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# Essays on the Empirical Analysis of U.S. Home Video Game Market

A Dissertation Presented

by

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The Graduate School

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Abstract of the Dissertation

**Essays on the Empirical Analysis of U.S.  
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in

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This dissertation focuses on the empirical analysis of U.S. home video game market and contains three essays.

The first essay investigates one aspect of competition among the console manufacturers. SONY launched its latest PlayStation 3 game console in 2006 and integrated Blue-ray DVD playback function in it. This feature is believed to contribute to PlayStation 3's high price and weak sales performance. At the same time, differentiations in hardware attributes among the latest-generation consoles also contribute to consoles' different prices and therefore their different sales performances. In this essay, I present a structural model to quantify the effect of Blue-ray DVD as well as the effect of product differentiation on console manufacturers' profitability. The estimation and simulation results show that (1) consumers

are willing to pay an extra premium to SONY's Blue-ray DVD function, but they are also sensitive to console prices; (2) Blue-ray DVD function adds significant costs to PlayStation 3; (3) in terms of profitability to SONY, the value of Blue-ray DVD is mostly offset by its added costs; (4) PlayStation 3's weak sales performance is partially caused by the competition from the same-generation, less-advanced but low-priced competitors.

The second essay studies the complementary good side in the U.S. video game market. The central question it studies is that whether exclusive game titles have higher sales than non-exclusive game titles. This question is important for us to better understand the incentives for both platform (game consoles) and complements (video games) to adopt strategies about exclusion, multi-homing, and vertical integration. I use a unique and rich dataset to compare the sales number of exclusive and non-exclusive video game titles sold in U.S. between Nov. 2006 to Dec. 2008. I also adopt various approaches to deal with possible selection biases in the estimation caused by unobservable product characteristics and potential game developer selections into platforms. The estimation results show that exclusive titles do have higher sales per platform after controlling various observed and unobserved game attributes. And further analysis show that such premium on exclusivity has different implications in terms of platform location choice for top-selling and average-selling game titles, respectively. This is mainly due to the presence of "porting" costs for non-exclusive titles.

In the third essay, using the data set of home video game console sales in U.S. between 2005 and 2008, we estimate the demand for game consoles using a regression discontinuity design (RDD) method. Our method exploits a unique feature of the price changes in the industry during our sample period, i.e. prices are cut periodically but remain generally unchanged between the two consecutive cuts. This discontinuity in the price changes allows us to obtain

a reliable estimate of the effect of the prices on consumers console demand semiparametrically and without using instrumental variables. We find that consumers demand for video consoles is elastic, and the elasticities are between -1.11 and -5.40. In addition, we compare our results to other's using the standard IV approach, and find that our estimated elasticities are similar to the existing works.

To my wife and my parents.

# Contents

List of Figures	ix
List of Tables	x
Acknowledgements	xii
<b>1 Product Differentiation and Competition</b>	<b>1</b>
1.1 Introduction . . . . .	1
1.2 Related Literature . . . . .	4
1.3 The Home Video Game Console Industry . . . . .	6
1.4 The Model . . . . .	9
1.4.1 Demand for Consoles . . . . .	9
1.4.2 Game Provision . . . . .	11
1.4.3 Supply of Consoles . . . . .	11
1.5 Data . . . . .	15
1.6 Identification and Estimation . . . . .	16
1.6.1 Identification . . . . .	16
1.6.2 Estimation . . . . .	18
1.6.3 Estimation Results . . . . .	20
1.7 Counterfactual Analysis . . . . .	25
1.7.1 Value of Blue-ray DVD . . . . .	25
1.7.2 Effects of Product Differentiation . . . . .	27
1.8 Conclusion . . . . .	29



<b>2</b>	<b>Exclusive Title and Platform Sales</b>	<b>31</b>
2.1	Introduction . . . . .	31
2.2	Related Literature . . . . .	34
2.3	Home Video Game Market . . . . .	34
2.4	Data . . . . .	35
2.5	Results . . . . .	37
2.5.1	Sales of Exclusive and Non-exclusive Titles . . . . .	37
2.5.2	Selection . . . . .	39
2.5.3	Selection of Game Publishers . . . . .	41
2.6	Discussion of the Results . . . . .	44
<b>3</b>	<b>RDD Method in Estimation Demand</b>	<b>46</b>
3.1	Introduction . . . . .	46
3.2	The Market Background and Data . . . . .	49
3.3	Model and Estimation . . . . .	52
3.3.1	Model of Demand for Video Game Consoles . . . . .	52
3.3.2	IV Estimation . . . . .	54
3.3.3	Regression Discontinuity Design Method . . . . .	55
3.4	Estimation Result . . . . .	58
3.5	Conclusion . . . . .	62
	<b>Bibliography</b>	<b>66</b>

# List of Figures

- 1.1 Desktop Market . . . . . 8
- 3.1 Market Share and Price Trend . . . . . 56

# List of Tables

1.1	Major Desktop Console Characteristics . . . . .	7
1.2	Descriptive Statistics of the Sample . . . . .	16
1.3	Parameters in Mean Utility Function . . . . .	21
1.4	Parameters for Random Coefficients . . . . .	22
1.5	Parameters for Software Provision Equation . . . . .	23
1.6	Parameters for Marginal Cost Function . . . . .	23
1.7	Average Own- and Cross-Price Elasticities of Desktop Consoles	24
1.8	Changes in Prices and Sales of Desktop Consoles (Since 2006.11)	26
1.9	Changes in Variable Profits of Console Manufacturers (Since 2006.11) . . . . .	26
1.10	Changes in Prices and Sales of Desktop Consoles without PS2 (Since 2006.11) . . . . .	27
1.11	Changes in Variable Profits of Console Manufacturers without PS2(Since 2006.11) . . . . .	28
2.1	Descriptive Statistics . . . . .	36
2.2	Sample Properties Comparison . . . . .	37
2.3	Effects of Exclusivity on Sales . . . . .	38
2.4	Effects of Exclusivity on Sales: Unobserved Characteristics . .	41
2.5	Effects of Exclusivity on Sales: First- and Third-party Exclusive Titles . . . . .	43
2.6	Effects of Exclusivity on Sales: Developer Fixed Effect . . . .	44
3.1	Overview of Home Video Game Console Market . . . . .	51
3.2	Specification of Selected Consoles . . . . .	51

3.3	Estimation Result . . . . .	59
3.4	Implied Own Price Elasticity of Demand . . . . .	61

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Chapter 3 of this dissertation is a reprint of the materials as it appears in “Demand for Video Game Consoles: A Regression Discontinuity Design Approach”, co-authored with Professor Wei Tan.

# Chapter 1

## Blue-ray DVD, Product Differentiation and Competition in the Video Game Console Market

### 1.1 Introduction

The home video game console market has long been a perfect example of indirect network effect, whereby the consumer valuation of the primary product (consoles) increases with the size of a complementary good market (video games), and consoles themselves do not have any value apart from facilitating the use of compatible games. Therefore, for decades, consoles compete to win over consumers mainly through the variety of compatible game titles (Clements and Ohashi, 2005). Between 2005 to 2006, the console manufacturers launched their latest, so-called 7th-generation consoles. Among them, SONY integrated Blue-ray DVD<sup>1</sup> playback function into its PlayStation 3 console. This unique feature makes PlayStation 3 the first console ever that has practical functions besides playing video games. On the other hand, PlaySta-

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<sup>1</sup>Blue-ray DVD is a format of “high-definition” DVD which means that the format should support up to 1920×1080 resolution (compared to standard DVD’s 720 × 480), and 8 channels of sounds (compared to standard DVD’s 6 channels).

tion 3 is much more expensive than its same-generation competitors, and it was widely believed by the public due to the costs of its Blue-ray DVD function. In addition, PlayStation 3 has been outsold in every month since it was launched, and such weak sales performance incurred much debate and analysis among video game fans and mass media about the worthiness of SONY's decision of integrating Blue-ray DVD function.

Traditionally, video game consoles did not carry any unnecessary function for several reasons. First of all, video game consoles have much longer life cycles compared to other home electronic products, such as PC<sup>2</sup>. Therefore, console manufacturers usually adopt the most advanced but also expensive technology so that consoles can meet rapidly increasing computational demand from gaming industry in the future of their life cycles. At the same time, console manufacturers often use penetrating pricing for their products (Shapiro and Varian, 1999), whereby they offer low introductory prices in order to quickly build up the installed base in consumers, which will lead to more software provision and, in return, a higher willingness to pay later in the product cycle. As a result, console manufacturers usually remove any unnecessary function in order to keep the production cost, especially the initial production cost, at a low level to allow them to sell consoles in large quantities quickly at a lower price. However, extra "unnecessary" but appealing functions, such as SONY's Blue-ray DVD, can indeed attract "marginal" customers and therefore boost consoles sales, even if such functions may add additional costs to the consoles. For example, a casual game player might choose to purchase PlayStation 3 over other consoles because he or she wants to watch Blue-ray DVD movies and does not want to buy the player separately.

At the same time, the product structure in the console market also gives ambiguous indications. First, SONY is the only manufacturer that is able to keep two desktop consoles, PlayStation 3 and the less advanced, last-generation PlayStation 2<sup>3</sup>. Such advantage potentially allows SONY to market PlaySta-

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<sup>2</sup>For example, the major components (like CPU and GPU) and structure design of consoles are updated, on average, every 5 to 7 years, compared to 1 to 2 years in PC industry.

<sup>3</sup>SONY is the only manufacturer that makes major parts of its consoles, such as CPU and GPU, by its own. In contrast, Microsoft, for example, sources the design and production

tion 3 as the high-end product while keeping its low-price PlayStation 2 on the market aiming at the price-sensitive consumers. Second, in contrast to the previous generations, prices and hardware specifications vary significantly among the latest-generation consoles. For example, Nintendo's latest console, Wii, is much less advanced in terms of hardware capability, but it is also priced as half expensive as PlayStation 3. Therefore, PlayStation 3's advanced hardware design, which leads to higher price even if without the Blue-ray DVD function, could be another reason for its weak sales performances.

In this paper, I empirically separate and quantify the effects of Blue-ray DVD function and the effect of the product differentiation on SONY and other console manufactures' profitability. My empirical strategy includes two steps. First, a structural model of console demand and supply is set up and estimated using market and individual level data to obtain parameters in the consumers utility function and manufacturers's cost functions. Consumer demand for consoles is modeled using the random coefficient discrete choice model by Berry, Levinsohn, and Pakes (1995) (henceforth BLP). In the consumer's utility function, I explicitly incorporate the measure of game availability, which accounts for the indirect network effect of compatible games on console demand. Therefore, consumers derive utilities not only from console's attributes, but also from the size of compatible games. As the network effect is mutual, the effect of console sales on game provision is modeled by a reduced-form supply function derived from the free-entry equilibrium in the video game industry. In the supply side, each console manufacturer takes into account the own and cross price effects as well as the indirect network effects on the profits, and sets prices according to the Bertrand-Nash equilibrium. Second, using the parameters estimated from the empirical model, I conduct the counterfactual analysis in two scenarios. In the first scenario, I artificially drop the Blue-ray DVD function from PlayStation 3 and recalculate market equilibrium. It allows me to assess the direct effect of such function on the SONY and its competitors' profitability. In the second scenario, I drop the older PlayStation 2 from

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of its CPU to Intel, while Nintendo sources it to IBM. Therefore, the supply of Microsoft and Nintendo's consoles is constrained by the capacity of upstream firm, i.e. Intel and IBM, whose priority in business is PC industry. Therefore, neither Microsoft nor Nintendo has enough capacity to support two consoles.



SONY's product line after the introduction of PlayStation 3 and recalculate the market equilibrium. In this scenario, I allow manufacturers to compete with each other only with their latest-generation consoles so that I can assess the effects of product differentiation among the latest-generation consoles on manufacturers' profitability.

The estimation shows that consumers are willing to pay extra premium to SONY's Blue-ray DVD function, but at the same time, such function adds significant costs to the system. Counterfactual analysis shows that, in terms of profitability to SONY, the attractiveness of such feature to consumers is largely offset by its own extra cost. In addition, PlayStation 2 is vital for SONY's profitability since its lower price attracts the price-sensitive consumers, and therefore it enables SONY to better compete with same-generation but low-priced competitors, especially Nintendo's Wii. This suggests that the weak sale performance of PlayStation 3 is partly caused by the competition from same-generation, less-advanced, but also cheaper consoles.

The remainder of this paper is organized as follows. Section 2 reviews the related literature. Section 3 presents an overview of U.S. home video game console industry. Section 4 presents the empirical model. Section 5 discusses the data set. Section 6 discusses the identification strategy and presents the estimation results. Section 7 presents the results of counterfactual analysis. Section 8 concludes.

## 1.2 Related Literature

First of all, this paper is related to the literature of theoretical and empirical analysis of indirect network effects in two-sided markets. The utility function for consoles and software provision equation are derived from the theoretical works by Chou and Shy (1990), Church and Gandal (1992, 1993), and Nair, Chintagunta, and Dubé (2004). In addition, this paper uses the results from recent works that study the platform manufacturer's strategy about license fees charged to complementary suppliers when the platforms are proprietary and therefore mutually incompatible. In particular, Economides and Katsamakas (2006) study the pricing decision of platform manufacturers in several scenarios

in the market of indirect network effect. Lin and Kulatilaka (2007) compare three kinds of license fee scheme: fixed royalties, linear licence fee, and hybrid contract, in the context of indirect network effect. They show that if the network effect is large, it is optimal for the platform manufacturer to set the fixed royalties.

Among the empirical analysis about industries with indirect network effect, some early works measure network effects only by the installed base of consumers. These include Bayus and Shankar (2003), which study the home video game console industry, Ohashi (2003), and Park (2002), both of which study the format war between Beta-Max and VHS VCRs in late 1970s. These papers essentially model indirect network effects as though they were direct, i.e., consumers benefit directly from the size of other consumers who use the same product<sup>4</sup>, rather than indirectly through the market for a complementary good. Empirical studies of markets in which indirect network effects are introduced through the demand of complementary good include Gandal, Kende and Rob (2000), which explains the diffusion process of a single technology with network effects in the CD market; Dranove and Gandal (2003), which estimates indirect network effects of DVD and Divx players; Nair, Chintagunta, and Dubé (2004), which studies indirect network effect in personal digital assistants (PDA) industry; and Clements, Ohashi (2005), and Prieger and Hu (2007), which all study the indirect network effect in home video game console industry. In particular, Nair, Chintagunta, and Dubé (2004) formulates a model of joint determination of platform (PDAs) sales and software availability in the market. They show that under certain assumptions, the demand of platforms can be estimated by the discrete choice model, and the supply of softwares can be estimated by a simple linear function.

This paper is also related to the literatures that use discrete choice model to study the effects of various industry activities. Among them are Nevo (2000) who studies the effects of mergers in the ready-to-eat cereal industry, Petrin (2001) who studies the value of new product (minivan) in the automo-

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<sup>4</sup>The model of direct network effect is most appropriate for products like a telephone network. As more consumers use telephones, the value of the telephone to an individual consumer increases because it is possible to call more people. It is as if the quality of the telephone is increasing in the number of consumers.

bile industry, Armentier and Richard (2008) who study the effects of airline alliances agreements on consumer welfare in U.S. domestic airline market, and Villas-Boas (2009) who studies the welfare effects of banning wholesale price discrimination in German retailer market.

### 1.3 The Home Video Game Console Industry

Video games play a large role in the American entertainment market. In 2004, the total sales of video game industry in U.S. is nearly \$10 billion, greater than the Hollywoods total global box-office revenue<sup>5</sup>. At the same time, the development of the new game consoles has become increasingly expensive since 1990s so that many once significant firms, such as Panasonic and Sega, have exited the industry. Now, the industry is highly concentrated and there are only three firms, SONY, Microsoft, and Nintendo, competing in the market.

There are two kinds of consoles. Desktop consoles are the full-featured, advanced system, and use optical-drive as game storage media. Portable consoles are PDA-size, less advanced, but portable system using cartridges as storage media. Consoles from different manufacturers are mutually incompatible, and desktop and portable consoles from same manufacturers are also incompatible because of the difference in storage media. Currently, SONY and Nintendo have both desktop and portable consoles on the market, while Microsoft has only desktop consoles on the market. Consoles manufacturers typically withdraw the old consoles when the successors became available. SONY, however, has been able to keep both old and new consoles on the market due to its advantages in production capacity.

Table 1.1 summarizes the major characteristics of desktop consoles available in U.S. since 2000s. PlayStation 3's price is much higher than its same-generation competitors. Its introductory price is about 100% higher than Nintendo's less advanced Wii, and 25% higher than the Microsoft's Xbox360 which is comparable in terms of hardware specification. The added cost of

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<sup>5</sup>Entertainment Software Association, *Essential facts about the computer and video game industry*, May, 18, 2005.

Console	Introduction (Month Year)	Manufacturer	Price	Hardware Characteristics		
				CPU	GPU	RAM
<b>Sixth Generation</b>						
PS 2	Oct. 2000 - Present	SONY	149.99 (2005.3) 129.99 (2006.5)	294	150	32
Xbox	Nov. 2001 - Nov. 2005	Microsoft	149.99 (2005.3)	733	233	64
GameCube	Sept. 2001 - Nov. 2006	Nintendo	149.99 (2005.3)	486	162	43
<b>Seventh Generation</b>						
PS 3	Nov. 2006 - Present	SONY	499.99 (2006.11) 399.99 (2007.7)	3200	550	512
Xbox360	Nov. 2005 - Present	Microsoft	399.99 (2005.11) 349.99 (2007.8)	3200	500	512
Wii	Nov. 2006 - Present	Nintendo	249.99 (2006.11)	729	243	88

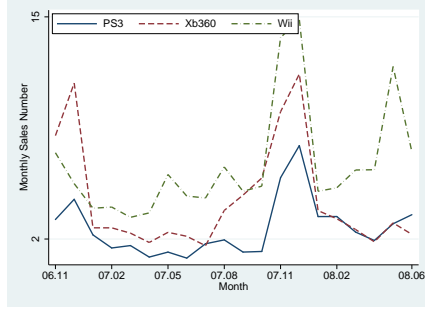
Table 1.1: Major Desktop Console Characteristics

its Blue-ray DVD function is believed to be the major reason<sup>6</sup>. On the other hand, 6th-generation consoles (PlayStation 2, Xbox, and GameCube) have relatively similar hardware specifications and prices, while 7th-generation consoles (PlayStation 3, Xbox 360, and Wii) have quite wide range in hardware configurations and prices. Among the latest generation, PlayStation 3 and Xbox 360 are “high-end” consoles while Wii is a less-advanced platform. As a result, PlayStation 3 and Xbox 360 are more expensive than Wii. This fact illustrates different strategies the console manufacturers designed and promoted their latest products, and therefore indicates that the competition between the latest-generation consoles might be quite different from the previous generations.

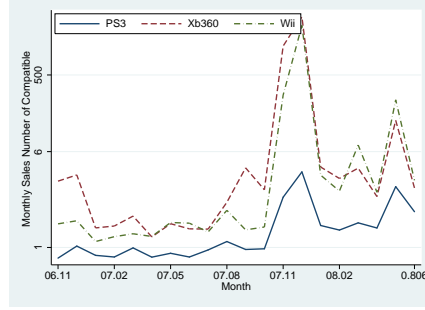
Since launching, both PlayStation 3 and its compatible games have been outsold by the competitors (Xbox 360 and Wii) in every month (Figure 1.1).

<sup>6</sup>CNET: “PlayStation 3 Cost Analysis”, Nov. 13th, 2006

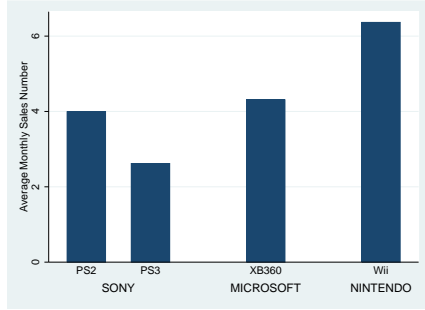
On the other hand, combined average monthly sales of SONY’s old (PlayStation 2) and new desktop consoles (PlayStation 3) are higher than Microsoft and are comparable to Nintendo (Figure refDesktop Market).



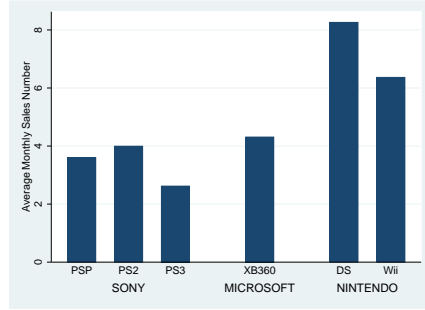
(a) Figure5



(b) Figure6



(c) Figure4



(d) Figure3

Figure 1.1: Desktop Market

At the same time, there has been intensive discussion and debate among the mass media about the worthiness of SONY’s strategy of integrating Blue-ray DVD into PlayStation 3. Some believed the integration would be a success since the consumers would be attracted and like to pay a premium for the feature, especially when DVD player is now a “must-have” for most families and SONY’s Blue-ray DVD is the winning format of future high-definition DVD system. In addition, since SONY has PlayStation 2 to serve price-sensitive consumers, the high price should not be a major problem for SONY<sup>7</sup>. In contrast, some analysis suggests that such function would not be valued very much since consumers mainly, if not only, use consoles to play games,

<sup>7</sup>For example, see “*Strategy Analytic: Sony Will Win 61% Market Share In The War Of Next Generation Consoles*, Business Wire, July.19th, 2005”

and therefore the added costs of any extra function would drive price sensitive consumers away<sup>8</sup>. Furthermore, the popularity of Wii suggests that Nintendo’s low price strategy and family oriented game inventories are the key to success, and SONY and Microsoft’s high-end, but high-price strategy is the major reason to the weak sales. However, such analysis mainly uses basic data and trend description and does not allow us to draw any conclusion on the discussed hypothetical scenarios. In the present paper, I adopt a structural model to quantify the effects.

## 1.4 The Model

In this section, I describe the empirical model in the paper capturing the main feature of demand and supply in the video game console market.

### 1.4.1 Demand for Consoles

Demand for consoles is modeled by a random coefficient discrete choice model. Let  $i$  denote a household and  $j$  denote a console. A household chooses one console from the total  $J$  models available on the market at time  $t$  or an outside alternative  $j = 0$ . The utility of household  $i$  from purchasing console  $j$  in the period (month)  $t$  is defined as

$$U_{ijt} = \alpha_i P_{jt} + \beta_i \ln(N_{jt}) + Y'_{jt} \psi_i + Z'_{jt} \delta + \xi_{jt} + \varepsilon_{ijt} \quad (1.1)$$

where  $P_{jt}$  is the price of console  $j$  at period  $t$ ;  $N_{jt}$  is a measure of the availability of game titles compatible to console  $j$  at the beginning of period  $t$ ;  $(Y, Z)$  are vectors of the observable product characteristics;  $\xi_{jt}$  represents the product characteristics that are observable to households but unobservable to econometricians (e.g. effect of advertisement, reputation, popularity of games, etc);  $(\alpha_i, \beta_i, \psi_i)$  are random coefficients specific to household  $i$ ;  $\delta$  is a vector of deterministic parameters; finally,  $\varepsilon_{ijt}$  is an error term independently and

---

<sup>8</sup>See, for example, “*Playing the Fool: How Sony inadvertently helped a competitor and lost position in the video game market.*”, Wall Street Journal, Dec. 31, 2008

identically distributed from a type-I extreme value distribution, representing the unobserved idiosyncratic preference of household  $i$  for console  $j$  in period  $t$ , and it is assumed to be independent of all other random variables.

The random coefficients  $(\alpha_i, \beta_i, \psi_i)$  are characterized by

$$(\alpha_i, \beta_i, \psi_i)' = (\alpha, \beta, \psi)' + \Pi D_i + \Sigma \nu_i \quad (1.2)$$

where  $D_i$  is a vector of demographic variables of households, which includes the variable of household income and a dummy variable that is equal to 1 if any of the household member is younger than 35 years old (who are the major population of video game players).  $\nu_i$  is the error term which is assumed to have standard normal distribution and independent of all other random variables.

Each household  $i$  purchases the console (or chooses to purchase the outside alternative) that maximizes the indirect utility defined in (1), i.e.

$$U_{ijt} > U_{iht}, \quad \text{for all } h \in J, j \neq h$$

then the probability that household  $i$  purchases console  $j$  is

$$\pi_{ijt} = \frac{\exp[\alpha_i P_{jt} + \beta_i \ln(N_{jt}) + Y'_{jt} \psi_i + Z'_{jt} \delta + \xi_{jt}]}{\sum_{h \in J} \exp[\alpha_i P_{ht} + \beta_i \ln(N_{ht}) + Y'_{ht} \psi_i + Z'_{ht} \delta + \xi_{ht}]} \quad (1.3)$$

Therefore, the market share of console  $j$  implied by the model can be written as the average purchase probability across all households in the market:

$$\begin{aligned} s_{jt} &= E \left\{ \frac{\exp[\alpha_i P_{jt} + \beta_i \ln(N_{jt}) + Y'_{jt} \psi_i + Z'_{jt} \delta + \xi_{jt}]}{\sum_{h \in J} \exp[\alpha_i P_{ht} + \beta_i \ln(N_{ht}) + Y'_{ht} \psi_i + Z'_{ht} \delta + \xi_{ht}]} \right\} \\ &= \int \int \int \pi_{ijt} dF(\alpha) dF(\beta) dF(\psi) \end{aligned} \quad (1.4)$$

In the paper, the total market size in each period  $t$  is defined by the number of households in U.S. who own a television but do not have a video game console until the previous period. Therefore, the potential market for consoles is allowed to be decreasing over time.

### 1.4.2 Game Provision

In this section, I describe the determination of game availability. When more households buy a particular console, the corresponding compatible games will face increasing demand due to the network effects. To derive the empirical model on game provision, I follow Church and Gandal (1992, 1993), Chou and Shy (1990), Nair, Chintagunta, and Dubé (2004) and Ohashi and Clements (2005), and assume that there are many firms in the game developing industry and each firm develops a single game to a particular console  $j \in J$  in each period  $t$ , and such game production exhibits increasing return to scale and free entry. Furthermore, each household has a CES demand for games. Under the above assumptions, the symmetric Bertrand equilibrium determines the game supply as<sup>9</sup>

$$N_{jt} = A_{jt}(Q_{jt})^\gamma$$

where  $A_{jt}$  is the constant for console  $j$  at period  $t$ , and  $Q_{jt}$  is the console  $j$ 's installment base at period  $t$ . I thus use the following reduced-form equation to estimate the game provision:

$$\ln(N_{jt}) = \kappa_{jt} + \gamma \ln(Q_{jt}) + v_{jt} \quad (1.5)$$

where  $v_{jt}$  is a mean-zero error,  $\kappa_{jt}$  includes the console fixed effects and time fixed effects.

### 1.4.3 Supply of Consoles

Suppose that there are  $F$  firms manufacturing game consoles,  $1, 2, \dots, F$ , each of which produces some subsets,  $\mathcal{F}_f$ , of the  $j = 1, 2, \dots, J$  consoles. The marginal cost of console  $j$  at period  $t$  is assumed to take the form of

$$MC_{jt} = W'_{jt}\eta + \omega_{jt} \quad (1.6)$$

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<sup>9</sup>Park (2001), Nair, Chintagunta, and Dubé (2004), and Ohashi and Clements (2005) give the detailed derivation of the following game provision function under the same assumptions made in this paper.



where  $W_{jt}$  is a vector of product characteristics that affect the marginal cost of the console,  $\omega_{jt}$  is the supply side shock that is unobserved by econometricians, and  $\eta$  is the vector of cost parameters to be estimated.

In the video game industry, it is the common practice that console manufacturers charge game developers license fees to allow them to access to their proprietary systems. Therefore, in a comprehensive model, console manufacturers need to determine both the optimal license fees and the optimal console prices. In the theoretical literatures, such decision is modeled through a two-stage game, in which platform (console) manufacturers set license fees in the first stage, and both platform manufacturers and application suppliers (game developers) set their product prices simultaneously in the second stage. To model the entire game in the video game console industry, we need to model demand for games as well as the demand for consoles. This requires, in particular, detailed data on game prices, which is very difficult to obtain. Instead, in this paper, I only model the pricing decision of console manufacturers in the second-stage of the model, leaving the license fee as given for both console manufacturers and game developers.

The profits of firm  $f$  at time  $t$ ,  $\Pi_{ft}$ , therefore, are

$$\Pi_{ft} = \sum_{f \in \mathcal{F}_f} [(P_{ft} - MC_{ft})M_{ft}s_{ft}] + L_{ft} - C_{ft} \quad (1.7)$$

where the first term is the profit from selling the console itself, the second term  $L_{ft}$  is the profit earned from license fees charged on the compatible game titles, and  $C_{ft}$  is the fixed cost of production<sup>10</sup>.

Lin and Kulatilaka (2007) shows that fixed royalty is optimal for platform (console) manufacturers when the network effect is large. Therefore, under such assumption on network effect, console manufacturers' profits from license

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<sup>10</sup>It is helpful pointing out the effects of differences between economic costs and accounting costs on the model. The research and development (R&D) expenditures and initial production costs are very high in the console industry. These expenditures and costs are allocated through several years by the accounting rules, therefore, console manufacturers may incur losses in the console manufacturing business. However, by the concept of economic cost, such costs are treated as sunk costs. Therefore, console manufacturers make positive economic profit in the console manufacturing business in the economic models.

fees  $L_{ft}$  are a constant term in (7). Assuming that the observed structure of game titles is the the only equilibrium game developers play, the existence of a pure-strategy Bertrand-Nash equilibrium in console prices, and that the prices that support the equilibrium are strictly positive, the profit maximizing price level  $P_{jt}$  for manufacturer  $f$  at period  $t$  must satisfy the following first-order condition

$$s_{jt} + \sum_{r \in \mathcal{F}_f} (P_{rt} - MC_{rt}) \left[ \frac{\partial s_{rt}}{\partial P_{jt}} + \frac{\partial s_{rt}}{\partial \ln(N_{rt})} \frac{\partial \ln(N_{rt})}{\partial \ln(Q_{rt})} \frac{\ln(Ms_{rt})}{\partial P_{jt}} \right] = 0 \quad (1.8)$$

This equation illustrates the sources of price sensitivity for console demand. The effect of price changes on demand not only comes directly from the price changes ( $\partial s_{rt}/\partial P_{jt}$ ), but also from the fact that direct price effect is amplified through the mutual network effects between consoles and compatible games ( $[\partial s_{rt}/\partial \ln(N_{rt})] \times [\partial \ln(N_{rt})/\partial \ln(Q_{rt})][\partial \ln(Ms_{rt})/\partial P_{jt}]$ ).

In the matrix notation, the markup at the equilibrium prices is defined as:

$$P - MC = \Omega^{-1} s(P) \quad (1.9)$$

where  $s(\cdot)$ ,  $P$ , and  $MC$  are  $J \times 1$  vectors of market shares, prices, and marginal cost, respectively, and the element of  $\Omega$  is

$$\Omega = \begin{cases} -\frac{\partial s_{rt}}{\partial P_{jt}} + \frac{\partial s_{rt}}{\partial \ln(N_{rt})} \frac{\partial \ln(N_{rt})}{\partial \ln(Q_{rt})} \frac{\ln(Ms_{rt})}{\partial P_{jt}} & \text{if } \exists f : \{r, j\} \subset \mathcal{F}_f \\ 0 & \text{otherwise} \end{cases} \quad (1.10)$$

Using estimates of the demand parameters, I can estimate price-cost margin without observing actual costs.

Before going to the discuss the estimation of the model, I discuss some limitations of the model. First, the model presented in this section is a static model. Since a game console is durable, it may be more appropriate to use a dynamic model, such as the one in Gowrisankaran and Rysman (2009), to describe the market. The major issue of dynamics in the video game market concerns the timing of hardware adoption. In particular, consumers decide to

purchase a console based on their expectations of the future popularity of the console. We can think of two types of console buyers: (1) those who did not purchase a console before; and (2) those who has already owned older consoles. At each period, the first type of buyers compare the net benefit of purchasing a game system to the value of outside option, and the second type of buyers compare it to the net benefit of keeping the older system. While the framework adopted in this paper is static, I try to capture such dynamic features of the market in the empirical implementation. I include in the demand equation console-time interaction dummies that proxy for console-specific events affecting expectations. To account for the second type of consumers, I allow for the installment base to depreciate<sup>11</sup>, so that the outside market share changes with the flow of returning consumers.

There are also assumptions made in order to simplify the modeling supply side of consoles. First, I make the assumption of fixed royalties on game titles from the fact that it is supported by the theoretical works. Nair (2007) conducts interviews with video game studio managers and confirms that such license fee scheme is popular in the market. However, different license fee schemes (e.g. linear license fees) may be present in the market. Second, the supply side is modeled as license fees are given, and more broadly that the production decision, are set. This does not allow us to consider the effects of fixed costs, such as research and development costs, on the manufacturer's profits. Therefore, the results are only valid given the assumption that such costs are independent of changes in product attributes or structure<sup>12</sup>. Last, the assumption of fixed royalties does not allow it changes with the changes

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<sup>11</sup>The annual depreciation rate of 6th generation consoles (PlayStation 2, Xbox, and GameCube) is set to be 15%, which is estimated by IGN entertainment. It is higher than the one used in Clements and Ohashi (2005), who set it at 5%, since the sample used in my paper is in the transition period between two generations. Therefore, the depreciation rate of older consoles should be higher. The depreciation rate of 7th generation consoles (PlayStation 3, Xbox 360, and Wii) is set to be 5%.

<sup>12</sup>To be more specific, this requires the assumptions that development decision of PlayStation 3 is uncorrelated with PlayStation 2, and that the development of Blue-ray DVD technology is uncorrelated with the decision of PlayStation 3's adoption. The first assumption is validated since PlayStation 3 has little in common with PlayStation 2. The second is validated by the fact that SONY and other firms (e.g. LG, Samsung, etc) also produce stand alone Blue-ray DVD players.

in the availability of game titles, and therefore, it is implicitly assumed that the license fee revenue is fixed in the counterfactual analysis. As a result, the calculated changes in profits are the lower bound (upper bound) when the console sales increase (decrease).

## 1.5 Data

There are several sources of the data used in the paper. The console sales data is obtained from NPD group, a consultant firm specialized in consumer products. It consists of SKU-level monthly sales of all console models sold through the retail channel in the U.S. market from March 2005 to December 2008. These data were collected using point-of-sale scanners linked to over 80% of the consumer-electronic retail ACV in the U.S. After removing model-month observations with insignificant overall market shares in each period (less than 1%), the data contained 342 model-month observations of 8 different models across 46 months. These represents all the console models, desktop and portable, that are available in the market during the period. Detailed hardware attribute data for each model is manually collected from online sources and trade publications, and is cross-checked with manufacturer model descriptions for consistency. Because I conduct counterfactual analysis on products structures and firm's profits, I include all the models (both desktop and portable consoles) sold in the U.S. to achieve more accurate estimates.

Because of the presence of network effect, the measure of the benefit provided by compatible games to the console owners is needed. The ideal measure would be an index of utility that households obtain from the use of compatible games in each period. To estimate such an index, I would need data on sales, prices, and "quality" of games. These data are unavailable to me. Therefore, I instead collect data on game availability from *vgchartz.com*, a membership sponsored website, which maintains an extensive database on game titles. The availability of a particular game title at period  $t$  is defined as the sales of the title is above a certain threshold, typically about 1500 copies per week. If there is no accurate sales data, I assume that the life span of a particular game title

is 12 month or until the successor title is available<sup>13</sup>, whichever is shorter. In addition, same titles but available on different consoles are counted separately.

A comprehensive analysis of firm entry and pricing decision in the game provision side would require additional data such as the fixed costs of development and prices in each period. The former is typically unavailable. Manually collecting game title price data is not feasible due to the large number of titles in the market, and to the fact that comprehensive historical price data is extremely difficult to obtain. These limitations on data of software side require much simplifying assumptions for the underlying model of game developer’s entry and pricing decisions.

Finally, the household sample used to model random coefficients is sampled from Current Population Survey (CPS) and sample size is set to be 500.

Variable	Mean	Standard	Max	Min
Price (in 1982-1984 dollars)	101.34	55.99	248.13	39.23
Memory (MB)	141.35	190.97	512	0.375
CPU (MHz)	952.64	1241.29	3276.8	16.8
GPU (MHz)	261.18	355.96	1331.2	16.8
Game Titles	288.80	373.93	475	23
Holiday	0.083	0.28	1	0
DVD	0.17	0.37	1	0

Table 1.2: Descriptive Statistics of the Sample

## 1.6 Identification and Estimation

### 1.6.1 Identification

The first identification problem arises from the correlation between the console prices  $P_{jt}$ , availability of game titles  $N_{jt}$  and unobserved console attributes  $\xi$  in the console demand function. Console prices ( $P_{jt}$ ) may be endogenous, because if  $\xi_{jt}$  is correctly perceived by households, a console with a better reputation or better marketing effort may induce higher willingness to pay, and thus the

<sup>13</sup>Many game titles are updated every certain period. For example, Electronic Art’s *FIFA* soccer game series are updated every year.

manufacturer may be able to charge higher prices in an oligopolistic market. The endogeneity of the availability of compatible games ( $N_{jt}$ ) comes from the interaction with the software provision equation (5), and the autocorrelation on  $\xi_{jt}$ . An increase in console demand at period  $t - 1$ , because of the change in the unobserved error, would increase the installed base at the beginning of period  $t$ , leading to an expansion of the game sales through network effects. Thus  $\xi_{jt}$  and  $N_{jt}$  are positively correlated with each other in the presence of the autocorrelation in  $\xi_{jt}$ .

One common strategy to identify the endogenous coefficients is to exploit the rival product attributes and the competitiveness of the market environment. All else being equal, products with closer substitutes have lower prices because of the tougher competition. As suggested by Berry (1994) and BLP (1995), the observed attributes of other products are valid instruments. The instruments include the rivals' memory size, CPU speed, and GPU speed. The second identification strategy is to search for variables that affect manufacturing costs but not demand, known as "cost shifters". These variables correlate with console demand through marginal costs, but not  $\xi$  since  $\xi$  captures the effects outside the production process. The first set of the instruments of this kind includes the exchange rates of Japanese Yen, Korea Won, and Taiwanese Dollar. These three countries are the host countries of major producers of console CPU, memory, and GPU. Change in these exchange rates will affect the costs of consoles in terms of US dollar, but not on unobserved product attributes in U.S. market since console attributes and manufacturers's marketing effort are independent of such exchanges, and also independent of other market conditions. However, these instruments are an industry aggregate and do not vary by console model, the use of instruments thus only helps identify the demand through the variation of the instruments over time, but not within products in the same period. The second set of the instruments of such "cost shifters" is the technology of semiconductor production adopted by each console manufacturer (or its suppliers), which is measured by the minimum distance between two elements on the circuit of major console components (e.g. CPU and GPU) in terms of micrometer ( $\mu\text{m}$ ). The closer this distance can be achieved, the less the costs of production of console components, therefore

these instruments are correlated with demand through marginal costs, but not with  $\xi$ .

The second identification problem is that the correlation between the  $v_{jt}$ , the unobserved shock on the video game market, and  $Q_{jt}$ , the console installment, in the software provision equation (5). If software sales associated with console  $j$  increases due to  $v_{j,t}$ , an unobserved shock in the software market at  $t$ , this shock would induce new console adoption and boost the share of the console  $j$ ,  $s_{jt}$ , and hence the installed base in the period,  $Q_{jt}$ . Thus endogeneity in  $Q_{jt}$  arises. I use as an instrument the total number of console  $j$ 's compatible game titles that are among the top 50 best-selling games published every month by GameStop Inc. GameStop is the largest U.S. video game retailer and it publishes its top selling list every month. I collected the data manually from its website *www.gamestop.com*. The titles in top 50 games correlate with console installment  $Q$  through network effect. However, there still are certain cases where the average software sales correlates with the error term  $v_{jt}$ . If potential entrants perceive the presence of large number of best-selling titles as sign of profitable opportunity due to the potential popularity of the console, the instrument would be positively correlated with  $v_{jt}$ . On the other hand, if the potential entrants see it as a sign of tough competition, the instrument would be negatively correlated with  $v_{jt}$ . Thus the direction of the bias by use of this instrument, if it exists, could go either way. I therefore rely on the statistical test of overidentifying restrictions to check if the instruments are orthogonal to the error.

### 1.6.2 Estimation

In general, the estimation of this model is essentially a two step procedure of a contraction mapping in the first and GMM in the second. First of all, the indirect utility function (1) can be written as

$$u_{ijt} = \phi_{jt} + \mu_{ijt} + \varepsilon_{ijt} \tag{1.11}$$

where  $\phi_{jt}$ , the mean utility of console  $j$  in period  $t$ , is the same for all the households in period  $t$ . The mean utility from the outside alternative is normalized to zero.  $\mu_{ijt}$  is the household specific utility. The mean utility is specified as follows

$$\phi_{jt} = \alpha P_{jt} + \beta \ln(N_{jt}) + (\psi, \delta)(Y_{jt}, Z_{jt}) + \xi_{jt} \quad (1.12)$$

and household specific utility  $\mu_{ijt}$  is

$$\mu_{ijt} = [P_{jt}, \ln(N_{jt}), Y_{jt}](\Pi D_i + \Sigma \nu_i) \quad (1.13)$$

Denote  $\theta_1 = \{\alpha, \beta, \psi, \delta\}$ , and  $\theta_2 = \{\Pi, \Sigma\}$ .

The estimation involves an iteration procedure with two steps in each iteration. The first step uses a contracting mapping technique introduced in Berry (1994) and BLP (1995) to recover the mean utility  $\phi_{jt}$  for each market in each period as a function of  $\theta_2$  by matching the predicted market share of each product (as a function of  $\theta_2$  and  $\phi_{jt}$ ) to the observed market shares. For the given  $\theta_2$ , the iteration used to recover the unique  $\phi$  for each market is:

$$\phi^{n+1} = \phi^n + \ln(s^o) - \ln[s(\phi^n, \theta_2)] \quad (1.14)$$

where  $n$  denotes the number of iterations, and  $s^o$  is the observed market share.

The second step is a GMM with sets of moment conditions  $M$  that the instruments discussed above are independent of the unobserved product characteristics  $\xi_{jt}$  for any given  $\theta_2$  based on the recovered mean utilities  $\phi$  from the first stage.

From equation (12),  $\xi_{jt}$  can be written as a function of  $\theta_1$  and  $\phi_{jt}$ , which is recovered as a function of  $\theta_2$  from the first step. The set of moment conditions is based on:

$$E[Z\xi(\theta_1, \theta_2)] = 0 \quad (1.15)$$

where  $Z$  is the vector of instrument variables discussed above.

With an initial value of  $\theta_2$ , I recover  $\phi_{jt}$  using the contraction mapping defined by equation (14). I construct the objective function by stacking the



set of moment conditions, which is the function of the initial value of  $\theta_2$  and the recovered  $\phi_2$  as a function of  $\theta_2$ . Then, the GMM estimators  $\hat{\theta}_1$  and  $\hat{\theta}_2$  minimize the objective function

$$J = \xi(\theta_1, \theta_2)' ZW^{-1} Z^{-1} \xi(\theta_1, \theta_2)$$

where  $W$  is a consistent estimate of  $E(Z'\xi\xi'Z)$ . The procedure then involves iteratively updating  $\theta_2$  and then  $\phi_{jt}$  to minimize the above objective function. I start with using  $Z'Z$  as the starting point of  $W$  to obtain consistent initial estimates of the parameters and optimal weighting matrix. I then estimate the model using the new weighting matrix.

The game provision equation (5) is estimated by standard 2SLS. With the estimation of the demand side and game provision, I can recover the marginal cost for each model based on manufacturers first order condition for profit maximization in equation (9). The first order condition can also be used to simulate new equilibrium prices in the counterfactual scenarios. Marginal cost function (6) is estimated by standard OLS.

### 1.6.3 Estimation Results

#### Console Demand

The last two columns in Table 1.3 present parameter estimates in the mean utility function  $\phi$  defined by equation (12). The first 2 columns report estimation results of a standard logit model for the purpose of comparison <sup>14</sup>.

The key parameters of interest are price, log(game availability) and Blue-ray DVD dummy. The estimation result shows that consumers are sensitive to prices but are willing to pay extra premium for the Blue-ray DVD function in both specifications. In addition, the market exhibits intensive network effects. In addition, the coefficients for memory and GPU are insignificant, while coefficient for CPU is barely significant. This may illustrate the fact that, especially for the latest-generation consoles, the hardware specifications of different con-

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<sup>14</sup>As in Berry (1994), the dependent variable in the logit model is  $\ln(s_{jt}) - \ln(s_{0t})$ , where  $s_{jt}$  and  $s_{0t}$  are the market share of console  $j$  and outside choice in the period  $t$ , respectively.

Variable	Logit		Random Coefficient	
	Para	Std Err	Para	Std Err
Price	-0.294	0.160	-0.430	0.143
Log(Game Availability)	0.235	0.036	0.584	0.039
Blue-ray DVD dummy	0.711	0.295	0.963	0.388
Memory	0.086	0.013	0.048	0.958
CPU	0.016	0.006	0.034	0.016
GPU	0.008	0.004	0.021	0.012
Portable dummy	1.534	0.346	1.832	0.843
Microsoft dummy	-3.561	0.732	0.483	0.224
Nintendo dummy	1.077	0.216	1.712	0.704
Holiday dummy	0.995	0.079	1.213	0.157

Table 1.3: Parameters in Mean Utility Function

soles are not directly comparable due to the different system structures. At the same time, consumer observe advantages of advanced hardware configuration mainly through the capability of running computationally demanding games (e.g. action games, sports games, etc.), which is also captured partially by the game availability effect  $\beta$  and by the unobservable product attributes term  $\xi_{jt}$ . The dummy variable for Nintendo is positive and significant in both models. This reflects the fact that Nintendo, although its consoles are less advanced in hardware capabilities, enjoys its legendary game titles, such as the “Mario” series, and its exclusive movement detection technology<sup>15</sup>. Dummy variable for Microsoft is positive and marginally significant in the random coefficient model. This may be due to the fact that most of Microsoft game titles are developed by U.S. studios and are more appealing to U.S. customers than SONY’s<sup>16</sup>.

Table 1.4 presents the estimates of the random parameters  $(\alpha_i, \beta_i, \psi_i)$  and  $\sigma_i$ . Most estimates have expected signs. For instance, high income consumers

<sup>15</sup>Nintendo’s motion detection technology allows players to play games not only by using buttons on the remote controls, but also using their body movement. This feature is greatly valued by U.S. consumers and largely offset Nintendo’s less advanced technology in hardware configuration.

<sup>16</sup>Some of SONY’s legendary titles are developed by Japanese studios and are aimed primarily for Asian customers, whose preferences are significantly different from American customers’.

Variable	$\sigma$	Income	Teen
Price	0.298 (2.382)	0.148 (0.0989)	-0.215 (1.427)
Blue-ray DVD Dummy	0.679 (0.159)	-1.544 (1.122)	0.389 (0.130)
Log(Game Availability)	0.220 (0.0412)	0.0294 (0.0316)	0.142 (0.0726)

Table 1.4: Parameters for Random Coefficients

are less sensitive to prices since the coefficient of income for price (0.148) is positive. The income effect on Blue-ray DVD function is negative but insignificant. The negative sign may be due to the fact that wealthy households may choose to buy stand-alone Blue-ray DVD players to get better function, while insignificance may be due to heterogeneity among consumer's preferences. In addition, the households with young members value Blue-ray DVD function positively (0.389), and it may be due to the fact that young people are generally more willing to pay extra money to the latest technology. Households with young members also value more about game variety (0.142) since they are the main population of "hardcore" video game players.

### Software Provision

Table 1.5 presents the estimates of software provision equation (5). I present the result from both IV estimation and standard OLS estimation. The  $J$ -statistic shows that the model fits moderately well with the instruments, and the  $F$ -statistic indicates that the instruments are not weak. The coefficient of software sales variable increases from 1.063 in OLS to 2.165 under IV model. The estimate then shows that 1% increase in sales of compatible games leads to approximately 2.17% increase in console sales.

### Marginal Cost Function

Table 1.6 presents the estimates of console's marginal cost function. We see that Blue-ray DVD function is expensive in that the estimated cost is about 25 dollars in real 1982-84 term, which accounts for about 20% of PlayStation

Variable	2SLS		OLS	
	Para	Std Err	Para	Std Err
Log(Console Sales)	2.165	0.227	1.063	0.044
Constant	Yes		Yes	
Manufacturer Dummy	Yes		Yes	
Period Dummy	Yes		Yes	
No. Observation	342		342	
$R^2$	-		0.88	
1st stage $F$ stats	6.24E+04		-	
J Statistics (D.F.)	0.29(1)		-	

Table 1.5: Parameters for Software Provision Equation

3's marginal cost.

Variable	Parameter	Standard Error
DVD dummy	0.258	0.049
Memory	0.019	0.009
CPU	0.073	0.010
GPU	0.034	0.023
Portable dummy	0.723	0.329
Microsoft dummy	0.010	0.003
Nintendo dummy	-0.023	0.015

Table 1.6: Parameters for Marginal Cost Function

### Estimated Price Elasticity

The price elasticities of the market shares,  $s_{jt}$ , defined by equation (4) are

$$\eta_{jkt} = \frac{\partial s_{jt} p_{kt}}{\partial p_{kt} s_{jt}}$$

$$= \begin{cases} -\frac{p_{jt}}{s_{jt}} \int \int \int \alpha_i (1 + \frac{\beta_i \gamma}{Ms_{jt}}) \pi_{ijt} (1 - \pi_{ijt}) dF(\alpha) dF(\beta) dF(\psi) & \text{if } j = k, \\ \frac{p_{kt}}{s_{jt}} \int \int \int \alpha_i (1 + \frac{\beta_i \gamma}{Ms_{kt}}) \pi_{ijt} \pi_{ikt} dF(\alpha) dF(\beta) dF(\psi) & \text{otherwise,} \end{cases}$$

where  $\pi_{ijt}$  is the probability of consumer  $i$  purchasing console  $j$  at period  $t$ . Again, the elasticities are amplified through the presence of network effects, which is measured by the term  $(\beta_i \gamma)/(Ms_{jt})$ .

Table 1.7 presents selected own and cross-price elasticities across major desktop consoles considered in this paper. We see that own-price elasticities of all consoles are greater than 1 (in absolute terms). In addition, the cross-price elasticity between PlayStation 2 and other consoles is relatively lower since PlayStation 2 is last-generation console and therefore not very much comparable to others. Meanwhile, PlayStation 3 and Xbox 360 are closer substitutes to each other, while Wii is placed farther from the above two consoles because of the hardware capability and gaming styles.

	PlayStation 2	PlayStation 3	Xbox 360	Wii
PlayStation 2	-4.47	0.117	0.267	0.242
PlayStation 3	0.063	-5.93	1.168	0.167
Xbox 360	0.100	0.840	-4.84	0.105
Wii	0.655	0.399	0.145	-3.47

Table 1.7: Average Own- and Cross-Price Elasticities of Desktop Consoles

To check the robustness of my estimates, I compare my estimated elasticities with existing literatures. Clements and Ohashi (2005) estimate that the range of average own-price elasticities of major consoles sold during 1994 to 2002 in U.S. market are between -2.47 to -1.06. In particular, they estimate the average own-price elasticity of PlayStation 2 during 2000 and 2002 is at -2.20. Prieger and Hu (2006), using a data of major desktop consoles sold in U.S. during 2002 and 2004, estimate that the average own-price elasticities range from -2.29 to -1.80. My estimates are higher in absolute terms. There are mainly three reasons for the difference. First of all, papers cited above only account for the direct price effect on the console demand, while I take into account both direct price effect and indirect price effect through network effect. Therefore, the estimates of elasticities are inherently larger (in absolute term) in my models. Second, in the data used by previous papers, consoles are very similar to each other in hardware specification and therefore in prices. As a result, there is relatively little price variation over periods and, more importantly, between consoles. Therefore, the estimates in the previous literature explain the differences in market shares mainly by differences in game variety. In contrast, my sample exhibits price variety between products due to different

hardware designs (for example, the “high-end” consoles, such as PlayStation 3 and Xbox 360, and “low-end” consoles, such as Wii) and different price cutting strategies from different manufactures over time. My estimates, as a result, explain bigger part of demand variation through differences in prices. Lastly, papers above use either nested-logit (Clements and Ohashi) or logit (Prieger and Hu) model, which imposes restricted substitution patterns on the products, while I use random coefficient logit model to allow more flexible substitution patterns<sup>17</sup>.

## 1.7 Counterfactual Analysis

This section quantifies the effects of console manufacturers’ different strategies on their profitabilities. There are mainly two factors. The first factor is the trade-off between the extra attraction and added costs of such function, and the second factor is the effects of product differentiation among the latest-generation consoles on console manufacturers’ profitability.

### 1.7.1 Value of Blue-ray DVD

To quantify the first factor, I artificially drop the Blue-ray DVD function off from PlayStation 3 and recalculate market shares and prices in the new equilibrium. The changes to the market equilibrium are through three channels. First, PlayStation 3’s marginal cost is lowered because of the drop of Blue-ray DVD function. The second is through the changes in consumers’ utility about the characteristics of “new” consoles. The last one is through the network effects since changes in market shares of consoles will affect the sales of compatible games, which in turn affect the console market shares. Specifically, I calculate the new marginal cost of “new” PlayStation 3 console without Blue-ray DVD using estimates of marginal cost function. Then, I solve equation (4) and (5) simultaneously to find the new equilibrium given the new set of

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<sup>17</sup>It is well known that the own elasticities in standard logit model is proportional to own prices, therefore, own-elasticities of consoles will fall significantly along with the significant falling of console prices.

console characteristics. The base period is set to be October 2006, which is the month ahead of the launch of PlayStation 3.

Console	Price Change (%)	Sales Change (%)
PlayStation 2	-7.47	4.12
PlayStation 3	-15.93%	4.76
Xbox 360	-9.35	-6.13
Wii	-2.47	2.26

Table 1.8: Changes in Prices and Sales of Desktop Consoles (Since 2006.11)

Manufacture	Profit Change (%)
SONY	0.32
Microsoft	-11.63
Nintendo	-6.93

The profit change includes profits from all consoles, desktop and portable.

Table 1.9: Changes in Variable Profits of Console Manufacturers (Since 2006.11)

As seen from Table 1.8 and Table 1.9, by dropping the Blue-ray DVD function, the marginal cost of PlayStation 3 is lowered and therefore, SONY is able to lower PlayStation 3's price. In turn, such move triggers price cuts from other manufacturers. In terms of sales, Microsoft's Xbox 360 decreases more significantly because of the elimination of PlayStation 3's DVD function. It is mainly due to the fact that Xbox 360 is the closer substitute for PlayStation 3 in terms of hardware specification, and therefore some of its buyers would be attracted by PlayStation 3's "new" lower price. At the same time, Wii's sales increases after the price cuts. It illustrates the fact that Wii is farther positioned in the product attributes space than its rivals. Taking into account both desktop and portable consoles, SONY's profits increase very slightly by 0.32% if Blue-ray DVD function is removed from PlayStation 3. These results show that the almost all the benefits of cost reduction by removing Blue-ray DVD function from PlayStation 3 is offset by the decrease in the product value to the consumers and diminished margin of PlayStation 3. At the same time, Microsoft's profits decrease by 11.63%, and Nintendo's profits decrease

by 6.93%. Microsoft has higher loss partially because, unlike SONY and Nintendo, it does not have portable consoles on the market and therefore relies solely on the desktop console business. In addition, PlayStation 3 without Blue-ray DVD feature would be able to capture more market share from Xbox 360 than from Wii due to the similarity in the product attributes.

### 1.7.2 Effects of Product Differentiation

The second counterfactual analysis is to quantify the effects of product differentiation among the latest-generation (7th generation) consoles on manufacturers' profitability. To do this, I drop PlayStation 2 from SONY's product line immediately after it launched PlayStation 3, and recalculate the market equilibrium since then. This examines the effects of much more differentiated product attributes among the 7th generation consoles on manufacturers' profitability. I consider two cases in this scenario. In the first case, I keep PlayStation 3 with its Blue-ray DVD function, and in the second case, I remove Blue-ray DVD function from it. Table 1.10 and Table 1.11 summarize the counterfactual results under these two cases.

Manufacture	Without Blue-ray DVD		With Blue-ray DVD	
	Price Change (%)	Sales Change (%)	Price Change (%)	Sales Change (%)
PlayStation 3	-14.25	10.25	-4.93	-15.76
Xbox 360	-10.17	7.27	-8.35	11.98
Wii	-9.26	19.15	-5.47	28.26

Table 1.10: Changes in Prices and Sales of Desktop Consoles without PS2 (Since 2006.11)

As presented in Table 1.10 and 1.11, PlayStation 2 plays a vital role for SONY since it attracts price-sensitive buyers. Either with or without Blue-ray DVD function in PlayStation 3, SONY's profits decrease significantly if PlayStation 2 is dropped. At the same time, Nintendo's Wii benefits the most from the retraction of PlayStation 2 in terms of sales and profits increase. The main reason is that most buyers of PlayStation 2 are price-sensitive consumers so that, without PlayStation 2, more of them turn to Wii, which is less ad-



Manufacture	Profit Change (%) (without Blue-ray DVD)	Profit Change (%) (with Blue-ray DVD)
SONY	-32.68	-57.45
Microsoft	-2.57	9.82
Nintendo	22.36	30.02

The profit change includes profits from all consoles, desktop and portable.

Table 1.11: Changes in Variable Profits of Console Manufacturers without PS2(Since 2006.11)

vanced but also much less expensive. On the other hand, PlayStation 3 can attract a relative larger number of former PlayStation 2 buyers compared to specification-comparable Xbox 360 only if its Blue-ray DVD function is removed. This is because that, by dosing so, SONY is able to lower PlayStation 3's price further to make it more appealing to former PlayStation 2 buyers. However, with Blue-ray DVD on it, PlayStation 3 cannot compete with its competitors in prices because of the added costs, and therefore it loses market share more significantly.

The simulation result also illustrates the effects of different system designs among the latest-generation consoles on profitability. Until the latest generation, video game consoles has been designed very similarly to each other in hardware designs. In addition, similar hardware specifications make introductory prices and the later price-cutting strategies similar among console manufacturers. As a result, manufacturers compete mainly through game variety<sup>18</sup>. Therefore, network effects play the dominant role in deciding console sales during their life cycles (Clements and Ohashi, 2005). In contrast, hardware specifications are much more differentiated among the latest-generation consoles, and therefore their prices also vary significantly. As a result, expensive high-end consoles, such as PlayStation 3, face much more intensive competitions from less expensive consoles, such as Wii, and are less attractive to price-sensitive consumers. Consequently, retail prices are therefore more important in the determination of console sales, and PlayStation 3's higher price due to its advanced hardware even if without Blue-ray DVD function is

<sup>18</sup>See Chou and Shy (1990), Church and Gandal (1992, 1993), Clements and Ohashi (2005), and Prieger and Hu (2006) for detailed analysis.

partially the reason to its weak sales performances.

Finally, I conclude this section by noting the consequences of integrating Blue-ray DVD function into PlayStation 3 may not be confined in the context of console market alone. In fact, by the help of such integration, SONY is able to quickly build up the installment base of Blue-ray DVD player in the consumers, and such strategy is important for SONY to win the format war of next-generation DVD media over Microsoft and Toshiba's HD-DVD technology<sup>19</sup>. Furthermore, as showed in the section 7.1, such integration does not hurt SONY's profits in console business very much, and therefore, such strategy may be favorable to SONY in a broader context.

## 1.8 Conclusion

SONY's latest video game console PlayStation 3 entered into the market with integrated Blue-ray DVD function. This feature can, on one hand, contribute to PlayStation 3's sales through its extra value to consumers, while, on the other hand, it can also have negative impacts on the sales of PlayStation 3 because of its added cost. In addition, differentiation in hardware specifications among the latest-generation consoles is another important reasons of PlayStation 3's relatively weak sales. The objective of the paper is to quantify the consequences of above two effects on console manufacturers' profitability. To address this problem adequately, I set up and estimate a random coefficient discrete choice model based on console attributes as well as the measure of game variety to account for the network effects in the market. At the same time, the model incorporates the software provision equation to reflect the mu-

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<sup>19</sup>Blue-DVD (SONY) and HD-DVD (Microsoft and Toshiba) are two competing formats of next-generation high-definition DVD media. In February 2008, Toshiba abandoned the format, announcing it would no longer develop or manufacture HD-DVD players or drives. The HD-DVD Promotion Group (a group of manufacturers and media studios formed to exchange thoughts and ideas to help promote the format worldwide) was dissolved on March 28, 2008. For various reasons, Microsoft never integrated HD-DVD drives into its Xbox consoles. In contrast, Microsoft did offer stand-alone HD DVD players for Xbox 360 at the end of November 2006 with MSRP \$199.99. However, the attach ratio of this player to Xbox consoles has been consistently less than 1%. On February 23, 2008 Microsoft discontinued the Xbox 360 HD-DVD player

tual network effects of consoles on game variety. The supply side of the model is constructed based on the assumption of fixed license fees and Bertrand competition.

I find that (1) consumers do value the integrated Blue-ray DVD function in PlayStation 3 and are willing to pay an extra premium for it; (2) at the same time, such function adds significant cost to the PlayStation 3 console. The simulation results show that, in terms of profitability, the benefit of the Blue-ray DVD function for SONY is largely offset by its added cost. At the same time, traditionally, consoles have similar hardware designs and prices. Yet, latest-generation consoles have much different hardware designs and therefore prices. In the absence of PlayStation 2, price-sensitive consumers, who are the majority of PlayStation 2's buyers, would turn to less expensive consoles, such as Nintendo's Wii, while PlayStation 3 could not attract enough of those consumers because of its higher price. This illustrates that SONY's high-end but high-priced PlayStation 3 may not be as successful as Nintendo's less advanced, but cheaper and family-oriented Wii in terms of sales and profitability even if Blue-ray DVD function is dropped.

More generally, my paper highlights some key features in the market with network effects. The platform (consoles) price has direct effects on platform demand as in the regular market, but at the same time it also has indirect effects through network effects, and thus it plays a larger role in the determination of platform sales in this market. Therefore, the platform attributes can contribute to the demand only if they do not add too much costs to the system. In fact, less advanced platforms in terms of product attributes can also be successful if their low prices can boost sales of complementary good and, in return, the sales of platform itself. This paper then suggests that price differentiations stemmed from different platform attributes and design philosophy may be a significant factor in the competition in the market with network effects.

## Chapter 2

# Exclusive Titles and Sales Performance in the Home Video Game Market

### 2.1 Introduction

The home video game industry is a perfect example of two-sided market, where consumers must associate with a platform (video game consoles) in order to utilize the complements (video games) and consoles from different manufacturers are mutually incompatible to each other. Therefore, the issue of video games' compatibility arises: some games are compatible with multiple consoles, while others are exclusively available on one particular console. In addition, Such exclusivity has two folds: first, independent game developers develop exclusive titles on a particular console through the exclusive contract with the console manufacturers<sup>1</sup>; second, console manufacturers also have game titles exclusive to their own video game consoles (first-party titles).

Such exclusive game titles have significant effects on home video game industry's competitive landscape. First of all, although the number of exclusive titles may not be large, they are dominant on the best-selling game lists for all

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<sup>1</sup>A very similar example is that, to purchase the Apple iPhone, consumers must subscribe to AT&T Wireless, since there is a exclusive contract between Apple and AT&T

the consoles. Second, they are important for the console manufacturers since the latter can reduce competition and increase attractiveness of their own platforms by developing first-party titles or by rewarding such exclusive contract to the third-party independent game developers. Exclusive game titles can add extra appeal to consumers through its uniqueness, and, at the same time, it can eliminate potential multi-platform availability of the title (Church and Gandal, 2000). This practice further increases console manufactures' market power because of the network effects in this market.

The existing literatures are mainly focused on the effects of the complement's exclusivity and integration on the competition among platforms. In this paper, I study the effect of exclusivity on the sales of complementary good directly. More specific, I quantify the effects of exclusivity on the sales performance in the seventh-generation home video game market. I compare the sales of exclusive (including first-party and third-party) and non-exclusive game titles.

I focus on the video games for the 7th generation video game consoles, which include three competing platforms: PlayStation 3 from SONY, Xbox 360 from Microsoft, and Wii from Nintendo. With the help of [vgchartz.com](http://vgchartz.com), a website dedicated to maintain a comprehensive dataset of video game industry, I gathered the information of all game titles that are available on these three consoles in US from November 2006 to October 2009. The dataset has 974 observations and it contains the information of launch date (by month), platform availability, sales performance, launch prices, genres, ratings from the Entertainment Software Rating Board (ESRB) and other aspects of games. In addition, the [vgchatz.com](http://vgchatz.com) also contains review scores from major entertainment magazines and websites for a large number of games. I manually collect those scores and I have a sample of 643 titles with review scores.

After controlling for title and developer heterogeneity, I find that the exclusive game titles do have higher sales. At the same time, such premium in sales suggests the possible platform (in terms of exclusivity) selection, and I take three approaches to deal with selection issues, and all the results support the conclusion that exclusive titles have higher sales.

There are two concerns due to platform selection. First, there might be

unobserved game characteristics that affects the decision on console platform adoption and the sales outcome. For example, since consoles are different in their hardware capabilities, exclusive game titles on a particular platform may have specially designed features to better take advantage of the console's capability, and such features may not be captured by the game characteristics and controls. To deal with possible unobserved game heterogeneity I follow Hendel, Nevo, and Ortalo-Magne (2009) to examine that game series that have multiple titles<sup>2</sup>. The inclusion of a game fixed effect is essentially insignificant, which suggests that unobserved game heterogeneity is not a problem.

The second concern is the selection of game developers into console platforms. Console manufacturers may offer financial or marketing assistance to exclusive game titles. For example, console manufacturers may bundle their consoles and exclusive game titles at a discounted price to promote the sales. At the same time, the differences in functions and consumer base of each console also potentially cause the selection problem. For example, most of Wii's players are children or casual players and Wii's unique motion detection function is the biggest attraction for those players. Therefore, developers which design family oriented games would tend to make titles exclusive on Wii in order to better exploit the motion-detection technology and to attract targeted consumers. These practices thus affect both the platform choice and the sales performances. I use two approaches to deal with unobserved developer heterogeneity. The first approach is related to Levitt and Syverson (2006), and Hendel, Nevo, and Ortalo-Magne (2009). I compare the sales of first-party exclusive titles to the sales of third-party exclusive titles. After controlling for time, game and platform characteristics, I find nonsignificant third-party sales premiums.

The second approach for controlling developer selection is to include developer fixed effects. I then use a sample which contains titles from developers who design both exclusive and non-exclusive games. After including developer fixed effect into the regression, I find marginally nonsignificant sales premium

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<sup>2</sup>For example, EA updates its FIFA series every year. Each year, EA released a new title in the series, e.g. FIFA 06, FIFA 07, etc. Titles in the series are very similar in the effects, control, and other aspects, since they use the same gaming engine.

on exclusive titles.

## 2.2 Related Literature

This paper first is related to the empirical analysis of effects exclusivity and vertical integration in the two-sided markets. The existing literatures are mainly focused on the impacts on the side of platform competitions. For example, Hastings (2004) and Hastings and Gilbert (2005) both investigate the impact of vertical integration in the retail gasoline market. Hortacsu and Syverson (2007) analyze vertical integration among the cement and ready-mixed concrete industries. In particular, Hu and Prieger (2008), Derdenger (2009) and Lee (2009) both study the effects of exclusive game titles on the competition among game console manufacturers. In contrast to them, in this paper, I answer the question that whether third-party exclusive titles process sales premium.

In terms of empirical framework, this paper is closely related to Hendel, Nevo, and Ortalo-Magne (2009). They compare outcomes on transaction prices and time by property sellers using real estate agents and using For-Sale-By-Owner web site, and control for the potential seller selection problems. I follow their framework to compare the sales performances of exclusive and non-exclusive video games.

## 2.3 Home Video Game Market

Starting as a fringe industry in the early 1970's with the introduction of a home version of Pong, the U.S. video game industry has since grown to reach \$21.3 billion in revenues in 2008.<sup>5</sup> Increasingly, as evidenced by the widespread adoption of the new generation of consoles introduced in 2006, video games have broadened their appeal and user base from a child's hobby to something more mainstream: 69% of American heads of households engage in computer and video games, with the average age of a player being 35 years old,<sup>6</sup> and market penetration of video game consoles reached 41% of U.S. television

households (45 million) in 2006.

A video game system consists of a hardware platform (the “console”) and software (video games). In the current and most recent generations, each console is and has been provided by one firm - the console manufacturer - as a tightly integrated and standardized device that is required in order to utilize any software provided for the system. Video game software, on the other hand, is brought to market by two vertically related entities: developers, who undertake the programming and creative execution of each title; and publishers, who market and distribute each game. Publishers may be integrated into software development; although independent software development studios exist, as the costs of developing games have increased over time (average costs reached \$6 million during the late 1990’s) these studios often turn to software publishers for financing in exchange for distribution and publishing rights.

Consoles from different manufacturers are mutually incompatible, therefore, the issue of exclusivity on the software side arises. Exclusive game titles can only run on one particular console, while non-exclusive titles can run on multiple platforms. Any title produced by the console manufacturer’s own studios or distributed by its own publisher, known as the “first-party” title, is exclusive to that console platform. All other games are “third-party” titles and are published by other independent firms. Within the same generation of consoles, games developed for one console are not compatible with others; in order to be played on another console, the game must explicitly be “ported” by a software developer and another version of the game created. These porting costs for supporting an additional console, which includes additional development and distribution costs, are non-negligible, and range from a few hundred thousand to a few million dollars. Because of such significant porting costs, the same non-exclusive games on different consoles are counted as different game titles although they may share many common characteristics.

## 2.4 Data

The data is collected from the website [www.vgchartz.com](http://www.vgchartz.com). The website maintains a comprehensive dataset about video game consoles and video games. In



this paper, I focus on the games for the three seventh-generation video game consoles: SONY’s PlayStation 3, Microsoft’s Xbox 360, and Nintendo’s Wii. The dataset contains the information about release date, sales number, genre<sup>3</sup>, console availability and publishers of each game title from November 2005 to December 2008. In particular, Xbox 360 was launched one year earlier than the other two consoles, as a result, data for PlayStation 3 and Wii’s game starts from November 2006. In addition, the website also provides review scores for 634 game titles from various website and print magazines. I normalize all review scores on the scale of 10, and take average as the quality index. Because of the “porting” cost discussed above, same games on different consoles are counted as different titles although they have the same game characteristics. In total, there are 974 game titles in the dataset.

Table 2.1 summarizes the general descriptive statistics about the data.

Platform	PlayStation 3	Xbox 360	Wii
Total Number of Titles	229	371	378
Number of Exclusive Titles	38 (16.6%)	92 (24.8%)	123 (32.5%)
Number of First Party Titles	17 (7.4%)	29 (7.8%)	24 (6.3%)
Total Quantity Sold (Million)			
Average	0.16	0.18	0.26
Standard Deviation	0.10	0.07	0.07
Median	0.28	0.30	0.58
Max	3.69	4.82	6.96
Min	0.02	0.01	0.01
Starting Price			
Average	40.83	39.72	39.63
Standard Deviation	11.22	10.69	9.83
Number of Exclusive Titles in Top 15 Games	11	9	15
Exclusive Titles Sales Percentage	27.8%	39.4%	67.2%

Table 2.1: Descriptive Statistics

<sup>3</sup>The genre of the game includes action, family, fighting, platform, racing, RPG, shooting, sports, and other.

There is significant variation in game exclusivity across platforms: although 30% of all game titles are exclusive to one console, the majority are located on the Wii, while the majority of PlayStation 3 titles are available on all systems. On the other hand, the exclusive titles dominate the best selling lists for all three consoles. Xbox 360 and PlayStation 3 has 9 and 11 titles among their top 15 best-selling games, respectively, while Wii's top 15 titles are all exclusive. In addition, exclusive titles have much stronger sales than non-exclusive titles in general. They account for 27.8%, 39.4%, and 67.2% of the total game sales for PlayStation 3, Xbox 360, and Wii, respectively.

The Table 2.2 presents the comparison between exclusive and non-exclusive game titles across console platforms. The table suggests that there is some difference in the observed characteristics of exclusive and non-exclusive game titles. Especially, exclusive game titles have higher review score, implying that they may have higher quality perceived by the consumers.

Variables	Exclusive Titles		Non-exclusive Titles		Diff	<i>t</i> -stat
	Mean	Std. Dev.	Mean	Std. Dev.		
Sales (in Million)	0.37	0.12	0.15	0.10	0.22	4.84
Review Scores	6.92	1.24	6.28	2.58	0.64	3.73
Launch Price	41.22	10.83	40.01	11.22	1.21	0.60
Movie Adaptation	0.03	0.17	0.09	0.29	-0.06	-0.96

Table 2.2: Sample Properties Comparison

## 2.5 Results

### 2.5.1 Sales of Exclusive and Non-exclusive Titles

I now explore the differences in sales of exclusive and non-exclusive game titles across different console platforms. Table 2.3 presents the results from regressing logarithm of sales number of game titles on a dummy variable for exclusive title and various controls.

The result in column (i) suggests that there is a large sales premium on exclusive titles on average, roughly 20 percent. However, because of the presence of indirect network effects, the sales of consoles have large impact on the

	(i)	(ii)	(iii)	(iv)
Dependent variable: logarithm of game sales				
Exclusive	19.78 (2.92)	12.25 (1.85)	8.32 (1.24)	7.76 (1.17)
Review Scores	-	-	4.06 (0.62)	4.57 (0.53)
ln(Platform Sales)	-	2.43 (0.17)	2.59 (0.40)	2.32 (0.56)
Launch Price	-	-	1.02 (1.43)	0.87 (1.10)
$R^2$	0.015	0.131	0.663	0.714
Platform Controls	No	Yes	Yes	Yes
Additional Game Characteristics	No	No	Yes	Yes
Time Controls	No	No	No	Yes
$N$	974	974	643	643

Table 2.3: Effects of Exclusivity on Sales

sales of compatible games. For example, the popularity of Wii's games may largely be the result of the consoles's own popularity. Therefore, in column (ii), I include console characteristics into the regression. As expected, console sales is a significant factor contributing to the game sales and the magnitude of sales premium of exclusive titles then goes down to about 12 percent, but is still statistically significant. Furthermore, Table 2 suggests that there is difference in the observed characteristics of exclusive and non-exclusive game titles. In particular, exclusive titles on average have higher review scores than non-exclusive titles, suggesting that the exclusive game titles may have higher quality. If such difference is not controlled for, then the dummy variable for exclusivity will be biased since it will also capture the effects of these features. Thus, in column (iii), I further include additional game characteristics into the regression. The review scores have significant and positive impact on sales as expected, and the effect of exclusivity on sales further goes down to about 8 percent, but is still highly significant. Finally, the sales of both consoles and games are highly seasonal, with much higher volume occurs during summer (July and August) and the holiday season (November and December) since

the majority of the consumers in the video game market are teenagers. At the same time, developers generally choose the same time to launch their “big hit” titles in order to achieve maximum sales. Consequently, such observation indicates that time effects may be another factor that potentially affects the sales performance. In order to control for such impact, I include dummies for the month of the launch date into the regression, and the result is showed in column (iv). The effect of exclusivity slightly goes down to approximately 7.7 percent.

Overall, the results in Table 2.3 provides the evidence that exclusive video game titles have higher sales relative to non-exclusive titles after controlling for various factors that affects sales. The casual interpretation of the results relies on random assignment to console conditional on time, console and game characteristics. However, random assignment is a strong assumption in the context, and there is reasonable doubt that such assignment may not be held in the data used in this paper. Therefore, we need to deal with selection problem.

## 2.5.2 Selection

The previous section documents the difference in sales outcomes for exclusive and non-exclusive game titles. A major concern for the results is the possible platform selection issue. First, although I have controlled for a rich set of observed game characteristics, it is still possible that there are unobserved characteristics that are correlated with the choice regarding exclusivity. If this is the case, the estimates of the effect of exclusivity will be biased without correction. Second, it is also possible that attributes of game publishers may affect their choice in terms of console availability, which, in turn, may affect the sales performance of games. Now, I will discuss these two issues in detail.

### Unobserved Game Title Characteristics

As shown in Table 2.2, there are differences in the observed characteristics between exclusive and non-exclusive titles. These different observed characteristics might suggest that the unobserved game characteristics are different

between the two types of game titles as well. To account for this issue, I examine a sample of game titles in series in the dataset. The game titles in one series share the same game engine, architecture, genre and controls, with only minor modifications. For example, EA's FIFA series publish a new game title every year (e.g. FIFA 06 for 2006, 07 for 2007), and these titles are essentially same games with updated team squads each year. As a result, as long as the unobserved characteristics in the same series are constant over time, then including a series fixed effect will control for the unobserved characteristics. However, there are series whose titles are different at least in one major aspects. For example, game titles in Final Fantasy series are vastly different in terms of story, game architecture, and genres. Therefore, I exclude such series from the sample used in this section. In the sample, there are 15 exclusive series with 40 titles, 13 non-exclusive series with 98 titles, and 5 mixed series (series with both exclusive and non-exclusive titles in different years) with 21 titles. In total, there are 33 series and 159 titles.

In Table 2.4, I present the result using this sample. The first column shows the results with game series fixed effects. At the same time, for comparison, I also run the regression using the same sample as in the previous section by dropping the fixed effects and controlling for differences using game title characteristics alone. The results are presented in the second column. In all regressions I include month, year and holiday dummy variables, a linear time trend, and console platform characteristics.

The results with series fixed effects and with characteristics controls are very similar. The exclusive titles on average have around 6 percent higher sales. In addition, the estimates are also very close to the results from the full sample in magnitude. There are two folds of implications from the result. First, the result suggests that there is virtually no bias in the estimates due to the possible fixed unobserved game effect over time. Second, since the estimates using the full and sub-sample are very close, it highlights that the sample of series game titles is representative. Therefore, the unobserved game characteristics do not play a significant role in determining the sales.

	(i)	(ii)
Dependent variable: logarithm of game sales		
Exclusive	6.22 (1.44)	6.56 (1.69)
Review Scores	5.06 (1.22)	4.77 (0.66)
ln(Platform Sales)	2.47 (0.29)	3.02 (0.36)
Launch Price	1.82 (2.43)	1.07 (0.88)
$R^2$	0.763	0.684
Game Series Fixed Effect	Yes	No
Game Characteristics	No	Yes
Console Characteristics	Yes	Yes
Time Controls	Yes	Yes
$N$	159	159

Table 2.4: Effects of Exclusivity on Sales: Unobserved Characteristics

### 2.5.3 Selection of Game Publishers

Video games are designed by game developers and publishers. Therefore, the unobserved developer/publisher characteristics may affect both the sales and console platform choice. In this case, the estimates will be biased. If a game developer are more capable or even specialized to develop a certain types of games (shooting, family, etc), it may choose to make the games exclusive on a particular console since the consumer base of each console is differentiated. For example, most of Nintendo's Wii buyers are children and casual players, who mostly play family oriented games. Therefore, game developers who are developing family games may choose to make the game on Wii exclusively and adopt specialized effects accordingly to better attract the consumers. At the same time, such games would potentially have higher sales due to its developer's capability and specialization. Without appropriate controls for such selection, the effect of exclusivity on sales would be overestimated. I adopt two ways to deal with such selection issues.

## **First-party and Third-party Exclusive Titles**

The first approach to quantify the effect of possible unobserved developer characteristics is to compare the sales of first-party titles and the sales of third-party, but exclusive titles. First-party titles are developed or published by console manufacturers, and are naturally exclusive. Such comparison is inspired by Hendel, Nevo and Ortalo-Magné (2009), who compare the transaction prices of houses sold by owners to the transactions of realtors' own houses. They use such method to quantify the effect of possible selection problem that more patient sellers tend to sell their houses by their own and they are also able to have higher sale prices due to their patience. In the context of video games, I assume that, on average, console manufacturers are no worse at developing games on their own consoles than the independent developer. Therefore, the effect of console manufacturers developing or selling the first-party titles represents an upper bound on the impact of developer selection.

The results are shown in Table 2.5. “Exclusive” is a dummy variable that equals one for all exclusive titles, which include both first-party and third-party titles. “Third-party Exclusive” is a dummy variable that equals one for third-party exclusive titles, so its coefficient measures directly the difference between the sales performance of third-party exclusive titles and the first-party console manufacturer titles.

I find that exclusive titles do have the premium in sales. However, there is no statistically significant difference between first-party and third-party exclusive game titles.

## **Developer Fixed Effects**

Another approach to deal with possible selection issue is to include fixed effects for developers. Therefore, I use a sample in which every game developer have supplied both exclusive and non-exclusive titles, and use the observed multiple titles to control for unobserved developer heterogeneity. The sample contains 53 developers and 371 game titles. The results are presents in Table 2.6, in which I compare the results with and without developer fixed effects. All the

	(i)	(ii)
Dependent variable: logarithm of game sales		
Exclusive	16.12 (3.45)	4.56 (1.69)
Third-Party Exclusive	2.71 (1.09)	-1.02 (0.62)
Review Scores	-	4.37 (1.26)
ln(Platform Sales)	-	3.52 (1.06)
Launch Price	-	0.97 (0.58)
$R^2$	0.163	0.884
Game Characteristics	No	Yes
Console Characteristics	No	Yes
Time Controls	No	Yes
$N$	974	643

Table 2.5: Effects of Exclusivity on Sales: First- and Third-party Exclusive Titles

regressions contain the controls for game, console and times.

The results suggest that exclusive titles are indeed likely to have higher sales. Without developer fixed effect, exclusive titles on average are sold about 5 percent more than the non-exclusive ones. However, after controlling developer fixed effect, the coefficient for exclusivity drops to about 3.5 percent and becomes insignificant, suggesting the presence of possible selection in the game developer side.

After exploring various ways to control for the selection problem in the game developer/publisher's decision to supply exclusive or non-exclusive game titles, I find that the selection is indeed present. When the selection issue is controlled for, the sales premium for exclusive titles is still positive, but its magnitude decreases and becomes statistically insignificant.



	(i)	(ii)
Dependent variable: logarithm of game sales		
Exclusive	3.59 (1.71)	5.56 (1.49)
Review Scores	3.06 (1.02)	4.77 (0.66)
ln(Platform Sales)	2.57 (0.29)	2.19 (0.36)
Launch Price	0.82 (1.43)	1.02 (0.88)
$R^2$	0.763	0.684
Developer Fixed Effect	Yes	No
Game Characteristics	Yes	Yes
Console Characteristics	Yes	Yes
Time Controls	Yes	Yes
$N$	371	371

Table 2.6: Effects of Exclusivity on Sales: Developer Fixed Effect

## 2.6 Discussion of the Results

In this section, I discuss several implications of the results found in the previous sections.

First of all, note that the definition of game titles in the paper is console specific, namely that same games on different consoles are counted differently in term of “title”. Therefore, although exclusive “titles” have higher sales, it may be the case that non-exclusive games have higher sales when considering the total sales across all console platforms. However, this kind of advantage of non-exclusive titles can be only justified financially when the “porting costs” between different console platforms are not very large.

Indeed, the sample period in this paper is the early stage of the 7th-generation consoles. In look at the most recent game list for all the consoles<sup>4</sup>, I find that the proportion of exclusive titles are increasing for all the consoles: 20.3% for PlayStation 3, 32.0% for Xbox 360, and 43.8% for Wii, compared

<sup>4</sup>The *wikipedia.org* contains an up-to-date list of games for all the consoles, but it does not have other information.

to 16.6%, 24.8%, and 32.5%, respectively. It suggests that there is indeed an increasing incentive for game developers or publishers to supply exclusive titles.

Second, the regression results suggest that there is selection of game developers into console platforms. Such selection indicates that there is difference in the characteristics between developers who supply exclusive titles and those who supply non-exclusive titles. Therefore, the further analysis is needed to address the strategies behind the platform adoption decisions.

Finally, the results have different implications for different types of game titles. The sales premium and “porting” costs are the incentives for game developers to develop exclusive titles. However, the sales premium alone is not high enough to attract independent developers or publishers to publish “blockbuster” titles exclusively on one particular platforms. Therefore, console manufacturers have to give extra incentives to them to have independent, high quality game titles. Another way to tackle this problem for console manufacturers is to develop high quality titles by their own, and it is supported by the fact that the proportion of first-party titles have been increasing over time for all platforms.

## Chapter 3

# The Demand for Home Video Game Console: The Regression Discontinuity Approach

### 3.1 Introduction

The standard framework of demand estimation now is the discrete-choice models of demand by Berry (1994) and Berry, Levinsohn and Pakes (1995). The major attraction of such discrete-choice models of demand is that they treat products as the set of characteristics, and therefore solves the problem of dimensionality of linear expenditure model (Stone, 1954). At the same time, however, since some product characteristics are observed only by consumers, but not by econometrician (e.g. product reputation, brand images, etc), and they are summarized into the error term, which is correlated with the product prices, the problem of price endogeneity arises. Therefore, the discrete-choice models rely on proper exogenous instrumental variables to deal with the endogeneity of prices to obtain the correct price coefficients.

The standard, textbook instruments are variables that shift costs but are uncorrelated with demand shocks, known as cost shifters. The problem with this kind of instruments is that it is rarely the case that econometricians can observe cost data fine enough so that the cost shifters will vary by brand.

Therefore, such instruments usually can only identify parameters through time variation but not variations within brands. The most popular identifying assumption made to deal with the endogeneity problem is to assume that the location of products in the characteristics space is exogenous or at least determined prior to the revelation of the consumers' valuation of the unobserved product characteristics. BLP (1995) derive an explicit set of instrumental variables built on these assumptions. They use the observed product characteristics (excluding price and other potentially endogenous variables), the sums of the values of the same characteristics of other products offered by that firm, and the sums of the values of the same characteristics of the products offered by other firms. However, there are some plausible situations in which such assumption will not hold. For example, as in our paper, video game consoles are better characterized by the observed attributes, such as memory size and CPU speed, since bigger memory size and higher CPU speed usually mean higher overall performances, and therefore are more appealing to consumers. Finally, in case of time series data in which same markets are observed repeatedly for some periods, unless the products offered in different periods are different or products are updated frequently, there is little or no variation between periods in these instruments.

The last set of instrumental variables are obtained from the idea that, after controlling brand-specific effects and market characteristics, the unobserved market-specific valuations of the product are independent across markets but are allowed to be correlated within a market over time (Hauman 1996, Nevo 2000). Under this assumption, the prices of the brand in other markets are valid instruments since prices in different markets are correlated due to the common costs, but are uncorrelated with the unobserved market-specific valuations of the product. Still, there are situations in which such assumptions do not hold. For example, in the video game console market, a worldwide popular game on one console will increase the unobserved valuation of that particular console in all market, and therefore the independent assumption will be violated.

Since instrumental variable method has such limitations, in this paper, we propose an alternative method to identify the price coefficient without using

instrumental variables in the discrete choice models. Instead, we exploit the unique pattern of price adjustment of products, home video game consoles, in our sample and identify the price coefficient nonparametrically. The main idea comes from the fact that, unlike other home electronic devices, such as PC and digital camera, the video game consoles have much longer life span, in average over five years, and the retail prices are primarily in line with the manufacturer suggested retail prices (MSRP). At the same time, console manufacturers reduce the console's prices periodically during its life span. As a result, the console prices exhibit the kinky, down-ward trend with very little dispersion. Since the periodical price cut creates discontinuity in the price the consumers face around the cutoff point, consumers who purchased a particular console just before and after the price cut should have very similar underlined demand for it after controlling other observable characteristics, such as indirect network effect (i.e. effects of variety of compatible games on the demand for consoles), as the specification of the console remains the same throughout its life cycle. Yet these consumers faced different prices. Therefore, the differences in demand, reflected by the changes in the market share, should be driven primarily by the change in prices after controlling other observable.

Our method is in essence a regression discontinuity design (RDD) method. The recent development in the program evaluation literature shows that RDD method can be used to obtain reliable estimate of the causal effects (Hann, Todd and Van Der Klaauw (2001), Imbens and Lemieux (2007)). The main advantage of RDD method in this context is that it could identify the causal effects (in this paper, the effects of prices on demand) under much weaker assumptions and does not require instrumental variables.

The RDD method has recently become a standard evaluation framework for estimating the causal effects with non-experimental data. The key feature of RDD method is that treatment is given if and only if an observed covariant crosses a known threshold. Thus under weak smoothness conditions, the probability of receiving treatment near the cut-off behaves as if random. This feature helps to identify the causal effect without imposing arbitrary exclusion restrictions, functional forms, or distributional assumptions on error terms. Hahn, Todd, and van der Klauuw (2001) and Porter (2003) link RD design

to the program evaluation literature and formally establish weaker conditions for identification. In addition, RD design method has been used in a number of empirical applications to successfully estimate the causal effect using non randomized data, such as the effects of class size on students' performance (Angrist and Lavy 1999) and the effects of financial aid on college enrollment (Van der Klauuw 2003). In addition, Lee (2003), Lemieux and Milligan (2004), and Chen and Van der Klauuw (2004), exploit randomized variation near the point of discontinuity to solve selection bias.

Our paper is also related to the small but growing literatures about the application of RDD method in industrial organization and marketing science. Huang and Tan (2009) use RDD method to estimate the demand for credit using a unique dataset from a credit card issuer, who gives consumers different interest rates based on the cutoff points of consumers' credit scores. Hartman, Nair and Nayarana (2009) use RDD method to estimate the effects of target marketing, in which observed discreteness and kinks in the heuristics are used for distinguish consumers. They present two empirical applications. The first application is to measure the effects of casino's email promotions based on consumers' average daily won; the second is to quantify the effects of a B2C company's direct mail promotion based on thresholds of expected response rate.

## **3.2 The Market Background and Data**

Our data on console sales and the number of available game titles come from the NPD Group, a market research firm. NPD Group collects data from approximately two dozen of the largest game retailers in the United States. These retailers account for approximately 65% of the U.S. market; from this data, NPD formulates estimates of figures for the entire U.S. market. However, these estimates do not take into account sales to rental outlets such as Blockbuster.

We have monthly data for the period from March 2005 to June 2008. Since our alternative identification strategy relies on the presence of "discontinuity" in the console prices, we include 4 consoles, PlayStation Portable, PlayStation 2, and PlayStation 3 from SONY and Xbox 360 from Microsoft, because they

have major price cut during out sample period. We exclude consoles from Nintendo, since their prices stayed the same throughout our sample period.

We define the potential video game market as the number of people who had a TV but did not have a video game system prior to their purchase. The number of U.S. households with at least one television set in the study period comes from the Census Bureaus 2003 Statistical Abstract of the United States. The size of the installed base by console and by month is obtained by the cumulative console sales up to the previous month. The installed base at the beginning of 2003 is obtained from Clements and Ohashi (2004), which reports the installed base of all major consoles in 2003.

We use manufacturer suggested retail prices (MSRP) as our price variable and adjust it using CPI. Although the real transaction prices are more desirable, it is very difficult to obtain and, in fact, the real transaction prices of the consoles are very close to the MSRP<sup>1</sup>.

The Table 3.2 summarizes the consoles that are used in the paper. SONY, the legendary Japanese firm, maintains the full product line producing both desktop and portable consoles, while Microsoft, who just entered into the market in 2002, only has desktop console on the market. At the same time, SONY, which had been the dominant firm for many years in 1990s, keeps two desktop consoles, the older PlayStation 2 and the latest PlayStation 3, on the market due to its advantages in production<sup>2</sup>.

As can be seen in the Table 3.2, Microsoft and SONY, as manufacturers of other electronic devices, lowered their console prices periodically since the production costs fell across time. At the same time, prices affect the sales of the consoles significantly. PlayStation 3, although most advanced, is the most

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<sup>1</sup>Clements and Ohashi (2003) divide total revenue from console sales by total unit of sales to calculate the unit prices, and find that the calculated prices are very close to MSRP. Prieger and Hu (2007) argue that retailers, even as powerful as Walmart, nearly never cut prices of consoles under MSRP, instead, the most frequently used promotion method by retailers is to bundle selected games to the sales of consoles. Such effects can be captured by the error term  $\xi_{jt}$

<sup>2</sup>SONY is the only manufacture that make its own production of major parts of its consoles, such as CPU and GPU. In contrast, Microsoft, for example, sources the design and production of its CPU to Intel, while Nintendo sources the work to IBM. Therefore, the supply of Microsoft and Nintendo's consoles is constrained by the capacity of upstream firm, like Intel and IBM, whose business is mainly in PC industry.

expensive among the competing consoles, and it is also the least selling one.

As expected, the indirect network is significant in this market. The better selling consoles also have larger network of games. Nintendo’s Wii and DS, which are the best-selling consoles in their own categories, enjoy the highest average game sales; while at the same time, PlayStation 3 has the least average sales of compatible games as it is the least popular console.

Console (Manufacture)	Type	MSRP	Average Annual Console Sales (unit)	Average Annual Compatible Game Sales (unit)
Xbox 360 (Microsoft)	Desktop	399.99 (2005.11) 349.99 (2007.8)	3,926,967	37,570,119
PlayStation 2 (SONY)	Desktop	149.99 (2005.3) 129.99 (2006.5)	4,686,990	39,282,305
PlayStation 3 (SONY)	Desktop	499.99 (2006.11) 399.99 (2007.7)	2,477,544	18,582,722
PSP (SONY)	Portable	249.99 (2005.3) 199.99 (2006.3) 169.99 (2007.4)	3,926,083	16,412,509

Table 3.1: Overview of Home Video Game Console Market

Console	Introduction Year (U.S. Market)	CPU(MHz)	GPU(MHz)	RAM (MB)
PSP	2005	333	166	36
PS2	2000	300	147	32
PS3	2006	3200	550	512
Xbox 360	2005	3200	500	512

Table 3.2: Specification of Selected Consoles



### 3.3 Model and Estimation

#### 3.3.1 Model of Demand for Video Game Consoles

We assume that a representative household maximizes the following utility function at time  $t$  by choosing console  $j$  among  $J_t + 1$  alternatives, one of which is the option of not purchasing a console:

$$u_{jt} = \beta_0 + \sum_k x_{jtk} \beta_k + \alpha x_{jt} + \omega \ln(N_{jt}) + \xi_{jt} + \varepsilon_{jt} \quad (3.1)$$

where  $u_{jt}$  is a representative households utility from choosing console  $j$  at time  $t$ .  $p_{jt}$  is the price of console  $j$  at time  $t$  (adjusted by the CPI),  $x_{jtk}$  is the console characteristic that consumers value, and  $\beta_0$  is the constant term. The term  $\ln(N_{jt})$  captures the indirect network effect, and  $N_{jt}$  is the number of compatible game titles available on console  $j$  up to time  $t$ . We estimate only an indirect network effect, not a direct effect. There might be a direct network effect in the video game market if consumer utility, and thus console demand, depended on the number of consumers who own the same console. As pointed out by Clements and Ohashi (2005), this would be the case if, for example, console users derived value from borrowing games from other users of the same console. However, with the country-level data as in our paper, the indirect effect should be of more significance since the direct effects are mainly confined into the region level.  $\xi_{jt}$  is the unobserved (by the econometrician, but observed by consumers) product characteristic. Such unobserved error also reflects other factors that lead consumers to purchase a particular console that are not present in the data. A process of building console image, perhaps partly stimulated by advertising, may be one example of such a factor.  $\varepsilon_{jt}$  is a mean-zero error term.

#### Logit Demand Model

If  $\varepsilon_{jt}$  is a mean-zero error term and is assumed to be i.i.d and distributed according to Type I extreme-value distribution. The model is then the (aggregate) logit model. Therefore, the market share of console  $j$  in period  $t$  can

be calculated by the following equation:

$$s_{jt} = \frac{\exp(\beta_0 + \sum_k x_{jtk}\beta_k + \alpha x_{jt} + \omega \ln(N_{jt}) + \xi_{jt})}{1 + \sum_{j=1}^J \exp(\beta_0 + \sum_k x_{jtk}\beta_k + \alpha x_{jt} + \omega \ln(N_{jt}) + \xi_{jt})} \quad (3.2)$$

Berry (1994) shows that a logit demand can be transformed into a linear model that can be estimated using only market level data:

$$\ln\left(\frac{s_{jt}}{s_0}\right) = \beta_0 + \sum_k x_{jtk}\beta_k + \alpha p_{jt} + \omega \ln(N_{jt}) + \xi_{jt} \quad (3.3)$$

where  $s_0$  is the market share of outside good (choosing not to buy a console in period  $t$ ). Then, the price elasticities of of console  $j$  defined by the above equation is

$$\eta_{jkt} = \frac{\partial s_{jt} p_{kt}}{\partial p_{kt} s_{jt}} = -\alpha p_{jt}(1 - s_{jt}) \quad (3.4)$$

### Nested Logit Demand Model

To achieve more realistic substitution pattern between products, we also estimated the nested logit demand model in which  $\varepsilon_{jt}$  is assumed to be generated as follows: On the first node, a household owning a TV that does not have a game system decides whether or not to purchase a game console. If the household decides to buy, it makes a console choice on the second node. In addition, we assume that the household makes the decisions of purchasing desktop or portable consoles separately and independently. Following Berry (1994), a linear regression model for this two-stage logit model is derived as follows:

$$\ln\left(\frac{s_{jt}}{s_0}\right) = \beta_0 + \sum_k x_{jtk}\beta_k + \alpha p_{jt} + \omega \ln(N_{jt}) + \theta \ln(s_j|_{I_t=1}) + \xi_{jt} \quad (3.5)$$

where  $s_{jt}$  is the share of the console market captured by console  $j \in J_t$  during period  $t$ , and  $s_{jt}|_{I_t=1}$  is the console  $j$ 's market share given that consumers decide to purchase video game consoles at period  $t$  (i.e.,  $I_t$  takes 1 when purchase is made); thus  $s_{jt}|_{I_t=1}$  equals  $s_{jt}/(1 - s_{0t})$ , where  $s_{0t}$  is the market share of the outside option at time  $t$  (Thus,  $s_0 + \sum_j s_j = 1$ ).

The price elasticities of console  $j$  defined by the nested logit demand model is then

$$\eta_{jt} = \frac{\partial s_{jt}}{\partial p_{jt}} = \frac{\alpha}{1 - \theta} p_{jt} [1 - \theta(s_{jt}|I_t=1) - (1 - \theta)s_{jt}] \quad (3.6)$$

### 3.3.2 IV Estimation

The endogeneity problem in equation (3) and (5) arises since the unobserved product characteristic  $\xi_{jt}$  is correlated with price  $p_{jt}$ , which, if uncorrected, would lead to inconsistency of the price coefficient  $\alpha$ . One common strategy to identify the price coefficients is to exploit the rival product attributes and the competitiveness of the market. All other things being equal, products with closer substitutes tend to have relatively lower prices. As suggested by Berry (1994) and BLP (1995), the observed attributes of other products are valid instruments for prices. However, since we estimate the demand of consoles separately by brand, this kind of instrument does not have variation across the sample periods. Therefore, we use another kind of instruments known as “cost shifters”. The first set of the instruments of this kind includes the exchange rates of Japanese Yen, Korea Won, and Taiwanese Dollar. These three countries are the biggest producer of console CPU, memory, graphic card/GPU, and hard drives, respectively. The variation of the exchange rates will affect the cost of console, but not on the demand since the prices of the console in dollar have been very stable. However, these instruments are an industry aggregate and do not vary by console model, the use of instruments thus only helps identify the demand through the variation of the instruments over time. The second set of the instruments of “cost shifters” is the technology of semiconductor production adopted by each console manufacture, which is measured by the minimum distance between two elements on the circuit in terms of micrometer( $\mu\text{m}$ ). The closer the distance can achieve, the less the cost of production of CPU and GPU is, and CPU and GPU account for a large part of the production cost of the console.

The equations (3) and (5) then are estimated by the 2SLS method.

### 3.3.3 Regression Discontinuity Design Method

Our alternative strategy of estimating the correct causal relationship between prices and console demand uses the simple fact that the console manufactures lower the prices periodically. More specifically, the prices can be expressed as a function of time indicator  $t$  as the following:

$$p_{jt} = \begin{cases} p_j^1, & 1 \leq t \leq t_1; \\ p_j^2, & t_1 < t \leq t_2; \\ \dots, & \dots \\ p_j^n, & t_{n-1} < t \leq t_n \end{cases} \quad (3.7)$$

where the discrete indicator  $t$  measures the number of months passed since the first time the console  $j$  appears in the sample period. Therefore, the price is a kinky function of time indicator. And the relationship between market shares and prices for the four consoles considered in the paper is showed in Figure 3.1.

As discussed above, our identification strategy of price coefficient relies on these discrete changes in the prices over time, since when prices are cut, the underlined demand remains unchanged after controlling other factors that affect demand. Therefore, the main effect that drives up the console's market share is from the price change. Furthermore, since the price can be treated as a kinky function of time indicator  $t$  alone, the bias of price effect can also be treated as a function of  $t$ . This fact enables us to find correct price effects if we can correctly control the bias. This can be done by using nonparametric or semiparametric techniques without using instrumental variables. The idea is exactly the regression discontinuity design method that has been widely used in other fields.

A critical requirement on data we would like to point out to validate this identification strategy is that the price cut should not be made when other more significant factors also have major changes. In terms of the data set we use, this requires the price cut should not be made during the holiday season, which is typically in November and December for video game consoles, to make our alternative approach effective. The reason is that holiday season

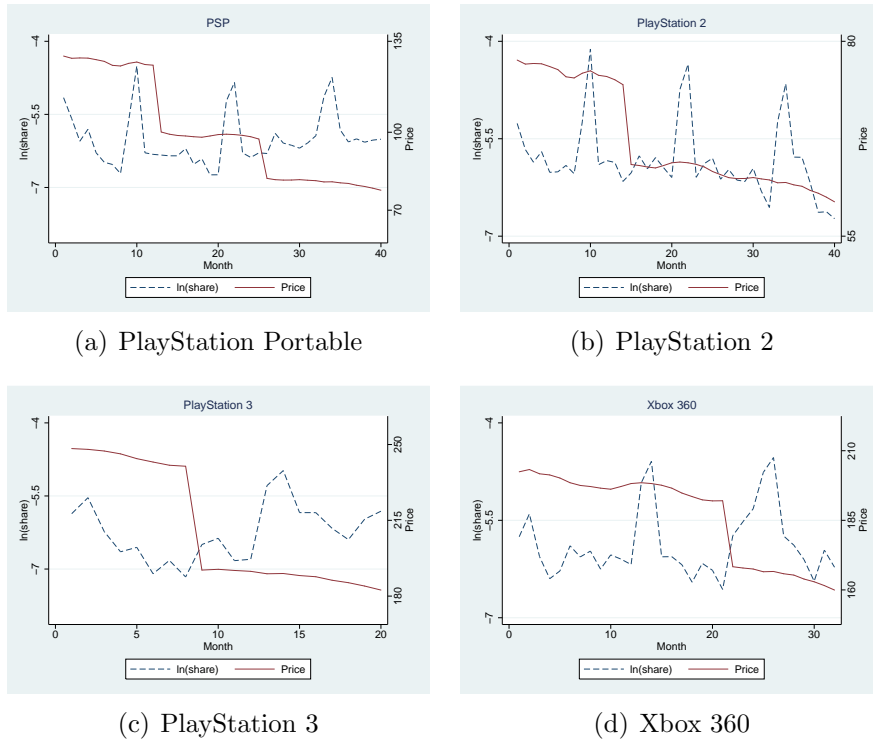


Figure 3.1: Market Share and Price Trend

itself is a far more significant factor to boost demand and price cut during the holiday season would have much weaker impact on sales. Since the price effects are identified only by the changes in the market share around price cut points in our alternative approach, such scenario would undermine the its effectiveness seriously. Fortunately, all console manufacturers choose to cut console prices not on the holiday seasons. Some choose to do it in the spring or summer, while others choose to cut prices several months before the holiday seasons. As reflected in figure 1, the most significant jump in market share is corresponding to holiday seasons. However, for most consoles (PlayStation Portable, PlayStation 3, and Xbox360), the demand, measured by the market share, also increases significantly after the price cut, although the scale is much less than the effect of holidays.

The type of regression discontinuity model in our paper is commonly referred to as Sharp Design, in which whether consumers purchase consoles be-

fore or after any the price cut solely depends on the time indicator  $t$ . As argued in Kahn, Todd and Van der Klauuw (2001) and Van der Klauuw (2003), under the local continuity assumptions, the local average treatment effect (the price coefficient  $\alpha$ ) at each cut off points of time indicator  $t$  can be identified by:

$$\alpha = \frac{\lim_{t \downarrow t_i} E(S|t) - \lim_{t \uparrow t_i} E(S|t)}{E_{t \downarrow t_i}(p|t) - E_{s \uparrow t_i}(p|t)} \quad (3.8)$$

where  $t_i$  is one cut-off point for the price changes.

An advantage of using regression discontinuity design method is that the effect of prices can be identified under much weaker assumptions and no instrumental variables are needed. The only identification assumption needed is the local continuity assumption. A limitation of regression discontinuity design method is that only the effect at the cut off point can be identified.

We use the control function approach (Van der Klauuw (2003)) to control for the biases. Namely, we add the correct specification of the control function  $k_j(t)$ , which is console specific, to the equation (3) and (5):

$$\ln\left(\frac{S_{jt}}{s_0}\right) = \beta_0 + \sum_k x_{jtk} \beta_k + \alpha x_{jt} + \omega \ln(N_{jt}) + k_j(t) + v_{jt} \quad (3.9)$$

and

$$\ln\left(\frac{S_{jt}}{s_0}\right) = \beta_0 + \sum_k x_{jtk} \beta_k + \alpha x_{jt} + \omega \ln(N_{jt}) + \theta(s_{jt}|I_t=1) + k_j(t) + v_{jt} \quad (3.10)$$

where  $k_j(t)$  is the conditional mean function  $E(\xi_{jt}|t)$  and  $v_{jt} = E(\ln(\frac{S_{jt}}{s_0})|E, t)$ . If the control function  $k_j(t)$  is correctly specified, the estimate of  $\alpha$  gives us the correct causal effect of prices on the market shares.

This control function method requires a specification of the control function  $k_j(t)$ . Incorrect specification of  $k_j(t)$  leads to inconsistency, and hence the control function should be as flexible as possible. In practice, most studies use a semi parametric specification of the control function. For example, Van der Klauuw (2002) uses a power series approximation for  $k(t) = \sum_{j=1}^J \eta_j t^j$ , where the number of power function  $J$  is estimated by generalized cross validation method. In our study, we use the approach described in Huang and Tan (2009)

to estimate the equation.

### **3.4 Estimation Result**

The following tables present the estimation result and implied price elasticities from IV estimation and regression discontinuity method.

Variable	Logit Model		Nested Logit Model		Parameter	Std Error	Std Error	Std Error
	IV Estimation	Regression Discontinuity	IV Estimation	Regression Discontinuity				
<b>PSP</b>								
Price	-0.0141	0.0027	-0.011	0.0044	-0.0109	0.0022	-0.0145	0.00336
ln(Game)	0.622	0.150	0.645	0.095	0.383	0.0892	0.422	0.0778
Holiday	0.493	0.205	0.604	0.126	0.903	0.125	0.826	0.104
Within Share					6.79	0.728	5.746	0.627
Constant	-9.438	0.848	-7.608	0.685	-7.88	0.512	-9.10	0.529
<b>PS2</b>								
Price	-0.0211	0.0060	-0.0104	0.0117	-0.0178	0.0133	-0.00503	0.00909
ln(Game)	0.541	0.116	0.680	0.103	0.294	0.128	0.515	0.089
Holiday	0.597	0.179	0.473	0.159	0.925	0.187	0.664	0.131
Within Share					3.82	1.20	5.047	1.049
Constant	-10.398	0.693	-8.730	1.203	-7.16	1.19	-9.79	0.951
<b>PS3</b>								
Price	-0.0026	0.0050	-0.0061	0.0036	-0.000988	0.00185	-0.00186	0.00175
ln(Game)	0.540	0.170	0.693	0.147	0.269	0.0680	0.430	0.079
Holiday	0.788	0.171	0.395	0.164	0.984	0.0665	0.788	0.085
Within Share					8.83	0.789	7.56	0.857
Constant	-9.562	1.809	-7.694	1.063	-8.87	0.674	-8.46	0.527
<b>Xbox 360</b>								
Price	-0.018	0.0080	-0.029	0.0060	-0.017	0.0054	-0.009	0.004
ln(Game)	0.641	0.179	0.665	0.136	0.391	0.0900	0.265	0.118
Holiday	0.610	0.185	0.813	0.147	0.888	0.0956	0.980	0.131
Within Share					4.24	0.506	3.84	0.686
Constant	-12.818	2.400	-10.783	1.457	-9.44	1.200	-6.20	1.10

Table 3.3: Estimation Result



First of all, observe that the coefficients of within share variable in the nested logit specification are all greater than 1 for all consoles. This leads to the fact that the own-price elasticity implied by equation (6) is positive. Other research also reported similar result. For example, Prieger and Hu (2006) used a very similar sample during 2002 and 2004 to estimate the demand for three major desktop consoles in U.S. market (PlayStation 2, Xbox, GameCube), and they also suggested that the nested logit model did not fit well for the console demand equation. Instead they estimated the standard logit model. On contrast, the earlier work by Clements and Ohashi (2005), which used a sample of home video game console in U.S. market during 1994 and 2002, set up and estimated a nested logit model. In their estimation, the nested model fits the demand quite well. Since the main focus of this paper is the comparison between instrumental variable and regression discontinuity design approach, we now turn our focus in the standard logit model, but keep in mind that the restricted substitution pattern it implies.

The price coefficients from IV estimation are all significant, while the price coefficients of PlayStation 2 and PlayStation 3 in the RD design regression are not significant. This is probably due to the identification approach of RD design approach. Since RD design approach relies on the variation of market share around the point of price cut to identify the correct price effect, it requires that the changes in market share before and after price cut should be significant. However, the market share of PlayStation 2, as can be seen from figure 1, remains flat during the whole sample periods, while the holiday effect is the dominant factor that drives the sales up. Therefore, the price coefficient under RD design approach is insignificant. At the same time, the market share of PlayStation does increase after the price cut, however, the increase is moderate, and actually, it decreases right after the increase. As a result, the price effect also cannot be identified clearly under the RD design approach.

Next, we calculate the own price elasticity implied by the standard logit demand specification using estimated parameters from both IV and RD design approach, and the results are shown in Table 3.4.

	Logit Model	
	IV Estimation	Regression Discontinuity
<b>PSP</b>	-1.41	-1.11
<b>PS2</b>	-1.15	-0.70
<b>PS3</b>	-1.60	-3.75
<b>Xbox 360</b>	-3.35	-5.40

Table 3.4: Implied Own Price Elasticity of Demand

The implied elasticities for all consoles are in the elastic region except the one of PlayStation 2 under RD design approach. This is predictable since its price coefficient under RD design approach is not significant. We compare the result with other works to see whether our estimation result is reasonable, and the work discussed above by Clements and Ohashi (2005), and Prieger and Hu (2006) are natural benchmarks. Clements and Ohashi (2005) used a sample of home video game console in U.S. market during 1994 and 2002 and estimated the price elasticities of demand between -1.07 to -2.20. Prieger and Hu (2006) used a sample during 2002 and 2004 to estimate the demand for three major desktop consoles in U.S. market (PlayStation 2, Xbox, GameCube), and find the implied elasticities are between -1.789 and -2.289. In particular, the estimated price elasticity of PlayStation 2 in their sample is -2.20. Our estimated elasticities of PlayStation 2 in the IV estimations are smaller in absolute value. The difference is mainly due to the different sample period in our analysis. The price of PlayStation 2 is lower in our sample than in Prieger and Hu's since we use a later sample. As the price elasticities implied by (4) are proportional to prices, the elasticities estimated from our sample are smaller. Our estimation of the price elasticity of Xbox 360 (-3.35 under IV and -5.40 under RD design approach) is out of the range in the existed literatures (between -1 and -3). The reason for that is probably the much stronger reaction of Xbox 360's market share to the price cut. After the price cut, the market share almost doubled, which is far more than other consoles. Therefore, such response between market share and price cut leads to the higher price elasticity.

## 3.5 Conclusion

In this paper, we propose an alternative method to estimate the standard discrete choice demand function to have correct price coefficient without using instrument variable. This method is essentially a regression discontinuity design method. Using a data set of video game console sales in U.S. during 2005 to 2008, we estimate the demand function using both IV and RD design approach. The estimation result is similar between two approaches, and the calculated price elasticities are comparable to result in other similar works.

We show that the regression discontinuity method could be a very useful tool to estimate the demand function. In many applications in empirical IO and marketing, dealing with the endogeneity problem is usually one of the most important parts of the analysis. Instrumental variable methods are the most commonly used method. However, in many applications, it is very difficult to find good instruments. In this case, regression discontinuity design method could provide an alternative way to solve the endogeneity problem. Comparing with the IV method, RD design method has several advantages. First, RD design method relies on much weaker assumptions about the underlying data generating process. The only assumption that RD design method uses is the continuity assumption. In contrast, the IV method usually relies on exclusion restriction assumptions. Second, many applications in empirical IO and marketing could use the RD design method. Similar to the application in this paper, in many cases, firms make decisions based on some cut off rules. As long as the researchers have knowledge of the decision process, this information could be used in RD design as illustrated in this paper.

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