Nin}))$ and $\sum_g \max(S_g^{Nin}(\tau_1^{Nin}, \tau_2^{Nin} | \tau_1^{Sony}, \tau_2^{Sony}))$ and the total sales of both players (the sum of the last two terms).

A.2 Imitation

In this strategy firm 1 pre-commits to a launch-timing for its two product generations while firm 2 imitates the launch-timing of firm 1. That is, both firms launch at the same time each of their product generations. In our application we set Nintendo the be the firm that pre-commits to a certain launch date and Sony to be the firm that imitates. We assume that Nintendo pre-commits to a randomly chosen pair of dates τ_1^{Nin} and τ_2^{Nin} and Sony sets $\tau_1^{Sony} = \tau_1^{Nin}$ and $\tau_2^{Sony} = \tau_2^{Nin}$. In this strategy we assume Nintendo ignores that Sony will imitate and we do not assume Nintendo might pre-commit strategically to the best pair of dates. However, it is straightforward to identify the best pre-commitment dates of Nintendo given Sony is imitating.

A.3 Pre-commitment and Optimization

In this strategy firm 1 pre-commits to a launch-timing for its two product generations while firm 2 optimizes its launch-timings given the launch dates of firm 1. As before, we set Nintendo the be the firm that pre-commits to a certain launch date and Sony to be the firm that optimizes. We assume that Nintendo pre-commits to a randomly chosen pair of dates τ_1^{Nin} and τ_2^{Nin} and Sony sets τ_1^{Sony} and τ_2^{Sony} such that $\sum_g \max(S_g^{Sony}(\tau_1^{Sony}, \tau_2^{Sony} | \tau_1^{Nin}, \tau_2^{Nin}))$ is maximized. In this strategy we assume Nintendo ignores that Sony will optimize and we do not assume Nintendo might pre-commit strategically to the best pair of dates. However, it is straightforward to identify the equilibrium if both firms are optimizing. Finally, we note that pre-commitment and perfect foresight are usual assumptions in the literature, for examples see Reinganum (1981) and Bayus et al. (1997).

A.4 Uncertain Launch Dates and Stochastic Optimization

In this strategy firm 1 selects a pair of launch dates for its two generation products but does not reveal these dates to firm 2. However, we assume firm 2 can derive the best response of firm 1 given any pair of dates assigned by firm 2 to its own products. That is, firm 2 has knowledge on the reaction function of firm 1 however firm 2 does not know which date launch will be picked for certain by firm 1. The reaction function is a function that maps any launch-timing of firm 2 to the best launch-timing of firm 1. In our application, the best reaction function of Nintendo

$$f(\tau_1^{Sony}, \tau_2^{Sony}) = \Omega\left(\max_{\tau_1^{Nin}, \tau_2^{Nin}} (\sum_g S_g^{Nin}(\tau_1^{Nin}, \tau_2^{Nin} | \tau_1^{Sony}, \tau_2^{Sony}))\right) \tag{23}$$

$\Omega()$ returns a pair of dates τ_1^{Nin} and τ_2^{Nin} that maximize the sales of Nintendo given the launch dates of Sony (τ_1^{Sony} and τ_2^{Sony}). We further assume that firm 2 assigns a probability that firm 1 will launch on dates τ_1^1 and τ_2^1 proportional to the sales achieved by selecting these two dates. That is,

$$p(\tau_1^{Nin}, \tau_2^{Nin}) = \frac{\sum_g \max(S_g^{Nin}(\tau_1^{Nin}, \tau_2^{Nin} | \tau_1^{Sony}, \tau_2^{Sony}))}{\sum_{(\tau_1^{Nin}, \tau_2^{Nin}) \in f(\tau_1^{Sony}, \tau_2^{Sony})} \sum_g \max(S_g^{Nin}(\tau_1^{Nin}, \tau_2^{Nin} | \tau_1^{Sony}, \tau_2^{Sony}))} \tag{24}$$

Note that τ_1^1 and τ_2^1 should belong to the set of dates given by the reaction function of firm 1 and that is why they should be contained in the reaction function $f(\tau_1^{Sony}, \tau_2^{Sony})$; otherwise the strategy is not considered. Given these assumptions the strategy of firm 2 is to select the pair of launch dates that maximize its expected sales. The best reaction function of Sony is

$$f(\tau_1^{Nin}, \tau_2^{Nin}) = \Omega\left(\max_{\tau_1^{Sony}, \tau_2^{Sony}} (\sum_g S_g^{Sony}(\tau_1^{Sony}, \tau_2^{Sony} | \tau_1^{Nin}, \tau_2^{Nin}))\right) \tag{25}$$

and hence Sony selects τ_1^{Sony} and τ_2^{Sony} such that

$$p(\tau_1^{Nin}, \tau_2^{Nin}) \times \sum_g \max(S_g^{Sony}(\tau_1^{Sony}, \tau_2^{Sony} | \tau_1^{Nin}, \tau_2^{Nin}))_{(\tau_1^{Sony}, \tau_2^{Sony}) \in f(\tau_1^{Nin}, \tau_2^{Nin})} \tag{26}$$

is maximized.

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