JEROEN L.G. BINKEN

# System Markets

## Indirect Network Effects in Action, or Inaction?

# System markets:

## Indirect network effects in action, or inaction?

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## Indirect network effects in action, or inaction?

Systeem markten: indirecte netwerk effecten in actie of inactie?

PROEFSCHRIFT

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Copromotor: Prof.dr. H.R. Commandeur

Overige leden: Prof.dr.ir. B.G.C. Dellaert

Prof.dr. Ph.H.B.F. Franses

Dr. A. Lemmens

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We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.

T. S. Eliot,
1942.

# Preface

The completion of this dissertation is the culmination of my endeavors at the Erasmus University. During my education, while following the courses of Harry Commandeur, network effects, especially indirect network effects, caught my attention. After reading ‘Information Rules’ by Carl Shapiro and Hal Varian, I was hooked on network effects. This addiction accumulated into first in my doctoral thesis ‘Are Digital Market Failing: An In-depth Look at Supply-side and Demand-side Positive Feedback,’ and now in this dissertation ‘System Markets: Indirect Network Effects in Action, or Inaction?’

First and foremost, I wish to thank my promoter Stefan Stremersch for his enthusiasm, guidance, support and high standards. Without him, this dissertation would not have existed, and our papers would not have been published.

I also would like to give special thanks to the members of the committee, for their valuable contribution to this dissertation.

In addition, I would like to thank, co-authors, colleagues from marketing and econometrics, editors and reviewers, roommates, fellow PhD’s, and everybody from ERIM and the marketing department, for their advice and support during my years as a PhD. My thanks also go out to NPD, for providing part of the sales data.

Last, but certainly not least, I would like to thank my family and close friends, for their unconditional love, guidance, friendship and support.

Jeroen,
2009.

# Chapter 1

# Introduction

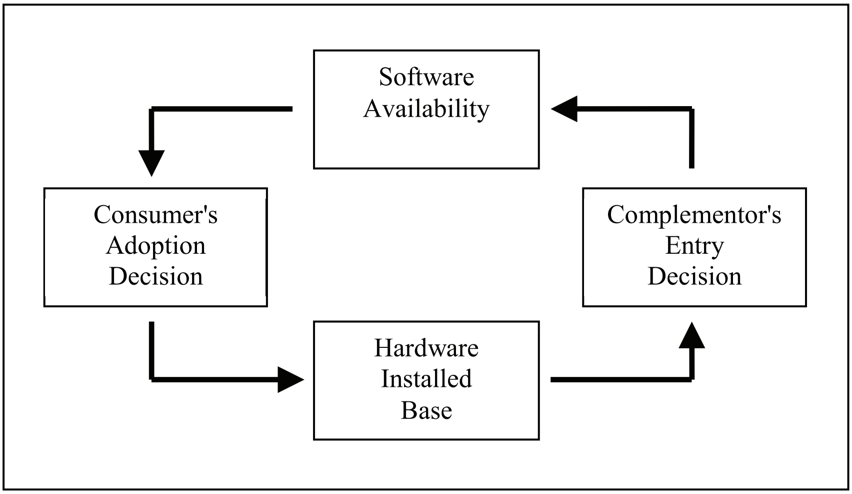
## 1.1 Motivation

In this dissertation, I will examine system markets up close. More specifically I will examine indirect network effects, both demand-side and supply-side indirect network effects. Indirect network effects are the source of positive feedback in system markets, or so network effect theory tells us.

Systems are composed of complementary and interdependent products, such as hardware and software (Farrell and Saloner 1986; Katz and Shapiro 1986a). For instance, a video game system is composed of the video game console, on the one hand, and video games, on the other hand (Chou and Shy 1990; Clements and Ohashi 2005; Gandal, Kende and Rob 2000).

When indirect network effects are present, the increased adoption of the hardware by consumers, and thereby the larger hardware installed base, increases the complementor's likelihood to enter the system and start introducing software (i.e., supply-side indirect network effects). This larger availability of software increases the utility of the system to consumers, thereby increasing the consumers' likelihood to adopt the hardware, thus increasing hardware sales (i.e., demand-side indirect network effects), and so on (Caillaud and Jullien 2003; Church and Gandal 1993 and 1996; Katz and Shapiro 1994). Figure 1.1 depicts this positive feedback cycle.

Figure 1.1: The Positive Feedback Cycle of Indirect Network Effects



Indirect network effects give rise to the chicken-and-egg paradox. This coordination problem is the result of both complementors and consumers taking a 'wait-and-see' attitude towards the new system (Gupta, Jain, and Sawhney 1999; Katz and Shapiro 1994). Complementors delay entry and thus the introduction of software products, until enough consumers have adopted the system, while consumers wait to adopt the system until enough software firms have entered and introduced their software products (Caillaud and Jullien 2003; Gandal 2002; Gupta, Jain, and Sawhney 1999; Srinivasan, Lilien and Rangaswamy 2004; Stremersch et al. 2007). Subsequently, sales of the system's hardware and software products do not take off.

While network effects theory has grown extensively during the last 25 years, the existing body of empirical research relating to indirect network effects is still very small. We know very little about the behavior of indirect network effects in actual markets.

In addition, as the economy becomes more and more interconnected, the importance of markets with network effects increases, thereby increasing its relevance for the firm's marketing strategy (Gupta, Jain and Sawhney 1999; Srinivasan, Lilien and Rangaswamy 2004; Yoffie 1997). The financial implications of these marketing strategies in system markets are immense. The introduction of a new system, whether it is Sony's PlayStation 3, or Microsoft's Vista operating system, is often a multibillion-dollar gamble, which will receive massive worldwide media attention. Financial losses can be huge and severely affect the firm's survival. 3DO, Atari and Sega almost ceased to exist because their systems failed, while Microsoft lost over $4 billion dollars in just 4 years on its Xbox system (Murphy 2005), and that was a reasonable successful system.

To enhance our understanding of indirect network effects in actual markets, in order to alleviate the chicken-and-egg paradox, we undertook the 3 empirical studies presented in this dissertation (Chapter 2, 3 and 4). These 3 studies should help academics, practitioners, and government agencies, when dealing with system markets.

## 1.2 Outline

For each of the following 3 chapters I gathered uniquely new data. This process alone took over 2 years. This gave us the unique opportunity, to be the first to examine demand-side and supply-side indirect network effects across a large number of system markets, and examine them in-depth.

In chapter 2, we focus our attention on both demand-side and supply-side indirect network effects across a large number of system markets. We examine the occurrence and strength of indirect network effects, the temporal pattern of indirect network effects by examining the take-off of software availability and hardware sales, and the 'chicken-and-egg' problem. We collected data on 9 system markets from their introduction onward, without resorting to proxies, and use a takeoff analysis, time series model, and historical case analyses to examine indirect network effects. This work was co-authored with Stefan Stremersch, Gerard Tellis, and Philip Hans Franses, and published in the *Journal of Marketing* as "Indirect Network Effects in New Product Growth".

In chapter 3, we focus on demand-side indirect network effects. We examine the heterogeneity in the effect of demand-side indirect network effects. Do certain superstar software products (e.g., Super Mario 64) have a disproportionately large effect on hardware unit sales (e.g., Nintendo N64 console sales). We collected 4 million quality ratings of around 5,800 software products, and use a Prais-Winsten dynamic panel data model to examine demand-side indirect network effects. This work was co-authored with

Stefan Stremersch, and published in the *Journal of Marketing* as “The Effect of Superstar Software on Hardware Sales in System Markets”.

In chapter 4, we focus on supply-side indirect network effects. We examine the complementor’s probability and timing of entry. Specifically, we examine the heterogeneity in the effect of supply-side indirect network effects. We examine the entry behavior of complementors (i.e., independent software firms) in a system market across successive incremental technology generations. We collected data on around 2,900 entry opportunities during a 35-year period, and use a split-population duration model to examine the effects of supply-side indirect network effects and pre-entry experience. This work was co-authored with Stefan Stremersch, and is being prepared for submission.

Each chapter addresses many of the existing shortcomings of prior research, combined they greatly enhance our understanding of system markets. Each individual chapter presents its findings and implications for academics, practitioners, and government agencies at the end of the chapter in the results, discussion and implications sections.

In chapter 5, we present a short summary of the main findings and implications, related to indirect network effects. We conclude by providing directions for future research.

# Chapter 2

# New Product Growth in System Markets[1]

## 2.1 Introduction

> "*A familiar high-tech variation on an age-old conundrum is stalling acceptance of the much-heralded computer storage medium known as DVD-ROM: Which comes first, affordable hardware or a wealth of software? The installed base or the content providers?*"
>
> David Pescovitz in: The LA Times, 1997.

TV sets. CD players. DVD players. Economists regularly claim that such markets exhibit indirect network effects[2]. The expected utility of the primary product – and thereby its sales – increases as more complements become *available*, and this availability of complements[3], in turn, depends on the installed base of the primary product (Caillaud and Jullien 2003; Church and Gandal 1993 and 1996; Cottrell and Koput 1998; Hill 1997; Katz and Shapiro 1994). Prior research has typically referred to the primary product, such as a TV set, a CD player and a DVD player, as hardware and to the product that complements the primary product, such as programming (TV), Compact Discs (CD player), and DVD movies (DVD player), as software (Church and Gandal 1992b; Ducey and Fratrik 1989; Gandal, Kende and Rob 2000; Gupta, Jain and Sawhney 1999).

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[1] This work was co-authored with Stefan Stremersch, Gerard Tellis, and Philip Hans Franses, and published in the Journal of Marketing as "Indirect Network Effects in New Product Growth".

[2] The phenomenon of indirect network effects is different from the possible interdependence between hardware *sales* and software *sales,* such as CD Player sales and CD sales (Bayus 1987; Peterson and Mahajan 1978).

[3] The literature is inconsistent in terminology. Scholars have used the term availability (e.g. Dranove and Gandal 2003; LeNagard-Assayag and Manceau 2001), variety (e.g. Church and Gandal 1992a and 1993), or both interchangeably (e.g. Basu, Mazumdar and Raj 2003; Frels, Shervani and Srivastava 2003; Gandal, Kende and Rob 2000; Katz and Shapiro 1985; Nair, Chintagunta and Dubé 2004), in theory development. Most, if not all, of the empirical studies that have used the term variety operationalize this construct through counting the total complements available (e.g. Basu, Mazumdar and Raj 2003; Gandal, Kende and Rob 2000; Nair, Chintagunta and Dubé 2004). In the present study, we consistently use the term availability, as that corroborates with our measures.

Indirect network effects give rise to the ‘chicken-and-egg’ paradox: consumers wait to adopt the hardware until enough software is available and software manufacturers delay releasing software until enough consumers have adopted the hardware (Caillaud and Jullien 2003; Gandal 2002; Gupta, Jain and Sawhney 1999). A recent example is the High-Definition television (HDTV) market. The expected utility of HDTV sets to consumers (and therefore HDTV set sales) increases the more HD broadcasting becomes available. On the other hand, broadcasters will make more HD broadcasting available, as the number of consumers owning a HDTV set increases. For HDTV to succeed, this ‘chicken-and-egg’ paradox must be resolved (Farrell, et al. 1992; Gandal 2002; Pope 1999).

In the last two decades, several economists have researched various aspects of indirect network effects, including (1) coordination between software and hardware industries (Church and Gandal 1992b; Economides and Salop 1992; Farrell, et al. 1992); (2) standard setting (Church and Gandal 1992a; Clements 2004; Economides 1989; Katz and Shapiro 1985, 1986a, 1992 and 1994); and (3) buyers’ technology adoption decisions (Gandal, Kende and Rob 2000; Saloner and Shepard 1995; Shy 1996). While most research in the first two streams relates to choice between rival incompatible systems, the third studies why consumers adopt a given system (Majumdar and Venkataraman 1998). Our study fits within this third research tradition.

Marketing researchers have only recently started to study *indirect* network effects (Basu, Mazumdar and Raj 2003; Gupta, Jain and Sawhney 1999, LeNagard-Assayag and Manceau 2001; Nair, Chintagunta and Dubé 2004), although the discipline has a relatively longer tradition of studying *direct* network effects[4] (e.g. Brynjolfson and Kemerer 1996; Majumdar and Venkataraman 1998; Sun, Xie and Cao 2004; Xie and Sirbu 1995). In addition, some marketing studies focus on network effects per se, independently of whether they are direct or indirect (e.g. Shankar and Bayus 2003; Srinivasan, Lilien and Rangaswamy 2004; Van den Bulte and Stremersch 2004).

Tables 2.1 and 2.2 summarize the prior economics and marketing literature. Table 2.1 contains all empirical papers on indirect network effects and stipulates whether they study demand-side or supply-side indirect network effects or both; whether they define

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[4] In direct network effects markets, the utility of the product depends *directly* on the number of others using the same product (Katz and Shapiro 1985).

indirect network effects from only the demand-side, only the supply-side, or both; what the focal dependent and independent variables in their inquiry are; whether they use proxies to measure focal constructs; how many markets they study; whether they have data from the introduction of the new technology; and which markets they study. Table 2.2 contains a selection of non-empirical papers on indirect network effects. It illustrates what the main focus of this prior work is (whether on indirect network effects specifically or on network effects generally); what the method is (whether mathematical or conceptual); whether they define indirect network effects from only the demand-side, only the supply-side, or both; and which focal dependent and independent variables are included. While this prior literature is valuable and insightful, it also shows some limitations.

First, empirical analysis of indirect network effects is rare and, as evidenced by Table 2.1, limited to the study of one, exceptionally two, markets. Of the eighteen empirical studies of indirect network effects, seventeen study only one market and only one (Gandal 1995) studies two markets. This situation is probably due to a lack of data on both hardware sales and software availability. Some authors have even claimed that such data is unavailable (Putsis et al. 1997), whereas others (six out of eighteen studies) have used distant proxies, such as the amount of advertising (Gandal, Greenstein and Salant 1999). Still other authors have modeled indirect network effects as if they were direct network effects (Hartman and Teece 1990; Ohashi 2003; Park 2004; Shankar and Bayus 2003). Authors often also do not use data that start at the introduction of the new technology either (rare exceptions are Dranove and Gandal (2003) and LeNagard-Assayag and Manceau (2001)), leading to potential left-censoring biases. Often, authors also have modeled only one side of indirect network effects, most often so the effect of software availability on hardware sales (demand-side indirect network effects). Moreover, the literature is diverse and inconsistent as to the definition of indirect network effects. Many papers do not even explicitly state a definition of indirect network effects, others provide (inexplicitly) multiple definitions (see the variation on the definition of indirect network effects in Tables 2.1 and 2.2). The literature is also inconsistent as to the empirical models employed (see the list of dependent and independent variables in Table 2.1). Therefore, we can conclude that the literature lacks a unifying framework to empirically examine indirect network effects.

## Table 2.1: Overview of Empirical Literature on Indirect Network Effects

| | Demand or Supply-side | Definition of Indirect Network Effects | | | | Dependent Variable | |
|---|---|---|---|---|---|---|---|
| | | Demand-side | Supply -side | Both | Other | In HW* equation | In SW* equation |
| Basu, Mazumdar and Raj (2003) | Demand | V | | | | HP | |
| Clements and Ohashi (2005) | Both | | | V | | HMS | SA |
| Cottrell and Koput (1998) | Demand | | | V | | HP | |
| Dranove and Gandal (2003) | Demand | | | V | | HS | |
| Frels, Shervani and Srivastava (2003) | Demand | V | | | | RA | |
| Gandal (1995) | Demand | | | V | | | SP |
| Gandal, Greenstein and Salant (1999) | Both | | | V | | HS | SA |
| Gandal, Kende and Rob (2000) | Both | | | V | | HIB | SA |
| Gupta, Sachin and Sawhney (1999) | Both | | | V | | CD | CR |
| Hartman and Teece (1990) | Demand | | V | | | HMS | |
| LeNagard-Assayag and Manceau (2001) | Both | | | V | | HIB | SA |
| Nair, Chintagunta, Dube (2004) | Both | | | V | | HS | SA |
| Ohashi (2003) | Demand | | | V | | HMS | |
| Park (2004) | Demand | | | V | | HMS | |
| Rysman (2004) | Both | | | V | | CD | SP |
| Saloner and Shepard (1995) | Supply | | | | V | | SD |
| Shankar and Bayus (2003) | Demand | | | V | | HS | |
| Shurmer (1993) | Demand | | V | | | CD | |
| **This Study** | **Both** | | | **V** | | **HS** | **SA** |

* C: Compatibility, CD: Consumer Demand, CR: Complementor Response, HIB: Hardware Installed base, HMS: Hardware Market Share, HP: Hardware Price, HS: Hardware Sales, RA: Resource Allocation, SA: Software Availability, SD: Software Deployment SP: Software Price.

## Table 2.1: Overview of Empirical Literature on Indirect Network Effects (ctd.)

| | Independent Variable | | Uses Proxies | Nr. of Markets | Data from intro-duction | Markets |
|---|---|---|---|---|---|---|
| | In HW* equation | In SW* equation | | | | |
| Basu, Mazumdar and Raj (2003) | SA | | No | 1 | No | CD |
| Clements and Ohashi (2005) | SA | HIB | No | 1 | Partial | Video Game |
| Cottrell and Koput (1998) | HMS, SA | | No | 1 | No | Microcomputer |
| Dranove and Gandal (2003) | SA | | Yes | 1 | Yes | DVD Player |
| Frels, Shervani and Srivastava (2003) | SA | | No | 1 | No | Computer |
| Gandal (1995) | | C | No | 2 | No | Spreadsheet & DMS |
| Gandal, Greenstein and Salant (1999) | SA | HS | Yes | 1 | No | CP/M and DOS |
| Gandal, Kende and Rob (2000) | SA | HIB | No | 1 | No | CD |
| Gupta, Sachin and Sawhney (1999) | SA | CD | No | 1 | No | Television |
| Hartman and Teece (1990) | HMS, HIB | | Yes | 1 | No | Minicomputer |
| LeNagard-Assayag and Manceau (2001) | SA | HIB | No | 1 | Yes | CD (France) |
| Nair, Chintagunta, Dube (2004) | SA | HIB | No | 1 | No | PDA |
| Ohashi (2003) | HIB | | Yes | 1 | No | VCR |
| Park (2004) | HMS, HIB | | Yes | 1 | No | VCR |
| Rysman (2004) | SA | CD | No | 1 | No | Yellow Pages |
| Saloner and Shepard (1995) | | HS | Yes | 1 | No | ATM |
| Shankar and Bayus (2003) | HIB | | No | 1 | No | Video Game Console |
| Shurmer (1993) | SA | | No | 1 | No | PC Sofware (UK) |
| **This Study** | **SA** | **HIB** | **No** | **9** | **Yes** | **B&WTV, CD, CD-ROM, CTV, DVD, GB, i-Mode, Internet, LD** |

## Table 2.2: Overview of Non-Empirical Literature on Indirect Network Effects

| | Main Focus* | Method** | Definition of Indirect Network Effects | | | |
|---|---|---|---|---|---|---|
| | | | Demand-side | Supply-side | Both | Other |
| Bental and Spiegel (1995) | NE | C | | V | | |
| Bonardi and Durand (2003) | NE | C | | | V | |
| Caillaud and Jullien (2003) | INE | M | | | V | |
| Choi (1994) | NE | C | V | | | |
| Chou and Shy (1990) | INE | M | V | | | |
| Chou and Shy (1993) | INE | M | V | | | |
| Chou and Shy (1996) | INE | M | V | | | |
| Church and Gandal (1992a) | INE | M | V | | | |
| Church and Gandal (1992b) | INE | M | V | | | |
| Church and Gandal (1993) | INE | M | | | V | |
| Church and Gandal (1996) | INE | M | | | V | |
| Clark and Chatterjee (1999) | NE | M | | | V | |
| Clements (2004) | NE | M | | | V | |
| Conner (1995) | NE | C | V | | | |
| Dhebar (1995) | INE | C | | | V | |
| Economides (1996) | INE | C | | | | V |
| Economides and Himmelberg (1995) | NE | C | V | | | |
| Economides and White (1994) | NE | C | | | | V |
| Esser and Leruth (1988) | NE | C | V | | | |
| Farrell and Saloner (1985) | NE | C | | V | | |
| Farrell and Saloner (1986) | NE | M | V | | | |
| Gandal (2002) | NE | M | | | V | |
| Garud and Kumaraswamy (1993) | NE | C | | V | | |
| Hahn (2003) | NE | C | | | | V |
| Hill (1997) | O | C | | | V | |
| Katz and Shapiro (1985) | NE | C | | V | | |

*: main focus can be on network effects in general, denoted by NE, indirect network effects, denoted by INE, or other, denoted by O. **: method can be conceptual (containing verbal or graphical logic), denoted by C, or mathematical (containing a mathematical formulation), denoted by M.

## Table 2.2: Overview of Non-Empirical Literature on Indirect Network Effects (ctd.)

| | Dependent Variable Model | | Independent Variable Model | |
|---|---|---|---|---|
| | Hardware*** | Software*** | Hardware*** | Software*** |
| Bental and Spiegel (1995) | | | | |
| Bonardi and Durand (2003) | | | | |
| Caillaud and Jullien (2003) | CU | CP | SA | HMS |
| Choi (1994) | | | | |
| Chou and Shy (1990) | CU | CP | SA | SA |
| Chou and Shy (1993) | CU | SA | SA | HMS |
| Chou and Shy (1996) | CU | SA | SA | HIB |
| Church and Gandal (1992a) | CU | CP | SA | SA |
| Church and Gandal (1992b) | CU | CP | SA | HMS |
| Church and Gandal (1993) | CU | SE | SA | HIB |
| Church and Gandal (1996) | CU | CP | SA | SA |
| Clark and Chatterjee (1999) | CU | | SA | |
| Clements (2004) | | SE | | HIB |
| Conner (1995) | | | | |
| Dhebar (1995) | | | | |
| Economides (1996) | | | | |
| Economides and Himmelberg (1995) | | | | |
| Economides and White (1994) | | | | |
| Esser and Leruth (1988) | | | | |
| Farrell and Saloner (1985) | | | | |
| Farrell and Saloner (1986) | CU | | HIB | |
| Gandal (2002) | CU | | SA | |
| Garud and Kumaraswamy (1993) | | | | |
| Hahn (2003) | | | | |
| Hill (1997) | CU | SA | SA | HIB |
| Katz and Shapiro (1985) | | | | |

*** CU: Consumer Utility, CP: Complementor Profit, HIB: Hardware Installed Base, HMS: Hardware Market Share, SA: Software Availability, SE: Software Entry.

## Table 2.2: Overview of Non-Empirical Literature on Indirect Network Effects (ctd.)

| | Main Focus* | Method** | Definition of Indirect Network Effects | | | |
|---|---|---|---|---|---|---|
| | | | Demand-side | Supply-side | Both | Other |
| Katz and Shapiro (1986a) | NE | M | | V | | |
| Katz and Shapiro (1986b) | NE | M | | V | | |
| Katz and Shapiro (1992) | NE | C | | V | | |
| Katz and Shapiro (1994) | INE | C | | V | | |
| Koski and Kretschmer (2004) | NE | C | | | V | |
| Kotabe, Sahay and Aulakh (1996) | O | C | | | V | |
| Kristiansen (1996) | NE | C | | | V | |
| Kristiansen (1998) | NE | C | V | | | |
| Lee and O’Connor (2003) | NE | C | | | V | |
| Loch and Huberman (1999) | NE | C | | V | | |
| Matutes and Regibeau (1988) | O | C | | V | | |
| Matutes and Regibeau (1992) | O | C | | V | | |
| Postrel (1990) | NE | C | V | | | |
| Rohlfs (2001) | NE | C | | | V | |
| Schilling (1999) | O | C | | | V | |
| Schilling (2002) | O | C | | | V | |
| Shapiro and Varian (1998) | NE | C | | | V | |
| Sheremata (2004) | NE | C | | | V | |
| Shy (2001) | NE | M | | | V | |
| Srinivasan, Lilien and Rangaswamy (2004) | NE | C | | | V | |
| Thum (1994) | NE | C | | V | | |
| Valente (1995) | O | C | V | | | |
| Viswanathan (2005) | NE | C | | V | | |
| Wade (1995) | NE | C | | | V | |
| Xie and Sirbu (1995) | NE | C | | | V | |

*: main focus can be on network effects in general, denoted by NE, indirect network effects, denoted by INE, or other, denoted by O. **: method can be conceptual (containing verbal or graphical logic), denoted by C, or mathematical (containing a mathematical formulation), denoted by M.

## Table 2.2: Overview of Non-Empirical Literature on Indirect Network Effects (ctd.)

| | Dependent Variable Model | | Independent Variable Model | |
|---|---|---|---|---|
| | Hardware*** | Software*** | Hardware*** | Software*** |
| Katz and Shapiro (1986a) | CU | | HIB | |
| Katz and Shapiro (1986b) | CU | | HIB | |
| Katz and Shapiro (1992) | | | | |
| Katz and Shapiro (1994) | | | | |
| Koski and Kretschmer (2004) | CU | SA | SA | HIB |
| Kotabe, Sahay and Aulakh (1996) | | | | |
| Kristiansen (1996) | | | | |
| Kristiansen (1998) | | | | |
| Lee and O'Connor (2003) | CU | SA | SA | HIB |
| Loch and Huberman (1999) | | | | |
| Matutes and Regibeau (1988) | | | | |
| Matutes and Regibeau (1992) | | | | |
| Postrel (1990) | | | | |
| Rohlfs (2001) | | | | |
| Schilling (1999) | HIB | SA | SA | HIB |
| Schilling (2002) | | | | |
| Shapiro and Varian (1998) | | | | |
| Sheremata (2004) | | | | |
| Shy (2001) | | SA | | HIB |
| Srinivasan, Lilien and Rangaswamy (2004) | | | | |
| Thum (1994) | | | | |
| Valente (1995) | | | | |
| Viswanathan (2005) | | | | |
| Wade (1995) | | | | |
| Xie and Sirbu (1995) | | | | |

*** CU: Consumer Utility, CP: Complementor Profit, HIB: Hardware Installed Base, HMS: Hardware Market Share, SA: Software Availability, SE: Software Entry.

Second, while the chicken-and-egg paradox is cited a lot, it is unclear how it is resolved. Which comes first, the chicken or the egg? Many business analysts (e.g. Midgette 1997; Tam 2000; Yoder 1990; Ziegler 1994, all in the Wall Street Journal) and academics (Bayus 1987; Bucklin and Sengupta 1993; Clements 2004; Frels, Shervani and Srivastava 2003; Sengupta 1998) have casually observed that a critical mass of software titles is required for hardware sales to take off. Take-off is the point of transition between the introduction stage and the growth stage of a growth curve (Golder and Tellis 1997). Several academics (e.g. Church and Gandal 1992a) have made similar arguments based on theoretical models. However, no one – to our knowledge – has empirically examined whether software availability leads hardware sales or not.

We aim to fill these voids in the present paper. To do so, the present paper examines the temporal pattern of indirect network effects across multiple markets using secondary data, based on prior theories developed in economics and marketing. To do so, the authors have constructed a database, on both hardware sales and software availability, for nine markets, since their inception (the appendix contains a detailed description of the data): Black & White Television, Compact Disc, CD-ROM, Color Television, DVD, Gameboy, i-Mode, Internet (WWW), and Laserdisc.

The second section of the paper develops the theoretical background of this study. The third section details the data we use. The fourth section presents our empirical analysis. We conclude by summarizing the results, presenting the implications and limitations of our study, and discussing avenues for further research.

## 2.2 Theoretical Background

The essence of indirect network effects theory is the understanding that software and hardware form a system (Chou and Shy 1996; Economides 1989; Katz and Shapiro 1994). As they form a system, the supply of software and the demand for hardware may affect each other, according to a specific temporal pattern. Both may also be affected by other variables. For instance, the supply of software may be affected by the supply of software in previous periods and hardware sales may be affected by its price and past hardware sales. We next theorize on all these effects.

### 2.2.1 Indirect Network Effects

The theory of indirect network effects argues that the supply of software and the demand for hardware affect each other. The amount of software that is available for a certain technology has a positive influence on the utility of the entire hardware-software system to the consumer (Church and Gandal 1992a; Katz and Shapiro 1985), which draws ever more new adopters to adopt the new hardware (Rogers 1995) and thereby increases hardware sales and the installed base of hardware. In turn, the hardware installed base positively affects software companies' decisions to make software titles available (Church and Gandal 1993; Gandal 2002). The more consumers that have adopted the hardware product, the larger the market potential for software products for that particular hardware product and therefore the larger the impetus for software companies to provide software titles for the hardware.

Our in-depth review of the literature of indirect network effects (see Tables 2.1 and 2.2) suggests at least three forms of indirect network effects, dependent upon the conditions authors have imposed to define them. We call these forms: *demand-side indirect network effects*, *supply-side indirect network effects* and *demand- and supply-side indirect network effects. Demand-side indirect network effects* mean that software availability significantly and positively affects hardware utility of an individual consumer and therefore, at the aggregate level, also hardware sales. *Supply-side indirect network effects* imply that hardware installed base significantly and positively affects the software provision by software manufacturers and therefore, at the aggregate level, software availability. *Demand- and supply-side indirect network effects* imply that both characteristics exist.

### 2.2.2 Temporal Pattern in Indirect Network Effects

The temporal pattern in indirect network effects is important as it can indicate how the chicken-and-egg paradox is resolved. Prior literature has not covered this issue in detail. At the same time, academic scholars and business analysts have expressed very different opinions on this temporal pattern.

A first opinion expressed is that, given extensive coordination between hardware and software manufacturers, growth of software availability coincides with growth in hardware sales (e.g. Katz and Shapiro 1994). Government intervention may coordinate the actions of market participants – both software and hardware – to achieve that. The guidelines of the FCC towards new broadcasting and radio technologies are an example. Hardware manufacturers may also give subsidies, kick-backs, and side payments to software manufacturers to fine-tune software availability to the hardware sales evolution. In the extreme, hardware manufacturers may even vertically integrate into the software industry. An example is RCA's ownership of NBC (when Color Television was introduced).

Others have argued that growth in software availability may precede growth of hardware sales (Bayus 1987; Bucklin and Sengupta 1993; Clements 2004; Frels, Shervani and Srivastava 2003; Sengupta 1998). Church and Gandal (1992a) and business analysts (Midgette 1997; Tam 2000; Yoder 1990; Ziegler 1994) claimed that software availability needs to achieve a critical mass in order for hardware to become a viable alternative, and hardware sales can take off. The reason is that consumers need a sign of sufficient software availability, before they start to adopt the hardware a mass. Also, software companies may invest in software provision before any marked hardware sales occur. For instance, Microsoft invested in the CD-ROM long before any significant sales of CD-ROM hardware occurred. Because the CD-ROM was the first mass market high capacity medium that might prove useful in copyright protection, Microsoft envisioned the dramatic advantages it might have for software delivery and installation.

Still other economists (e.g. Dranove and Gandal 2003) have argued that software companies may balk at making software available for new hardware that has not yet taken off. In the early years of most new technologies, the benefits of the new technology are unclear to the software industry. Moreover, different standards may be fighting for dominance, generating even more uncertainty for the software industry. The future mass acceptance of the hardware, and therefore the future profitability of software for the new technology are highly uncertain. Faced with such uncertainty, software companies are unlikely to commit substantial resources to making software available for the new hardware, especially if it requires a high upfront lump sum investment (Ducey and Fratrik 1989). Software providers may only make such investment after hardware sales have taken off and grow rapidly, thus signaling the viability of the new hardware.

At the same time, a critical mass of consumers that adopt the new hardware may develop before a sizeable library of software is available, for several reasons. First, early adopters may like the snob appeal of owning new hardware (Tellis, Stremersch and Yin 2003). Second, cascade effects may prompt consumers to buy new hardware because of their popularity among "opinion leaders" rather than their intrinsic utility (Golder and Tellis 2004). Third, early adopters may create their own content (e.g. i-Mode, Internet (WWW), or VCR) after buying the hardware. Fourth, a killer application (a single software application of very high quality and popularity) may be available, by which a sizeable consumer segment "must own" the hardware, regardless of the sheer number of applications available (Frels, Shervani and Srivastava 2003).

### 2.2.3 Other Effects

When one empirically examines indirect network effects, other considerations come into play as well, both at the hardware and the software side. At the hardware side, also price of the hardware[5] and prior hardware sales need to be accounted for. Hardware price will affect the affordability of the new technology, which may affect the adoption of the hardware by consumers, and thereby future sales (Golder and Tellis 1998). Prior hardware sales may affect future hardware sales for several reasons. The most salient reason is probably social contagion, in that past hardware adoptions will influence future hardware adoptions, either through learning under uncertainty or status considerations (Van den Bulte and Stremersch 2004). But there can be several other reasons as well, such as market inertia.

At the software side, two variables may affect software availability. First, past software availability may have an influence on future software availability, though the direction of the influence may be, a priori, unclear (Chou and Shy 1996; Church and Gandal 1992a). It may be positive, because higher past software availability likely

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[5] One could argue that also software price affects consumers' utility and thereby hardware sales. While this is valid, software prices are in most cases small (or even equal to zero, such as in broadcasting or Internet content), as compared to hardware prices. It is also in most cases, more difficult to obtain information on average software price as compared to average hardware price. Moreover, variation over time may be less in software price than in hardware price. The production of software is likely characterized by high up-front investments and low reproduction costs. Combined with intense competition, software prices are likely to be low (Shapiro and Varian 1998).

increases the utility of the new hardware, thereby increasing the future software sales software providers may expect, consequently encouraging them to make more software available (the "network" effect). It may also be negative, because higher past software availability yields more intense competition among software providers, thereby decreasing the margins software providers can make on their software, consequently discouraging them from making more software available (the "competition" effect). Second, software costs may affect software availability decisions by software providers. High costs involved in providing software for a new technology may discourage software provision by software companies.

## 2.3 Data

This section describes the data collection and the characteristics of the sample.

### 2.3.1 Data Collection

To collect data for the present study, we conducted extensive archival research. The data collection took a great deal of time and effort, because for each market we needed data on hardware sales (and/or hardware installed base), software availability, and hardware price from the time of introduction. As one can see from Table 2.1, prior empirical research has most often examined the effect of software availability on hardware sales to test for *demand-side indirect network effects* and the effect of hardware installed base on software availability to test for *supply-side indirect network effects*. We sought to obtain exactly these variables, rather than any other proxies, as some prior scholars have done (again see Table 2.1).

We used the following procedure to obtain our data. First, we examined the published literature on consumer electronics (e.g. Ducey and Fratrik 1989; Golder and Tellis 1997). Second, we examined statistical yearbooks (e.g. the Broadcasting and Cable Yearbook, the TV Factbook, the Broadcasting Yearbook, the International TV and Video Almanac, and the CD-ROM directory) in the libraries of two large research universities in the U.S. Some of these sources are also available electronically, but only for more recent years. Third, we contacted organizations directly to assess and access their data archives. Our search led us through approximately 30 public institutions and their libraries (e.g., U.N., the U.S. Federal Communications Commission, U.S. Senate Committees, recording and broadcasting associations, consumer electronics manufacturers' associations) and about 20 private companies that are market research companies, media consultants, manufacturers or software providers. For instance, NPD – a leading research company for marketing and sales information – graciously provided us with hardware sales data and software availability data for Gameboy. In addition, we tried to combine different sources to check for consistency in the data series.

### 2.3.2 Characteristics of the Sample

For this study, we focused on consumer electronics, because economic and marketing researchers claim that this class of products shows substantial indirect network effects (Church and Gandal 1993; Ducey and Fratrik 1989; Farrell, et al. 1992; Gupta, Jain and Sawhney 1999).

While we tried to gather data on all consumer electronics markets post WWII, we were able to gather annual data on nine network markets as follows: Black & White Television, CD, CD-ROM, Color Television, DVD, Gameboy, i-Mode, Internet (WWW), and Laserdisc. The markets we have data on vary widely from music to video entertainment and ICT to broadcasting. These markets also have the nice feature of being quite diverse in market structure, e.g. in number of manufacturers (from one (Nintendo) for Gameboy to many for television sets and Internet (WWW)), government involvement (from relatively high in television broadcasting to low in Compact Disc or DVD), etc.

All data are from the U.S., except three, namely Compact Disc, Laserdisc, and i-Mode. CD and Laserdisc title availability data were unavailable for the U.S. from their introduction (even after many consultations with the industry and leading publishers), but they were available for Compact Disc in the U.K. (which is clearly a lead market in music) and for Laserdisc in Japan (which is clearly a lead market in the most popular Laserdisc applications, such as Karaoke).[6] I-Mode data were not available for the U.S., while it was for the lead market for i-Mode, Japan.

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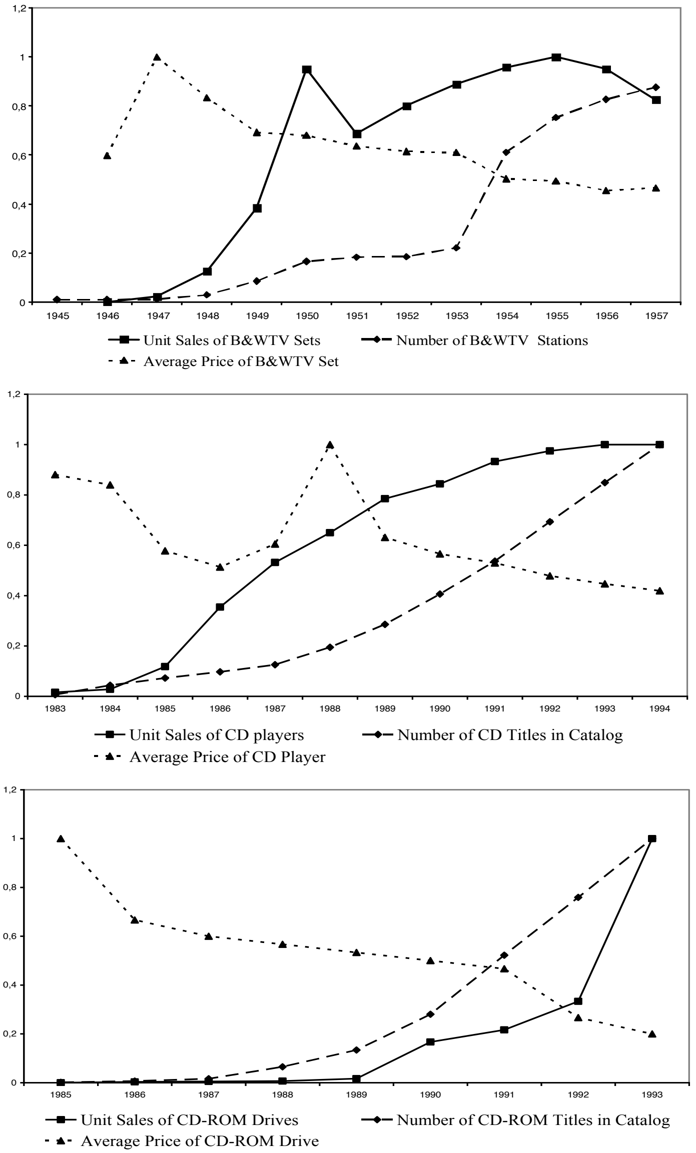
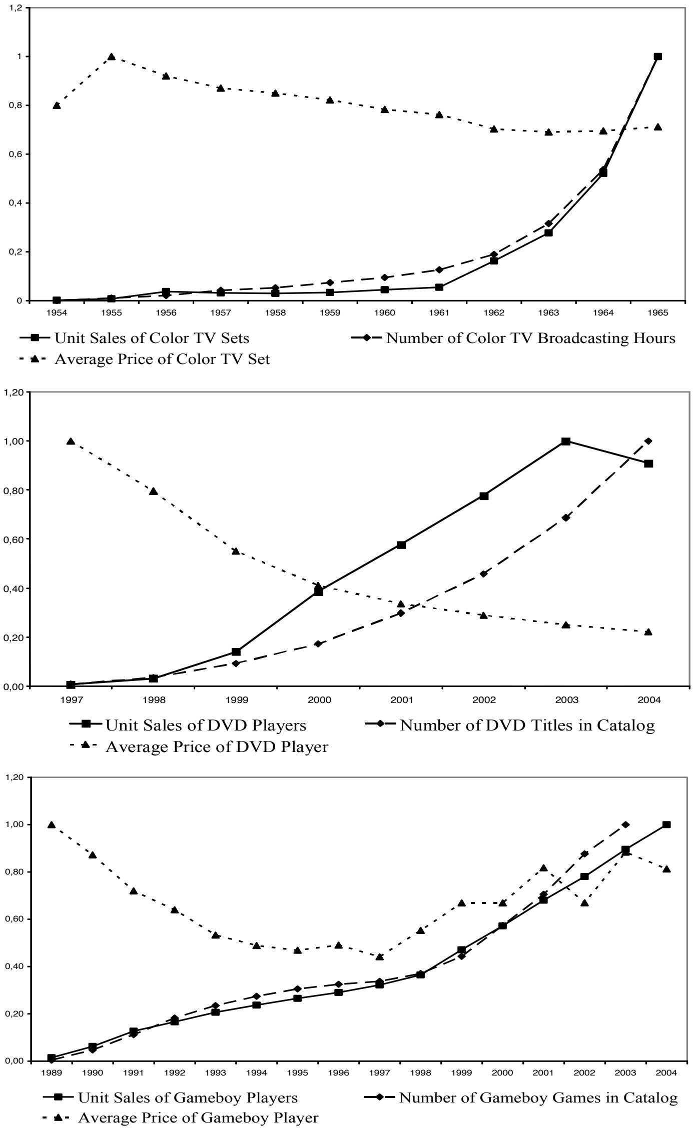
[6] Note that for the CD market, the main problem with data from the U.S. is that the number of released CD's by independent labels is unavailable, which is about 1/3 to 1/4 of the CD market.

Figure 2.1: Graphical Illustration of the Sample



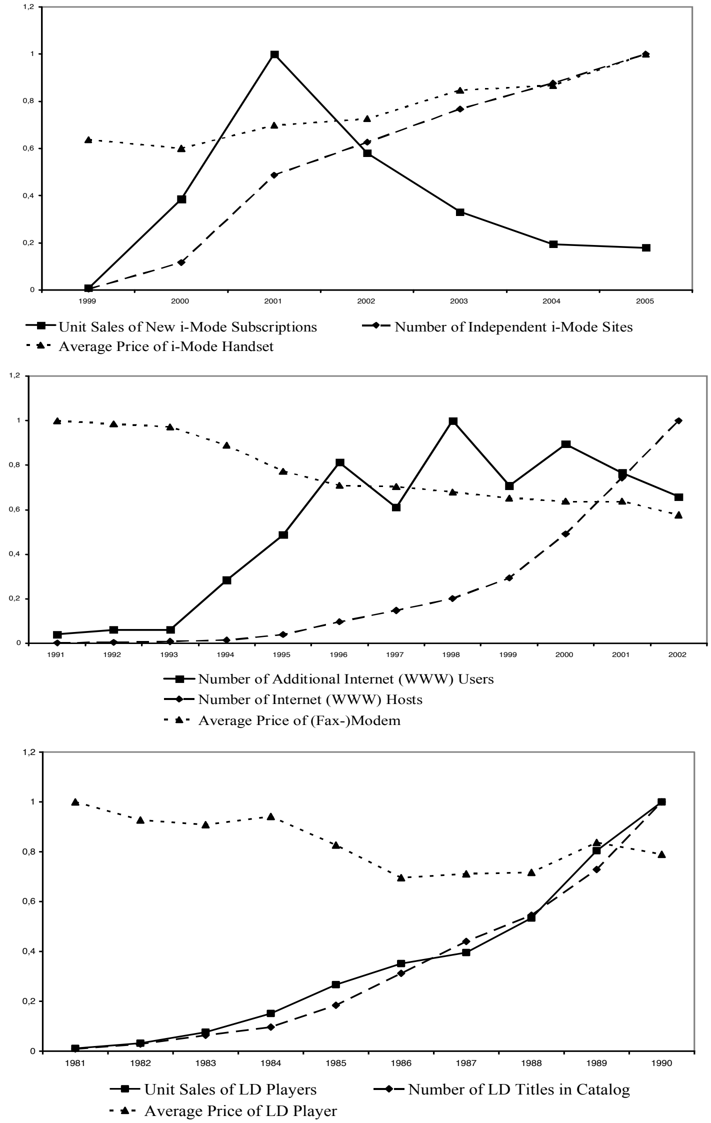
Legend:
The full lines with squares indicate hardware unit sales. Dashed lines with diamonds indicate software availability. Dotted lines with triangles indicate the hardware price evolution.
A full arrow indicates hardware sales takeoff. A dashed arrow indicates software availability takeoff.

Figure 2.1: Graphical Illustration of the Sample (ctd.)



Legend:
The full lines with squares indicate hardware unit sales. Dashed lines with diamonds indicate software availability. Dotted lines with triangles indicate the hardware price evolution.
A full arrow indicates hardware sales takeoff. A dashed arrow indicates software availability takeoff.

Figure 2.1: Graphical Illustration of the Sample (ctd.)



Legend:
The full lines with squares indicate hardware unit sales. Dashed lines with diamonds indicate software availability. Dotted lines with triangles indicate the hardware price evolution.
A full arrow indicates hardware sales takeoff. A dashed arrow indicates software availability takeoff.

The precise measures for all our variables and their sources are provided in the Appendix. For some markets, we derived hardware installed base from hardware sales by taking the cumulative sales, as data on hardware installed base was unavailable. Such derivation assumes there are no replacement sales – which is likely in many of our markets as we study the early diffusion process – and is in line with prior literature (Clements and Ohashi 2005; Dranove and Gandal 2003; Gandal, Kende and Rob 2000; Hartman and Teece 1990; Nair, Chintagunta and Dubé 2004; Shankar and Bayus 2003).

Our measures for software availability are consistent with measures other scholars have used in the past. For example, Nair, Chintagunta and Dubé (2004) use the number of software titles available for different PDA platforms. Basu, Mazumdar and Raj (2003), LeNagard-Assayag and Manceau (2001) and Gandal, Kende and Rob (2000) use the number of available Compact Disc titles.

Our measures for hardware prices are the average prices across brands, as is again similar to prior literature (LeNagard-Assayag and Manceau 2001; Shankar and Bayus 2003). For three markets, our measure for price shows specific limitations. In the Compact Disc market, we were unable to obtain hardware prices from the U.K. As we assume the U.K. market has undergone a similar CD player price pattern as the U.S. – e.g. because CD player brands are global players with global manufacturing capacity that determines their prices – we have included the U.S. CD player price as a proxy. In the i-Mode market, we included the average price of i-Mode handsets, which does not include access fees, for which we could not obtain data. In the Internet (WWW) market, we included the average price of a (fax-) modem, as that is the hardware component, and made abstraction of the average price of Internet access.

We display all our data graphically in the results section below (Figure 2.1), where series have been normalized by dividing the values by the maximum value in the series. This normalization enables better comparison and graphical conclusions, while also retaining confidentiality required to obtain some of the data.

## 2.4 Empirical Analysis

One can conceive of two ways in which one can empirically analyze the theoretical framework conceived above. First, one can focus on the concept of takeoff and contrast takeoff of hardware sales with takeoff of software availability. Second, one can conceptualize a time series model, based upon the notion of Granger causality. We apply both techniques and discuss each in turn. We end with relating our findings to the historical industry development, lending further credence to the pattern we found.

### 2.4.1 Takeoff Analysis

This section explores takeoff in indirect network effects markets. It first derives the concept of takeoff and develops its usefulness in empirically examining the theory derived above. Then it presents the measurement of takeoff, after which it turns to our findings.

#### ***Conceptual***

Initially, sales of a new product are generally flat. After some time, a critical mass[7] of adopters may develop, causing sales to show a distinct takeoff (Golder and Tellis 1997; Rohlfs 2001; Shapiro and Varian 1998). The concept of critical mass was born in physics, where it refers to the point of no return, after which nuclear fision becomes self-sustaining, and it has subsequently been adopted in sociology, where it refers to the minimum level of activity needed to make an activity self-sustaining (Schelling 1978). Thus, new product takeoff is followed by rapid self-sustaining growth, in which additional consumers adopt the new technology, until the market is saturated and sales show a decline (Golder and Tellis 2004). Hardware sales takeoff has been recognized as an important phenomenon in the marketing literature (Agarwal and Bayus 2002; Golder and Tellis 1997; Tellis, Stremersch, and Yin 2003).

Scholars have argued that the critical mass concept – and thus by consequence, takeoff – is pronounced in markets that are strongly influenced by interdependence of players – as is the case in system markets (Andreozzi 2004; Granovetter 1978; Valente 1995). This fits diffusion literature in marketing that has found that diffusion curves are more pronouncedly S-shaped in markets with competing standards (Van den Bulte 2000; Van den Bulte and Stremersch 2004).

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[7] Threshold and critical mass are terms that are used interchangeably in the sociology and economics literatures (Witt 1997, Macy 1991). For clarity, we consistently use the term critical mass.

In markets with direct network effects, the utility of the product to consumers depends upon the number of prior adopters. Thus, the critical mass is a certain number of adopters (Katz and Shapiro 1986a). In markets with indirect network effects, there is interdependence, between the utility an adopter derives from the system, and the number of other adopters of the system, because of the availability of complementary products (Katz and Shapiro 1986a; Srinivasan, Lilien and Rangaswamy 2004). Thus, markets with indirect network effects exhibit critical mass not only in consumer adoption of hardware (i.e., the demand side), but also in the amount of available software (i.e., the supply side). Therefore, software availability may show a pattern similar to hardware sales. At first, software companies may balk at providing software, because they doubt the viability of the new technology. After some time, a critical mass of software availability may develop and software availability will show a distinct takeoff. Prior business analysts (e.g. Midgette 1997; Tam 2000; Yoder 1990; Ziegler 1994) and academics (e.g. Church and Gandal 1992a) have made reference to such phenomenon without examining it in depth.

The takeoff in both hardware sales and software availability are important events in indirect network effects markets in view of the "chicken-and-egg" paradox. The order of takeoff of hardware sales and software availability may provide insight into the temporal pattern of indirect network effects. As we stipulated in our theoretical framework, prior theory is ex ante indeterminate as to what the temporal pattern may be, or in popular terms, what comes first: the chicken or the egg? The empirical study of the temporal order in which takeoff of software availability and hardware sales occur may provide a preliminary answer.

### Measurement

Most prior research has identified takeoff using a heuristic, much like the rules used by Golder and Tellis (1997), Stremersch and Tellis (2004), and Tellis, Stremersch and Yin (2003) (for the only exception, see Agarwal and Bayus (2002)). The spirit of these rules was to call takeoff the first time hardware sales crossed a boundary growth percentage, taking into account the base sales (past sales, as in Golder and Tellis (1997) or penetration, as in Stremersch and Tellis (2004) and Tellis, Stremersch and Yin (2003)).

The reason is that growth of 400% is not that significant when it entails unit sales growth from 100 to 500 units, while it is when it entails unit sales growth from 50,000 to 250,000.

There are two issues we face in applying these rules to our data that encompass hardware sales as well as software availability. First, there is no natural base against which to benchmark growth of software availability. For instance, 10,000 i-Mode sites may actually be very high, while 10,000 Internet hosts may be extremely low. Second, we have no prior guidance whether the growth percentages set forth by these prior studies actually make sense for software availability, as they were developed as heuristics for consumer durable sales.

We define takeoff of hardware sales as the year in which the ratio of change in the growth of sales relative to base sales reaches its maximum before the inflection point in hardware sales. To clarify, change in sales growth is akin to acceleration in sales and is equal to the second difference in sales. Thus, takeoff is the year in which the ratio of the second difference in hardware sales to hardware sales itself is at its maximum. Note that this rule is similar in spirit to the rule provided in the appendix of Golder and Tellis (1997). We define takeoff in software availability, analogously, as the year in which the ratio of change in the growth of software availability relative to base software availability reaches its maximum before the inflection point in software availability.

Earlier studies on takeoff contain four of our nine series on hardware sales. Our identification of the year of takeoff is identical or very similar to that of prior studies in three cases out of four (for CD player sales identical to Tellis, Stremersch and Yin (2003); for CD-ROM sales identical to Golder and Tellis (1997) and for Black & White Television Set sales 1 year earlier than Golder and Tellis (1997)). These results provide face validity to our method. For Color Television Set sales, our identification of takeoff is 6 years earlier than that of Golder and Tellis (1997). These earlier studies also found that takeoff identified through their heuristic coincided with that from visual inspection in more than 90% of the cases. In our case, the heuristic rule for takeoff matches with visual inspection in all cases (see Figure 2.1).

# Table 2.3: Takeoff Analysis Results

| Market | Intro-duction Year | Hardware Sales |  |  | Software Availability |  |  |
|---|---|---|---|---|---|---|---|
|  |  | Takeoff Year | Time to Takeoff (in years) | Software Availability at Hardware Sales Takeoff | Takeoff Year | Time to Takeoff (in years) | Hardware Sales at Software Availability Takeoff |
| B&W Television | 1939 | 1947 | 8 | 7 stations on air | 1948 | 9 | 970,000 unit sales |
| Compact Disc | 1983 | 1985 | 2 | 5,000 titles | 1988 | 5 | 770,000 unit sales |
| CD-ROM | 1985 | 1990 | 5 | 1,522 titles | 1988 | 3 | 20,000 unit sales |
| Color Television | 1954 | 1956 | 2 | 560 hours in color | 1956 | 2 | 100,000 unit sales |
| DVD | 1997 | 1999 | 2 | 3,084 titles | 1999 | 2 | 3,095,654 unit sales |
| Gameboy | 1989 | 1991 | 2 | 156 games | 1991 | 2 | 4.4 mln unit sales |
| i-Mode | 1999 | 2000 | 1 | 10,000 sites | 2001 | 2 | 23,039,000 subscribers |
| Internet (WWW) | 1991 | 1994 | 3 | 2,217,000 hosts | 1995 | 4 | 25 mln subscribers |
| Laserdisc | 1981 | 1983 | 2 | 649 titles | 1985 | 4 | 229,012 unit sales |

## ***Findings***

Table 2.3 provides an overview of the takeoff in all markets, while Figure 2.1 displays them graphically. Comparing columns 4 and 7 of Table 2.3 and the arrows in Figure 2.1, shows that for five out of nine markets (Black & White TV, Compact Disc, i-Mode, Internet (WWW), and Laserdisc), hardware sales take off before software availability does. For three out of nine markets (Color TV, DVD, and Gameboy), hardware sales take off at the same time as software availability does. For one market out of nine (CD-ROM), hardware sales take off after software availability has taken off. Table 2.3 also shows in columns 5 and 8 the amount of available software when hardware sales took off and the level of hardware sales when software availability took off.

We can conclude that, for the nine markets we examined, *hardware sales takeoff leads or coincides with software availability takeoff* (except in the case of CD-ROM). Moreover, Table 2.3 shows that hardware sales can take off at very low levels of software availability. For instance, we find that sales of television sets took off with only 7 stations on air. This level is very low compared to over a 1,000 TV stations today. It is also low compared to the 2,000+ radio stations in 1947 (the year of takeoff for Black & White TV sets). Color TV took off with even remarkably less software – again admittedly judgmental – namely 560 hours a year broadcast in color for the entire United States.

However, the analysis of takeoffs provides only a limited picture on indirect network effects in these markets for several reasons. First, even though we find a clear temporal pattern between takeoffs, it does not prove that indirect network effects actually exist in these markets. Second, one has to be cautious regarding the temporal pattern we find. As our and prior research shows (e.g. Tellis, Stremersch and Yin 2003), uncertainty of several years may surround identification of takeoff. Thus, a difference of one year between the takeoff in hardware sales and the takeoff in software availability is statistically not very meaningful. Third, while drops in hardware price seem to coincide with takeoff in hardware sales (similar to Golder and Tellis 1997), our takeoff analysis is a pure bivariate exercise into the temporal pattern of takeoffs. Given all these limitations, our takeoff analysis should be interpreted with caution. To address these limitations, we next develop a more sophisticated econometric time series model to examine indirect network effects. This time series analysis provides other benefits. It allows us to examine the temporal pattern of indirect network effects, while taking the entire history of a market into account, rather than merely one point that is takeoff. Also, it allows us to include other variables that may affect hardware sales, such as past hardware sales and hardware price.

### 2.4.2 Time Series Analysis

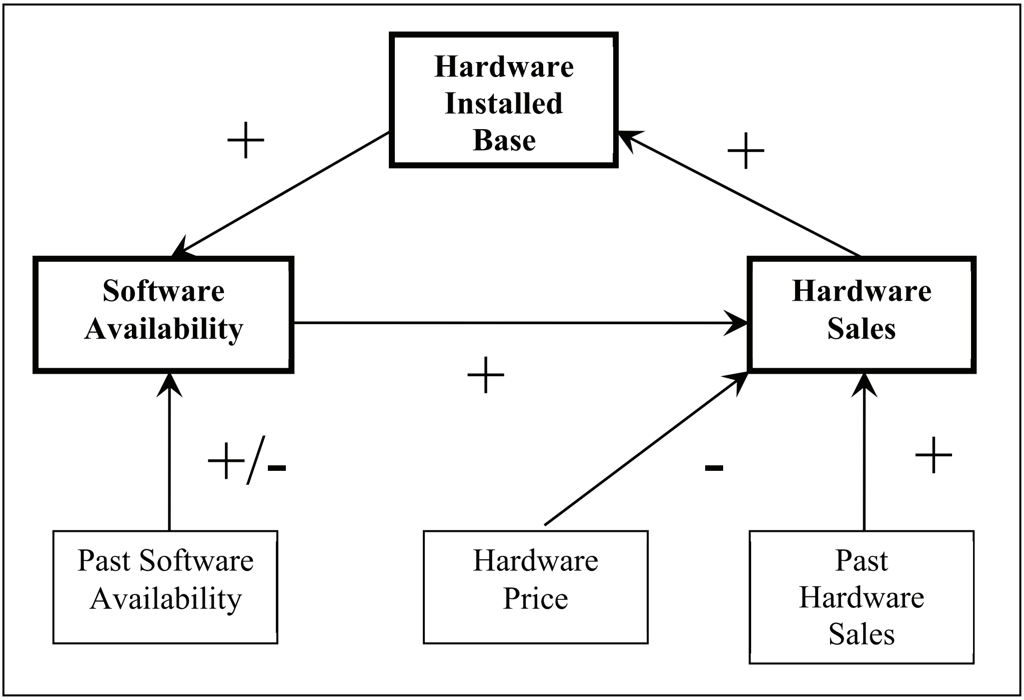
This section develops a time series analysis to examine indirect network effects and its temporal pattern. It first conceptualizes the modeling framework, after which it turns to the model specification. It then presents the findings from estimating the model and discusses some further analyses we conducted.

#### *Conceptual*

If one wishes to empirically examine the temporal pattern in indirect network effects with aggregate-level secondary data, several considerations should guide the model specification.

First, as we test the model on actual, aggregate-level market data, we need to make some further simplifications to the theory. We do not have data on consumer utility, because such data can only be obtained through experiments, surveys or panels. We also do not have data on the profits software companies expect. Such data would be hard to gather using any empirical methodology. Regarding price, one often has data on only the hardware price and not on the software price. Software price is often complex and thus it is difficult to obtain reliable software price information. Yet, it is often of minor importance and its omission may not seriously compromise conclusions of the model. We also do not have information on software costs, because it is proprietary to software firms. Thus, the empirical model one would wish to specify to empirically examine indirect network effects on secondary data reduces to the model in Figure 2.2. This model assumes – rather than tests – that the influence of software availability and hardware price on hardware sales occurs through consumers' utility considerations, while it also assumes – rather than tests – that the influence of past hardware installed base and past software availability on future software availability occurs through software providers' profit considerations. In addition, it makes abstraction of both software costs and software prices.

Figure 2.2: Graphical Illustration of the Sample



Second, given our interest in the temporal pattern of indirect network effects, we wish to refer to the notion of Granger causality (Granger 1969). A process $x_t$ is said to Granger cause a process $y_t$ if future values of $y_t$ can be better predicted using both the past values of process $x_t$ and process $y_t$, than merely the past values of the process $y_t$. Or in mathematical formulation, one says that $x_t$ does not Granger cause $y_t$ if:

$$f(y_t | y_{t-1}, x_{t-1}) = f(y_t | y_{t-1}) \tag{1}$$

In such case, lagged values of $x_t$ do not add any information to the explanation of the movements in $y_t$, beyond the past of $y_t$ itself. The principle of Granger causality rests on the extent to which a process $x_t$ is leading a process $y_t$. To include this notion of Granger causality in our model specification, we lag all independent variables in our models.

Third, one may expect (see Figure 2.1) non-linearities. Therefore, we should use a log transformation to linearize the model in most, if not all, cases.

Fourth, our model is a growth model and thus as time passes, one may expect that the processes we study may approach a certain maximum value (Franses 1998). For this reason, our model also needs to capture a non-linear trend, which we can easily obtain by including a linear trend in log-transformed data. Prior network effects models also include a trend (e.g. Basu, Mazumdar and Raj 2003; Gandal 1994; Shy 2001). We next formally specify our model based on these considerations.

### Model

We specify the following model:

$$\log(S_t^H) = \alpha + \beta * \log(S_{t-1}^H) + \gamma * \log(A_{t-1}^S) + \rho * \log(P_{t-1}^H) + \delta * t + \varepsilon_t \tag{2}$$

$$\log(A_t^S) = \upsilon + \lambda * \log(A_{t-1}^S) + \eta * \log(IB_{t-1}^H) + \tau * t + \zeta_t \tag{3}$$

In which: $S_t^H$ is hardware sales at time $t$, $A_t^S$ is software availability at time $t$, $P_t^H$ is price of the hardware at time $t$, $IB_t^H$ is hardware installed base at time $t$, $\alpha$ and $\upsilon$

are intercepts, while $\delta$ and $\tau$ capture the time trend. This model specification is a flexible time series model, which we estimate for each market separately, using seemingly unrelated regression (SUR).

### Findings

Table 2.4 shows the results from estimating equations (2) and (3). The fit statistics for all models are satisfactory. The adjusted $R^2$ ranges from 0.75 to 0.99. The models also seem to behave well, because there is only one effect that seems implausible, namely the negative coefficient for past software availability on future hardware sales, in the Gameboy market. We next discuss the results.

Theoretically, the most interesting result is that we find that past hardware installed base significantly and positively affects – “leads” in Granger terminology – future software availability in 5 of the 9 markets we examined: Black & White TV, Compact Disc, Gameboy, Internet (WWW), and Laserdisc. Only one of these markets shows the presence of both demand- and supply-side indirect network effects: Compact Disc. None of the markets we study show only demand-side indirect network effects. This result also allows to conclude that – based on the operationalization of indirect network effects commonly used in the literature and applied in our model through the quantity of available software – demand-and supply-side indirect network effects are less pervasive in the markets we examined than commonly assumed. We graphically represent our results in Figure 2.3.

These results are consistent with our earlier findings on takeoff. Of the five markets in which we found supply-side indirect network effects – in Granger’s terminology, in which hardware installed base “leads” software availability – four (Black & White TV, Compact Disc, Internet (WWW), and Laserdisc) show an earlier takeoff of hardware sales than of software availability. On the other hand, in markets where the time series analysis did not show evidence of indirect network effects, the pattern is diverse: the takeoff of hardware sales of CD-ROM lagged the takeoff of CD-ROM software availability; the takeoff of hardware sales and the takeoff of software availability coincided in the cases of Color TV and DVD; the takeoff of hardware sales preceded the takeoff in software availability in one case, i-Mode.

# Table 2.4: Time Series Analysis Results

| | Black & White TV | | Compact Disc | | CD-ROM | |
|---|---|---|---|---|---|---|
| | $\log(S_t^H)$ | $\log(A_t^S)$ | $\log(S_t^H)$ | $\log(A_t^S)$ | $\log(S_t^H)$ | $\log(A_t^S)$ |
| Intercept | 13.38*** | -0.71 | 1.40** | 6.15*** | 3.10 | 1.41 |
| | (4.05) | (0.62) | (0.57) | (0.38) | (10.21) | (1.62) |
| Time | 0.00 | 0.17* | -0.24*** | 0.23*** | 0.97 | -0.13 |
| | (0.07) | (0.09) | (0.02) | (0.02) | (0.58) | (0.35) |
| $\log(S_{t-1}^H)$ | 0.69*** | | 0.51*** | | -0.09 | |
| | (0.11) | | (0.03) | | (0.11) | |
| $\log(A_{t-1}^S)$ | -0.39 | 0.15 | 0.77*** | 0.08 | 0.13 | 0.95*** |
| | (0.32) | (0.24) | (0.05) | (0.07) | (0.65) | (0.25) |
| $\log(IB_{t-1}^H)$ | | 0.22*** | | 0.09* | | 0.03 |
| | | (0.07) | | (0.05) | | (0.25) |
| $\log(P_{t-1}^H)$ | -1.28 | | -0.04 | | 0.54 | |
| | (0.87) | | (0.08) | | (1.37) | |
| Adj R-squared | 0.96 | 0.95 | 0.99 | 0.99 | 0.91 | 0.96 |
| # observations | 11 | 11 | 11 | 11 | 8 | 8 |

***: $p < 0.01$; **: $p < 0.05$; *: $p < 0.10$ (two-sided tests).

## Table 2.4: Time Series Analysis Results (ctd.)

| | Color TV | | DVD | | Gameboy | |
|---|---|---|---|---|---|---|
| | $\log(S_t^H)$ | $\log(A_t^S)$ | $\log(S_t^H)$ | $\log(A_t^S)$ | $\log(S_t^H)$ | $\log(A_t^S)$ |
| Intercept | -7.92 | 4.41*** | 7.04*** | -10.65* | -2.69 | 4.57*** |
| | (13.18) | (1.00) | (1.88) | (5.13) | (14.89) | (0.42) |
| Time | 0.51** | 0.19*** | 0.13*** | 0.02 | -0.19 | 0.19*** |
| | (0.20) | (0.06) | (0.03) | (0.03) | (0.31) | (0.04) |
| $\log(S_{t-1}^H)$ | 0.54* | | 0.66** | | 0.58 | |
| | (0.28) | | (0.26) | | (0.44) | |
| $\log(A_{t-1}^S)$ | -0.87 | -0.07 | -0.42** | -0.32 | 0.83 | 0.38* |
| | (0.60) | (0.40) | (0.18) | (0.24) | (0.47) | (0.18) |
| $\log(IB_{t-1}^H)$ | | 0.14 | | 1.11** | | 0.01 |
| | | (0.19) | | (0.41) | | (0.10) |
| $\log(P_{t-1}^H)$ | 2.69 | | -0.13 | | 0.72 | |
| | (2.38) | | (0.61) | | (1.88) | |
| Adj R-squared | 0.91 | 0.92 | 0.77 | 0.99 | 0.99 | 0.99 |
| # observations | 11 | 11 | 15 | 15 | 7 | 7 |

***: $p < 0.01$; **: $p < 0.05$; *: $p < 0.10$ (two-sided tests).

# Table 2.4: Time Series Analysis Results (ctd.)

| | i-Mode | | Internet (WWW) | | Laser Disc | |
|---|---|---|---|---|---|---|
| | $\log(S_t^H)$ | $\log(A_t^S)$ | $\log(S_t^H)$ | $\log(A_t^S)$ | $\log(S_t^H)$ | $\log(A_t^S)$ |
| Intercept | 51.54 | 1.60*** | -60.16 | -0.43 | -4.69 | 0.33 |
| | (46.25) | (0.22) | (50.58) | (1.92) | (4.90) | (0.69) |
| Time | -0.30 | 0.01 | -0.36 | 0.17 | 0.03 | 0.13*** |
| | (1.70) | (0.01) | (0.48) | (0.11) | (0.05) | (0.03) |
| $\log(S_{t-1}^H)$ | -0.25 | | 0.86* | | 0.47* | |
| | (2.08) | | (0.48) | | (0.23) | |
| $\log(A_{t-1}^S)$ | 3.95 | 0.74 | 1.34 | -0.04 | 0.30 | -0.28 |
| | (20.99) | (0.69) | (1.25) | (0.41) | (0.30) | (0.25) |
| $\log(IB_{t-1}^H)$ | | -0.06 | | 0.96** | | 0.70*** |
| | | (0.09) | | (0.36) | | (0.19) |
| $\log(P_{t-1}^H)$ | -4.11 | | 8.57 | | 0.75 | |
| | (4.21) | | (6.94) | | (0.43) | |
| Adj R-squared | 0.82 | 0.98 | 0.75 | 0.99 | 0.99 | 0.99 |
| # observations | 6 | 6 | 11 | 11 | 9 | 9 |

Figure 2.3: Indirect Network Effects in Nine Markets

| Supply-Side Indirect Network Effects | No | Yes |
|---|---|---|
| **Yes** | Black & White TV<br>Gameboy<br>Internet (WWW)<br>Laserdisc | Compact Disc |
| **No** | CD-ROM<br>Color TV<br>DVD<br>i-Mode | |

Demand-Side Indirect Network Effects

We next discuss the effects of the other variables we included. As one would expect, many – Black&White TV, Compact Disc, Color TV, Gameboy, Internet (WWW) and Laserdisc – of our markets show a positive influence of past hardware sales on future hardware sales, either due to contagion or other effects, such as inertia. Contrary to what one would expect hardware price does not play a major role in hardware sales growth. However, prior research has presented similar findings (Bayus, Kang and Agarwal 2006). The explanation for these results may be that in many of the markets we study, hardware price is generally not prohibitive. The average hardware price for the markets we study, at introduction, was $570. Probably, when one considers more expensive devices the impact of price will be more pronounced. Finally, we find that in two markets (CD-ROM, and DVD) the effect of past software availability on future software availability is positive and significant, consistent with the "network" effect hypothesis. In the other markets, the coefficient is not significant, either because past software availability does not affect future software availability, or because past software availability affects future software availability both positively (the "network" effect) and negatively (the "competition" effect), or because past software availability affects future software availability in a much more complex pattern than we modeled.

### 2.4.3 Further Analyses

We conducted several other analyses to see how changes to the model may affect our conclusions.

First, one could claim that it would be better to work in first differences. However, econometric theory cannot offer clarity whether this approach is appropriate in our case, as conducting unit root tests is not informative given the limited number of data points (Elliott, Rothenberg, and Stock 1996; Franses 1998). The estimates for the lagged terms of the models in equations (2) and (3) (see Table 2.4) suggest that differencing may be inappropriate. The reason is that these estimates are far from 1, while differencing would impose these parameters to be equal to 1. Prior authors in the indirect network effects literature typically do not difference either, with the exception of Gandal, Kende and Rob (2000), who use it to check the robustness of their model. Nonetheless, we decided to conduct these analyses and compare the estimates with our own from estimating the model in equations (2) and (3).

Our findings were the following. First, we found weaker (= insignificant or negative) evidence of indirect network effects, for supply-side indirect network effects in the case of Black & White TV and Internet (WWW), for demand-side indirect network effects in the case of Compact Disc player. We found stronger evidence of indirect network effects, for supply-side indirect network effects in the case of Color TV and for demand-side indirect network effects in the case of CD-ROM. Second, we found many effects to be implausible. We found one additional case (Compact Disc) in which indirect network effects were found to be negative and two cases (CD-ROM and Internet (WWW)) in which past hardware sales growth has a negative effect on future hardware sales growth. These findings hint that working in first differences is inappropriate.

Second, we conducted many checks common in time series analysis. As Franses (2005) would categorize our model as a descriptive model, we focused our diagnostic tests on residual autocorrelation, heteroscedasticity, and omitted variables. These tests revealed relatively few problems, considering the complexity of our model and the small number of observations. Thus, none of these tests revealed a need for revisions to our model specification.

### 2.4.4 Historical Industry Analysis

We next describe each market historically, as it relates to our findings.

*Compact Disc.* We found strong demand- and supply-side indirect network effects in the Compact Disc market. This market has also been empirically examined the most. Our findings are in line with prior findings. LeNagard-Assayag and Manceau (2001) find that software availability has a positive and significant effect on the consumer's utility, and the hardware installed base has a positive and significant effect on software availability. Basu, Mazumdar and Raj (2003) find that software availability has a significant positive effect on hardware prices. Gandal, Kende and Rob (2000) find that software availability has a positive and significant effect on hardware sales and hardware sales have a positive (but not significant) effect on software availability.

*Black & White TV.* We found – both in the takeoff and the time series analysis – that in this market hardware leads software. The reason for these effects may lie in the massive investments involved in starting a TV station. It required large outside revenue during the initial years of massive losses. Therefore, many of the early stations were owned by television set manufacturers (e.g. GE and RCA). The revenues they used to sponsor these early TV stations were generated by sales of TV sets (Sterling and Kittross 2002). Therefore, the significant and positive effect of hardware installed base on software availability need not come as a surprise. On the other hand, the sales of TV sets was not much affected by the quantity of software available (as evidenced by the results of our time series analysis), but rather by the technological appeal of television. Television was such a revolutionary new product, that families gave their new TV set a dominant location in their living room and for the first couple of weeks, all members of the family marveled at the phenomenon (Sterling and Kittross 2002).

*Gameboy.* We found that in the Gameboy market hardware leads – though the takeoff analysis shows simultaneous takeoffs in hardware sales and software availability, the time series analysis shows that past hardware installed base positively affects future software availability – and positively affects software availability. Independent software providers respond strongly to the adoption of hardware (Nair, Chintagunta and Dubé 2004), as was the case with Gameboy. Therefore, our finding that availability of Gameboy games grew as more consumers had adopted the Gameboy seems logical. However, why did consumers not react to a growing catalog of Gameboy games? The answer: TETRIS! Tetris is considered to have been a killer application for the Gameboy (Allen 2003; Rowe 1999). Tens of millions of copies of Tetris have been sold since it was introduced simultaneously with the introduction of the Gameboy. It was often bundled with the Gameboy hardware itself. Thus, rather than the evolution in the full catalog of titles available for Gameboy, the availability of one game, Tetris, fueled Gameboy growth.

*Internet (WWW).* We found – both in the takeoff and the time series analysis – that in the Internet (WWW) market hardware leads software. Again these findings seem logical when one considers the industry evolution. First, Internet users can easily become a software provider by the provision of on-line content (e.g. web pages). Therefore, a growing installed base of users will automatically also lead to a growing base of software providers and thus more Internet hosts (e.g. web servers providing web pages). On the other hand, why do we not find that Internet content stimulates growth in Internet (WWW) adoption? In the first year, the World Wide Web (WWW) already had 80,000 hosts that provided millions of web pages to consumers, more than a single human can possibly read in a lifetime. Also, people used Internet also for other types of communication. E-mail predated the birth of the World Wide Web (WWW) and was already a very important application right at the start of the World Wide Web (WWW).

*Laserdisc.* We found – both in the takeoff and the time series analysis – that in the Laserdisc market hardware leads software. The reason may be very similar to the history of the Black & White TV. The most important provider of Laserdisc titles was the leading manufacturer of Laserdisc players (Pioneer), because Laserdisc publishing entailed a substantial start-up investment (McClure 1992, 1993a and 1993b; McGowan 1994). Pioneer used hardware sales as a measure for how strong or weak the Laserdisc market was, and accordingly, released a fitting number of titles on Laserdisc. Therefore, we find that past hardware installed base positively affects future software availability. On the other hand, the number of titles available does not affect future hardware sales. This is most likely because most Laserdisc titles released in the 1980s (the time period we study) are not very different from their VHS counterpart, lacking digital sound, widescreen, and extra’s (Dick 1990). The provision of such titles did not provide would-be Laserdisc owners with an opportunity to exploit Laserdisc players to their fullest potential. Thus, it gave would-be consumers little reason to purchase a Laserdisc player. Until 1993, Laserdisc titles could only be bought and could not be rented (McClure 1993a), which also made consumers less likely to react to an increase in title availability.

*CD-ROM.* We find no evidence of a significant relationship between software availability and hardware sales in the CD-ROM market. We also find that it is the only market where software availability takes off before hardware sales take off. These findings are in line with the historical development of the CD-ROM market. The early support of Microsoft for the CD-ROM is well-known and the outcry of Bill Gates “I have no idea what the future will bring for the CD-ROM, but I am willing to invest 1 billion dollars just to find out!” is notorious. Microsoft also hosted the first CD-ROM conferences and developed networks with other content and software providers to write for the CD-ROM medium. Microsoft did all this, before a substantial hardware installed base developed. On the other hand, the evolution in hardware sales has been independent from that of software availability, probably due to technological compatibility issues. The first Multimedia PC specifications were only announced at the start of the 1990s – CD-ROM was introduced in 1985 – which also set a standard for connecting CD-ROM drives to IBM-compatible PC's. That eased customers' fears about incompatibility. After years of anticipation, the CD-ROM was finally making its way into the home (Alpert 1992).

*Color Television.* We find no evidence of a significant relationship between software availability and hardware sales in the Color TV market. There may be two major reasons for this result. First, during the first ten years of color broadcasting, NBC was the only vivid supporter of color broadcasting among the major networks. In 1961, CBS and ABC provided their viewers with zero hours of color broadcasting (Ducey and Fratrik 1989). In 1964, NBC would still deliver 95% of all color broadcasting (Ducey and Fratrik 1989). Because NBC was the only supporter among the main national broadcasters, expansion in color broadcasting (by NBC alone) may not have had a major effect on consumers. Second, networks had to invest a massive 30 to 40 million dollars (1960 dollars!) to purchase the required color equipment, which still excluded additional investments in new graphics, costumes, sets and so on, that were needed as well when going color (Sterling and Kittross 2002). On the other hand, broadcasters did not perceive a major upside of Color TV that would match this massive investment. Broadcasters, such as ABC and CBS did not expect it to expand the installed base of viewers or increase the number of hours viewers watched television. Therefore, there was little incentive to react to growing color television set sales, with increasing color broadcasting, even more as the technology was backward compatible with black-and-white broadcasting. It was only when the majority of advertising was recorded in color that broadcasters started to invest a mass in color broadcasting equipment (Sterling and Kittross 2002).

*DVD.* Also for DVD we found no evidence of a significant relationship between software availability and hardware sales. Also, Dranove and Gandal (2003) examined the DVD market. They use two proxies for software availability in the DVD market: 1) when a particular studio committed to releasing movies on DVD, and 2) the percentage of US box-office top 100 movies released on DVD. Only one (percentage of US box-office top 100 films released on DVD) of the two proxies has a positive and significant effect on hardware sales. Thus, the reason why we do not find significant demand-side indirect network effects may be due to the killer application phenomenon cited earlier when we discussed Gameboy history. Consumers may only care about the top titles and on which format they appear, rather than the entire catalog of movies supporting a format. The reason why we do not find supply-side indirect network effects may be due to the immense and early support the DVD technology received from the movie studios (Gandal 2002). Within 18 months after the introduction of the DVD format, all the major movie studios had adopted the DVD format (Dranove and Gandal 2003) and additional hardware sales therefore had no longer any impact on the major movie studios decision to adopt the new DVD technology, making the supply of software largely independent of hardware sales.

*i-Mode.* Also for i-Mode, we do not find any demand- or supply-side indirect network effects. NTT DoCoMo the parent of i-Mode, positioned i-Mode as essentially an extension of pre-existing mobile phone services (Ratliff 2002); this may well have contributed to the fact that consumers do not seem to react to increases in the availability of i-Mode services. New hardware characteristics like a built-in camera, and i-Mode's "always on" feature, may have been the main divers behind hardware sales, rather than the total number of i-Mode sites. i-Mode uses C-HTML (Compact Hyper-Text Markup Language), a form of HTML with a reduced instruction set, which eases the transition for content providers from their already existing HTML web sites to i-Mode-ready content (Ratliff 2002). This low barrier to entry makes is very easy and relatively profitable for content providers to render their services on i-Mode handsets. With the required up-front investment to provide i-Mode services being so small, service providers require only a small number of i-Mode users to turn a profit. This fact may make their decision to provide i-Mode services largely independent of hardware adoption by consumers.

## 2.5 Discussion

This section summarizes our findings and discusses their implications and limitations.

### 2.5.1 Summary of Findings

This study has two main findings. First, we find that indirect network effects as commonly operationalized are less pervasive in the examined markets than expected on the basis of prior literature. This finding contrasts sharply with the “current wisdom”, that the amount of available software is of critical importance to hardware sales growth (e.g. Church and Gandal 1992a; Gupta, Jain and Sawhney 1999; Katz and Shapiro 1986a and 1994).

Second, in most of the markets we examined, hardware sales lead software availability, while the reverse almost never happens. These findings illuminate the temporal pattern of indirect network effects, underlying the chicken-and-egg paradox, which was never empirically examined before. They contradict the widely held view that software availability should lead hardware sales (Bayus 1987; Bucklin and Sengupta 1993; Clements 2004; Frels, Shervani and Srivastava 2003; Midgette 1997; Sengupta 1998; Tam 2000; Yoder 1990; Ziegler 1994).

While there may be many reasons underlying our results – including sampling issues and method artifacts – the most credible, given the variation in the markets examined and the consistency of our findings across methods (takeoff – time series – historical case detail), is that a considerable segment of consumers makes decisions to buy hardware relatively independently of the quantity of software that is available. Thus a critical mass of hardware adopters may gather before a critical mass of software titles is available. One probable reason may be the snob appeal of owning new hardware (Tellis, Stremersch and Yin 2003). Other reasons may be cascade effects that prompt consumers to buy new hardware because of their popularity rather than their intrinsic utility (Golder and Tellis 2004) or the fact that users can create their own content after buying the hardware. It may also be that a killer application is available, by which a sizeable consumer segment must own the hardware, regardless of the sheer number of applications available (Frels, Shervani and Srivastava 2003; Williams 2002).

### 2.5.2 Implications

To firms, the most important implication is that hardware manufacturers should not overstate the importance of software quantity. Rather, hardware manufacturers should take their fate into their own hands and produce high quality technology with a few (not necessarily many) exciting applications, rather than aiming for very wide availability of a huge library of software. For instance, our results contradict previous calls for hardware manufacturers to pay a lot (in the form of kickbacks and subsidies) to get software companies to provide a huge library of titles.

To public policy, our study is relevant towards government intervention in indirect network effects markets. Often, governments or public institutions are under pressure to intervene in indirect network effects markets to improve coordination between hardware and software companies. Critics claim that the lack of coordination especially in terms of availability of software can slow down the takeoff of the new technology. This claim is hard to maintain in view of our findings. In contrast, we find that in many markets, hardware sales take off before software availability does and, in some markets, at very limited quantities of available software. We also found in our time series that hardware sales mostly lead software availability, instead of software availability leading hardware installed base. Therefore, an important argument for government intervention fades. On the other hand, if intervention were necessary, it might take the form of subsidizing the cost of new hardware. While such subsidies may not be reasonable for entertainment products, they might be appealing for products with social benefits, such as electric or hydrogen powered cars.

To academics, the weak evidence we found – using traditional operationalizations of indirect network effects, based on a very long tradition in economics (Church and Gandal 1992a and 1992b; Gandal, Kende and Rob 2000) – fits into new conceptualizations of indirect network effects that may prove more powerful. A first conceptualization is to examine software quality, rather than quantity. Our case detail already illustrated that in some cases (e.g. Tetris in the case of Gameboy), quantity does not matter, but the presence of killer applications does. There is very little scholarly research that examines the role of killer applications, while the phenomenon is deemed very important, especially in certain industries, such as the video game console market. A second conceptualization may revolve around the notion that network effects may be more restricted in scope than previously assumed (Tucker 2006). As such, the entire catalog of software may not be relevant to consumers, but only a very small selection of it may be (e.g. a genre). A third conceptualization may revolve around the notion of thresholds. Software availability may need to cross a threshold at introduction to make the technology credible. Research that extends indirect network effects in these directions may be very impactful.

### 2.5.3 Limitations

This paper examines a complex phenomenon in an area in which data are very scarce. It is easy to point at its limitations, which we hope future research will address. First, due to data limitations, we could not include other important explanatory variables, such as software price, software costs, software and hardware entry, nor could we address possible threshold effects (also see Bayus 1987). We were also unable to test the underlying theoretical mechanisms – consumers' utility considerations and software providers' profitability considerations – of our model.

Second, we study only nine network markets. Although this is a relatively small sample, it compares favorably with prior studies in this area that examined only one or two markets.

Third, we study only surviving technologies. Future research that studies the role of indirect network effects in new technology failure would be interesting.

Fourth, we focused on countries that can generally be considered lead countries in the given technology. It would be interesting to examine if uncertainty from indirect network effects is lower in lag countries than in lead countries. Research that focuses on indirect network effects in an international setting would be most fruitful.

Fifth, the role of consumer expectations is of great importance in indirect network effects markets. However, it is not included in our model due to data limitations. Incorporating consumer expectations in future models may provide new insights.

# Appendix: Data

| **Network Market** | **Series** | **Operationalization** |
|---|---|---|
| B&W Television | Hardware Sales | Retail Unit Sales of B&W Television Sets to Consumers |
| | Hardware Installed Base | Cumulative Retail Unit Sales of B&W Television Sets to Consumers |
| | Hardware Price | Average Price of B&WTV Set |
| | Software Availability | Number of TV Stations on Air |
| Compact Disc | Hardware Sales | Retail Unit Sales of Compact Disc Players to Consumers |
| | Hardware Installed Base | Cumulative Retail Unit Sales of Compact Disc Players to Consumers |
| | Hardware Price | Average Price of CD Player |
| | Software Availability | Number of Compact Disc Titles in Catalog |
| CD-ROM | Hardware Sales | Retail Unit Sales of CD-ROM Drives to Consumers |
| | Hardware Installed Base | Cumulative Retail Unit Sales of CD-ROM Drives to Consumers |
| | Hardware Price | Average Price of CD-ROM Drive |
| | Software Availability | Number of CD-ROM Titles in Catalog |
| Color Television | Hardware Sales | Retail Unit Sales of Color Television Sets to Consumers |
| | Hardware Installed Base | Cumulative Retail Unit Sales of Color Television Sets to Consumers |
| | Hardware Price | Average Price of Color TV Set |
| | Software Availability | Number of Hours Broadcasted in Color (all stations) |

# Appendix: Data (ctd.)

| **Network Market** | **Time Period** | **Country** | **Data source** |
|---|---|---|---|
| B&W Television | 1946-1957 | U.S. | The Broadcasting Yearbook |
| | 1946-1957 | U.S. | Own derivation |
| | 1946-1957 | U.S. | eBrain Market Research |
| | 1945-1957 | U.S. | The Broadcasting Yearbook and FCC |
| Compact Disc | 1983-1994 | U.K. | Philips Consumer Electronics |
| | 1983-1994 | U.K. | Own derivation |
| | 1983-1994 | U.S. | eBrain Market Research |
| | 1983-1994 | U.K. | The British Phonographic Industry |
| CD-ROM | 1985-1993 | U.S. | Peter Golder |
| | 1985-1993 | U.S. | Own derivation |
| | 1985-1993 | U.S. | Peter Golder |
| | 1985-1993 | U.S. | CD-ROM Directory |
| Color Television | 1954-1965 | U.S. | Consumer Electronics Association |
| | 1954-1965 | U.S. | Own derivation |
| | 1954-1965 | U.S. | eBrain Market Research |
| | 1954-1965 | U.S. | Ducey and Fratrik (1989) |

# Appendix: Data (ctd.)

| **Network Market** | **Series** | **Operationalization** |
|---|---|---|
| DVD | Hardware Sales | Number of DVD Players Shipped to Dealers |
| | Hardware Installed Base | Cumulative Number of DVD Players Shipped to Dealers |
| | Hardware Price | Average Price of DVD Player |
| | Software Availability | Number of DVD Titles in Catalog |
| Gameboy | Hardware Sales | Retail Unit Sales of Gameboy to Consumers |
| | Hardware Installed Base | Cumulative Retail Unit Sales of Gameboy to Consumers |
| | Hardware Price | Average Price of Gameboy Player |
| | Software Availability | Number of Gameboy Games Available to Consumers |
| i-Mode[8] | Hardware Sales | Number of New i-Mode Subscribers |
| | Hardware Installed Base | Total Number of i-Mode Subscribers |
| | Hardware Price | Average Price of Advertised i-Mode Handset |
| | Software Availability | Number of Independent i-Mode Sites |
| Internet (WWW) | Hardware Sales | Number of Additional Internet (WWW) Users |
| | Hardware Installed Base | Total Number of Internet (WWW) Users |
| | Hardware Price | Average Price of (Fax-)Modem |
| | Software Availability | Number of Internet (WWW) Hosts |
| Laserdisc | Hardware Sales | Number of Laserdisc Players Shipped to Dealers |
| | Hardware Installed Base | Cumulative Number of Laserdisc Players Shipped to Dealers |
| | Hardware Price | Average Manufacturer Suggested Retail Price of in year *t* released Laserdisc Player |
| | Software Availability | Number of Laserdisc Titles in Catalog |

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[8] i-Mode is a high-speed mobile Internet service (2.5G) introduced first in Japan by NTT DoCoMo.

## Appendix: Data (ctd.)

| Network Market | Time Period | Country | Data source |
|---|---|---|---|
| DVD | 1997-2004 | U.S. | Consumer Electronics Association |
| | 1997-2004 | U.S. | Own derivation |
| | 1997-2004 | U.S. | eBrain Market Research |
| | 1997-2004 | U.S. | http://www.hometheaterinfo.com/ |
| Gameboy | 1989-2004 | U.S. | NPD |
| | 1989-2004 | U.S. | Own derivation |
| | 1989-2002 | U.S. | NPD and Nintendo |
| | 1989-2003 | U.S. | Nintendo |
| i-Mode | 1999-2005 | Japan | Own derivation |
| | 1999-2005 | Japan | NTT DoCoMo |
| | 1999-2005 | Japan | Ascii24.com |
| | 1999-2005 | Japan | OH!NEW i-search (www.ohnew.co.jp) |
| Internet (WWW) | 1991-2002 | U.S. | Own derivation |
| | 1991-2002 | U.S. | Internet Software Consortium |
| | 1991-2002 | U.S. | eBrain Market Research |
| | 1991-2003 | U.S. | International Telecommunication Union |
| Laserdisc | 1981-1990 | Japan | Philips Consumer Electronics |
| | 1981-1990 | Japan | Own derivation |
| | 1981-1990 | Japan | Variety of sources |
| | 1981-1990 | Japan | Philips Consumer Electronics |

# Chapter 3

# Superstars in System Markets[9]

## 3.1 Introduction

"*You can have the best technology, the most advanced box in the world. But without the applications, that box will only collect dust on the retail shelves*." -

Kazuo Hirai, president of Sony Computer Entertainment of America
(Huffstutter 1999)

Systems are composed of complementary and interdependent products, such as hardware and software (Farrell and Saloner 1986; Katz and Shapiro 1986b; Stremersch et al. 2003; Wuyts et al. 2004). For instance, video game systems are composed of the video game console, on the one hand, and video games, on the other hand (Chou and Shy 1990; Clements and Ohashi 2005; Gandal, Kende and Rob 2000). Other examples are plenty. The Compact Disk consists of CD Players and CD's. Television consists of TV sets and TV programming. Research in economics and marketing has argued that in such system markets, hardware sales depend mainly on the available software (Farrell and Saloner 1986; Gupta, Jain and Sawhney 1999; Katz and Shapiro 1986b and 1994). To avoid any misunderstanding, we should immediately stress that software availability in this theory never refers to software sales (= demand), but rather refers to the catalog of software titles that is available for a particular hardware (= supply).

The major importance of software in system markets has made it into the prime concern for hardware firms (i.e., system owners). For instance, in the video game console industry, system owners spend a fortune on software development to guarantee a sufficient supply of software, either through internal development, or through subsidizing independent software developers (Coughlan 2004). Microsoft put $375 million in cash on the table to acquire just one software development studio (Kent 2002). Sony alone has 14

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[9] This work was co-authored with Stefan Stremersch, and published in the Journal of Marketing as "The Effect of Superstar Software on Hardware Sales in System Markets".

of these software development studios (GamePro 2006). Sony shipped over 10,000 Playstation 3 development kits, to software developers, before selling even one Playstation 3 (Guardian 2006), to secure the supply of attractive software titles.

The main shortcoming of the academic literature on this phenomenon is that mathematical and empirical analyses have almost exclusively focused on a single dimension of software availability, namely software *quantity*[10], i.e., the number of software titles introduced (for an overview, Stremersch et al. 2007). While not substantiated with empirical evidence, case illustrations raise that certain individual software titles may have had disproportionately large effects on hardware sales (Allen 2003; Dickson 2008; Frels, Shervani and Srivastava 2003; Gilroy 1994; Rowe 1999; Shapiro and Varian 1998; Williams 2002). We call these individual software titles of exceptional high quality "superstars"[11]. Prior literature has studied superstars in the music industry (Chung and Cox 1994), major league baseball (MacDonald and Reynolds 1994), and the movie industry (Collins, Hand and Snell 2002). However, the returns software superstars may have on hardware sales in system markets remains unexamined. This lack of academic inquiry does not match the importance of the role such software titles may play in system markets. The present study aims to fill that void.

We examine to what extent superstars may increase hardware unit sales, in the context of the U.S. home video game console industry. We find that the introduction of a superstar software title significantly increases hardware unit sales, with on average 14% (167,000 units), over and above the effects of other hardware and software attributes. This positive effect persists only for the first 5 months after their introduction. Software type does not substantially alter this effect. Therefore, the traditional operationalization of software quantity (i.e., the number of software titles introduced) may be limited, as it

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[10] Prior literature also refers to software quantity as software availability or software variety.

[11] There exists considerable confusion between terms such as superstars, and terms such as blockbusters, hits, killer applications, or more specifically in the case of the video game industry, killer games, or triple A games. Our focus is on software titles of exceptional quality, which yields a disproportionate pay-off, a concept most akin to the "superstar" concept, as originally introduced by Rosen (1981). We therefore will consistently use the term "superstars" throughout this paper. Concepts such as "hits" or "blockbusters" often refer to software titles with a high sales volume, rather than high quality. The term "killer applications" refers to specific games that allowed one system to "kill" or dominate another.

overlooks both superstar power, and potential time decays. We also find that superstars display increasing returns (i.e., hardware unit sales) to software quality.

We gather data on 11 home video game consoles in the U.S., between January 1993 and December 2004. The video game console industry is an appropriate context, as it is a system market, in which software (i.e., video games) is thought to be crucial to promote hardware (i.e., video game console) sales (Clements and Ohashi 2005; Williams 2002).

We organize the remainder of the paper as follows. The next section develops the theory on superstar introductions and other determinants of hardware sales. The third section discusses the video game console industry, and presents the sample, data collection, and the measurement of the variables. The fourth section presents the model. The fifth section presents the results, and further analyses we conducted. The sixth section presents the discussion of the results, their implications, and the limitations of the paper.

## 3.2 Superstar Introductions and Other Determinants

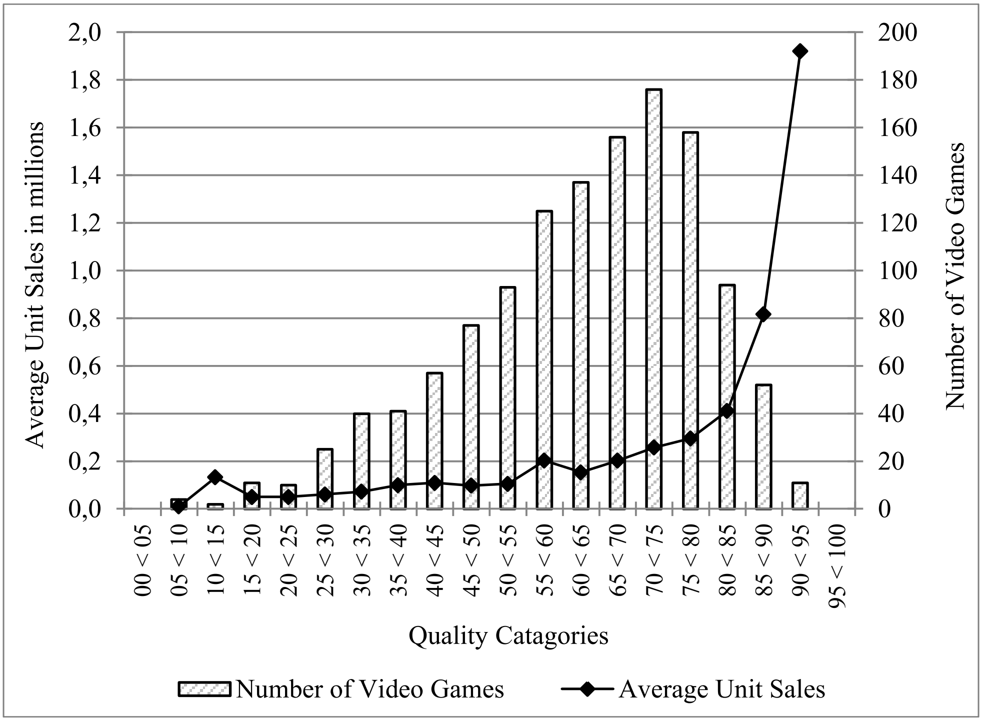
This section first explains the concept of software superstars and discusses how their introduction may affect hardware unit sales. Second, it argues how this relationship may be dependent upon software type. Third, it adds other variables that may also affect hardware unit sales, for which we need to control in our empirical testing. We will tailor the theory development to our empirical context, the U.S. home video game console market, for clarity of exposition. However, the theory we develop is also applicable in many other system markets, such as the DVD market (e.g. the effect of superstar introductions, such as The Matrix, on DVD sales) or the Satellite radio market (e.g. the effect of radio superstars joining a Satellite radio network, such as Howard Stern, on Satellite radio sales).

### 3.2.1 Superstars

Superstars possess unique and superior attributes or skills that command a disproportionately large payoff (Rosen 1981). In a superstar industry, a small number of high-quality superstars, demand disproportionately large compensation packages, and dominate their respective industry (Rosen 1981). A superstar industry displays increasing returns to quality, due to the scarcity of high quality (Mayer 1960; Rosen 1981). There is a monotonic increasing returns relationship between quality and the payoff. Or as Cox and Kleiman (2000) put it “*If a golfer, is on average, but one stroke better than other competitors then a disproportionate number of tournament championships would be won by said athlete*.” It is very hard for competing golfers to copy Tiger Woods’ skills. Similarly, competitors will find it hard to copy the quality characteristics of other superstars, such as The Beatles, Star Wars or Super Mario Brothers, especially after they have introduced their products on the market, as often the quality is unknown until the product is in the hands of the consumer.

Illustrations of superstar industries are plenty. Chung and Cox (1994) find a high concentration of output among top music performers, the top 10.8% of gold record receivers collected 43.1% of all gold records during the period 1958 to 1989. De Vany and Walls (1996) report that just 20% of the films earned 80% of box office revenues. Exploratory research by Liebowitz and Margolis (1999) suggests that the highest quality software titles conquer a disproportionately large part of the total software market.

Figure 3.1: The Video Game Industry is a Superstar Industry



The video game industry is also a superstar industry. Figure 3.1 categorizes video game quality for the Sony Playstation in 20 quality categories from [0-5] to [95-100] (we discuss the operationalization of video game quality in the data section). The columns in Figure 3.1 represent the number of video games in each quality category. The line with diamonds represents the average unit sales of a video game in each quality category. The first conclusion we can draw, is that this market shows a disproportionate response of software sales to software quality, and that there is a monotonic increasing returns relationship between software quality and software unit sales. The second conclusion is that the frequency distribution of quality follows a bell-shaped curve, with a negative skewness, indicating scarcity of high quality products, which results in the increasing returns to quality (e.g., Mayer 1960; Rosen 1981). Both of these conclusions imply that the video game industry is indeed a superstar industry, showing disproportionate returns to quality, with a small number of high quality games that are very popular. Other systems depict similar patterns. Using software dollar sales instead of software unit sales, does not alter this picture. Recent examples of superstar video games are ‘Grand Theft Auto: Vice City’ and ‘Halo 2’, which both sold over 4 million copies in the U.S. alone, within the first three months after introduction.

In system markets, high quality software titles are likely to have a positive effect on hardware unit sales (Frels, Shervani and Srivastava 2003). Superstar software titles are so desirable, that they can easily trigger the adoption of the system by consumers. Williams (2002) argues that superstar video games entice consumers to spend several hundred dollars to buy the video game console and accessories required, to play those highly desirable video games. Shapiro and Varian (1998) believe that Walt Disney’s Wonderful World of Color was the prime reason why consumers invested in color television sets. The spreadsheet (e.g., VisiCalc, Lotus 1-2-3, Excel) and the word processor (e.g., WordStar, WordPerfect, Word) are credited for selling millions of Personal Computers (Frels, Shervani and Srivastava 2003; Gilroy 1994). Business press has claimed that the video game Tetris has been a major driving force behind the success of the original Nintendo Gameboy (Allen 2003; Rowe 1999). Therefore, we expect the introduction of a superstar software title to increase hardware unit sales in system markets.

Moreover, if superstars display increasing returns from software quality to software unit sales, then we may expect superstars in system markets, to display increasing returns from software quality to hardware unit sales (e.g., Liebowitz and Margolis 1999; Mayer 1960; Rosen 1981).

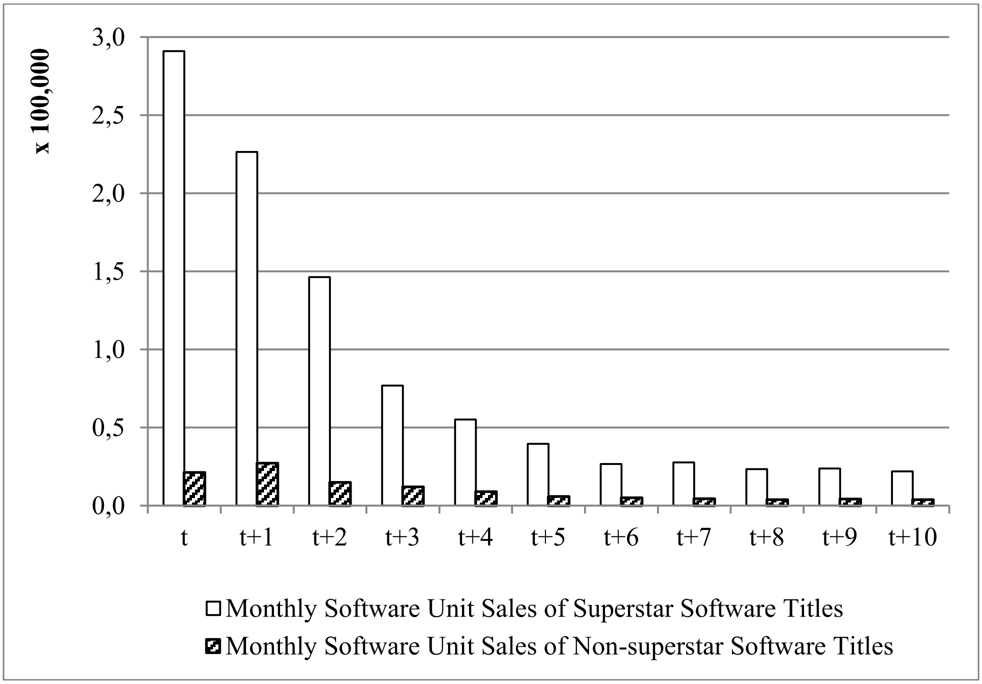
### 3.2.2 Software Life Cycle

In many system markets, software titles only have a limited life expectancy, due to continuous innovation and changing consumer tastes, thereby limiting the sales potential of software titles to only a short period after their introduction. Sales of a software title peak during or soon after introduction, and subsequently decline. This sales pattern is observed across many, similar markets: CD's, DVD's, LP's, PC software applications, television and radio broadcasts, and video cassettes (e.g., Ainslie, Drèze and Zufryden 2005; Krider and Weinberg 1998; Luan and Sudhir 2007).

Video games also have a short life expectancy, approximately 3 months, but this life cycle can stretch to 12 months for very successful video games (Gaume 2006). Figure 3.2 depicts the evolution of software unit sales of superstar and non-superstar software titles, from the month of introduction at *t*, and later. The software unit sales of superstars also peak during introduction (291,000 units) and subsequently decline. Superstars achieve software unit sales of around 1.3 million units on average, while non-superstar software titles achieve unit sales of just 187,000 units. Software unit sales of superstars turn flat after 6 months, and subsequently the sales evolution of superstars and non-superstars depicts a similar pattern, of slow declining sales over time.

Because of the limited life expectancy of software, we expect the introduction of a superstar software title to positively affect hardware unit sales, during the month of introduction and a limited number of months after introduction. In addition, we expect that this effect, will peak during the month of introduction, and subsequently decline.

Figure 3.2: Software Unit Sales of Superstar and Non-superstar Software Titles



### 3.2.3 Software Type

Software type may influence the effects we posited above. While one can typify video games along multiple dimensions, three are particularly salient and relevant, as they are often used in the video game industry to describe the differences between individual video games (Clements and Ohashi 2005; Venkatraman and Lee 2004; Williams 2002). Other software markets, like movies and music use similar software types.

The first dimension is whether a superstar software title is exclusively available for only one system, or is available for multiple systems. Prior literature suggests that exclusivity of software (i.e., content) is a valuable commodity in system markets, because it creates a competitive advantage (Shapiro 1999). System owners often pay software publishers top dollar for the exclusive availability of their attractive software. Sony paid a sum in the tens of millions of dollars to software publisher Take-Two to make the superstar franchise ‘Gran Theft Auto’ exclusive to the Playstation 2 (IGN 2002). Toshiba (the system owner of the HD-DVD standard) paid Paramount and DreamWorks Animation $150 million in incentives for their exclusive commitment to HD-DVD, and dropping their support for Sony’s competing Blu-ray standard (Barnes 2007). Sony allegedly paid Warner Brothers $400 in incentives to drop Toshiba’s standards (Edwards and Grover 2008). System owners (e.g., Microsoft) want exclusive content (e.g., Halo 3) because it (supposedly) increases hardware sales (e.g., video game console sales) (Gibson 2007). If a superstar software title is introduced on multiple systems, the resulting new hardware adopters are dispersed across multiple systems. If the introduction of a superstar title is exclusively for just one system, the new hardware adopters will all adopt the same system. Following this line of thought, exclusive superstar software titles could prove to be a crucial factor in positive feedback markets, because of their ability to tip the market outcome towards one specific system, during a systems war (i.e., standards war) (e.g., Arthur 1989 and 1996; Shapiro and Varian 1998). We therefore expect exclusive superstar software titles to have a larger effect on hardware unit sales of the system in question, compared to non-exclusive superstar software titles.

The second dimension is whether the software title is a sequel to a prequel for the same system. Research on movies has shown that sequels have an already established brand name, and a higher awareness among consumers, and therefore have higher sales than the prequel (Ainslie, Drèze and Zufryden 2005; Basuroy, Desai and Talukdar 2006; Sawhney and Eliashberg 1996). As consumers are more aware about superstar sequels compared to original superstars (i.e., non-sequel superstars) and sequels have a proven record, one may expect the introduction of superstar sequels to have a larger effect on hardware unit sales, compared to the introduction of original superstars. On the other hand, consumers who buy the superstar sequel are likely to have already bought the prequel, which means that they already own the hardware. Also, original superstars are introduced earlier in the life cycle of the system, meaning that the hardware installed base is smaller, leaving more potential hardware adopters available. In addition, a recent study of Luan and Sudhir (2007) finds that sequels in the DVD market perform worse than non-sequels. According to this reasoning, superstar sequels may have a smaller impact on hardware unit sales, compared to original superstars. Because of these contradictory arguments, the direction of the effect is an interesting, empirical matter.

The third dimension is the genre to which the superstar software title belongs. The video game market consists of six different genres. There are two large genres (action and platformer), and four small – niche – genres (first-person shooter (FPS), racing, role playing (RPG), sports). Software titles from the large genres appeal to a very broad range of gamers, from hardcore gamers to casual gamers. The small genres serve a smaller more specialized niche market. The introduction of software in popular genres helps hardware sales grow more rapidly (Basu, Mazumdar and Raj 2003). We therefore expect the introduction of superstars from the large genres to have a larger impact on hardware unit sales, compared to the introduction of superstars from the small genres.

### 3.2.4 Other Variables

We next discuss other variables that may also affect hardware unit sales. We carefully identified which variables are key in determining the attractiveness of the hardware and software of a system by examining the prior literature (e.g. Basu, Mazumdar and Raj 2003; Brynjolfsson and Kemerer 1996; Clements and Ohashi 2005; Gandal 1994; Gandal, Kende and Rob 2000; Nair, Chintagunta and Dubé 2004; Shankar and Bayus 2003; Shy 2001; Stremersch et al. 2007). We control for these variables in our empirical testing.

Variables we include, relating to the attractiveness of the software side of the system, are *software catalog* (i.e., all software introduced up to and including *t-1*) and *software introductions* (in *t*); we expect both to positively affect hardware unit sales (e.g., Basu, Mazumdar and Raj 2003; Clements and Ohashi 2005; Gandal, Kende and Rob 2000; Nair, Chintagunta and Dubé 2004). An increase in the catalog of past software introductions increases the utility a consumer may derive from the system. In addition, a larger number of present software introductions may also increase the utility a consumer derives. The latter effect may be greater than the former as entertainment products typically have short life cycles (Luan and Sudhir 2007; Williams 2002); also video games typically have short life cycles. We expect *software quality* (the average quality of all video games available to consumers) to positively affect hardware unit sales. While prior literature has not examined the effect of the overall quality of the software available on hardware unit sales, there are several reasons to expect higher catalog quality to translate into higher hardware unit sales. One reason is that higher average quality of the software catalog reflects positively on the perceived quality of the system. Another reason may be that a high quality catalog increases the probability that consumers have positive experiences with the console prior to buying it, e.g. when playing at a friend's house, or when trying it out in the store. We expect *software price*, to negatively influence hardware unit sales, but we expect the effect size to be small (prices show relatively little variance in this industry). The reason is that as the price of software decreases, the attractiveness of the hardware increases.

Variables we include, relating to the attractiveness of the hardware side of the system, are *hardware price*, which we expect to negatively affect hardware unit sales, but we expect the effect size to be small in our application (prices show relatively little variance in this industry). As the price of hardware decreases, consumers become more inclined to adopt the system (e.g. Clements and Ohashi 2005; Shankar and Bayus 2003). We also included *hardware age*, which we expect to negatively affect hardware unit sales. The hardware becomes less attractive as it ages, because it becomes less "cutting-edge". Hardware age can also be interpreted as the time trend in the hardware unit sales series, which is common in this area (e.g. Basu, Mazumdar and Raj 2003; Brynjolfsson and Kemerer 1996; Gandal 1994; Shy 2001; Stremersch et al. 2007).

We also include a *December dummy*, which controls for the December holiday effect, due to the holiday buying spree that typically drives consumer electronic markets (i.e., the video game market). We expect the sign of the December dummy parameter to be positive (Christmas and New Year shopping).

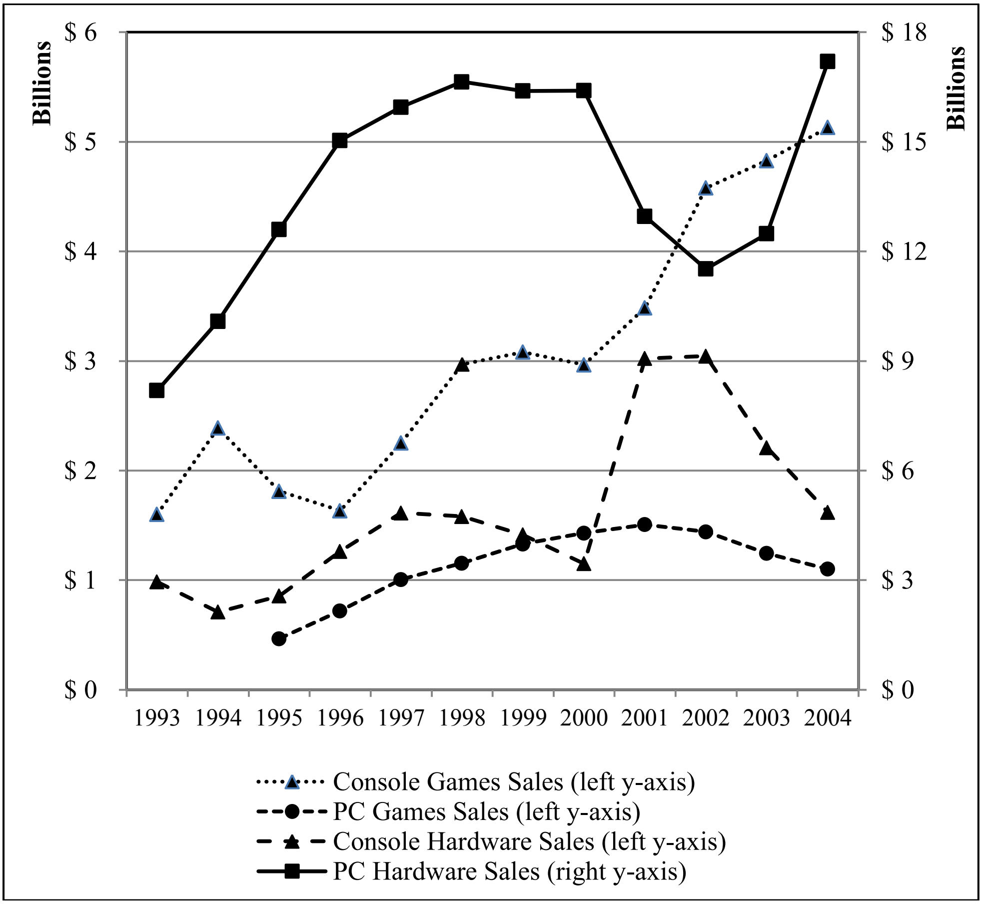
## 3.3 Data

This section first discusses the video game industry and the sample. Next, it presents the data collection procedures, and it ends with providing the measures for our variables.

### 3.3.1 Video Game Industry

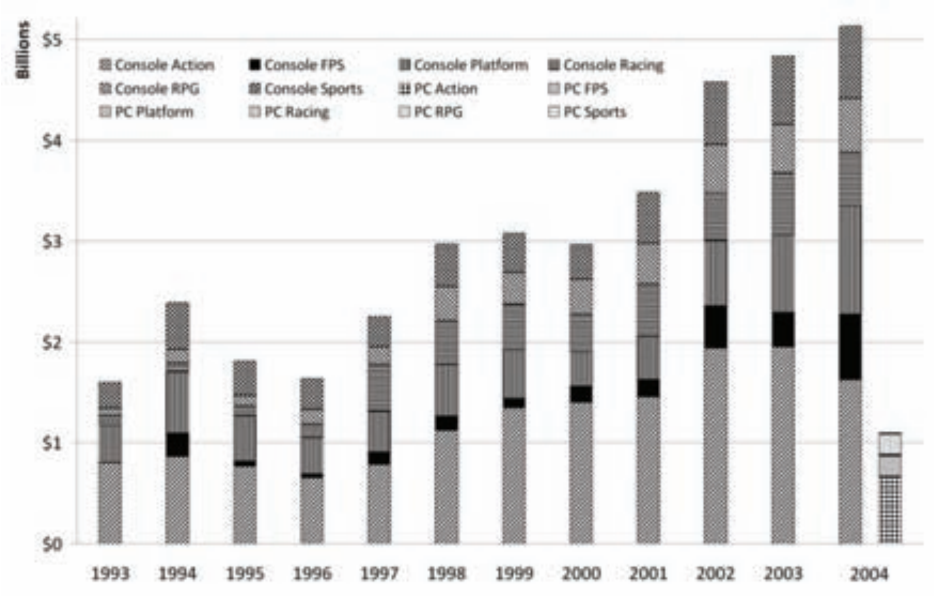
Playing video games isn't child's play anymore. American households rate playing video games as the most fun entertainment activity, beating watching television, surfing the Internet, reading books and going to, and renting, movies (IDSA 2001). Many young gamers spend more time playing games than watching TV (Bloom 1982; Funk and Buchman 1996). The average game player is 33 years old, has been playing games for 12 years, and plays games for over 7 hours per week (ESA 2007). The video game industry has become a mature industry, dominated by mainstream content (Williams 2002). The business of publishing video games is highly similar to that of other software markets like CD's, (e)books, DVD's, radio shows, videocassettes and television shows (e.g., Greco 2000; Komiya and Litman 1990; Williams 2002).

Figure 3.3: Hardware and Software Sales of Consoles and PC's



(Source: Consumer Electronics Association (CEA), NPD)

Figure 3.4: Video game and PC game sales according to Game Genre*



* Information on PC Genres is only available from 2004.

In 2007, sales of PC and video games, video game consoles, and video game accessories exceeded $18.8 billion dollars in the U.S. alone (NPD 2008). During our sample period, video game software sales increased from $1.8 billion in 1993 to $5.4 billion in 2004, a 200% increase, while video game hardware sales increased from $1.0 billion in 1993 to $1.6 billion in 2004, a 65% increase. Game sales in the PC market also show an increase, from $0.5 billion in 1995 to $1.1 billion in 2004, a 137% increase, while PC hardware sales increased from $8.2 in 1993 to $17.2 billion, a 110% increase. Figure 3.3 depicts the evolution of PC and video game sales over time. The dotted line with triangles depicts video game sales, the dashed line with circles depicts PC game sales, and the dashed line with triangles depicts console hardware sales; all depicted against the left y-axis. The solid line with squares depicts PC hardware sales and uses the right y-axis. Figure 3.4 decomposes video game sales and PC game sales according to the six game genres.

During our sample period, consumers bought over 127 million video game consoles and over 1 billion software titles. Thus, on average a hardware adopter buys more than 8 software titles. For every hardware unit sold, for which consumers pay around $152, consumers spend around $287 on software, spread out over the entire life cycle of the hardware. Thus, consumers spend 65% of their allocation on software, and only 35% on hardware. This clearly indicates the importance of software in this system market. This is similar to other system markets, like CD-player and CD's or DVD-player and DVD's, where buyers also spend most of their money on software (e.g., Bayus 1987).

### 3.3.2 Sample

The data covers 11 home video game consoles (e.g., 3DO Multiplayer, Atari Jaguar, Microsoft Xbox, Nintendo 64, Nintendo GameCube, Nintendo Super NES, Sega Dreamcast, Sega Genesis, Sega Saturn, Sony Playstation, and Sony Playstation 2), in the U.S. home video game industry during the period January 1993 to December 2004 (144 consecutive months). The data cover the entire population of home video game consoles available to U.S. consumers during this period. The data also cover all information we require on the software for these 11 systems, which comprises around 5,800 software titles.

The monthly hardware unit sales range between 3 units and almost 2.7 million units. However, about a third of these monthly observations, contain very few hardware unit sales. 195 observations contain hardware unit sales of less than 5,000 units, because hardware unit sales very slowly dry up, after consumers and software publishers have abandoned the system. Nintendo sold more than 16 million units of its SNES console in the U.S., but during the last 36 months, less than 2,500 units were sold, and no new software was introduced. Thus, there are two regimes, the 'life' regime (i.e., when typically substantial sales occur), and the 'death' regime (i.e., when very few sales occur). As we are only interested in the 'life' regime, we will eliminate the data observations of the 'death' regime, because using one model across these two regimes is likely to create biases.

Therefore, we remove all monthly observations at the end of a system's life, after which either consumers, or software publishers, have abandoned the system. We assume the system to be abandoned, if software providers do not introduce any software titles for the next three months, or if hardware unit sales drop below 5,000 units. Using these two cutoffs, leaves us with 513 observations (see Table 3.1).[12] The number of observations reduces by 32%, but the total amount of hardware units sold decreases by less than 4%, to 120 million units.

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[12] Tests indicate that at our cutoff point (i.e., breakpoint) of the dependent variable, a large negative structural change (i.e., regime switch) is present (-0.797; P<0.01). The findings in this paper are robust to selecting somewhat stricter, or more lenient, cutoffs.

Table 3.1: The Video Game Consoles We Study

| System | Start & End | Number of Months |
|---|---|---|
| 3DO Multiplayer | Sep-93 to Sep-96 | 37 |
| Atari Jaguar | Nov-93 to Dec-95 | 26 |
| Microsoft Xbox | Nov-01 to Dec-04 | 38 |
| Nintendo 64 | Sep-96 to Nov-01 | 63 |
| Nintendo GameCube | Nov-01 to Dec-04 | 38 |
| Nintendo Super NES | Jan-93 to Jan-96 | 37 |
| Sega Dreamcast | Sep-99 to Dec-01 | 28 |
| Sega Genesis | Jan-93 to Dec-96 | 48 |
| Sega Saturn | May-95 to Mar-98 | 35 |
| Sony Playstation | Sep-95 to Dec-04 | 112 |
| Sony Playstation 2 | Oct-00 to Dec-04 | 51 |

### 3.3.3 Data Collection

The data originated from two databases, which we subsequently integrated. NPD provided retail hardware unit sales, hardware price, software unit sales, software price and software introductions. NPD is a market research firm that covers the video game industry and their data has been previously used by other researchers (e.g. Clements and Ohashi 2005; Shankar and Bayus 2003; Stremersch et al. 2007; Venkatraman and Lee 2004).

We collected information on video game quality ratings and software type for all 5,800 video games in our data set by hand. Gathering these data was a long, labor-intensive process. We used leading U.S. video game magazines, and websites, like Electronic Gaming Monthly (EGM), Gamespot, and the Imagine Games Network (IGN), to obtain expert quality ratings of video games. Prior research has also used magazine expert ratings, as an indicator for product quality (e.g. Archibald, Haulman and Moody 1983; Conlon, Devaraj and Matta 2001; Liebowitz and Margolis 1999).

Besides collecting expert ratings, we also collected consumer quality ratings of video games, through these publications. In total, we collected over 132,000 expert ratings, and over 3.8 million user ratings. To obtain the quality of an individual video game, we average these ratings, giving the same weight to the overall expert rating as to the overall user rating.[13]

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[13] We follow this procedure, as it enhances the quality of the data, by increasing the accuracy through averaging individual-level errors and biases that are random (Rousseau 1985). It also fits the behavior of consumers as they often combine multiple separate pieces of information into an overall evaluation by averaging them (Anderson 1996; Kahn and Ross 1993). From our data, we also learn that experts have tastes similar to users (inter-rater reliability = .652; n=5,650). This correlation is somewhat depressed, because a large number of software titles are of low quality and achieve only very low sales, for which there are only a few expert and user ratings available. Eliminating these video games and their ratings greatly increases the inter-rater reliability between expert and user ratings. The inter-rater agreement for video games for which there are at least 5 expert and at least 5 user ratings available is .828 (n=3,748). The conclusion is that experts do not seem to systematically rate video games differently from users. This is because experts, have been, and are, themselves active gamers. In addition, by publishing the quality rating of videogames, experts and users are open to public scrutiny by other experts and users, and this will help to minimize biases (Kane 1981).

### 3.3.4 Measures

We will now briefly discuss our measures, all of which are at a monthly periodicity for the system of interest. We start with the variables at the hardware side. *Hardware unit sales* are the monthly number of video game consoles sold for the system of interest. *Hardware price* for a video game console is the price of the bare bone version of the video game console in that month. *Hardware age* (i.e., the time trend) of a video game console is equal to the number of months the hardware has been on the market.

At the software side, we first discuss the operationalization of our focal construct, the introduction of superstars.[14] As stated above, superstars are characterized by their high quality (Frels, Shervani and Srivastava 2003; Rosen 1981). Therefore, we have developed a heuristic. To be called a superstar software title, a software title must have a quality rating of 90 or above. A quality threshold of 90 identifies only the very best software titles as superstars. This threshold identifies 89 games out of approximately 5,800 software titles as superstars. Typically, these software titles sell over 1 million copies. Software unit sales of 1 million is considered to be an important threshold in the video game industry (Cadin and Guerin 2006; Pereira 2002). This threshold is also the point at which increasing returns to quality kick in. We list all 89 superstars, per system, in Table 3.2. Representatives of the NPD video game division perceived our heuristic and our list of superstars as valid. The findings in this paper are robust across a wide range of thresholds (see the results section).

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[14] We use superstar introduction and not superstar software sales, to model the effect of superstars on hardware unit sales, for a number of reasons. First, in the analytical literature, the introduction of a single software title by a software firm has a positive effect on the utility of the hardware, thereby increasing hardware sales (Church and Gandal 1992; Katz and Shapiro 1986a). Given this literature, there is no reason to assume that superstar software sales should affect the hardware utility. Second, the introduction of software titles especially superstar titles, are a clear signal of software developer support, whereas superstar sales are not. Third, the strong presence of seasonality in the video game industry, as in many other software markets, makes the use of sales less desirable. Fourth, using superstar software sales instead of superstar introductions would make this variable highly endogenous, due to its dependence on hardware unit sales.

## Table 3.2: The Superstars We Identify in the Video Game Industry

**Sega Genesis**

Earthworm Jim
Lunar: Eternal Blue
Snatcher

**Nintendo Super NES**

Xenogears
Chrono Trigger
Donkey Kong Country
Donkey Kong Country 2: Diddy's Quest
Final Fantasy 3
Secret of Mana
Super Mario All Stars
Super Mario RPG: Legend of the Seven Stars
Super Mario World 2: Yoshi's Island
Super Metroid

**Atari Jaguar**

Tempest 2000

**Sony Playstation**

Castlevania: Symphony of the Night
Chrono Cross
Final Fantasy 7
Final Fantasy 9
Gran Turismo
Metal Gear Solid
Resident Evil 2
Tekken 3
Tony Hawk's Pro Skater
Tony Hawk's Pro Skater 2

**Nintendo 64**

Conker's Bad Fur Day
James Bond 007: Goldeneye 007
Legend of Zelda: Majora's Mask
Legend of Zelda: Ocarina of Time
Perfect Dark
Super Mario 64

**Sega Dreamcast**

NBA 2K1
NFL 2K
NFL 2K1
Resident Evil Code: Veronica X
Skies of Arcadia
Soul Calibur
Tony Hawk's Pro Skater
Tony Hawk's Pro Skater 2
Virtua Tennis

**Sony Playstation 2**

Burnout 3: Takedown
Devil May Cry
Final Fantasy 10 X
Gran Turismo 3 A-Spec
Grand Theft Auto 3
Grand Theft Auto: Andreas
Grand Theft Auto: Vice City
Madden NFL 2004
Metal Gear Solid 2: Sons Of Liberty
Metal Gear Solid 3: Snake Eat
NBA Street Vol. 2
NCAA Football 2003
NCAA Football 2004
Prince of Persia: The Sands of Time
Ratchet & Clank: Going Commando
Ratchet & Clank: Up Your Arsenal
Soul Calibur 2
SSX 2 Tricky
SSX 3
Tiger Woods PGA Tour 2004
Timesplitters 2
Tony Hawk's Pro Skater 3
Tony Hawk's Pro Skater 4
Tony Hawk's Underground
Virtua Fighter 4: Evolution
Winning Eleven 6 World Soccer
Winning Eleven 7 International

**Nintendo GameCube**

Eternal Darkness: Sanity's Requiem
Legend of Zelda: The Wind Waker
Madden NFL 2004
Metroid Prime
Metroid Prime 2: Echoes
Paper Mario: The Thousand-Year Door
Pikmin 2
Prince of Persia: The Sands of Time
Soul Calibur 2
SSX 3
Super Smash Brothers 2 Melee
Viewtiful Joe

**Microsoft Xbox**

Burnout 3: Takedown
Grand Theft Auto (3 & Vice City)
Halo 1: Combat Evolved
Halo 2
NCAA Football 2004
Ninja Gaiden
Prince of Persia: The Sands of Time
Project Gotham 2
Star Wars: Knights Republic
Tom Clancy's Splinter Cell
Tom Clancy's Splinter Cell: Pandora Tomorrow

We operationalize the other software variables as follows. *Software catalog* is the size of the available software catalog, which is equal to the number of video games available to consumers and sold at least once, prior to the month of interest for the system of interest. *Software introductions* refers to the number of video games introduced in the month of interest for the system of interest (e.g. Basu, Mazumdar and Raj 2003; Clements and Ohashi 2005; Gandal, Kende and Rob 2000; Nair, Chintagunta and Dubé 2004). *Software price* is the average price of all the software titles available in the software catalog for the system in the month of interest. *Software quality* is the average quality of all software titles available in the software catalog for the system in the relevant month.

Table 3.3 shows the descriptive statistics of the variables of interest.

# Table 3.3: The Descriptive Statistics of the Relevant Variables

| | Correlation | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1 Hardware Unit Sales | | | | | | | | | |
| 2 Hardware Price | -0.09 | | | | | | | | |
| 3 Hardware Age | -0.02 | -0.63 | | | | | | | |
| 4 Software Catalog | 0.17 | -0.55 | 0.80 | | | | | | |
| 5 Software Quality | 0.17 | -0.25 | -0.14 | -0.05 | | | | | |
| 6 Software Price | -0.06 | 0.52 | -0.68 | -0.76 | -0.05 | | | | |
| 7 Software Introductions | 0.40 | -0.06 | -0.03 | 0.23 | 0.09 | -0.11 | | | |
| 8 December Holidays Effect | 0.58 | 0.02 | -0.00 | 0.03 | 0.00 | 0.01 | 0.04 | | |
| 9 Introduction Superstar | 0.17 | -0.01 | -0.07 | 0.08 | 0.20 | -0.09 | 0.39 | -0.04 | |
| Mean | 223,121 | 164 | 35 | 308 | 67 | 34 | 9.9 | 0.1 | 0.1 |
| Standard Deviation | 328,757 | 102 | 26 | 255 | 4.3 | 13 | 9.7 | 0.3 | 0.3 |

## 3.4 Model

To capture the influence of our explanatory variables on hardware unit sales, we specify a dynamic panel data model, taking the log transform of specific effects when appropriate, given prior literature (e.g., Basu, Mazumdar and Raj 2003; Cottrell and Koput 1998; Dranove and Gandal 2003; Gandal 1995; Gandal, Kende and Rob 2000; Stremersch et al. 2007). The log-transform functional form of the model is appropriate given the needs to pool data across video game consoles that represent different sales volumes. The dependent variable is the log-transform of hardware unit sales of console *i* in month *t*, denoted as $H_{it}^{S}$.

$$\log H_{it}^{S} = \mu_i + \alpha_1(\log H_{it}^{P}) + \alpha_2(H_{it}^{A}) + \beta_1(\log S_{it}^{P}) + \beta_2(\log S_{it-1}^{CAT})$$
$$+\beta_3(\log S_{it}^{INT}) + \beta_4(S_{it}^{QL}) + \sum_{p=0}^{N}\beta_{5p}(S_{it-p}^{SS}) + \gamma_1(C_t^{DEC}) + u_{it} \tag{1}$$

$$u_{it} = \delta(u_{it-1}) + \varepsilon_{it} \quad -1 < \delta < 1$$

$\mu_i$ is a fixed effect that captures heterogeneity across the different consoles *i* and controls for time-invariant, unobserved, console-specific variables. The Breusch and Pagan Lagrangian multiplier test for random effects rejects a random effects model, in favor of a fixed effects model. Also conceptually, a fixed effects model is more appropriate than a random effects model, as the selection of systems from the population is not random. Next, we include the price of video game console *i* in month *t* (denoted as $H_{it}^{P}$), and the age of video game console *i* in month *t* (denoted as $H_{it}^{A}$). These independent variables model the hardware attractiveness of the system.

At the software side, we include software price of video game console *i* in month *t* (denoted as $S_{it}^{P}$), software catalog of past software introductions of video game console *i* in month *t-1* ($S_{it-1}^{CAT}$), present software introductions of video game console *i* in month *t* ($S_{it}^{INT}$), and software quality of video game console *i* in month *t* ($S_{it}^{QL}$). We do not take the log of software quality, because we model software quality as increasing returns to quality, as suggested by superstar theory, and as modeled by prior empirical superstar literature (e.g. Jones and Walsh 1988). Next, $S_{it}^{SS}$ denotes the number of superstar software titles introduced in month $t$ for console $i$ (0 if no superstar was introduced, 1 if a superstar was introduced, 2 if two superstars were introduced, etc.). To examine the persistence of the effect superstars have on hardware unit sales over time, we also add $N$ lagged terms of this variable. We do not impose a structure on this effect, because we do not know if there is an effect, how long this effect lasts, or the shape of this effect over time (e.g., decaying, linear, inverted U-shape). This method is widely used in marketing (e.g., see Mitra and Golder 2006). These independent variables model the software attractiveness of the system. Finally, the model also includes a dummy variable for the December holiday effect ($C_t^{DEC}$).

Estimating this model with OLS is not appropriate, because there is evidence of serial correlation (both from Wooldridge's (2002) test ($F(1,10) = 35.64$; $p > .00$) and Arellano-Bond's (1991) test ($z$=8.03; $p > .00$) for autocorrelation), most likely due to the presence of social contagion, and heteroskedasticity (using a modified Wald statistic for groupwise heteroskedasticity following Greene (2003) ($x^2(11) = 846.09$; $p > .00$)) in the error term. Therefore, we use a Prais-Winsten model with panel-corrected standard errors to estimate equation (1) for all video game consoles jointly (Baltagi and Li 1991). We assume panel-level heteroskedastic errors, and a panel-specific first-order autocorrelation AR(1), thus capturing the social network exposure (i.e., social contagion) (e.g., Hedstrom 1994; Strang 1991; Van den Bulte and Lilien 2001; Van den Bulte and Stremersch 2004). This procedure is also appropriate with unbalanced panel data sets such as ours. The required diagnostic tests for descriptive models (Franses 2005) did not reveal any need to revise the model.

## 3.5 Results

We first discuss how superstar software introductions affect hardware unit sales, controlling for the other variables we discussed earlier. Then, we discuss our findings on the moderating role of software type on the effect of superstar software introductions on hardware unit sales.

### 3.5.1 The Effect of Superstars

We present the results of estimating equation (1) in Table 3.4, model 1. The adjusted $R^2$ shows that the model fits the data very well, which is not surprising, given that it also includes software introductions, the December holiday effect, and a time trend (through hardware age). We next discuss the model's parameter estimates.

## Table 3.4: Superstar Introductions Affect Hardware Unit Sales And Display Increasing Returns

| | **Variables** | **Model 1**<br>Coefficient | <br>(S.E.) |
|---|---|---|---|
| $\alpha_1$ | Hardware Price | -1.073** | (0.195) |
| $\alpha_2$ | Hardware Age | -0.008** | (0.002) |
| $\beta_1$ | Software Price | 0.345 | (0.261) |
| $\beta_2$ | Software Catalog | -0.019 | (0.064) |
| $\beta_3$ | Software Introductions | 0.274** | (0.025) |
| $\beta_4$ | Software Quality | 0.013* | (0.006) |
| $\beta_{50}$ | Superstar | 0.058** | (0.016) |
| $\beta_{51}$ | Superstar L1 | 0.081** | (0.017) |
| $\beta_{52}$ | Superstar L2 | 0.077** | (0.017) |
| $\beta_{53}$ | Superstar L3 | 0.064** | (0.017) |
| $\beta_{54}$ | Superstar L4 | 0.040* | (0.017) |
| $\beta_{55}$ | Superstar L5 | 0.015 | (0.016) |
| $\gamma_1$ | December | 0.550** | (0.023) |
| Adj-$R^2$ | | 0.98 | |
| Number of observations | | 503 | |

Standard errors are in parentheses.
Two-sided significance tests: **: $p < 0.01$; *: $p < 0.05$.

# Table 3.4: Superstar Introductions Affect Hardware Unit Sales And Display Increasing Returns (ctd.)

| **Variables** | **Model 2** | |
|---|---|---|
| | Coefficient | (S.E.) |
| Hardware Price | -1.109** | (0.192) |
| Hardware Age | -0.008** | (0.002) |
| Software Price | 0.265 | (0.262) |
| Software Catalog | -0.021 | (0.064) |
| Software Introductions | 0.265** | (0.025) |
| Software Quality | 0.013* | (0.006) |
| Lowest Quality Superstar | -0.009 | (0.025) |
| Lowest Quality Superstar L1 | 0.074** | (0.028) |
| Lowest Quality Superstar L2 | 0.049 | (0.030) |
| Lowest Quality Superstar L3 | 0.058 | (0.031) |
| Lowest Quality Superstar L4 | 0.049 | (0.032) |
| Lowest Quality Superstar L5 | 0.003 | (0.028) |
| Medium Quality Superstar | 0.098** | (0.030) |
| Medium Quality Superstar L1 | 0.083* | (0.033) |
| Medium Quality Superstar L2 | 0.090** | (0.033) |
| Medium Quality Superstar L3 | 0.056 | (0.031) |
| Medium Quality Superstar L4 | 0.004 | (0.030) |
| Medium Quality Superstar L5 | 0.033 | (0.029) |
| Highest Quality Superstar | 0.123** | (0.028) |
| Highest Quality Superstar L1 | 0.097** | (0.031) |
| Highest Quality Superstar L2 | 0.131** | (0.033) |
| Highest Quality Superstar L3 | 0.092** | (0.035) |
| Highest Quality Superstar L4 | 0.093** | (0.036) |
| Highest Quality Superstar L5 | 0.028 | (0.033) |
| December | 0.550** | (0.023) |
| Adj-$R^2$ | 0.98 | |
| Number of observations | 503 | |

Standard errors are in parentheses.
Two-sided significance tests: **: $p < 0.01$; *: $p < 0.05$.

All parameters have the expected sign and are highly significant, except for software price and software catalog, which are not significant. The introduction of a superstar has a significant and positive effect for the first 5 months, in the month of introduction ($\beta_{50} = 0.058$, $p < 0.01$), and 1 ($\beta_{51} = 0.081$, $p < 0.01$), 2 ($\beta_{52} = 0.077$, $p < 0.01$), 3 ($\beta_{53} = 0.064$, $p < 0.01$), and 4 months after introduction ($\beta_{54} = 0.040$, $p < 0.05$). The 5th lag (e.g., $t+5$), and all later lags are not significant.[15] We can also reject that the cumulative superstar effect at $t+5$ is equal to zero ($\beta_{50} + \beta_{51} + \beta_{52} + \beta_{53} + \beta_{54} + \beta_{55} = 0$), at the $p < 0.01$ level.

Using these parameters, we estimate both the monthly effects and the cumulative effect of superstar introductions on hardware unit sales, from their introduction at *t*, until 5 months after their introduction ($t+5$). Figure 3.5 depicts this graphically. The monthly effect peaks during 1 to 2 months after introduction, and decays afterwards. Remember that software unit sales flatten around the same time. A superstar software title increases hardware unit sales by 14% (167,000 units) on average, during these first 6 months[16] (29,000 units during the month of introduction (*t*), 39,000 ($t+1$), 38,000 ($t+2$), 32,000 ($t+3$), 21,000 ($t+4$) and 8,000 ($t+5$)). We report both the percentage increase in hardware unit sales, and the size of this effect in hardware unit sales, of a superstar software introduction. This allows us to compare the hardware effect, with the software effect, of superstars. However, we advise caution when interpreting these hardware unit effects, due to the large variance between and within systems. A superstar achieves software sales of 835,000 units on average, during these first 6 months (See Figure 3.2). Meaning that during these first 6 months, on average, 1 in every 5 buyers of a superstar software title, also purchases the hardware required to use the superstar software title.

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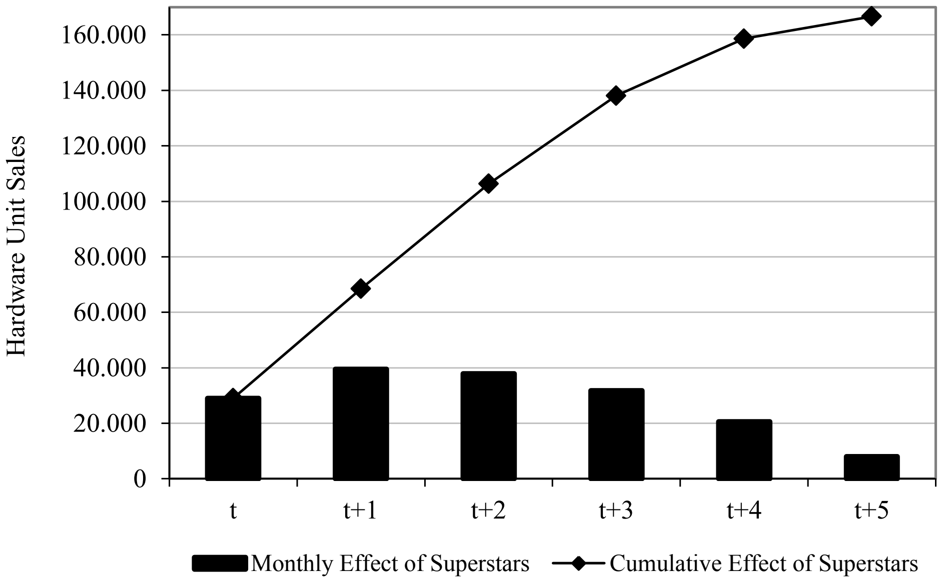
[15] We start with a large number of superstar lags (e.g., a large $N$ ) as suggested by Greene (2003), and reduce the number of lags until only the last lag (e.g., $t+5$) is not significant. By including the last not significant lag, we make sure that the coefficients are not biased and inconsistent because of this (Greene 2003; Judge et al. 1985).

[16] Using only expert ratings or only user ratings, instead of the average of both, to identify superstar software titles, also confirms the presence of a superstar effect, while all other estimated parameters were highly similar.

Figure 3.5: The Effect of Superstars on Hardware Unit Sales over Time



We also find that software introductions ($\beta_3$ = 0.274, $p < 0.01$) and software quality ($\beta_4$ = 0.013, $p < 0.05$) are significant. Hardware price ($\alpha_1$ = -1.073, $p < 0.01$) has a significant and negative effect on hardware unit sales, while the system becomes less popular as it ages ($\alpha_2$ = -0.008, $p < 0.01$) (i.e., a negative time trend)[17]. The effect of the software catalog ($\beta_2$ = -0.019) is not significant, because consumers do not seem to value old non-superstar software titles. Also the effect of software price ($\beta_1$ = 0.345) is not significant. Reasons for the latter may be that there is little variance in software price or that software price shows a high correlation with hardware age and software catalog, potentially inflating the standard error. We also find that there is a bump in hardware unit sales in December ($\gamma_1$ = 0.550, $p < 0.01$), due to the holiday effect.

We can re-estimate Model 1, using different software quality thresholds to identify superstars, in order to examine the relationship between the choice of the threshold and superstars' cumulative effect on hardware unit sales. The number of superstars drops sharply with an increasing quality threshold. Consistent with the superstar theory formulated by Rosen (1981), we again find a monotonic increasing returns relationship between software quality and hardware unit sales (See Figure 3.6), similar to the one between software quality and software unit sales. A software quality threshold of 86 – all games with a quality rating of 86 and above are considered superstars – identifies 337 software titles as a superstar. Software titles with a quality rating of 86 and above increase hardware unit sales with only 4% (48,000 units) on average during the first 6 months. A quality threshold of 92 – all games with a quality rating of 92 and above are considered superstars – identifies just 32 software titles as a superstar. Software titles with a quality rating of 92 and above increase hardware unit sales with 26% (285,000 units) on average during the first 6 months (See Figure 3.6).

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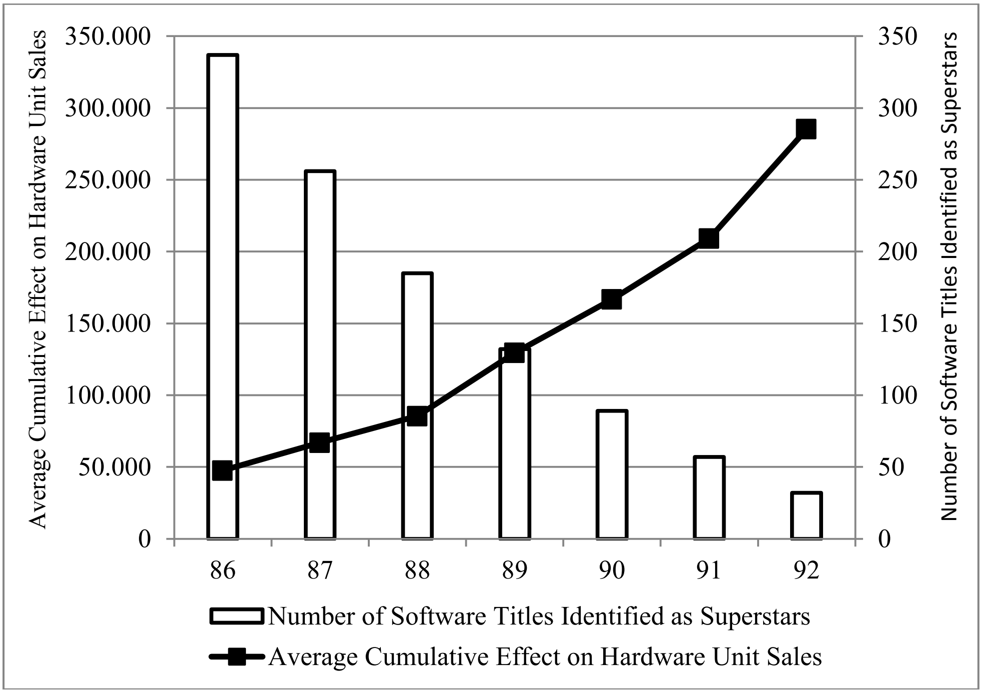
[17] Using trends that are even more flexible such as $t^2 + t$, or $t^2 + t + \log t$, to estimate equation (1) gave similar results.

Figure 3.6: Varying the Software Quality Threshold to Identify Superstars



We subsequently examine if this apparent monotonic increasing returns relationship, between software quality and hardware unit sales is significant, by dividing the 89 identified superstar software titles into 3 evenly sized groups, according to their software quality rating. The lowest quality superstars (N=30) are grouped together, and have an average software quality rating of 90.48. The medium quality superstars (N=30) are grouped together, and have an average software quality rating of 91.45. The highest quality superstars (N=29) are grouped together, and have an average software quality of 93.25. Model 2 in Table 3.4 shows the estimated parameters of the 3 superstar quality groups. Using these parameters, we can again estimate the monthly and cumulative effects of these 3 superstar quality groups on hardware unit sales, using a similar methodology as before.

The highest quality superstars increase hardware unit sales with 21% (242,000 units), the medium quality superstars increase hardware unit sales with 13% (160,000 units), while the lowest quality superstars increase hardware unit sales with only 8% (101,000 units).[18] We can reject that the cumulative superstar effect of the low, medium and high quality groups are equal to zero. We can also reject that the cumulative effect of the lowest quality superstars is equal to the cumulative effect of the highest quality superstars. We cannot reject that the cumulative effect of the medium quality superstar group differs from the other two effects. All these results support our theoretical rationale that superstars display increasing returns of software quality to hardware unit sales, as the returns to quality increase over quality tiers (low – medium – high).

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[18] Estimating the cumulative superstar effects presented in this section, using only the first 4 or 5 months, confirm the findings presented here.

# Table 3.5: The Effect of Superstar Introductions by Software Type

| **Variables** | **Model 3** | | **Variables** | **Model 4** | |
|---|---|---|---|---|---|
| | Coefficient | (S.E.) | | Coefficient | (S.E.) |
| Hardware Price | -1.076** | (0.197) | Hardware Price | -1.070** | (0.196) |
| Hardware Age | -0.009** | (0.002) | Hardware Age | -0.008** | (0.002) |
| Software Price | 0.320 | (0.263) | Software Price | 0.357 | (0.262) |
| Software Catalog | -0.014 | (0.064) | Software Catalog | -0.016 | (0.063) |
| Software Introductions | 0.266** | (0.025) | Software Introductions | 0.274** | (0.025) |
| Software Quality | 0.013* | (0.013) | Software Quality | 0.013* | (0.006) |
| Exclusive Superstar | 0.096** | (0.023) | Original Superstar | 0.066** | (0.024) |
| Exclusive Superstar L1 | 0.081** | (0.025) | Original Superstar L1 | 0.076** | (0.025) |
| Exclusive Superstar L2 | 0.085** | (0.026) | Original Superstar L2 | 0.059* | (0.025) |
| Exclusive Superstar L3 | 0.081** | (0.027) | Original Superstar L3 | 0.065* | (0.026) |
| Exclusive Superstar L4 | 0.056* | (0.028) | Original Superstar L4 | 0.015 | (0.026) |
| Exclusive Superstar L5 | 0.029 | (0.025) | Original Superstar L5 | -0.003 | (0.024) |
| Non-excl. Superstar | 0.006 | (0.024) | Superstar Sequel | 0.045 | (0.024) |
| Non-excl. Superstar L1 | 0.090** | (0.024) | Superstar Sequel L1 | 0.080** | (0.025) |
| Non-excl. Superstar L2 | 0.076** | (0.025) | Superstar Sequel L2 | 0.093** | (0.026) |
| Non-excl. Superstar L3 | 0.057* | (0.025) | Superstar Sequel L3 | 0.059* | (0.027) |
| Non-excl. Superstar L4 | 0.028 | (0.025) | Superstar Sequel L4 | 0.073** | (0.028) |
| Non-excl. Superstar L5 | -0.004 | (0.024) | Superstar Sequel L5 | 0.027 | (0.026) |
| December | 0.549** | (0.023) | December | 0.548** | (0.023) |
| Adj-R2 | 0.98 | | | 0.98 | |
| Number of observations | 503 | | | 503 | |

Standard errors are in parentheses.
Two-sided significance tests: **: $p < 0.01$; *: $p < 0.05$.

## Table 3.5: The Effect of Superstar Introductions by Software Type (ctd.)

| **Variables** | **Model 5** | |
|---|---|---|
| | Coefficient | (S.E.) |
| Hardware Price | -1.065** | (0.199) |
| Hardware Age | -0.008** | (0.002) |
| Software Price | 0.400 | (0.273) |
| Software Catalog | -0.015 | (0.066) |
| Software Introductions | 0.277** | (0.026) |
| Software Quality | 0.012* | (0.006) |
| Action Superstar | -0.007 | (0.026) |
| Action Superstar L1 | 0.077** | (0.029) |
| Action Superstar L2 | 0.050 | (0.027) |
| Action Superstar L3 | 0.047 | (0.027) |
| Action Superstar L4 | 0.038 | (0.026) |
| Action Superstar L5 | 0.038 | (0.026) |
| FPS Superstar | 0.223** | (0.056) |
| FPS Superstar L1 | 0.127* | (0.059) |
| FPS Superstar L2 | 0.127 | (0.067) |
| FPS Superstar L3 | 0.130* | (0.066) |
| FPS Superstar L4 | 0.003 | (0.065) |
| FPS Superstar L5 | -0.073 | (0.063) |
| Platformer Superstar | 0.102** | (0.044) |
| Platformer Superstar L1 | 0.127** | (0.049) |
| Platformer Superstar L2 | 0.044 | (0.047) |
| Platformer Superstar L3 | 0.085 | (0.044) |
| Platformer Superstar L4 | -0.044 | (0.045) |
| Platformer Superstar L5 | -0.015 | (0.040) |
| Racing Superstar | 0.046 | (0.063) |
| Racing Superstar L1 | 0.095 | (0.071) |
| Racing Superstar L2 | 0.163* | (0.075) |
| Racing Superstar L3 | 0.087 | (0.075) |
| Racing Superstar L4 | 0.228* | (0.098) |
| Racing Superstar L5 | 0.125 | (0.091) |
| RPG Superstar | 0.045 | (0.038) |
| RPG Superstar L1 | 0.074 | (0.042) |
| RPG Superstar L2 | 0.091* | (0.044) |
| RPG Superstar L3 | 0.076 | (0.045) |
| RPG Superstar L4 | 0.038 | (0.044) |
| RPG Superstar L5 | 0.011 | (0.039) |
| Sports Superstar | 0.146* | (0.059) |
| Sports Superstar L1 | 0.004 | (0.062) |
| Sports Superstar L2 | 0.094 | (0.066) |
| Sports Superstar L3 | 0.028 | (0.070) |
| Sports Superstar L4 | 0.051 | (0.074) |
| Sports Superstar L5 | 0.060 | (0.068) |
| December | 0.550** | (0.024) |
| | 0.97 | |
| | 503 | |

Standard errors are in parentheses.
Two-sided significance tests: **: $p < 0.01$; *: $p < 0.05$.

### 3.5.2 The Effect of Software Type

Models 3, 4 and 5, in Table 3.5, show the effect of superstar introductions on hardware unit sales moderated by software type. We first distinguish between superstars that are exclusively available for just one system (n=56), and non-exclusive superstars that are available for multiple systems (n=33). Model 3 in Table 3.5 shows the estimated parameters of the exclusive superstar and non-exclusive superstar effects. Using these parameters, we can again estimate the monthly and cumulative effects of exclusive and non-exclusive superstars on hardware unit sales, using a similar methodology as before.

Exclusive superstars increase hardware unit sales with 16% (196,000 units), while non-exclusive superstars increase hardware unit sales with only 9% (117,000 units). We can reject that both the cumulative exclusive superstar effect and the cumulative non-exclusive superstar effect are equal to zero. However, we cannot reject that these two cumulative effects are statistically equal to one another, due to the large standard errors and numerous non-significant parameter estimates. We can therefore not confirm the theoretical rationale, that exclusive superstars have a larger effect on hardware unit sales compared to non-exclusive superstars.

Next, we distinguish between superstars that are original titles (n=49) from superstars that are sequels (n=40). Model 4 in Table 3.5 shows the estimated parameters of the original superstar and superstar sequel effects. Original superstars increase hardware unit sales by 12% (146,000 units), while superstar sequels increase hardware unit sales by 16% (192,000 units). We can reject that both the cumulative original superstar effect and the cumulative superstar sequel effect is equal to zero. However, we cannot reject that these two cumulative effects are statistically equal to one another. We can therefore not confirm any of the two theoretical rationales.

Last, we distinguish superstars according to their genre. As stated before, there are 6 genres. The two large genres are action (n=36) and platformer (n=12). The four small genres are first-person shooter (FPS) (n=7), racing (n=5), role-playing (RPG) (n=20), and sports (n=9). Model 5 in Table 3.5 shows the parameters of the superstar effects per genre. The small size of some genres is likely a contributing factor to a number of insignificant parameters. First-person shooter (FPS) (25% (280,000 units)) and racing (26% (286,000 units)) superstars have the largest (i.e., above average) impact on hardware unit sales.

Superstars from the genres role-playing (RPG) (14% (170,000 units)) and sports (16% (190,000 units)) have a moderate effect on hardware unit sales. Surprisingly, superstars from the two large genres (action 10% (129,000 units) and platformer 11% (142,000 units)) have the smallest (i.e., below average) effect on hardware unit sales. We can reject that the cumulative effect, from each software genre is equal to zero. However, we cannot reject that these cumulative effects are statistically equal to one another. We can therefore not confirm the theoretical rationale that superstars from a larger genre have a larger effect on hardware unit sales.

We are unable to confirm that software type moderates the effect superstars have on hardware unit sales. However, this may be different in other system markets. Take for instance, the High Definition DVD market. Superstar movies will likely stimulate sales of High Definition DVD players; much like titles such as The Matrix did for the DVD format. At the same time, different movie types exist, which may generate different returns. For instance, action movies full of computer-generated images (CGI) are likely to have a larger impact on hardware unit sales, as compared to drama movies, which depend less on the high screen resolution and the large number of sound channels, therefore being less suitable to sell High-Definition DVD players.

### 3.5.3 Robustness and Further Analyses

Our estimations of various models show stability in parameter estimates. We conducted the following analyses to further test the robustness of our estimates.

We used different estimation methods (than our Prais-Winsten model) such as ordinary least squares (OLS) and generalized method of moments (GMM), and different sub-samples, to estimate equation (1). All these analyses confirm our findings reported above. We also estimated a model that included competition, through contemporaneous (0.509, $p < 0.01$) and lagged competitor hardware unit sales (-0.076, $p < 0.01$). This model again yielded similar findings. Finally, we also estimated a model lagging independent variables, which again confirmed our findings. In sum, our findings are highly robust to alternate model specifications.

One could also study the effect of the accumulation of superstar introductions over time for a certain system (i.e., the superstar catalog size), on hardware unit sales. We have done so, and found the effect of the accumulation of superstars on hardware unit sales to be positive (0.017, $p<0.01$), while all other estimated parameters were similar.

The correlation matrix in Table 3.3 shows high correlations between several independent variables (i.e., hardware age, hardware price, software quantity and software price). We assessed the consequences of these high correlations in two ways. First, we used multiple procedures to assess multicollinearity (e.g., Belsley 1991; Belsley, Kuh and Welsh 1980; Marquardt 1970). All these procedures indicate that the weak to moderate dependencies between the independent variables do not create harmful multicollinearity. The values of the condition indices are below 35, and variance inflation factors are below 5. In addition, the correlation between the different superstar types and their lags is low (i.e., below 0.25). Second, we dropped independent variables that showed a high correlation with another independent variable, one by one. The parameter estimates we obtained are very similar to the model that included the dropped independent variable, parameter estimates do not fluctuate dramatically, and parameter estimates do not change sign. Overall, we can conclude that our results are highly robust.

## 3.6 Discussion

We find that superstars are as attractive as popular belief suggests, and helped to sell over 14.8 million systems, which is around 12.4% of total hardware unit sales. During the first 6 months a superstar software title is on the market, 1 in every 5 buyers of a superstar software title, also purchases the hardware required to use the superstar software title. Systems with no or only one superstar failed miserably. Surprisingly, while superstar software unit sales peak during introduction and decline with each month, the monthly superstar effect on hardware unit sales peaks in the second to third month, and thus displays an inverted U-shape effect over time. Thus, high software unit sales of superstars do not automatically translate into a large, or similarly shaped, superstar effect on hardware unit sales. This different time pattern is likely because of the relative slower diffusion of information about superstars among non-adopters (i.e., potential hardware buyers), compared to adopters (i.e., software buyers). Software type, such as the exclusivity of a superstar, does not significantly moderate the effect of superstar software releases on video game console sales.

### 3.6.1 Implications

These findings have important implications for theory and research on system markets, as they invalidate prior operationalizations of software availability. Using the software catalog as an indicator for software availability, which is standard practice in network effects literature, may show insignificant indirect network effects (Stremersch et al. 2007). Using the number of software titles introduced may paint an incomplete picture, as it does not account for increasing returns to quality and thus the abnormal returns on superstars. Future research should use a software availability measure, which accounts for both software titles of varying superstar power, and varying durability (given the decay in effects over time we found with respect to superstars, and the non-significant effect of the old software catalog on hardware unit sales).

We find a monotonic increasing returns relationship, between software quality and software unit sales (See Figure 3.1), and between superstar quality and hardware unit sales (See Figure 3.6). Thereby, we contribute to the literature on quality by extending the relevance and importance of product quality in the product's own market (i.e., the superstar effect in the software market) to complementary and adjoining markets (i.e., the hardware market).

Software firms should examine their inventory of software titles for potential superstars, and negotiate with system owners to receive side-payments for the increase in hardware unit sales their superstars cause. Software firms could even initiate a bidding war between system owners for the rights to their superstars. System owners should examine the forthcoming software titles for potential superstar power. If a software franchise (e.g., Take-Two's Grand Theft Auto Franchise) is famous for creating superstar software titles, system owners should proactively act on this knowledge.[19] Microsoft paid $50 million to software publisher Take-Two, for producing two downloadable episodes of Grand-Theft Auto (Schiesel 2007). As superstars only have a positive effect on hardware unit sales for a limited period, system owners must convince consumers that the introduction of a superstar is not a fluke, but that there will be a steady supply of superstar software titles. System owners should inform consumers early on during the software development

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[19] We thank a reviewer for this insight.

process, that software developers of past superstars are developing new superstars, to manage expectations and in order to create positive expectations, which are so crucial in positive feedback markets (e.g., Shapiro and Varian 1998).

However, system owners must remember that when they pay software firms for the exclusivity of their superstars, they are not additionally increasing their own hardware sales -compared to a non-exclusive superstar software title - but that they are eliminating an opportunity for competing systems to increase their hardware unit sales. Eliminating competitor hardware sales while increasing one's own hardware sales, may well be the deciding factor in a positive feedback market (e.g., Arthur 1989 and 1996; Shapiro and Varian 1998). The Sega Dreamcast had plenty of superstars during its first year, and subsequently hardware sales exceeded expectations. However, when the introduction of superstars dried up during the second year, due to software publishers switching to the Sony Playstation 2, so did hardware sales, and Sega was forced to withdraw from the market, as a system's owner.

Superstars display increasing returns (both in software unit sales and hardware unit sales) to software quality. Cutting corners, while rushing a software title to market, to meet a deadline (e.g., the launch of the hardware, or the December holidays), will not only have an adverse effect on the software sales of the software title itself. It could also turn a potential superstar into a 'me-too' software title, without a superstar effect on hardware sales, just because of the slightly lower software quality. System owners should intervene, and pay software publishers to continue development, in order to improve quality. In addition, system owners should provide resources (e.g., popular franchises, more advanced game engines, etc.), if a software publisher does not have the resources to turn a 'me-too' software title into a superstar, because it will increase both software and hardware sales.

While our empirical test reflected upon the role of superstar introductions in system markets, in only one system market, namely the U.S. home video game console market, its conceptual conclusions – numbers may vary – are likely to be valid in other markets as well. In the High-Definition DVD market, the absence or presence of support from movie studios who have introduced recent superstar movies proved to be the deciding factor in the standards war between Toshiba's HD-DVD standard and Sony's Blu-ray standard, that tipped the market towards Sony's Blu-ray standard. In addition, the Satellite radio market in the U.S. is likely to be also such a superstar system market, in which multiple incompatible systems fought one another for dominance (Sirius and XM). The signing of superstars like Howard Stern, and the exclusive rights to live broadcasts of NFL games, are important events that likely increased sales of one of the two competing systems. In contrast, the lack of superstars (i.e., NFL games, superstar movies) in the HDTV market may well be the cause of the initial sluggish adoption of HDTV sets. Therefore, both hardware and software firms should carefully examine the role superstars play in their industry, as superstars affect both software and hardware sales.

### 3.6.2 Limitations and Future Research

The present paper is the first one to study the role of superstar software titles in system markets. Thus, this paper is an important contribution to the literature that may provoke further research. At the same time, it also has some limitations that such future research may address.

This paper only examines one system market. Future research could examine if the superstar phenomenon also exists outside the video game market, and if the effect superstars have on hardware unit sales is similar to that of superstars in the video game industry. Markets that may prove fruitful to examine are the High-Definition DVD market and the Satellite radio market.

This paper also only focuses on the hardware adoption side, and largely ignores the software provision side, as this is not the focus of the paper. While this is a common approach in modeling system markets (e.g. Hartman and Teece 1990; Shankar and Bayus 2003), it does raise potential endogeneity concerns. However, in our case, these concerns cannot be addressed by specifying both a demand and supply model (as in, Nair, Chintagunta and Dubé 2004; Sawhney and Eliashberg 1996). The reason is that important data in the supply equation is unavailable (e.g. software costs) and possible instruments (e.g. from a different geographic area) again are unavailable.

On the positive side, we have several indications that endogeneity is not a major concern in our case. First, prior studies on system markets that explicitly address potential endogeneity show the findings from a model that controls for endogeneity to be very similar to the findings from a model that does not (e.g. Dranove and Gandal 2003; Gandal, Kende and Rob 2000; Le-Nagard-Assayag and Manceau 2001; Ohashi 2003; Park 2004; Rysman 2004). Second, it is unlikely that the variables of focal interest to us, such as superstar introductions, software quantity, and software quality, depend upon contemporaneous hardware unit sales. The reason is that it takes 12 to 18 months to develop an average video game. Superstars can take many years to develop. Thus, while price may be endogenous, potentially creating a bias in our price parameters, this is very unlikely to occur in the software availability variables. Third, one way to reduce endogeneity is to lag all independent variables. We found that this did not affect our estimates much, again alleviating endogeneity concerns.

In addition, we do not study the technological characteristics of the hardware. We control for this effect in our model by including a fixed effect. However, the study of such technological characteristics may yield interesting managerial insights, as they seem to have become more important recently (e.g. What is the effect of Nintendo's unique game controller on hardware unit sales? What is the effect of the Blu-ray capability of the Sony Playstation 3 on hardware unit sales?).

Our research may also stimulate further research in this area, which does not necessarily focus on addressing shortcomings of the present study. First, the present study focuses on the sales gain from superstar introductions. Obviously, superstars may require a higher investment and are intrinsically more risky to develop. A study that examines the profitability of investments made by system owners in the supply of superstars would be intrinsically interesting, but challenging to conduct.

We have also shown that superstar introductions are an important indicator of hardware unit sales. Thus, the supply of superstars may be critical input in determining who will win system wars (e.g. the current battle between Microsoft's Xbox 360, Nintendo's Wii and Sony's Playstation 3). However, our study lacks foresight, in the sense that it studies actual introductions, rather than announcements. It would be highly valuable to study the effect of superstar announcements on hardware unit sales (foresight by consumers) or firm valuations (foresight by investors). The support of third parties (i.e., independent software publishers) for a certain system may also be very valuable information in this regard. Our approach also lacks foresight in the operationalization of superstars. We determine ex post which software titles are superstars, given their perceived quality. Studies that would enable us to determine which software titles have superstar potential prior to their introduction would be most valuable.

In addition, examining the role of horizontal concentration in the software and hardware market, as well as vertical integration between the software and hardware market, or examining the role side-payments play in system markets, will likely also be fruitful areas of future research.

We hope that these research ideas spark more interest in the phenomenon of superstars in system markets, which has remained deprived from academic attention for too long.

# Chapter 4

# Complementor Entry in System Markets[20]

## 4.1 Introduction

Systems are composed of complementary products (Gandal, Kende and Rob 2000; Katz and Shapiro 1994; Stremersch et al. 2007). For example, a video game system is composed of the video game console (the hardware) and video games (the software). System markets are characterized by indirect network effects. In such markets, increased adoption of the hardware by consumers, and thereby an increased hardware installed base, is said to positively affect the complementors' decision to introduce software products for the respective hardware (i.e., supply-side indirect network effects). Larger availability of software products is believed to increase the utility of the system to consumers, thereby affecting the consumers' decision to adopt the hardware, thus increasing hardware sales (i.e., demand-side indirect network effects) (Caillaud and Jullien 2003; Church and Gandal 1993 and 1996; Katz and Shapiro 1994; Stremersch et al. 2007).

Demand- and supply-side indirect network effects may lead to a coordination problem, commonly referred to as the 'chicken-and-egg' problem, because both complementors and consumers may take on a 'wait-and-see' attitude (Gupta, Jain, and Sawhney 1999; Katz and Shapiro 1994). In essence, independent software firms (i.e., complementors) stall entry and thus the introduction of software products, until enough consumers have adopted the system, while consumers wait to adopt the system until enough software firms have entered and introduced their software products (Caillaud and Jullien 2003; Gupta, Jain, and Sawhney 1999; Srinivasan, Lilien and Rangaswamy 2004; Stremersch et al. 2007). In the end, software firms may not even enter at all, leading to the system's failure.

While the indirect network effects literature has largely focused on demand-side indirect network effects (see Stremersch et al. (2007) for an overview), there are no studies we know of, which examine the entry decision of the complementor in a system market context. Supply-side indirect network effects are rarely tested empirically, in comparison

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[20] This work was co-authored with Stefan Stremersch, and is being prepared for submission.

to demand-side indirect network effects (see Stremersch et al. 2007 for an exception). At the same time, the firm entry literature, while a rich literature (e.g. Agarwal 1998; Agarwal and Audretsch 2001; Agarwal and Bayus 2002; Agarwal and Gort 1996; Bayus, Kang and Agarwal 2007; Gort and Klepper 1982; Gort and Konakayama 1982; Kim, Bridges and Srivastava 1999; Klepper and Graddy 1990; Klepper and Miller 1995), has focused on the entry pattern of firms in an industry, in a technology, or across industries (Geroski 1995), over time, but not on the entry of complementors in industries with indirect network effects. This chapter is the first to study the variation in entry timing and likelihood across complementors for the same system.

The omission in the indirect network effect and firm entry literatures that the present chapter addresses is important. The (lack of) entry of complementors may determine the success (or failure) of the entire system (Binken and Stremersch 2009; Church and Gandal 1993 and 1996; Farrell and Saloner 1986; Gupta, Jain and Sawhney 1999; Katz and Shapiro 1986b and 1994). In addition, as the economy becomes more and more interconnected, the number of markets that face indirect network effects, and thus, the risk of the system's failure because of slow or non-existent entry of complementors, increases (Gupta, Jain and Sawhney 1999; Srinivasan, Lilien and Rangaswamy 2004; Yoffie 1997).

We obtained data on 2,895 entry decisions (of which 775 resulted in entry) in the U.S. home video game industry, during the period 1976 to 2008. By the end of 2007, these 775 entries had generated over $67 billion in software sales alone. This industry is a fitting setting to study complementor entry, because prior research identifies it as a system market (e.g. Binken and Stremersch 2009; Church and Gandal 1992a; Katz and Shapiro 1994). Because complementors enter in less than 27% of the entry opportunities, we use a split-population duration model (Schmidt and Witte 1989; Sinha and Chandrashekaran 1992), as it relaxes the assumption that all entry opportunities will eventually experience the event of interest (i.e., entry). The split-population duration model uses a logit function to model the probability of entry and a hazard function to model the time of entry, which we estimate simultaneously. The model allows us to separate out the effects of our covariates on the probability of entry, from the effects on the timing of entry.

While we find that every pre-entry experience by the complementor itself, the system owner or other complementors makes the complementor a faster entrant, the effect of these pre-entry experiences on the complementor’s probability of entry is very mixed. Especially, the pre-entry relationship between complementor and system owner plays an important role in the complementor’s entry decision. Our findings allow marketing managers of system owners to alleviate the 'chicken-and-egg' problem their new system faces, by identifying the most probable early entrants (i.e., complementors) early on (even before they introduce their new system). In addition, it allows marketing managers of complementors and market analysts to early on identify if a system has or has not adequate support from complementors (i.e., differentiate between winning and losing systems). In addition, we find that the effect of supply-side indirect network effects (i.e., hardware installed base) on the complementor’s time of entry exhibits strong heterogeneity. Thereby identifying under which conditions supply-side indirect network effects are, and are not, an effective marketing instrument in the strategy of a system owner to win a systems war.

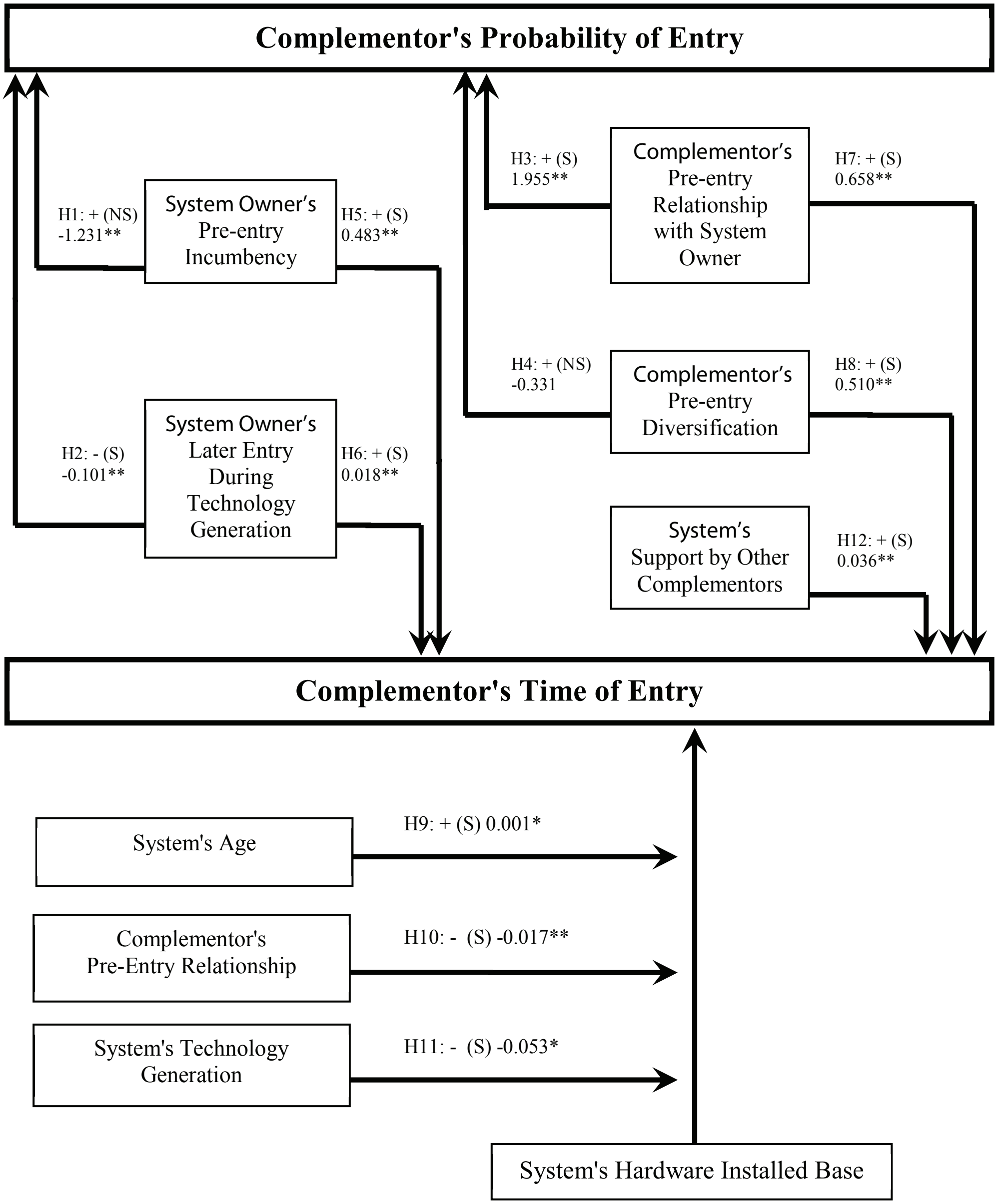
We organize the remainder of the chapter as follows. Next, we develop the conceptual framework and hypotheses. Then we discuss the data and model we use to test the hypotheses. We end with presenting the results and a discussion of this chapter´s implications and limitations.

## 4.2 Entry of Complementors in System Markets: Theory

In this chapter, we study two components of a complementor’s entry, whether to eventually enter or not (a binary outcome; a complementor has entered or not) and when to enter (a timing outcome; the time it took the complementor to enter, since introduction of the system). We develop theoretical expectations on the variables that may affect both components of the complementor’s entry decision. The main distinction between both entry components is that any variable that is explicitly time-varying (e.g. hardware installed base, system’s age) is excluded from the binary component (whether or not to enter) (Dekimpe et al. 1998; Gupta 1991). The entry-timing component has both time-varying and time-invariant explanatory variables.

Entrants differ in their capabilities (Klepper 2002). Examining the effect of pre-entry experience on firm entry will allow us to better understand the evolution of system markets. In our hypotheses derivation, we focus on the *pre-entry experience of the system owner* – whether the system owner was present with a system during the previous technology generation (i.e., incumbency) and whether it entered the present technology generation early or late (i.e., entry timing) – and *pre-entry experience of the complementor* – whether the complementor already had a relationship with the system owner in the previous technology generation, and how many other systems in entered and supported with software products in total, prior to the entry decision entry at hand (i.e., pre-entry diversification). Figure 4.1 depicts our conceptual framework, and provides an overview of the hypotheses we test.

Figure 4.1: Conceptual Framework, Hypotheses and Results



(S) indicates that hypothesis is supported, (NS) indicates that hypothesis is not supported. Two-sided significance tests: **: $p < 0.01$; *: $p < 0.05$.

## 4.3 Whether or Not to Enter: Drivers of Complementor Entry Probability

We first theorize on the variables that may explain whether a complementor will ultimately supply its complements for a specific system (whether or not to enter). We first detail our expectations on the pre-entry experience of the system owner (i.e., incumbency, entry timing), after which we turn to the pre-entry experience of the complementor (i.e., relationship with system owner, pre-entry diversification). We end with other covariates we will control for in our statistical tests.

### 4.3.1 System Owner

#### 4.3.1.1 Pre-entry Incumbency

Initially all system owners are entrants. However, in later technology generations, there will be both incumbents and entrants. We define incumbents, as system owners that were present with a system during the previous technology generation, similar to prior research (e.g. Chandy and Tellis 2000; Srinivasan, Lilien and Rangaswamy 2004). There are 35 systems, of which entrants introduced 23 systems and incumbents 12 (See Table 4.1).

# Table 4.1: Complementor Entry Evolution (1976 until April-2008)

| | Gen 2 | Gen 3 | Gen 4 | Gen 5 | Gen 6 | Gen 7 |
|---|---|---|---|---|---|---|
| Total Number of Entry Opportunities | 546 | 501 | 655 | 624 | 387 | 182 |
| Number of Entries | 48 (9%) | 99 (20%) | 146 (22%) | 182 (29%) | 212 (55%) | 88 (48%) |
| Average Time to Entry in Months | 60.1 | 39.4 | 25.9 | 22 | 20.9 | 9.3 |
| Number of Pre-entry Relationships Between Complementor and System Owner | 0 (0 %) | 38 (8%) | 64 (10%) | 89 (14%) | 100 (26%) | 127 (72%) |
| New System Owners (Entrants) | 10 | 4 | 3 | 4 | 2 | 0 |
| Incumbent System Owners | 0 | 2 | 2 | 2 | 3 | 3 |
| **Total Systems** | **10** | **6** | **5** | **6** | **5** | **3** |
| Unsuccessful Systems | 9 | 5 | 3 | 4 | 2 | 0 |
| Successful Systems | 1 | 1 | 2 | 2 | 3 | 3 |
| **Total Systems** | **10** | **6** | **5** | **6** | **5** | **3** |

We expect that if a system owner was present during the previous technology generation (i.e., has pre-entry experience from the prior generation), it will have a positive effect on the complementor's probability of entry. When a system owner is a player in the previous technology generation (i.e., an incumbent) it may well shape the evolution of the industry, greatly influencing future generations of products to its advantage (Schilling 1999). Incumbents have access to market knowledge, brand equity, and customer relationships from the past (Srinivasan, Lilien and Rangaswamy 2004; Thomas 1995), which will increase the incumbent's effectiveness in the next technology generation. Reputation and brand name are especially valuable in network markets, where expectations are pivotal (Shapiro and Varian 1998). In addition, the previous generation gives the incumbent additional --financial-- resources to persuade complementors to enter its next generation system. On the demand-side, consumers are more inclined to adopt a new system from an incumbent from which they purchased their prior system (Greenstein 1993). Therefore,

*H1: Incumbency of the system owner will have a positive effect on the complementor's probability of entry.*

#### 4.3.1.2 Entry Timing

System owners that enter early in a new technology generation may have key advantages, like preemption of scarce resources, in network markets (Shapiro and Varian 1998). Being early gives a system owner the opportunity to build a substantial hardware installed base and software catalog, and set the tone for future competition (Lieberman and Montgomery 1988 and 1998; Tushman and Anderson 1986). In contrast, later systems enter the market in a much more competitive environment and face an uphill battle against earlier introduced systems. In addition, early adopting consumers and early entering complementors have spent --part of-- their resources, and increased their familiarity with existing competing systems. For these reasons, systems that entered later within a generation may find it more difficult to entice complementors to support their systems. Therefore, *H2: The later introduction of the system during a technology generation has a negative effect on the complementor's probability of entry.*

## 4.3.2 Complementor

### 4.3.2.1 Pre-entry Relationship with System Owner

If a complementor has a pre-entry relationship with the system owner, it may be cheaper to provide complements for the system owner’s new system (Greenstein 1993). In addition, this pre-entry relationship may have required relationship-specific investments of the complementor that would be lost if the complementor does not continue its relationship with the system owner towards new generations of systems, thus driving them to long-term relationships across technology generations (Katz and Shapiro 1994). Therefore,

*H3: The existence of a pre-entry relationship with the system owner has a positive effect on the complementor's probability of entry.*

### 4.3.2.2 Pre-entry Diversification

Some complementors diversify their investment across a large number of systems (i.e., a large number of pre-entry entries into prior introduced systems of competing hardware sponsors), while others do not and specialize into fewer systems. These pre-entry entries create prior generation knowledge and resources, which will become the initial building blocks of next generation knowledge and resources (Wheelwright and Clark 1992; Garud and Kumaraswamy 1993). Diversification also allows complementors to leverage their --financial, organizational and technical-- resources (e.g. Bayus and Agarwal 2007; Teece 1986), across multiple emerging systems. Therefore,

*H4: Pre-entry diversification positively affects the complementor's probability of entry.*

## 4.3.3 Other Covariates

New technology generations may significantly expand the market to new consumers as each new technology generation is superior (i.e., more efficient, increased functionality) compared to its predecessor (Islam and Meade 1997; Mahajan and Muller

1996; Padmanabhan and Bass 1993). Therefore, we expect the probability of complementor entry to increase with each new technology generation. We also control for a complementor's pre-entry size (i.e., pre-entry accumulated economies of scale) and pre-entry age (i.e., pre-entry accumulated learning by doing). We expect larger and older complementors to show a higher probability to enter, as they have accumulated more knowledge than smaller and younger firms, which enhances efficiency and gives them a competitive advantage (i.e., lower costs, higher quality) (Arrow 1962; Gort and Konakayama 1982; Levy 1965). In addition, larger firms have cost advantages in marketing, distribution, and production, compared to smaller firms (Bayus and Agarwal 2007; Chandler 1990; Jovanovic and Mac Donald 1994; Sutton 1991).

## 4.4 When to Enter: Drivers of Complementor Entry Timing

Next, we theorize on the variables that may explain when a complementor starts to supply complements for a specific system (when to enter), for those complementors that did decide to enter. We first detail our expectations on system owner pre-entry experience, after which we turn to complementor pre-entry experience. Then, we turn to the time-varying covariates such as the evolution in the hardware installed base and complementor support for the respective system. We end with other covariates we will control for in our statistical tests.

### 4.4.1 System Owner

#### 4.4.1.1 Pre-entry Incumbency

There are several reasons why complementors will enter systems of incumbents faster than systems of newcomers. First, the system owner has already proven once, that it has the resources and knowledge to introduce a system, reducing the complementor's uncertainty, and consequently, its wait-and-see attitude. Second, incumbent system owners can offer complementors a migration path to its next system (Shapiro and Varian 1998), and mitigate switching, porting and upgrading costs. Similarly, the backward compatibility of the new system with the old system will have additional benefits for complementors allowing them to enter faster (Shapiro and Varian 1998; Srinivasan, Lilien and Rangaswamy 2004). Therefore, *H5: Incumbency of the system owner will have a positive effect on the complementor's time of entry.*

#### 4.4.1.2 Entry Timing

Above, we argued that systems that are introduced later have a lower likelihood of complementor entry. In contrast, complementors that do enter will typically enter faster in case the system is introduced later as compared to when it is introduced earlier. The reason is that the time to recoup their investment in the system is shorter, due to the closer proximity of the introduction of the next technology generation, as compared to a system that was introduced earlier. This shorter time to recoup the investment of entry in the system will trigger a faster pace in entering the system and introducing complementary software products for it. In addition, as time passes and firms enter, more and more information is revealed, about hardware specification, product positioning, system owner strategies, etc. This reduces the level of uncertainty, thus enhancing the speed at which a complementor can make an entry decision. Therefore,

*H6: The later the introduction of the system during a technology generation, the faster the complementor enters.*

### 4.4.2 Complementor

#### 4.4.2.1 Pre-entry Relationship with System Owner

The existence of a relationship between complementor and system owner will allow for faster communication and exchange of information and resources required for software development, which will reduce the time of entry. In addition, obligations from long-term contracts between complementor and system owner could force complementors to enter more quickly due to certain deadlines (i.e., system's introduction). Finally, the lower costs (Greenstein 1993) associated with the known system owner's new system will make entry profitable earlier on. Therefore, *H7: Complementors that have a pre-entry relationship with the system owner will enter more quickly than complementors that do not.*

#### 4.4.2.2 Pre-entry Diversification

The more systems the complementor supplies for, the more knowledge the firm has gained regarding the entry process itself (i.e., making cost-benefits analyses). This increased experience with the entry process itself will likely reduce the time required to assess future entry opportunities. The fact that the firm is still supporting prior systems indicates that the firm is also very capable of making a correct entry decision (i.e., make correct assumptions about future profitability). This will likely reduce the complementor's uncertainty about making the wrong entry decision in the future. In addition, with every entry the complementor acquires a larger body of knowledge. The larger this body of knowledge, the faster the firm will respond to market changes (i.e., needs to acquire fewer resources before it can enter) (Kim and Kogut 1996). Therefore,

*H8: The more diversified the complementor is pre-entry, the faster the complementor enters a new system.*

### 4.4.3 Time-Varying Covariates

Based on network effects literature (Chou and Shy 1996; Church and Gandal 1992a and 1993; Clements 2004; Shy 2001; Stremersch et al. 2007), one can expect complementors to monitor two key indicators that vary over time in their decision when to enter a certain system, namely hardware installed base and support by other complementors.

#### 4.4.3.1 Hardware Installed Base

As is commonly known in the network effects literature, a larger hardware installed base increases the potential sales of the complementor's software products upon entry. In addition, a larger hardware installed base will decrease the uncertainty a complementor has about the potential success of the system, and thus smoothen coordination between system owner and complementor. Thus, the larger the hardware installed base, the faster the complementor will enter.

More interestingly, we expect this effect to be moderated by the *system's age*, the *pre-entry relationship between complementor and system owner* and the *technology generation*. When the hardware is young, complementors have a long period to recoup the investments made, and are therefore expected to be more forward looking (i.e., look at the future hardware installed base). However, when the hardware is older, the time to recoup the investments made is much shorter, as the next technology generation is closer to being introduced, making complementors look more to the present hardware installed base. Scholars before us have observed that positive feedback only ignites in later stages of the life cycle and may be non-existent, or at least smaller, in the initial stages of the life cycle (Clements and Ohashi 2005; Park 2004; Ohashi 2003; Stremersch et al. 2007; Varian, Farrell and Shapiro 2004). Numerous pre-launch strategies (i.e., alliances, distribution, side payments and licensing agreements) of system owners are likely to reduce the initial effect of the hardware installed base. Therefore,

*H9: The effect of the hardware installed base on the complementor's time of entry becomes larger as the system ages.*

In contrast, the effect of the hardware installed base on entry timing is lower if the complementor has a pre-entry relationship with the system owner. The reason is that better coordination exists between system owner and complementor, thus reducing the coordination problem. Therefore, when such pre-entry relationship exists, hardware installed base becomes a less important criterion in complementor entry. Therefore,

*H10: The effect of the hardware installed base on the complementor's time of entry decreases if there is a pre-entry relationship between the complementor and the system owner.*

Economists often assume coordination between all market participants improves (Farrell 1987) – whether it concerns complementors that supplied software products to the prior generation system or not –, as with each new generation the opportunities to communicate and coordinate with one another increase, due to more and better developed trade shows, trade organizations and standard setting bodies. Each successive evolutionary technology generation reduces the coordination problem, as it reuses and enhances the existing coordination system (Stieglitz and Heine 2007). In addition, there will be a general improvement of communication and information channels (Shapiro and Varian 1998). System manufacturers continue to improve their skills in dealing with complementors in general, and such skill development is beneficial also to complementors they have never worked with before, alleviating the chicken-and-egg problem. Therefore,

*H11: The effect of the hardware installed base on the complementor's time of entry becomes smaller across technology generations.*

#### 4.4.3.2 Support by Other Complementors

Entry by other complementors may signal that the system is attractive, in line with Schumpeter’s imitation hypothesis (Gort and Konakayama 1982; Kim, Bridges and Srivastava 1999). The contagion between firms will affect a firm’s decision to enter (Debruyne and Reibstein 2005), setting the herd behavior in motion (Choi 1997). In addition, an increase in the number of firms can also spur growth in demand and market potential due to aggressive product development and promotion, and skills and product quality improvements (Agarwal and Bayus 2002; Gort and Klepper 1982; Horsky and Simon 1983; Kim, Bridges and Srivastava 1999; Parker and Gatignon 1994). Therefore,

*H12: Increased support by other complementors will lead to faster complementor entry.*

#### 4.4.3.3 Other Covariates

We control for the system’s age and technology generation when testing the above hypotheses. System age and technology generation have been shown to affect diffusion of new products (for an overview, see Stremersch, Muller and Peres 2010). Likewise, they may affect entry timing of complementors. We also control for a complementor’s pre-entry size (i.e., pre-entry accumulated economies of scale) and pre-entry age (i.e., pre-entry accumulated learning by doing). We expect larger and older complementors to show a faster entry, due to more resources and increased efficiency, because of economies of scale and learning by doing, which gives them a competitive advantage over smaller and younger complementors (e.g. Arrow 1962; Bayus and Agarwal 2007; Chandler 1990; Gort and Konakayama 1982; Jovanovic and Mac Donald 1994; Sutton 1991; Lévy 1965).

## 4.5 Data

This section first discusses the video game market, data collection, and sample. It ends with providing the measures for our variables.

### 4.5.1 The Video Game Market

The video game industry has become a large industry, dominated by mainstream content (Williams 2002). In 2007, sales of the game market exceeded \$18.8 billion in the U.S., almost double the \$9.6 billion North-American box-office ticket sales, and sales grew to over \$21 billion in 2008 (Forbes 2008; McGlaun 2008). The business of publishing video games is highly similar to that of other complementary products like CD’s, DVD’s, (e)books, LP's, videocassettes and television shows (e.g. Greco 2000; Komiya and Litman 1990; Liebowitz and Margolis 1999; Williams 2002). May of 1972 saw the introduction of the first home video game console (Magnavox Odyssey), it used transistors, because microprocessors were still very expensive (Herman 2001).

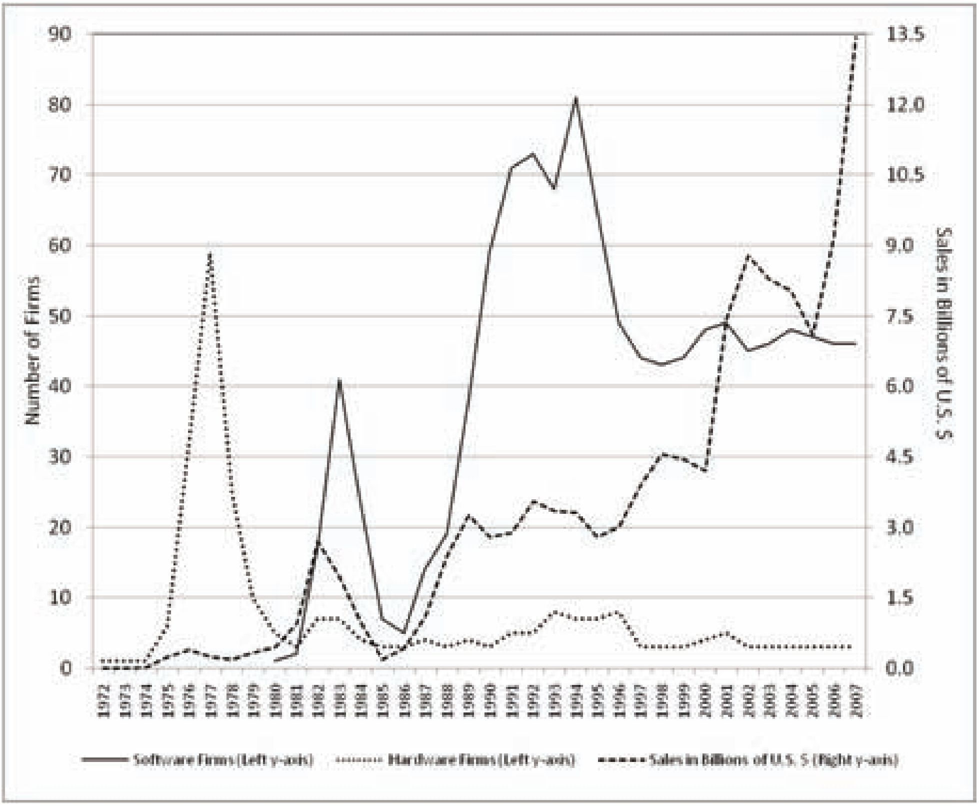
However less than 4 years later, in early 1976, semiconductor firm General Instruments introduced its new microchip that cost \$5 dollars, and with pong consoles selling for \$60 to \$80 dollars, there was profit to be made, so many hardware firms entered the market (Cohen 1984; Herman 2001). After Christmas 1976, the video game market crashed. The public was losing interest, Magnavox and Atari sold inventory at reduced rates. RCA pulled out entirely. Coleco nearly went bankrupt (Cohen 1984; Kent 2001; Schmedel 1978). First generation home video game sales imploded, from \$400 million in 1976, to \$15 million in 1979. First generation Pong video games had become a joke, with the introduction of the first second-generation system (e.g. Fairchild Channel F) (Cohen

1984; Kent 2001). However, it was only after the introduction of the superstar video game 'Space Invaders' that sales of Atari's second generation console really took off in 1979.

Activision became the first independent software publisher in 1980, and it soon replaced Atari as the fastest growing firm (i.e., achieve sales of over $1 billion) in American history. In 1981, 8.5% of U.S. households had bought a console, and this was predicted to grow to 50% by 1985 (Landro 1982). This prediction could not have been more wrong. The second generation began its decline after the 1982 December holidays (Kent 2001). Third generation sales did not pick up fast enough, and total industry sales imploded, again. Nintendo introduced its new third generation system in 1985, and received numerous prophecies of doom, as industry analysts predicted that Nintendo would fail with each coming year (Herman 2001; Kent 2001; Sheff 1999). Even after 15 years, 3 technology generations, 2 cyclical sales patterns with the industry going 'bust', software firms had little certainty if the industry would even exist the following year. Let alone know which system would fail, and which system would succeed.

Figure 4.2 depicts the yearly number of hardware firms, complementors, and overall sales of home video game hardware, software and accessories combined. Prior studies observe that the number of --hardware-- firms initially grows, and then reaches a peak, after which it declines steadily (i.e., a shakeout occurs and the industry becomes an oligopoly); despite continued growth in industry output (e.g. Gort and Klepper 1982; Klepper 1996 and 2002; Klepper and Grady 1990; Utterback and Suarez 1993). The evolution of the hardware side of our industry of interest is in line with this prior research.

Figure 4.2: Number of Firms and Sales from 1972 to 2007



### 4.5.2 Data Collection

We sourced hardware unit sales data largely from NPD, in line with prior research that used the same data source (e.g. Binken and Stremersch 2009; Clements and Ohashi 2005; Shankar and Bayus 2003; Venkatraman and Lee 2004). We then collected all other data, ourselves from public sources, using the historical method (Golder 2000), such as: (1) general publications like, *Business Week*, *New York Times, Time Magazine,* and the *Wall Street Journal*, (2) trade publications, both online and offline, like *Activision Funclub, allgame.com, AtariAge, Electronic Gaming Monthly, gamefaqs.com, gameranking.com, gamespot.com,* and *ign.com*, and (3) video game books like Cohen (1984), Herman (2001), Kent (2001), Santulli (2002 and 2004), Sheff (1999), and Slaven (2002).

### 4.5.3 Sample

Our data covers the period May 1972 to April 2008. The first generation did not have any independent software firms (i.e., complementors), so we will focus our empirical examination on generations 2 to 7 (September 1976 to April 2008). During this period, hardware sponsors introduced 35 incompatible systems, across 6 successive incremental technology generations. We gathered data on all entry opportunities (2895 in total) of 247 complementors. In 775 cases, the software firm of interest decided to enter, while in all other 2,120 cases the complementor decided not to enter. Complementors can enter from the moment the systems is introduced at $t=1$, until the time series reaches $t=102$ – we never observed entry after 102 months – or until the time the relevant system was abandoned – an event widely reported in the media. We never observed entry after abandonment. Table 4.1 describes the market we study on the dimensions relevant to this chapter.

### 4.5.4 Measures

*Firm entry* is our dependent variable. Entry occurs in the month during which the software firm of interest to entry decision *i*, introduces its first product (i.e., video game) for the relevant system. The introduction of its first product is the first credible signal that entry has occurred, and identifies the exact month of entry. Prior research almost exclusively uses the self-reported yearly entry from the *Thomas Register of American*

*Manufacturers* (e.g. Agarwal and Audretsch 2001; Agarwal and Gort 1996; Gort and Konakayama 1982; Klepper and Graddy 1990; Klepper and Miller 1995; Klepper and Simons 2000). We use a newly gathered dataset with data at monthly periodicity, which does not suffer from self-report bias.

*Incumbency of the system owner* is equal to 1 if the relevant system owner has introduced a system during the previous technology generation, and equal to 0 if not. The *system owner's entry timing* (later-mover (dis-)advantage) during the technology generation is equal to the number of months the system relevant to entry decision *i* is introduced after the start of the relevant technology generation.

For the *complementor's pre-entry relationship with the system owner,* we use a time invariant dummy variable to measure if the complementor introduced software products for the system owner's prior system (=1) or not (=0). *Complementor's pre-entry diversification* is equal to the number of systems (this generation and past generation) for which the software firm relevant to entry decision *i* is still introducing software products at $t=1$.

The *system's hardware installed base* is equal to the cumulative hardware unit sales in millions of the system relevant to entry decision *i*, for the month of interest *t*. The *system's age* is equal to the age measured in months of the relevant system for the month of interest *t*. *System's technology generation.* Following Bass and Bass (2001 and 2004), we group systems into successive generations with other systems if they are similar in customer-perceived functionality characteristics. The system relevant to entry decision *i* belongs to a specific technology generation. For generation 2 this variable is equal to 0, and increases with one for each next generation, up to generation 7, which is equal to 5.

The *complementor's pre-entry age (i.e., pre-entry accumulated learning by doing)* is equal to the number of months the complementor has been in the game business at $t=1$. Firm age is often used to measure the firm's learning by doing (e.g. Agarwal and Gort 1996; Klepper and Simons 2000; Geroski 1995; Gort and Konakayama 1982). The *complementor's pre-entry size (i.e., pre-entry accumulated economies of scale)* is equal to the number of software products is has introduced in the past 12 months at $t=1$. This measurement should give a good estimate regarding the size of the firm's relevant resources to develop, publish, and market software products, and its ability to leverage economies of scale. The *system's support by other complementors* is equal to the number of software firms that have entered the system relevant to entry decision *i*, and are still supporting it with product introductions at *t*.

## 4.6 Model

We use a split-population duration model (Schmidt and Witte 1989; Sinha and Chandrashekaran 1992), as this allows for the possibility that entry may never occur. We segment the population of entry opportunities into two subpopulations, one that will experience entry, and one that will never experience entry. Models that fail to recognize that not all firms will ultimately enter, will overestimate the probability of entry (as their long run entry rate is equal to one), and produce biased estimates of the effects of the covariates (Hettinger and Zorn 2001; Schmidt and Witte 1989). In marketing this model is often applied, to a very similar topic, knowingly to adoption, and non-adoption, of new products/innovations (e.g. Kamakura, Kossar and Wedel 2004; Prins and Verhoef 2007; Sinha and Chandrashekaran 1992; Srinivasan, Lilien and Rangaswamy 2006). The split-population duration model uses a logit function for the probability of entry, and a hazard function for the time of entry (for those entry opportunities that result in entry). The model simultaneously estimates both functions.

We use a complementary log-logistic parametric form for our hazard function, because it allows for a non-monotonic hazard rate as suggested by prior literature (e.g. Mahajan, Muller and Bass 1990; Rogers 1995; Schmidt and Witte 1989; Sinha and Chandrashekaran 1992). It is also frequently used in the relevant literature (e.g. Agarwal and Bayus 2002; Bayus and Agarwal 2007; Prins and Verhoef 2007; Schmidt and Witte 1989). The time of entry is a random variable with a cumulative distribution function $F(t)$, and density $f(t)=F'(t)$. The probability that entry has not yet occurred at time $t$ is provided by the survivor function $S(t)=1-F(t)$. The hazard rate $h(t)= f(t)/S(t)$ can be defined as the conditional likelihood that entry will occur at time $t$, given entry has not yet occurred. We estimate the hazard part of our model including covariates $X_i$ as follows:

$$h_{it} = 1 - \exp [ - \exp (\mathrm{X}_i) ] \tag{1}$$

We estimate the probability of entry ($p_i$) for every entry decision $i$. We use a logit function of covariates to model the probability of entry. The probability part of our model including covariates $X_i$ is as follows:

$$p_i = 1 / [\ 1 + \exp(X_i)\ ] \tag{2}$$

Thereby making the log-likelihood function of our total model including equation (1) and (2) as follows:

$$LL = \sum_{i=1}^{N} c_i\,.\,ln[p_i.\,h_{it}.\,S_{it-1}] + (1 - c_i).\,ln[(1 - p_i) + p_i.\,S_{it}] \tag{3}$$

In equation 3, $h_{it}$ is the hazard rate from equation 1, and $p_i$ is the probability of eventual entry from equation 2. The survival rate is denoted by $S_{it}$. $c_i$ is an indicator that denotes whether entry occurred in the interval $(1,T)$. For observed entry ($c_i = 1$), the contribution to the likelihood function by entry decision $i$ at time $t$ is the probability of eventual entry, as given by $p_i$, multiplied by both the conditional probability of entry at $t$, as given by the hazard rate $h_{it}$, and by the probability that entry has not occurred before $t$, as given by survival rate $S_{it-1}$. Censored observations ($c_i = 0$), belong to either the entry decisions that resulted in non-entry, with probability $(1 - p_i)$, or those entry decisions that will eventually result in entry but have yet to do so at $T$, denoted by $p_i.S_{it}$.

## 4.7 Results

Table 2 presents the estimations of our model. A positive coefficient of a covariate in the logit part indicates that the covariate has a positive effect on the likelihood of eventual entry. A positive coefficient of a covariate in the hazard part of our model indicates that the covariate increases the hazard rate, and thus reduces the complementor's time of entry. Figure 1 depicts which hypotheses are supported (indicated by (S)) and which are not supported (indicated by (NS)), followed by the coefficient and significance.

## Table 4.2: Estimations of our Model

| | ***Model*** | |
|---|---|---|
| | Logit Part: Probability of Entry (+: high; -: low) | Hazard Rate*:* *Speed of Entry* *(+: fast; -: slow)* |
| **System Owner Pre-entry Experience** | | |
| Pre-entry Incumbency $_{i}$ | *-1.231*** | *0.483*** |
| | *(0.375)* | *(0.129)* |
| Entry timing $_{i}$ | -0.101** | 0.018** |
| | (0.019) | (0.004) |
| **Complementor Pre-entry Experience** | | |
| Pre-entry Relationship with System Owner $_{i}$ | 1.955** | 0.658** |
| | (0.489) | (0.151) |
| Pre-entry Diversification $_{i}$ | -0.331 | 0.510** |
| | (0.254) | (0.064) |
| **Time-varying covariates** | | |
| System's Hardware Installed Base $_{t-1i}$ | | 0.050 |
| | | (0.030) |
| System's Hardware Installed Base $_{t-1i}$ x System's Age $_{t}$ | | 0.001* |
| | | (0.000) |
| System's Hardware Installed Base $_{t-1i}$ x System's Technology Generation $_{i}$ | | -0.017** |
| | | (0.004) |
| System's Hardware Installed Base $_{t-1i}$ x Pre-entry Relationship with System Owner $_{i}$ | | -0.053* |
| | | (0.022) |
| System's Support by Other Complementors $_{t-1i}$ | | 0.036** |
| | | (0.005) |
| **Control variables** | | |
| System's Age $_{t-1i}$ | | -0.005 |
| | | (0.005) |
| System's Technology Generation $_{i}$ | 0.416** | 0.045 |
| | (0.140) | (0.050) |
| Complementor's Pre-entry Age $_{i}$ | -0.006** | 0.005** |
| | (0.002) | (0.001) |
| Complementor's Pre-entry Size $_{i}$ | 0.079* | 0.011 |
| | (0.038) | (0.006) |
| Constant | 3.706** | -6.501** |
| | (0.769) | (0.233) |
| *N* | 92,826 | |
| Log-likelihood | -3921.27 | |
| Likelihood ratio test | $\chi^2$ (21) = 1099.58 | |

Standard errors are in parentheses.
Two-sided significance tests: **: $p < 0.01$; *: $p < 0.05$

### 4.7.1 Drivers of Complementor Entry Probability

We find that both covariates relating to the pre-entry experience of the system owner have a negative effect on the complementor's probability of entry. Surprisingly, incumbent system owners face a lower likelihood of entry by complementors (-1.231, P <.01), compared to newly entering system owners. Complementors do react very different to whether the system in introduced by an incumbent system owner, or by a newly entering system owner, but not as we expected. We were expecting incumbents to have a higher probability of entry by complementors. Therefore, we do not find support for H1. This lower probability is likely due to incumbent system owners having a higher level of vertical integration (i.e., larger internal development studios, more successful software franchises, and a larger back catalog of software products from the prior generation), compared to newly entering system owners. Therefore, complementors will face a higher level of competition in a system of an incumbent system owner. In addition, because incumbent system owner are less dependent on independent complementors to supply complementary products (and because their own software products generate a larger part of their profits), incumbents will allocate fewer resources to persuade complementors to enter. Whereas, system owners that are new to the market, will be more inclined to use side payments to persuade complementors to enter, in order to gain a foothold in the new market.

We do find the expected negative effect, of a later introduction of the system during the technology generation by the system owner, on the probability of complementor entry (-0.101, P < .01). Thus, there is an early mover advantage for system owners. Therefore, we find support for H2.

As hypothesized in H3, we find that the complementor's pre-entry relationship with the system owner has a positive effect on the probability of entry (1.955, P < .01). The effect of the complementor's pre-entry diversification on the probability of entry is not significant (-0.331, S.E. 0.254). Therefore, we do not find support for H4. Whether or not to enter is independent of the knowledge and resources acquired from prior entries into systems of *competing* system owners. More diversified complementors may have acquired more knowledge and resources, compared to less diversified complementors, but leveraging these assets across systems of *different* system owners does not look effective.

### 4.7.2 Drivers of Complementor Entry Timing

If the system is introduced by an incumbent system owner it will increase the complementor's hazard rate of entry (0.483, P <.01). Incumbent system owners are faster at persuading complementors that will ultimately enter, to enter. We thus find support for H5. The system's later introduction during a technology generation has the expected positive effect on the time of entry (0.018, P < .01), and thus reduces the complementor's time to entry. Therefore, we find support for H6.

As hypothesized in H7, the complementor's pre-entry relationship with the system owner, has a positive effect on the time of entry (0.658, P < .01). Thus, we find support for H7. Also, the pre-entry diversification (i.e., entries into systems of competitors) by the complementor has a positive effect on the complementor's time of entry (0.510, P < .01). Therefore, we find support for H8.

We do not find a negative effect, on either the likelihood or timing of complementor entry, of entries into systems of competing system owners (i.e., pre-entry diversification). Therefore, we find no evidence of harmful lock-in, due to for example exclusivity agreements, thereby providing empirical support to prior observations (e.g. Liebowitz and Margolis 1999). In addition, entry by complementors does not decrease across technology generations, as the likelihood of entry increases from 9% in generation 2 to 55% in generation 6. Hardware sponsors do not seem to be able to limit the entry behavior of complementors into newly emerging systems of competitors.

As hypothesized in H9, H10 and H11, we find strong heterogeneity in supply-side indirect network effects (i.e., the effect of the hardware installed base on the complementor's timing of entry). This effect increases across the system's life cycle (0.001, P < .05), while it decreases across technology generations (-0.017, P < .01), and with the existence of a pre-entry relationship between the complementor and the system owner (-0.053, P < .05). Thus, we find support for H9, H10 and H11. In addition, we find the expected positive effect of support for the system by other complementors at the complementor's time of entry (0.036, P < .01). Therefore, we also find support for H12.

### 4.7.3 Other Covariates

Finally, we find the effect of the system's age (i.e., time) does not significantly affect the hazard rate of entry (-0.005, S.E. 0.005). We find the expected positive relationship between the technology generation and the probability of entry (0.416, $P < .01$). However, the system's technology generation does not have a significant effect on the complementor's time of entry (0.045, S.E. 0.050). Although the average time of entry sharply decreases across technology generations (See Table 4.1), the system's technology generation did not contribute to the acceleration with which systems diffuse faster among complementors.

The complementor's pre-entry age (i.e., pre-entry accumulated learning by doing) has a negative effect (-0.006, $P < .01$) on the probability of entry. We were expecting a positive effect. Complementors become less likely to enter to more they learn. This is likely because, as complementors become better at making entry decisions, they make fewer wrong entry decisions, which will reduce their overall likelihood of entry. However, the complementor's learning by doing does have the expected positive effect (0.005, $P < .01$) on the time of entry.

The complementor's pre-entry size (i.e., pre-entry accumulated economies of scale) has the expected positive effect (0.079, $P < .05$) on the probability of entry, while it has no significant effect (0.011, S.E. 0.006) on the time of entry. While larger complementors are more likely to enter, they are not faster at entering compared to smaller complementors. The increased bureaucracy, associate with size increases, prevents them from becoming faster entrants.

### 4.7.4 Robustness and Further Analyses

We examined possible right censoring data issues. We now cutoff our time series after $t=102$. Using slightly more strict or relaxed cutoffs does not alter the findings presented in this chapter. In addition, estimating our model without the shorter time series from the last introduced systems (i.e., 7th generation systems) also confirm our findings. We could also include the data after abandonment (i.e., orphaning) of the system, and include a time varying *abandonment* dummy variable to the hazard part of our model. The abandonment variable is strongly negative and significant (-4.830, S.E. 0.733) (*N*=167439). The parameters of the other covariates remain similar. Sample selection variations should not be an issue, as we use all introduced systems. Finally, the size of our dataset compares very favorable to prior studies.

One could argue that not all incumbent system owners are similar. Incumbents can be either successful or unsuccessful during the prior technology generation.[21] Subsequently, their effect may well differ. However, we observe a similar effect of both on the entry decision. Both successful (0.494, S.E. 0.135) and unsuccessful incumbents (0.795, S.E. 0.192) have a significant positive effect on the time of entry. Similarly both successful (-1.296, S.E. 0.412) and unsuccessful incumbents (-3.763, S.E. 0.836) have a significant negative effect on the probability of entry. Just being present during the previous technology generation, whether successful or unsuccessful, is enough to reduce overall complementor entry, and facilitate faster entry, in the next technology generation.

Similarly, one could argue that not all pre-entry entries by complementors are similar, and have a positive effect. Prior entry into systems of direct competitors (i.e., same generation systems) may have a negative effect on the entry decision (instead of our expected positive effects), as it directly consumes, or at least temporally locks in, resources, which subsequently cannot be used for future entry. However, pre-entry entry into same generation systems (0.519, S.E. 0.073) and pre-entry entry into prior generations systems (0.685, S.E. 0.077) both have a significant positive effect on the time of entry. While both have no significant effect on the likelihood of entry.

In addition, we used multiple procedures to assess multicollinearity (e.g. Belsley 1991; Belsley, Kuh and Welsh 1980; Marquardt 1970). All these procedures indicate that the weak to moderate dependencies between the covariates do not create harmful multicollinearity. First, the value of the condition index is below 10, and variance inflation factors (VIF) are all below 3 (average = 1.6, maximum = 2.2). Second, we dropped covariates that showed a moderate correlation with other covariates one by one. The

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[21] Successful system owners achieved an economically viable hardware installed base during the previous technology generation. While unsuccessful incumbent owners did not achieve an economically viable hardware installed base, and subsequently their system is prematurely orphaned. The most successful unsuccessful system sold only 1.5 million hardware units, while the most unsuccessful successful system sold 11 million hardware unites. Thus, the two groups are easily distinguishable from one another.

parameter estimates we obtained are similar to a model that included the dropped covariates, parameter estimates do not change sign, and do not fluctuate dramatically. In all, multicollinearity is not a threat to the validity of our findings.

We also examined the effect of stepwise addition of covariates to our model. The estimated parameters are consistent in term of their signs in the stepwise models, indicating that there does not seem to be an issue regarding model misspecification. Overall, we can conclude that our results are highly robust.

## 4.8 Discussion, Implications and Limitations

In this section, we will first discus our findings and their implications, followed by the chapter's limitations and suggestions for future research.

### 4.8.1 Discussion and Implications

While we find that every pre-entry experience by the complementor itself, the system owner or other complementors makes the complementor a faster entrant, the effect of these pre-entry experiences on the complementor's probability of entry is very mixed. In addition, we find that the effect of supply-side indirect network effects (i.e., hardware installed base) on the complementor's time of entry exhibits strong heterogeneity. With each new pre-entry relationship and technology generation reducing the coordination problem, alleviating the chicken-and-egg problem new systems face.

If a system owner was present during the previous technology generation with a system, this pre-entry experience will reduce the likelihood of complementors entering its next generation system. Prior research (e.g. Christensen and Rosenbloom 1995; Christensen, Suarez, and Utterback 1998; Klepper and Simons 2000; Tushman and Anderson 1986; Stieglitz and Heine 2007) has only shown that the pre-entry experience can have a negative effect during the next technology generation in industries with disruptive technology generations (i.e., radical innovation). We can now extend this negative effect to industries with evolutionary technology generations (i.e., incremental innovation). Thus, the pre-entry experience of incumbent system owners gives newly entering system owners a larger chance to succeed, even in industries with incremental innovation.

The complementor's own pre-entry experience with systems of *other* system owners (i.e., its pre-entry diversification) does not have an effect on its probability of entry. Leveraging this pre-entry experience across systems of *different* system owners is not effective. Even in this industry with homogenous products and incremental innovation, the acquired knowledge and resources from this pre-entry experience are very relation specific (i.e., locked-in to the relationship with the original system owner).

The complementor's pre-entry experience (i.e., relationship) with the system owner does have a positive effect on the probability of entry. It also has a positive effect on the timing of entry, and decreases the effect of supply-side indirect network effect the timing of entry on. Therefore, this relationship it crucial to both complementors and system owners, and will to a large part determine the evolution of an industry over technology generations. These pre-entry relationships are likely a major contributor to the eventual oligopoly market structure we observe.

Pre-entry relationships will help marketing managers of system owners identify the most likely early entrants, even before the system owners has introduced it next generation system. This will help decrease the chicken-and-egg problem new systems face. In addition, identifying the most probable early entrants early on, will assure a faster return on investments, better allocation of resources under resource constraints, better utilization of innovators to influence imitators (i.e., later entering complementors), and generally increase efficiency throughout the organization (Kamakura, Kossar and Wedel 2004). Newly entering system owners will face a barrier to entry that may increase with each new technology generation, due to the increase in pre-entry relationships. However, it are late entering incumbent system owners who do not have these pre-entry relationships with complementors who are worst off, as they will have the hardest time convincing complementors to enter.

The effect of pre-entry experiences on the complementor's timing of entry is straightforward positive. Subsequently, marketing managers of system owners can easily differentiate between early entrants and late entrants, among complementors. Market analysts can expect complementor's timing of entry to accelerate over technology generations. These findings give marketing managers of both complementors and system owners, as well as market analysts the ability to early on detect if a system is going to succeed or fail (i.e., has or hasn't adequate timely support from complementors). Being able to quicker identity when systems are failing will create a substantive strategic advantage, as pulling the plug on a new product is an important decision, with tremendous implications (Foster, Golder and Tellis 2004).

We find strong heterogeneity in the effect of supply-side indirect network effects on the complementor's timing of entry. As the market evolves this effect diminishes, over technology generations and with each new pre-entry relationship between complementor and system owner. However, his effect increases during the system's life cycle. Combine our findings with prior research (e.g. Binken and Stremersch 2009; Clements and Ohashi 2005; Park 2004; Ohashi 2003; Stremersch et al. 2007) that find strong heterogeneity in --demand-side-- indirect network effects, and it is clear that the positive feedback cycle of indirect network effects is very dynamic, and may be very small under certain conditions, giving new systems an opportunity to flourish (i.e., give incumbents only a small indirect network effects advantage). Marketing managers and academics may well want to control for these sources of heterogeneity in the future. In addition, marketing managers of hardware owners should adopt a flexible marketing strategy (i.e., know when, and when not, their hardware installed base will have a --large-- effect on the complementor's entry decision).

Markets with network effects are often characterized as winner-takes-all markets (e.g. Arthur 1996; Liebowitz and Margolis 1999; Srinivasan, Lilien and Rangaswamy 2004; Schilling 2002). However, we observe that winner-takes-all outcomes disappear as the market matures. The number of winners (i.e., successful systems) in a single technology generation increases across technology generations (See Table 1). The decrease in the positive feedback of supply-side indirect network effects, across technology generations and with each additional pre-entry relationship between complementor and system owner, —partially—explains why the number of winners increases. The smaller positive feedback effect may very well allow for the more even distribution of entry by complementors and adoption by consumers, among competing systems.

As the technology generation progresses, it will become increasingly difficult to replace the leading system (i.e., market leader). Because later entry during a technology generation by a system owner negatively affects the complementor's likelihood of entry, and because the effect of the supply-side indirect network effect on the complementor's timing of entry, becomes stronger as the system ages. However, market leaders are in great danger to lose their hold on the industry with the introduction of a new technology generation. This is at least partially because of the negative effect of their pre-entry incumbency experience on the complementor's probability of entry. In our market of interest, in all but one new technology generation, was the previous market leader replaced. This is in line with prior non-system market research that states that the transition from the old generation to the new generation is rife with opportunities, and that new entrants exploit these technological discontinuities to displace existing incumbents (e.g. Bass and Bass 2001; Foster 1986; Lieberman and Montgomery 1988; Schumpeter 1961; Utterback 1994).

System markets do not seem to be more disposed to inefficiencies, compared to their non-system counterparts. We did not find support for strong inefficient path-dependencies, as first-movers never won a systems war, and the market leader of the prior technology generation was usually replaced in the next technology generation. In addition, we did not find evidence of harmful lock-in, because system owner do not seem to be able to prevent the entry of complementors into newly emerging systems of competitors.

### 4.8.2 Limitations and Future Research

The present chapter is the first to examine entry behavior of complementors. Thus, this chapter is an important contribution to the literature that may provoke further research. At the same time, it also has some limitations that such future research may address.

First, we only examine the entry behavior of complementors in the U.S. home video game market. Future research may want to examine if our findings hold for other geographical areas, or if our findings hold for other system markets. However, by our knowledge, data that is as detailed as the data on the video game industry we obtained is unavailable.

Second, we have no information about costs or switching costs. In addition, we have no information about side payments between software and hardware firms. Including these covariates in future models, would make an extremely interesting extension.

Third, we examine a system market with incremental innovation. It would be interesting to see if our findings also apply to markets with disruptive innovation.

Fourth, we ignore whether a software product was developed internally or externally. Future research may want to look if complementors that --partially-- outsource the development of software products are more agile (i.e., enter more systems faster).

Finally, future studies could make model extensions and refinements by incorporating other marketing mix variables, like advertising and prices. Future research may also incorporate endogenous covariates instead of our exogenous covariates.

# Chapter 5

# Summary and Conclusion

## 5.1 Introduction

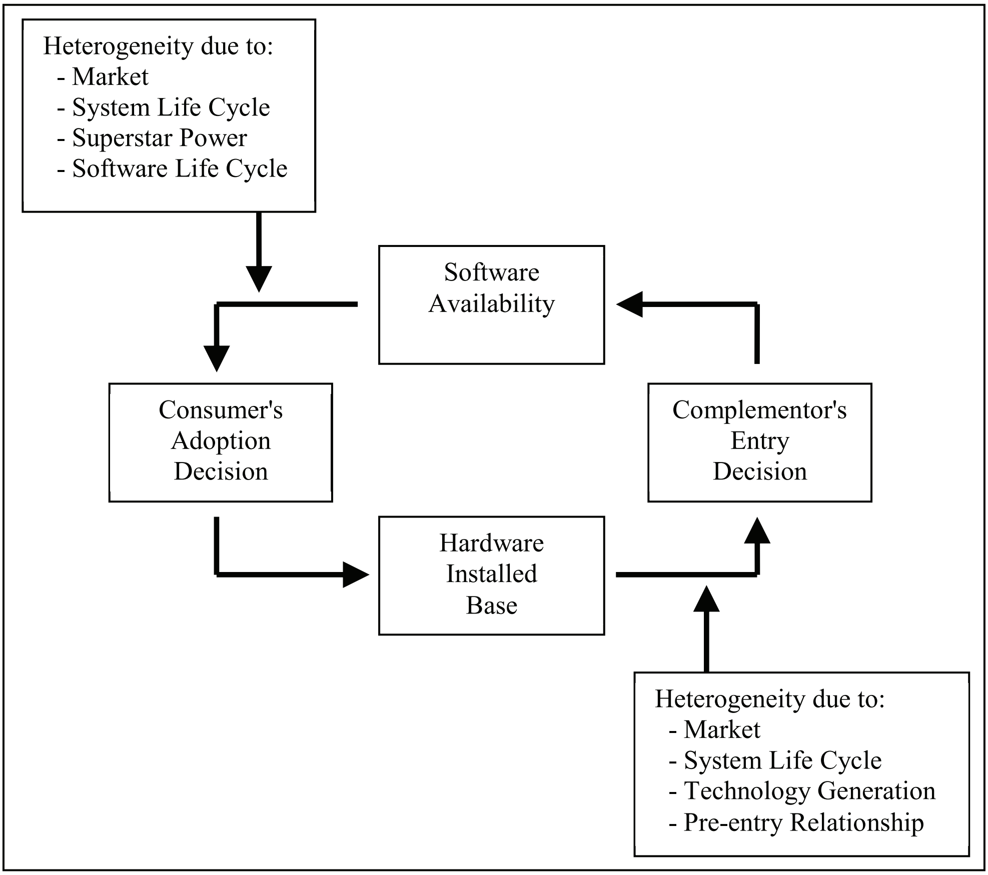
This last chapter presents the main findings and implications, relating to indirect network effects of our empirical studies. I conclude by providing directions for future research. Each of the three previous chapters also provides their own specific findings, implications and directions for future research, at the end of each chapter.

## 5.2 Summary of Findings and Implications

The positive feedback cycle of indirect network effects is less pervasive, or at least more complex, than "current wisdom" would have us believe. Supply-side and/or demand-side indirect network effects, as traditionally operationalized, are often not present. When present, they display strong heterogeneity. There is often no positive feedback cycle present in the initial stage of the system's life cycle.

The positive feedback cycle is not automatically present in system markets waiting to be harvested. Marketing manager of firms operating in system markets must start this cycle, and subsequently manage it. Our empirical studies already identify numerous factors marketing manager can manipulate to influence the positive feedback cycle (See Figure 5.1). Hardware sponsors must constantly create large events on both the demand-side and the supply-side to keep the positive feedback cycle present and running.

Figure 5.1: The Positive Feedback Cycle of Indirect Network Effects



Marketing managers should first identify which factors could influence the positive feedback cycle of indirect network effects. Subsequently, they must identify how to manipulate those factors to positively affect their own feedback cycle, while trying to disrupt the feedback cycle of competitors. Second, they must understand the temporal pattern in demand-side and supply-side indirect network effects, across the life cycle of systems and software, and across successive technology generations. Subsequently marketing managers must incorporate our findings in their marketing strategy, in order to outmaneuver competitors (i.e., competing systems, fellow complementors). Only then can marketing managers start to reap the benefits of indirect network effects and positive feedback, and alleviate the chicken-and-egg problem.

Some scholars (Arthur 1989; David 1985) have us believe that insignificant events (e.g., small economic shifts, chance, luck, managerial whim) during the initial stage of the system's life cycle determine which system wins a systems war. As these insignificant events are amplified due to the presence of positive feedback and tip the market towards a particular system. Even inferior systems may become locked-in and conquer the entire market (i.e., winner-takes-all), as systems cannot coexist indefinitely. However, our findings from our empirical studies indicate otherwise. The absence of –strong—indirect network effects in the initial stage of the system life cycle makes tipping of the market during this stage due to positive feedback highly unlikely. It also helps to explain why most first movers do not become the eventual market leaders, even though they have a substantial lead in hardware installed base and software availability, over later entrants.

In Chapter 2, I examine the positive feedback cycle of indirect network effects in numerous system markets.

In only 1 out of 9 system markets do I observe the presence of a positive feedback cycle (i.e., both supply-side and demand-side indirect network effects). In 4 system markets I observe only the presence of supply-side indirect network effects. Demand-side indirect network effects are not present in these 4 markets. While in 4 other system markets I do not observe any indirect network effects. The positive feedback cycle seems to be absent in most system markets. This contrasts sharply with "current wisdom" that the amount of available software is of critical importance to hardware sales growth (e.g.

Church and Gandal 1992a; Gupta, Jain and Sawhney 1999; Katz and Shapiro 1986a and 1994). Indirect network effects appear to be less pervasive –or at least more complex— than “current wisdom” would have us believe.

In most of the system markets examined, hardware sales (take off) lead software availability (take off), whereas the reverse almost never happens. Thus, again contradicting “current wisdom” that software availability should lead hardware sales (Bayus 1987; Bucklin and Sengupta 1993; Clements 2004; Frels, Shervani and Srivastava 2003; Midgette 1997; Sengupta 1998; Tam 2000; Yoder 1990; Ziegler 1994). Hardware sales takeoff often occurs when software availability is still very small. This suggests that a considerable segment of consumers (i.e., demand-side adopters) make their decisions to buy the hardware, relatively independently of the software quantity available for the hardware. It may be that a killer application (i.e., superstar software title) is available, which impels a sizeable consumer segment to own the hardware regardless of the sheer number of software applications available (Frels, Shervani and Srivastava 2003; Williams 2002), which would be in line with our findings presented in Chapter 3.

Given the findings of chapter 2, hardware manufacturers should not overstate the importance of software quantity. Subsidizing software firms in order to create a huge library of software available may be a very inefficient investment. Investing in a small number of high quality software products (i.e., superstars) may have a significant more positive impact on the consumer’s adoption decision.

Our findings also question the need for intervention in system markets. In many markets, hardware sales take off before software availability does. Lack of available software, due to the lack of coordination, does not seem to be an issue in preventing hardware sales to take off. If public policy is to intervene, subsidizing the cost of the new hardware may be a better alternative to subsidizing software availability, which is now often the preferred choice of public policy. As a critical mass of hardware adopters often develops before a critical mass of software titles is available.

In Chapter 3, I focus on demand-side indirect network effects. I examine the effects of the available software on the consumers’ adoption decision (i.e., hardware sales). Specifically, the effect of superstars (i.e., software titles of exceptional high quality), sometimes referred to as killer applications.

I again find that software availability (i.e., the software back catalog) has no significant effect on the consumer's adoption decision. Consumers do not seem to value old software titles. However, the introduction of superstars and the present software introductions do effect the consumer's adoption decision positively. Over 97% of software titles do not affect the demand-side (i.e., consumers' adoption decision) after their introduction.

The introduction of a superstar software title increases hardware sales by an average of 14% (167,000 hardware units) over a period of 5 months. Software type does not consistently alter this effect. Superstars display increasing returns of software quality to hardware unit sales (they also display increasing returns to software unit sales). Systems with no or only one superstar failed miserably.

Surprisingly, while superstar software unit sales peak during introduction and decline with each month, the monthly superstar effect on hardware unit sales peaks in the second to third month, and thus displays an inverted U-shape effect over time. Thus, high software unit sales of superstars do not automatically translate into a large, or similarly shaped, superstar effect on hardware unit sales. This different time pattern is likely because of the relative slower diffusion of information about superstars among non-adopters (i.e., potential hardware buyers), compared to adopters (i.e., software buyers). Thus, I find strong heterogeneity in the effect of a software title on the consumer's adoption decision, due to their varying quality, as well as, the temporal pattern observed.

These findings, consistent with chapter 2, again invalidate, or at least question, prior operationalizations of software availability. Using the software catalog as an indicator for software availability, which is standard practice in network effects literature (see Stremersch et al. 2007), may show insignificant indirect network effects. Using the number of software titles introduced may paint an incomplete picture, as it does not account for increasing returns to quality (i.e., disproportional high returns of superstars).

In light of our findings, both hardware and software firms should carefully examine the role superstars play in their industry, as superstars affect both software and hardware sales. Software firms (i.e., complementors) should examine their inventory of software titles for potential superstars, and negotiate with system owners to receive side-payments for the increase in hardware unit sales their superstars cause. As superstars only have a positive effect on hardware unit sales for a limited period, system owners must convince consumers that the introduction of a superstar is not a fluke, but that there will be a steady supply of superstar software titles.

However, system owners (i.e., hardware sponsors) must remember that when they pay software firms for the exclusivity of their superstars, they are not additionally increasing their own hardware sales -compared to a non-exclusive superstar software title - but that they are eliminating an opportunity for competing systems to increase their hardware unit sales. Eliminating the hardware sales of competitors while increasing one's own hardware sales, may well be the deciding factor in a positive feedback market (e.g., Arthur 1989 and 1996; Shapiro and Varian 1998). Cutting corners, while rushing a software title to market, to meet a deadline (e.g., the launch of the hardware, or the December holidays), will not only have an adverse effect on the software sales of the software title itself. It could also turn a potential superstar into a 'me-too' software title, without a superstar effect on hardware sales, just because of the slightly lower software quality. System owners should intervene, and pay software publishers to continue development, in order to improve quality.

Our findings of Chapter 3 also question the need for intervention in system markets, as I do not find any evidence of market failure. If public policy still wants to intervene, it should focus on increasing software quality and not on increasing software quantity, as has been the case in prior interventions.

In Chapter 4, I focus on supply-side indirect network effects. Whether or not, and when, do complementors start releasing complementary products for a specific system? Specifically, I examine the effect of the hardware installed base and pre-entry experience on the complementor's entry decision.

I find that the effect of supply-side indirect network effects (i.e., hardware installed base) on the complementor's timing of entry exhibits strong heterogeneity. Again, indirect network effects exhibit strong heterogeneity. As the market evolves this effect diminishes, over technology generations and with each new pre-entry relationship between complementor and system owner. However, this effect increases during the system's life cycle. Supply-side indirect network effects are small to non-existent during the initial stage of the system's life cycle. Combine these findings with our prior research that find strong heterogeneity in --demand-side-- indirect network effects, and it is clear that the positive feedback cycle of indirect network effects is very dynamic, and may be very small under certain conditions, giving new systems an opportunity to flourish (i.e., give incumbents only a small indirect network effects advantage). Marketing managers and academics may well want to control for these sources of heterogeneity in the future. In addition, marketing managers of hardware owners should adopt a flexible marketing strategy (i.e., know when, and when not, their hardware installed base will have a --large-- effect on the complementor's entry decision).

The complementor's pre-entry relationship with the system owner does have a positive effect on the probability of entry. It also has a positive effect on the timing of entry, and decreases the effect of supply-side indirect network effects on the timing of entry. These pre-entry relationships reduce the coordination problem new systems face, thereby alleviating the chicken-and-egg problem. Therefore, this relationship is crucial to both complementors and system owners, and will largely determine the evolution of an industry over technology generations. These pre-entry relationships are likely a major contributor to the eventual oligopoly market structure I observe. Newly entering system owners will face a barrier to entry that may increase with each new technology generation, due to the increase in pre-entry relationships. However, it are late entering incumbent system owners who do not have these pre-entry relationships with complementors who are worst off, as they will have the hardest time convincing complementors to enter.

Our findings allow marketing managers of system owners to identify the most probable early entrants early on (i.e., before the introduction of its next generation system). Marketing managers can thus easily differentiate between early entrants and late entrants, among complementors. Market analysts can expect the complementor's timing of entry to accelerate over technology generations, as every pre-entry experience accelerates entry. In addition, our findings give marketing managers of both complementors and system owners, as well as market analysts, the ability to early on detect if a system is going to succeed or fail (i.e., has or hasn't adequate timely support from complementors).

Markets with network effects are often characterized as winner-takes-all markets (e.g. Arthur 1996; Liebowitz and Margolis 1999; Srinivasan, Lilien and Rangaswamy 2004; Schilling 2002). However, I observe that winner-takes-all outcomes disappear as the market matures. The number of winners (i.e., successful systems) in a single technology generation increases across technology generations. The decrease in the positive feedback of supply-side indirect network effects, across technology generations, —partially— explains why the number of winners increases. With each new technology generation, tipping is thus less likely to occur because of the smaller positive feedback, due to presence of indirect network effects. The smaller positive feedback effect allows for a more even distribution of entry by complementors and adoption by consumers, among competing systems. This results in a more even distribution of market share among competing systems, the Herfindahl-Hirschman Index decreases over technology generations.

As the technology generation progresses, it will become increasingly difficult to replace the leading system (i.e., market leader). Because later entry during a technology generation by a system owner negatively affects the complementor's likelihood of entry, and because the effect of the supply-side indirect network effect on the complementor's timing of entry increases as the system ages. However, market leaders are in great danger to lose their hold on the industry with the introduction of a new technology generation. This is at least partially because of the negative effect of their pre-entry incumbency experience on the complementor's probability of entry. In our market of interest, in all but one new technology generation, was the previous market leader replaced. This is in line with prior non-system market research that states that the transition from the old generation to the new generation is rife with opportunities, and that new entrants exploit these technological discontinuities to displace existing incumbents (e.g. Bass and Bass 2001; Foster 1986; Lieberman and Montgomery 1988; Schumpeter 1961; Utterback 1994).

System markets are not more disposed to inefficiencies, compared to their non-system counterparts. I did not find support for strong inefficient path-dependencies, as first-movers never won a systems war, and the market leader of the prior technology generation was usually replaced in the next technology generation. In addition, I did not find evidence of harmful lock-in, because system owner are not able to prevent the entry of complementors into newly emerging systems of competitors. If public policy still wants to intervene, it should focus on creating and facilitation relationships between complementors and system owners, in order to assist market development.

## 5.3 Directions for Future Research

I will now present directions for future indirect network effects research. In addition, each of the three prior chapters contains its own suggestions for future research.

First, future research relating to indirect network effects should primarily focus on identifying which factors affect the positive feedback cycle of indirect network effects. How do these factors affect the positive feedback cycle? How can firms manipulate and control these factors? This will allow academics to improve the operationalization of indirect network effects in order to increase our understanding of indirect network effects. Subsequently, this will allow practitioners to enhance their marketing strategy, and will increase the effectiveness of public policy. Factors, which may prove fruitful to investigate, are exclusivity, the system life cycle and complementor exit.

I find that exclusive superstars do not increase hardware sales any differently than nonexclusive superstars. However, they are eliminating an opportunity for competing systems to increase their hardware sales. This raises the question; do system markets with a higher level of software exclusivity display a slower market penetration, compared to system markets with a lower level of software exclusivity? Does exclusivity lower the combined sales of all system, and thus in addition reduce total combined software sales?

All findings from our empirical studies indicate that the positive feedback cycle of indirect network effects strengthens across the system life cycle. The positive feedback is weak (or even absent) during the initial stage of the system life cycle, and strengthens as the system ages. However, future research should directly examine the positive feedback cycle over the life of systems. In addition, examining why this increase in strength occurs will be very fruitful. Is the absence of foresight in our models a possible –partial—explanation? Is it a result of survivor bias, as only successful systems remain over time?

I have already examined why and when complementors enter a system. However, why they exit a system (i.e., stop introducing software for a certain system) remains unexamined. In addition, the negative feedback effect from complementor exit on the consumer adoption decision and their spending behavior, remain unexamined as well. Does early exit by complementor –partially—explain why systems fail? Does complementor exit lead or lag disadoption (i.e., orphaning) by consumers?

I hope that the weak evidence for the presence of indirect network effects using the traditional operationalization, will spur new conceptualizations that may prove more powerful. Future research should use a software availability measure, which accounts for at least both software titles of varying superstar power, and varying durability. In addition, restricting the scope of network effects (Tucker 2006), using software thresholds may be impactful future research direction.

Second, future research dealing with empirical indirect network effects could address some of the existing limitations, relating to datasets, expectations and endogeneity.

Even though our datasets are better (e.g., no proxies), larger and more diverse compared to most previous studies, and took close to 3 years to collect, future research should do even better, if researchers want to increase their understanding of actual system markets. Datasets should span across markets and over technology generations, in order to provide a better understanding of the evolution of system markets, and as to why we see such strong heterogeneity in positive feedback among system markets. In order to examine the heterogeneity of indirect network effects over the system life cycle, future datasets should span the entire system life cycle. Using datasets with monthly instead of yearly periodicity should make this possible, even in fast pacing high-tech system markets with short life cycles, and could additionally be used to further examine the possible tipping potential of system markets.

Similarly, prior studies mainly use datasets consisting of successful systems. Our datasets already include successful, less than successful, and unsuccessful systems, but not enough to examine the strength of indirect network effects across the success level of system products (successful, less than successful, and unsuccessful systems). I hope that future research will be able to examine this, and eliminate the survivor bias, which is present in many datasets. Because it is not only important to understand why systems succeed, but also to understand why they fail. The snob appeal may explain why millions of early adopters adopt the hardware when few software titles are available. But why was this snob appeal effect not present at the introduction of an eventual unsuccessful product? What did these millions of early adopters know that practitioners and we academics do not? Finally, examining the strength of indirect network effects across lead and lag countries will be most fruitful. I hope that future research will follow our high standards regarding datasets, even though academics prefer to shirk the process of collecting data.

However, the payoff can be large as we now come close to being able to model two-sided market adoption simultaneously, of 230 million consumer adoptions and 2900 complementor entry opportunities, in a real system market during a 35-year period across numerous technology generations and competing systems. These adoptions generated close to $120 billion dollar in sales, of home video game hardware, software and accessories, in the U.S. alone.

Including foresight (i.e., expectations) in future models, should also be a focus of future research, as expectations are crucial in positive feedback markets (Shapiro and Varian 1998). The weak effects of indirect network effects during the initial stage of the system life cycle may well be the result from the absence of foresight in our models. Early adopters are the most risk seeking and forward looking of all adopters. By using operationalizations of key indirect network effect variables that are forward looking, besides the present and backward looking indirect network effect operationalizations (e.g., present software introductions, software back catalog), may be a good starting point. For example, including the number of present complementors will be a good indicator of the pool of potential future software releases. Future models could also include the announcements of future superstar releases, and the acquisition of popular and proven superstar franchises by system owners. Similarly including pre-announcements (e.g. Dranove and Gandal 2003) about future system introductions and future complementor entries will be valuable model extensions.

While I did not find evidence that endogeneity issues alter the findings presented in this dissertation, future empirical research may want to better address these potential endogeneity issues, by simultaneously estimating the demand-side (i.e., consumer adoption) and supply side (i.e., complementor entry) of system markets (i.e., two-sided market adoption). Future research may also incorporate endogenous covariates instead of our exogenous covariates, to better capture the competitive and ever changing market environment.

# Lessons

**Indirect network effects are often not present, and thus the positive feedback cycle is absent.** The positive feedback cycle in system markets is not automatically present, and available for managers to harvest. In addition, it is not self-sustaining. It must be explicitly started and subsequently managed by managers and/or public policy.

**Consumer adoption leads complementor entry.** When trying to solve the chicken-and-egg paradox, managers and public policy should focus on consumers to start the positive feedback cycle, instead of the presently preferred complementors. Most of the time we observe a takeoff in consumer adoption well before any substantial amount of software titles is available.

**Software quantity (i.e., the software back catalog) is of relative little importance, whereas software quality (i.e., software superstars) is of the utmost importance.** Superstar software titles (i.e., software products of exceptional high quality) display increasing returns to quality in both software and hardware sales. Managers and public policy should not diversify their investment across a number of software products (and/or product categories), but concentrate investment into a single superstar. As only superstars have a large effect on hardware sales, and are a perfect opportunity for creating early take off in consumer adoption.

**When indirect network effects are present, they display strong heterogeneity.** Indirect network effects increase across the system life cycle, but decrease over technology generations. **Tipping in the early stage of the system life cycle is not likely**, giving later entrants plenty of opportunity to flourish. First movers (i.e., the first new system of a technology generation) rarely become the eventual market leader.

**The relevance of indirect network effects is limited.** Indirect network effects are only important during the later stages of the system life cycle. In addition, the advantages of large indirect network effects (i.e., a large hardware installed base of users, and a large back catalog of software) are limited to this technology generation, and of little importance during the next technology generation. The market leader of the prior technology generation rarely becomes the market leader of the next technology generation. Market inefficiencies are not likely.

**Winner-takes-all market outcomes disappear**. The increased coordination and familiarization between hardware manufacturers and software publishers (i.e., the presence of pre-entry relationships), reduces the coordination problem underlining system markets. As the strength of indirect network effects, and thus the positive feedback cycle, diminishes across technology generations, we obverse a more and more even distributed market shares among systems. **Tipping is less and less likely to occur.** In early technology generations, public policy should focus on improving coordination between hardware manufacturers and software publishers in order to start and facilitate the positive feedback cycle. This will result in a speedier and eventually higher market penetration.

# Summary

In this dissertation, I empirically examine system markets up close. More specifically I examine indirect network effects, both demand-side and supply-side indirect network effects. Indirect network effects are the source of positive feedback in system markets, or so network effect theory tells us. Systems are composed of complementary and interdependent products, such as hardware and software. For instance, a video game system is composed of the video game console, on the one hand, and video games, on the other hand.

"Current wisdom" tells us that when indirect network effects are present, the increased adoption of the hardware by consumers, and thereby the larger hardware installed base, increases the complementor's likelihood to enter the system and start introducing software (i.e., supply-side indirect network effects). This larger availability of software increases the utility of the system to consumers, thereby increasing the consumers' likelihood to adopt the hardware, thus increasing hardware sales (i.e., demand-side indirect network effects), and so on.

I find that the positive feedback cycle of indirect network effects is less pervasive, or at least more complex, than "current wisdom" would have us believe. Supply-side and/or demand-side indirect network effects, as traditionally operationalized, are often not present. When present, they display strong heterogeneity. Software quantity if often of little interest to consumers, while software products of exceptional high quality (i.e., superstars) play an important role, in the eventual success or failure of a system. There is often no positive feedback cycle present in the initial stage of the system's life cycle. In addition, when present indirect network effects decrease across technology generations.

The positive feedback cycle is not automatically present in system markets waiting to be harvested. Marketing managers of firms operating in system markets must start this cycle themselves, and subsequently manage it. Our empirical studies already identify numerous factors marketing manager can manipulate in order to influence the positive feedback cycle. These factors are market, pre-entry relationship, software life cycle, superstar power, system life cycle and technology generation. Hardware sponsors must constantly create large events on both the demand-side and the supply-side to keep the positive feedback cycle present and running.

Marketing managers should first identify which factors could influence the positive feedback cycle of indirect network effects. Subsequently, they must identify how to manipulate those factors to positively affect their own feedback cycle, while trying to disrupt the feedback cycle of competitors. Second, they must understand the temporal pattern in demand-side and supply-side indirect network effects, across the life cycle of systems and software, and across successive technology generations. In addition, they should focus on improving software quality and not software quality. Subsequently marketing managers must incorporate our findings in their marketing strategy, in order to outmaneuver competitors (i.e., competing systems, fellow complementors). Only then can marketing managers start to reap the benefits of indirect network effects and positive feedback, and alleviate the chicken-and-egg problem.

# About the Author

Jeroen L.G. Binken (1974) obtained his degree of Doctorandus in the Economic Sciences, from the Erasmus University Rotterdam, The Netherlands. He later started his Ph.D. research at the Erasmus Research Institute of Management (ERIM) in the field of Marketing. This academic research has accumulated in numerous publications in leading scholarly journals such as the *Journal of Marketing*.

His main research interests are marketing of high-tech products, new product growth, and network effects. His two decade long experience in the fields of marketing and ICT has made him a marketing authority in the area of (new) business development and marketing analysis of high-tech products. Predominantly solving managerial issues for international clients related to strategic marketing and corporate strategy, pertaining to the introduction of new products.

# References

Agarwal, R. (1998), "Evolutionary Trends of Industry Variables," *International Journal of Industrial Organization*, 16 (4), 511–525.

Agarwal, R. and B.L. Bayus (2002), "The Market Evolution and Sales Takeoff of Product Innovations," *Management Science*, 48 (8), 1024-1041.

Agarwal, R. and D.B. Audretsch (2001), "Does Entry Size Matter? The Impact of the Life Cycle and Technology on Firm Survival," *Journal of Industrial Economics*, 49 (1), 21-43.

Agarwal, R. and M. Gort (1996), "The Evolution of Markets and Entry, Exit and Survival of Firms," *Review of Economics and Statistics*, 78 (3), 489-497.

Ainslie, A., X. Drèze and F. Zufryden (2005), "Modeling Movie Life Cycles and Market Share," *Marketing Science*, 24 (3), 508–517.

Allen, J. (2003), "Are You Game," *St. Petersburg Times,* January 27, 4E.

Alpert, M. (1992), "CD-ROM: The Next PC Revolution," *Fortune*, New York, June 29, 1992, 68-73.

Anderson, N. (1996), *A Functional Theory of Cognition,* Mahwah, NJ: Erlbaum.

Andreozzi, L. (2004), "A Note on Critical Masses, Network Externalities and Converters," *International Journal of Industrial Organization*, 22 (5), 647– 653.

Archibald, R.B., C.A. Haulman and C.E. Moody Jr. (1983), "Quality, Price, Advertising, and Published Quality Ratings," *Journal of Consumer Research,* 9 (4), 11-22.

Arellano, M. and S. Bond (1991), "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations," *Review of Economic Studies,* 58 (2), 277-297.

Arrow, K.J. (1962), "The Economic Implications of Learning by Doing," *Review of Economic Studies*, 29 (3), 155-173.

Arthur, W. B. (1989), "Competing Technologies, Increasing Returns, and Lock-in by Historical Events," *The Economic Journal*, 99 (394), 116-131.

Arthur, W. B. (1996), "Increasing Returns and the New World of Business," *Harvard Business Review*, 74 (4), 100-109.

Baltagi, B.H. and Q. Li (1991), "A Transformation that will Circumvent the Problem of Autocorrelation in an Error-component Model," *Journal of Econometrics,* 48 (3), 385-393.

Barnes, B. (2007), "Two Studios to Support HD DVD Over Rival," *New York Times*, August 21 (accessed August 21, 2007) [available at http://www.nytimes.com/2007/08/21/technology/21disney.html].

Bass, P., and F.M. Bass (2001), "Diffusion of Technology Generations: a Model of Adoption and Repeat Sales," *Working paper*.

Bass, P., and F.M. Bass (2004), "IT waves: Two Completed Generational Diffusion Models," *Working paper*.

Basu, A., T. Mazumdar and S.P. Raj (2003), "Indirect Network Externality Effects on Product Attributes," *Marketing Science,* 22 (2), 209-221.

Basuroy, S., K. K. Desai and D. Talukdar (2006), "An Empirical Investigation of Signaling in the Motion Picture Industry," *Journal of Marketing Research,* 43 (2), 287–295.

Bayus, B. L. (1987), "Forecasting Sales of New Contingent Products: An Application to the Compact Disc Market," *Journal of Product Innovation Management*, 4 (4), 243-255

Bayus, B.L. and R. Agarwal (2007), "The Role of Pre-entry Experience, Entry Timing, and Product Technology Strategies in Explaining Firm Survival," *Management Science*, 53 (12), 1887-1902.

Bayus, B.L., W. Kang, and R. Agarwal (2007), "Creating Growth in New Markets: Simultaneous Model for Firm Entry and Price," *Journal of Product Innovation Management,* 24 (), 139-155.

Belsley, D.A. (1991*), Conditioning Diagnostics, Collinearity and Weak Data in Regression*. New York, NY: John Wiley & Sons.

Belsley, D.A., E. Kuh and R.E. Welsch (1980), *Regression Diagnostics – Identifying Influential Data & Sources of Collinearity.* New York, NY: John Wiley & Sons.

Bental, B. and M. Spiegel (1995), "Network Competition, Product Quality, and Market Coverage in the Presence of Network Externalities," *Journal of Industrial Economics*, 43 (2), 197-208.

Binken, J.L.G. and S. Stremersch (2009), "The Effect of Superstar Software on Hardware Sales in System Markets," *Journal of Marketing,* 73 (2), 88-104.

Bloom, S. (1982), *Video Invaders*. New York, NY: Arco.

Bonardi, J-P. and R. Durand (2003), "Managing Network Effects in High-Tech Markets," *Academy of Management Executive*, 17 (4), 40-52.

Brynjolfsson, E. and C.F. Kemerer (1996), “Network Externalities in Microcomputer Software: An Econometric Analysis of the Spreadsheet Market,” *Management Science,* 42 (12), 1627-1647.

Bucklin, L.P. and S. Sengupta (1993), “The Co-Diffusion of Complementary Innovations: Supermarket Scanners and UPC Symbols,” *Journal of Product Innovation Management*, 10 (2), 148-160.

Cadin, L. and F. Guerin (2006), “What Can We Learn from the Video Games Industry,” *European Management Journal,* 24 (4), 248–255.

Caillaud, B. and B. Jullien (2003), “Chicken & Egg: Competition among Intermediation Service Providers,” *RAND Journal of Economics*, 34 (2), 309-328.

Chandler, A.D. (1990), *Scale and Scope: The Dynamics of Industrial Capitalism*. Cambridge, MA: Belknap Press.

Chandy, R.K. and G.J. Tellis (2000), “The Incumbent’s Curse? Incumbency, Size, and Radical Product Innovation,” *Journal of Marketing*, 64 (3), 1–17.

Choi, J.P. (1994), “Network Externality, Compatibility Choice, and Planned Obsolescence,” *Journal of Industrial Economics*, 42 (2), 167- 182.

Choi, J.P. (1997), “Herd Behavior, the "Penguin Effect," and the Suppression of Informational Diffusion: An Analysis of Informational Externalities and Payoff Interdependency,” *The RAND Journal of Economics*, 28 (3) 407-425.

Chou, C-F. and O. Shy (1990), “Network Effects Without Network Externalities,” *International Journal of Industrial Organization*, 8 (2), 259–70.

Chou, C-F. and O. Shy (1993), “Partial Compatibility and Supporting Services,” *Economics Letters*, 41 (2), 193-197.

Chou, C-F. and O. Shy (1996), “Do Consumers Gain or Lose When More People Buy the Same Brand,” *European Journal of Political Economy*, 12 (2), 309-330.

Christensen, C.M., and R.R. Rosenbloom (1995), “Explaining the Attacker's Advantage: Technological Paradigms, Organizational Dynamics, and the Value Network,” *Research Policy,* 24 (2), 233-257.

Christensen, C.M., F.F. Suarez, and J.M. Utterback (1998), “Strategies for Survival in Fast-changing Industries,” *Management Science*, 44 (12), 207-220.

Chung, K.H. and R.A.K. Cox (1994), “A Stochastic Model of Superstardom: An Application of the Yule Distribution,” *Review of Economics and Statistics,* 76 (4), 771-775.

Church, J. and N. Gandal (1992a), "Network Effects, Software Provision, and Standardization," *Journal of Industrial Economics*, 40 (1), 85-103.

Church, J. and N. Gandal (1992b), "Integration, Complementary Products, and Variety," *Journal of Economics and Management Strategy*, 1 (4), 651-675.

Church, J. and N. Gandal (1993), "Complementary Network Externalities and Technological Adoption," *International Journal of Industrial Organization*, 11 (2), 239-260.

Church, J. and N. Gandal (1996), "Strategic Entry Deterrence: Complementary Products as Installed Base," *European Journal of Political Economy*, 12 (2), 331-354.

Clark, B.H. and S. Chatterjee (1999), "The Evolution of Dominant Market Shares: The Role of Network Effects," *Journal of Marketing Theory and Practice*, 7 (2), 83-96.

Clements, M.T. (2004), "Direct and Indirect Network Effects: Are They Equivalent?" *International Journal of Industrial Organization*, 22 (5), 633–45.

Clements, M.T. and H. Ohashi (2005), "Indirect Network Effects and the Product Cycle: Video Games in the U.S., 1994–2002," *Journal of Industrial Economics,* 53 (4), 515-542.

Cohen, S. (1984), *Zap! The Rise and Fall of Atari*, New York, NY: McGraw Hill.

Collins, A., C. Hand and M.C. Snell (2002), "What Makes a Blockbuster? Economic Analysis of Film Success in the United Kingdom," *Managerial and Decision Economics,* 23 (6), 343-354.

Conlon, E., S. Devaraj and K.F. Matta (2001), "The Relationship Between Initial Quality Perceptions and Maintenance Behavior: The Case of the Automotive Industry," *Management Science,* 47 (9), 1191-1202.

Conner, K.R. (1995), "Obtaining Strategic Advantage from Being Imitated: When Can Encouraging "Clones" Pay?," *Management Science*, 41 (2), 209-225.

Cottrell, T. and K. Koput (1998), "Software Variety and Hardware Value: A Case Study of Complementary Network Externalities in the Microcomputer Software Industry," *Journal of Engineering Technology Management,* 15 (4), 309-338.

Coughlan, P.J. (2004), "Note on Home Video Game Technology and Industry Structure (Abridged)," *Harvard Business School Case* #9-704-488. Cambridge, MA: Harvard University.

Cox, R.A.K. and R.T. Kleiman (2000), "A Stochastic Model of Superstardom: Evidence from Institutional Investor's All-American Research Team," *Review of Financial Economics,* 9 (1), 43-53.

De Vany, A. and W.D. Walls (1996), “Bose-Einstein Dynamics and Adaptive Contracting in the Motion Picture Industry,” *Economic Journal,* 106 (439), 1493-1514.

Debruyne, M. and D. Reibstein (2005), “Competitor See, Competitor Do,” *Marketing Science*, 24 (1), 55–66.

Dekimpe, M., L. Van de Gucht, D.M. Hanssens and K.I. Powers (1998), “Long-run Abstinence after Narcotics Abuse: What Are the Odds?,” *Management Science*, 44 (11), 1478-1492.

Dhebar, A. (1995), “Complementarity, Compatibility, and Product Change: Breaking with the Past?,” *Journal of Product Innovation Management,* 12 (2), 136-152.

Dick, J.T. (1990), “Laserdisc Redux, Once Considered a Dead Format, Laser Videodisc may be your Library’s Next New Collection,” *Library Journal*, 115 (20), 36-40.

Dickson, G. (2008), “CEA: Super Bowl Boosts HD-Set Sales,” *Cable and Broadcasting*, January 24, 2008. , (accessed January 28, 2008) [available at http://www.broadcastingcable.com/article/CA6525439.html].

Dranove, D. and N. Gandal (2003), “The DVD-vs.-DIVX Standard War: Empirical Evidence of Network Effects and Preannouncement Effects,” *Journal of Economics and Management Strategy,* 12 (3), 363–386.

Ducey, R.V. and M.R. Fratrik (1989), “Broadcasting Industry Response to New Technologies,” *Journal of Media Economics*, 2 (Fall), 67-86.

Economides, N. (1989), “Desirability of Compatibility in the Absence of Network Externalities,” *American Economic Review*, 79 (5), 1165-1181.

Economides, N. (1996), “Network Externalities, Complementarities, and Invitations to Enter,” *European Journal of Political Economy*, 12 (2), 211-233.

Economides, N. and C. Himmelberg (1995), “Critical Mass and Network Size with Application to the US FAX Market,” *Working Paper*, Stern School of Business, New York University.

Economides, N. and L.J. White (1994), “Networks and Compatibility: Implications for Antitrust,” *European Economic Review*, 38 (3-4), 651-662.

Economides, N. and S.C. Salop (1992), “Competition and Integration Among Complements, and Network Market Structure,” *Journal of Industrial Economics*, 40 (1), 105-123.

Edwards, C. and R. Grover (2008), “Blu-ray's High-Definition Knockout,” *BusinessWeek*, January 4, 2008. , (accessed February 21, 2008) [available at http://www.businessweek.com/technology/content/jan2008/tc2008014_928006.htm].

Elliott, G., T.J. Rothenberg and J.H. Stock (1996), “Efficient Tests for an Autoregressive Unit Root,” *Econometrica*, 64 (4), 813-836.

ESA (2007), “Facts & Research,” *(ESA) Entertainment Software Association*, (accessed August 17, 2007) [available at http://www.theesa.com/facts/top_10_facts.php].

Esser, P. and L. Leruth (1988), “Marketing Compatible, yet Differentiated, Products: In Search of Competitive Equilibria when Network Externalities are at Work,” *International Journal of Research in Marketing*, 5 (4), 251-270.

Farrell, J. (1987), “Cheap Talk, Coordination, and Entry,” *Rand Journal of Economics*, 18 (1), 34-39.

Farrell, J. and G. Saloner (1985), “Standardization, Compatibility, and Innovation,” *RAND Journal of Economics*, 16 (1), 70-83.

Farrell, J. and G. Saloner (1986), “Installed Base and Compatibility: Innovation, Product Preannouncements, and Predation,” *American Economic Review,* 76 (5), 940-955.

Farrell, J., C. Shapiro, R.R. Nelson and R.G. Noll (1992), “Standard Setting in High-Definition Television,” *Brookings Papers: Microeconomics*. Brookings Institution, Washington D.C.

Forbes (2008), “Global Movie Ticket Sales Hit Record,” *Forbes.com*, March 5, (accessed May 23, 2008) [available at http://www.forbes.com/afxnewslimited/feeds/afx/2008/03/05/afx4735870.html]

Foster, J.A., P.N. Golder and G.J. Tellis (2004), “Predicting Sales Takeoff for Whirlpool’s New Personal Valet,” *Marketing Science*, 23 (2), 182-185.

Foster, R.N. (1986), *Innovation: The Attacker's Advantage*, New York, NY: Summit Books.

Franses, P.H. (1998), *Time Series Models for Business and Economic Forecasting*, Cambridge, UK: Cambridge University Press.

Franses, P.H. (2005), “On the Use of Econometric Models for Policy Simulation in Marketing,” *Journal of Marketing Research,* 42 (1), 4-14.

Frels, J. K., T. Shervani and R. K. Srivastava (2003), “The Integrated Networks Model: Explaining Resource Allocations in Network Markets,” *Journal of Marketing,* 67 (1), 29-45.

Funk, J. B., D. D. Buchman (1996), “Playing Violent Video and Computer Games and Adolescent Self-concept,” *Journal of Communication*, 46 (2), 19-32.

GamePro (2006), “GamePro Q&A: 5 Questions for Phil Harrison,” *GamePro.com,* September 24, (accessed May 21, 2007) [available at www.gamepro.com/news.cfm?article_id=82268].

Gandal, N. (1994), “Hedonic Price Indexes for Spreadsheets and an Empirical Test for Network Externalities,” *RAND Journal of Economics,* 25 (1), 160-170.

Gandal, N. (1995), “Competing Compatibility Standards and Network Externalities in the PC Software Market,” *Review of Economics and Statistics,* 77 (4), 599-608.

Gandal, N. (2002), “Compatibility, Standardization, and Network Effects,” *Oxford Review of Economic Policy*, 18 (1), 80-91.

Gandal, N., M. Kende and R. Rob (2000), “The Dynamics of Technological Adoption in Hardware/Software Systems: The Case of Compact Disc Players,” *RAND Journal of Economics,* 31 (1), 43-61.

Gandal, N., S. Greenstein and D. Salant (1999), “Adoptions and Orphans in the Early Microcomputer Market,” *Journal of Industrial Economics*, 47 (1), 87-105.

Garud, R. and A. Kumaraswamy (1993), “Changing Competitive Dynamics in Network Industries: An Exploration of Sun Microsystems' Open Systems Strategy,” *Strategic Management Journal*, 14 (5), 351-369.

Gaume, N. (2006), “Nicolas Gaume’s Views on the Video Games Sector,” *European Management Journal,* 24 (4), 299–309.

Geroski, P.A. (1995), “What Do We Know About Entry?,” *International Journal of Industrial Organization*, 13 (4), 421-440.

Gibson, E. (2007), “Halo 3 will help us sell consoles, says Microsoft,” gamesindustry.biz, April 27 [available at www.gamesindustry.biz/content_page.php?aid=24613].

Gilroy, J. (1994), “Ask the Computer Guy,” *Washington Post*, October 24, F19.

Golder, P.N. (2000), “Historical Method in Marketing Research with New Evidence on Long-Term Market Share Stability,” *Journal of Marketing Research*, 37 (2), 156–72.

Golder, P.N. and G.J. Tellis (1997), “Will It Ever Fly? Modeling the Takeoff of Really New Consumer Durables,” *Marketing Science*, 16 (3), 256-270.

Golder, P.N. and G.J. Tellis (1998), “Beyond Diffusion: An Affordability Model of the Growth of New Consumer Durables,” *Journal of Forecasting*, 17 (3-4), 259-280.

Golder, P.N. and G.J. Tellis (2004), “Growing, Growing, Gone: Cascades, Diffusion, and Turning Points in the Product Life Cycle,” *Marketing Science*, 23 (2), 207-218.

Gort, M. and A. Konakayama (1982), “A Model of Diffusion in the Production of an Innovation,” *American Economic Review*, 72 (5), 1111-1120.

Gort, M. and S. Klepper (1982), “Time Paths in the Diffusion of Product Innovations,” *The Economic Journal*, 92 (367), 630-53.

Granger, C.W.J. (1969), “Investigating Causal Relations by Econometric Methods and Cross-Spectral Methods,” *Econometrica*, 37 (3), 424-438.

Granovetter, M. (1978), “Threshold Models of Collective Behavior,” *American Journal of Sociology*, 83 (6), 1420-1443.

Greco, A. (2000), “The Structure of the Book Publishing Industry,” in *The Media and Entertainment Industries: Readings in Mass Communications*, Ed. A. Greco, 1-25, New York, NY: Allyn and Bacon.

Greene, W.H. (2003), *Econometric Analysis*, Fifth Edition, Upper Saddle River, NJ: Prentice Hall.

Greenstein, S.M. (1993), “Did Installed Base Give an Incumbent any (Measureable) Advantages in Federal Computer Procurement?,” *RAND Journal of Economics*, 24 (1), 19-39.

Guardian (2006), “Is Sony Fighting a Losing Battle,” *The Guardian*, August 3, (accessed August 8, 2006) [available at http://www.guardian.co.uk/technology/2006/aug/03/sonyplaystation.games].

Gupta, S. (1991), “Stochastic Models of Interpurchase Time with Timedependent Covariates,” *Journal of Marketing Research*, 28 (1), 1-15.

Gupta, S., D.C. Jain and M.S. Sawhney (1999), “Modeling the Evolution of Markets with Indirect Network Externalities: An Application to Digital Television,” *Marketing Science,* 18 (3), 396-416.

Hahn, J-H. (2003), “Nonlinear Pricing of Telecommunications with call and Network Externalities,” *International Journal of Industrial Organization*, 21 (7), 949-967.

Hartman, R.S. and D.J. Teece (1990), “Product Emulation Strategies in the Presence of Reputation Effects and Network Externalities: Some Evidence from the Minicomputer Industry,” *Economic Innovation and New Technology,* 1 (1), 157-182.

Hedström, P. (1994), “Contagious Collectivities: On the Spatial Diffusion of Swedish Trade Unions, 1890-1940,” *American Journal of Sociology*, 99 (5), 1157-79.

Herman, L. (2001), *Phoenix; The Fall and Rise of Videogames*, 3rd edition, Springfield, NJ: Rolenta Press.

Hettinger, V., and C.J.W. Zorn (2001), “Explaining the Incidence and Timing of Congressional Responses to the U.S. Supreme Court,” *Unpublished Manuscript*, Emory University, Atlanta, GA.

Hill, C.W.L. (1997), “Establishing a Standard: Competitive Strategy and Technological Standards in Winner-Take-All Industries,” *Academy of Management Executive*, 11 (2), 7-25.

Horsky, D. and L.S. Simon (1983), “Advertising and the Diffusion of New Products,” *Marketing Science*, 2 (1), 342–365.

Huffstutter, P.J. (1999), “Now Video Games are as Big as the Movies,” *Los Angeles Times*, May 10, 1.

IDSA (2001), “State of the Industry Report 2000-2001,” *(IDSA) Interactive Digital Software Association* (now called ESA, Entertainment Software Association), February 2001, http://www.theesa.com/.

IGN (2002), “Grand Theft Auto: Vice City,” August 27 (accessed November 10, 2007) [available at http://ps2.ign.com/articles/369/369155p1.html].

Islam, T., and N. Meade (1997), “The Diffusion of Successive Generations of a Technology: A more General Model,” *Technological Forecasting and Social Change,* 56 (1), 49-60.

Jones, J.C.H. and W.D. Walsh (1988), “Salary Determination in the National Hockey League: The Effects of Skills, Franchise Characteristics, and Discrimination,” *Industrial and Labor Relations Review,* 41 (4), 592-604.

Jovanovic, B. and G.M. Mac Donald (1994), “The Life Cycle of a Competitive Industry,” *Journal of Political Economy*, 102 (2), 322-347.

Judge, G.G., W.E. Griffiths, R. C. Hill. H. Lutkepohl, T. Lee (1985), *The Theory and Practice of Econometrics*, 2d ed. Singapore: John Wiley & Sons.

Kahn, B.E. and W.T. Ross Jr. (1993), “An Experimental Look and How People Combine Forecasts,” *Working paper*, Wharton School, University of Pennsylvania.

Kamakura, W.A., B.S. Kossar and M. Wedel (2004), “Identifying Innovators for the Cross-selling of New Products,” *Management Science*, 50 (8), 1120-1133.

Kane, J.S. (1981), “Systematic Error in Appraisals: Alternative Approaches to Their Control,” *Paper presented at the First Annual Scientist-Practitioner Conference in Industrial/Organizational Psychology*, Old Dominion University, Norfolk, VA.

Katz, M.L. and C. Shapiro (1985), "Network Externalities, Competition, and Compatibility," *American Economic Review*, 75 (3), 424-440.

Katz, M.L. and C. Shapiro (1986a), "Product Compatibility Choice in a Market with Technological Progress," *Oxford Economic Papers*, 38 (3), 146-165.

Katz, M.L. and C. Shapiro (1986b), "Technology Adoption in the Presence of Network Externalities," *Journal of Political Economy*, 94 (4), 822-841.

Katz, M.L. and C. Shapiro (1992), "Product Introduction with Network Externalities," *Journal of Industrial Economics*, 40 (1), 55-83.

Katz, M.L. and C. Shapiro (1994), "Systems Competition and Network Effects," *Journal of Economic Perspectives*, 8 (2), 93-115.

Kent, S. (2002), "'Kong' Developer Jumps over to Xbox," *USA Today*, September 25, 5D.

Kent, S.L. (2001), *The Ultimate History of Video Games*, Roseville, CA: Prima Publishing.

Kim, D-J and B. Kogut (1996), "Technological Platforms and Diversification," *Organization Science*, 7 (3), 283-301.

Kim, N., E. Bridges and R. Srivastava, (1999), "A Simultaneous Model for Innovative Product Category Sales Diffusion and Competitive Dynamics," *International Journal of Research in Marketing*, 16 (2), 95-111.

Klepper, S. (1996), "Entry, Exit, Growth, and Innovation over the Product Life Cycle," *American Economic Review*, 86 (3), 562-583.

Klepper, S. (2002), "Firm Survival and the Evolution of Oligopoly," *Rand Journal of Economics*, 33 (1), 37-61.

Klepper, S., and E. Grady (1990), "The Evolution of New Industries and the Determinants of Market Structure," *Rand Journal of Economics*, 21 (1), 27-44.

Klepper, S., and J.H. Miller (1995), "Entry, Exit, and Shakeouts in the United States in New Manufactured Products," *International Journal of Industrial Organization*, 13 (4), 567-591.

Klepper, S., and K.L. Simons (2000), "Dominance by Birthright: Entry of Prior Radio Producers and Competitive Ramifications in the U.S. Television Receiver Industry," *Strategic Management Journal*, 21 (10/11), 997-1016.

Komiya, K., and B. Litman (1990), "The Economics of the Prerecorded Videocassette Industry," in *Social and Cultural Aspects of VCR Use*, Ed. J. Dobrow. New York, NY: Erlbaum, 25-44.

Koski, H. and T. Kretschmer (2004), “Survey on Competing in Network Industries: Firm Strategies, Market Outcomes, and Policy Implications,” *Journal of Industry, Competition and Trade*, 4 (1), 5-31.

Kotabe, M., A. Sahay and P.S. Aulakh (1996), “Emerging Role of Technology Licensing in the Development of Global Product Strategy: Conceptual Framework and Research Propositions,” *Journal of Marketing*, 60 (1), 73-88.

Krider, R.E. and C.B. Weinberg (1998), “Competitive Dynamics and the Introduction of New Products: The Motion Picture Timing Game,” *Journal of Marketing Research,* 35 (1), 1-15.

Kristiansen, E.G. (1996), “R&D in Markets with Network Externalities,” *International Journal of Industrial Organization*, 14 (6), 769-784.

Kristiansen, E.G. (1998), “R&D in the Presence of Network Externalities: Timing and Compatibility,” *RAND Journal of Economics*, 29 (3), 531-547.

Landro, L. (1982), “New Video-Game Makers Jump into Fight for a Share of the Booming Home Market,” *Wall Street Journal*, January 27, 29.

Lee, Y. and G.C. O’Connor (2003), “New Product Launch Strategy for Network Effects Products,” *Journal of the Academy of Marketing Science*, 31 (3), 241-255.

LeNagard-Assayag, E. and D. Manceau (2001), “Modeling the Impact of Product Preannouncements in the Context of Indirect Network Externalities,” *International Journal of Research in Marketing,* 18 (3), 203-219.

Lieberman, M.B. and D.B. Montgomery (1988), “First-mover Advantages,” *Strategic Management Journal*, 9 (Summer), 41-58.

Lieberman, M.B. and D.B. Montgomery (1998), “First-mover (Dis)Advantages: Retrospective and Link with the Resource-based View,” *Strategic Management Journal*, 19 (12), 1111-1125.

Liebowitz, S. J. and S. E. Margolis (1999), *Winners, Losers, and Microsoft: Competition and Antitrust in High Technology,* 2nd ed., Oakland, CA: The Independent Institute.

Loch, C.H. and B.A. Huberman (1999), “A Punctuated-Equilibrium Model of Technology Diffusion,” *Management Science*, 45 (2), 160-177.

Luan, Y.J. and K. Sudhir (2007), “Forecasting Advertising Responsiveness for Short Lifecycle Products,” *Working paper*, Tuck School of Business at Dartmouth, November 2007.

MacDonald, D.N., and M.O. Reynolds (1994), “Are Baseball Players Paid their Marginal Products?” *Managerial Decision Economics,* 15 (5), 443-457.

Macy, M.W. (1991), “Chains of Cooperation: Threshold Effects in Collective Action,” *American Sociological Review*, 56 (6), 730-747.

Mahajan, V. and E. Muller (1996), “Timing, Diffusion and Substitution of Successive Generations of Technological Innovations: the IBM Mainframe Case,” *Technological Forecasting and Social Change*, 51 (1), 109-132.

Mahajan, V., E. Muller and F. Bass (1990), “New Product Diffusion Models in Marketing: A Review and Directions for Research,” *Journal of Marketing*, 54 (1), 1-26.

Majumdar, S.K. and S. Venkataraman (1998), “Network Effects and the Adoption of New Technology: Evidence from the US Telecommunications Industry,” *Strategic Management Journal*, 19 (11), 1045-1062.

Marquardt, D. W. (1970), “Generalized Inverses, Ridge Regression and Biased Linear Estimation,” *Technometrics*, 12 (3), 591-612.

Matutes, C. and P. Regibeau (1988), “"Mix and Match": Product Compatibility without Network Externalities,” *RAND Journal of Economics*, 19 (2), 221-234.

Matutes, C. and P. Regibeau (1992), “Compatibility and Bundling of Complementary Goods in a Duopoly,” *Journal of Industrial Economics*, 40 (1), 37-54.

Mayer, T. (1960), “The Distribution of Ability and Earnings,” *Review of Economics and Statistics*, 42 (2), 189-195.

McClure, S. (1992), “Laserdisc Japan: A Massive Hit,” *Billboard*, 104 (6), L8-L20.

McClure, S. (1993a), “Laserdisc Rentals Coming to Japan,” *Billboard* 105 (29), 8.

McClure, S. (1993b), “Recession Dampens Japan's LD Market; Karaoke Explosion Helps Soften Blow,” *Billboard*, February 27, L9.

McGlaun, S. (2008), “Nintendo Wii Tops for Console Sales in June,” *DailyTech.com*, July 18, (accessed July 18, 2008) [available at http://www.dailytech.com/article.aspx?newsid=12418].

McGowan, C. (1994), “Overcoming ‘93s Bad Press and Slow Start, the Market Finished Solid and is Well Set Up for ’94,” *Billboard*, 106 (9), 63-65.

Midgette, A. (1997), “Video: DVD’s Debut,” *Wall Street Journal*, April 21, A.20.

Mitra, D. and P. N. Golder (2006), “How Does Objective Quality Affect Perceived Quality? Short-term Effects, Long-term Effects, and Asymmetries,” *Marketing Science,* 25 (3), 230-247.

Nair, H., P. Chintagunta and J-P Dubé (2004), “Empirical Analysis of Indirect Network Effects in the Market for Personal Digital Assistants,” *Quantitative Marketing and Economics*, 2 (1), 23-58.

NPD (2008), “2007 U.S. Video Game And PC Game Sales Exceed $18.8 Billion Marking Third Consecutive Year Of Record-Breaking Sales,” www.npd.com, January 31, 2008, (accessed February 25, 2008) [available at http://www.npd.com/press/releases/press_080131b.html].

Ohashi, H. (2003), “The Role of Network Effects in the U.S. VCR Market, 1978-1986,” *Journal of Economics and Management Strategy,* 12 (4), 447-494.

Padmanabhan V. and F.M. Bass (1993), “Optimal Pricing of Successive Generations of Product Advances,” *International Journal of Research in Marketing*, 10 (2) 185-208.

Park, S. (2004), “Quantitative Analysis of Network Externalities in Competing Technologies: The VCR Case,” *Review of Economics and Statistics,* 86 (4), 937-945.

Parker, P. and H. Gatignon (1994), “Specifying Competitive Effects in Diffusion Models: an Empirical Analysis,” *International Journal of Research in Marketing*, 11 (1), 17–39.

Pereira, J. (2002), “A Season of Peace, Love -- and Decapitation,” *Wall Street Journal*, December 17, B1.

Pescovitz, D. (1997), “DVD Certainly Dazzles, but High Cost is Stalling its Acceptance,” *The Los Angeles Times*, July 21, 10.

Peterson, R.A. and V. Mahajan (1978), “Multi-Product Growth Models,” in Jagdish Sheth (ed.), Research in Marketing, Vol. 1, 201-231, JAI Press, Greenwich, CT.

Pope, K. (1999), “The Small Screen. Too-high Expectations: Top-quality Digital TV Was Supposed to be Thriving by Now; What Happened?,” *Wall Street Journal*, March 22, R8.

Postrel, S.R. (1990), “Competing Networks and Proprietary Standards: The Case of Quadraphonic Sound,” *Journal of Industrial Economics*, 39 (2), 169-185.

Prins, R. and P.C. Verhoef (2007), “Marketing Communication Drivers of Adoption Timing of a New E-Service Among Existing Customers,” *Journal of Marketing*, 71 (2), 169-183.

Putsis Jr., W.P., S. Balasubramanian, E.H. Kaplan and S.K. Sen (1997), “Mixing Behavior in Cross-Country Diffusion,” *Marketing Science*, 16 (4), 354-369.

Ratliff, J.M. (2002), “NTT DoCoMo and Its i-Mode Success: Origins and Implications,” *California Management Review*, 44 (3), 55-71.

Rogers, E.M. (1995), *Diffusion of Innovations*, 4th ed. New York, NJ: The Free Press.

Rohlfs, Jeffrey (2001), *Bandwagon Effects in High-Technology Industries.* Cambridge, MA: The MIT Press.

Rosen, S. (1981), "The Economics of Superstars," *American Economic Review,* 71 (5), 845-858.

Rousseau, D.M. (1985), "Issues of Level in Organizational Research: Multi-level and Cross-level Perspectives," *Research in Organizational Behavior,* 7 (1), 1-47.

Rowe, G. (1999), "Where's Your White Stick, Ref," *The Irish Times,* May 3, 18.

Rysman, M. (2004), "Competition Between Networks: A Study of the Market for Yellow Pages," *Review of Economic Studies,* 71 (2), 483–512.

Saloner, G. and A. Shepard (1995), "Adoption of Technologies with Network Effects: An Empirical Examination of the Adoption of Automated Teller Machines," *RAND Journal of Economics*, 26 (3), 479-501.

Santulli, J. (2002), *Classic Video Games Collector's Guide,* 7th edition, Digital Press, digitpress.com.

Santulli, J. (2004), *Classic Video Games Collector's Guide Advance Edition,* 1st edition, Digital Press, digitpress.com.

Sawhney, M.S. and J. Eliashberg (1996), "A Parsimonious Model for Forecasting Gross Box-Office Revenues of Motion Pictures," *Marketing Science,* 15 (2), 113-131.

Schelling, T. (1978), *Micromotives and Macrobehavior*. New York, NJ: Norton.

Schiesel, S. (2007), "Microsoft Has Deal to Get Exclusive Episodes of Grand Theft Auto IV for Its Xbox Unit," *New York Times*, June 20, (accessed August 17, 2007) [available at http://www.nytimes.com/2007/06/20/arts/20vide.html].

Schilling, M.A. (1999), "Winning the Standards Race: Building Installed Base and the Availability of Complementary Goods," *European Management Journal*, 17 (3), 265–274.

Schilling, M.A. (2002), "Technology Success and Failure in Winner-Take-All Markets: The Impact of Learning Orientation, Timing, and Network Externalities," *Academy of Management Journal*, 45 (2), 387–98.

Schmedel, S.R. (1978), "RCA Halts Video-Games Output, Studies Its Place in Highly Competitive Market," *Wall Street Journal*, February 13, 10.

Schmidt, P. and A.D. Witte (1989), "Predicting Criminal Recidivism using Split Population Survival Time Models," *Journal of Econometrics*, 40 (1), 141-159.

Schumpeter, J.A. (1961), *The Theory of Economic Development*, New York, NY: Oxford University Press.

Sengupta, S. (1998), "Some Approaches to Complementary Product Strategy," *Journal of Product Innovation Management*, 15 (4), 352-67.

Shankar, V. and B.L. Bayus (2003), "Network Effects and Competition: An Empirical Analysis of the Video Game Industry," *Strategic Management Journal,* 24 (4), 375-384.

Shapiro, C. (1999), "Exclusivity in Network Industries," *George Mason Law Review*, 7 (3), 673-684.

Shapiro, C. and H.R. Varian (1998), *Information Rules: A Strategic Guide to the Network Economy,* Boston, MA: Harvard Business School Press.

Sheff, D. (1999), *Game Over: How Nintendo Conquered the World,* New York, NY: Random House.

Sheremata, W.A. (2004), "Competing Through Innovation in Network Markets: Strategies for Challengers," *Academy of Management Review*, 29 (3), 359–377.

Shurmer, M. (1993), "An Investigation into Sources of Network Externalities in the Packaged PC Software Market*," Information Economics and Policy*, 5 (1), 231-251.

Shy, O. (1996), "Technology Revolutions in the Presence of Network Externalities," *International Journal of Industrial Organization*, 14 (6), 785-800.

Shy, O. (2001), *The Economics of Network Industries,* New York, NY: Cambridge University Press.

Sinha, R.K. and M. Chandrashekaran (1992), "A Split Hazard Model for Analyzing the Diffusion of Innovations," *Journal of Marketing Research*, 29 (1), 116–27.

Slaven, A. (2002), *The Video Game Bible, 1985-2002*. Victoria, Canada: Trafford Publishing.

Srinivasan, R., G.L. Lilien and A. Rangaswamy (2004), "First In, First Out? The Effects of Network Externalities on Pioneer Survival," *Journal of Marketing*, 68 (1), 41-58.

Srinivasan, R., G.L. Lilien and A. Rangaswamy (2006), "The Emergence of Dominant Designs," *Journal of Marketing*, 70 (2), 1-17.

Sterling, C.H. and J.M. Kittross (2002), *Stay Tuned: A History of American Broadcasting*, 3rd edition. Mahwah, NJ: Lawrence Erlbaum Associates Publishers.

Stieglitz, N. and K. Heine (2007), "Innovations and the Role of Complementarities in a Strategic Theory of the Firm," *Strategic Management Journal*, 28 (1), 1-15.

Strang, D. (1991), "Adding Social Structure to Diffusion Models: An Event History Framework," *Sociological Methods & Research*, 19 (3), 324-353.

Stremersch, S. and G.J. Tellis (2004), "Understanding and Managing International Growth of New Products," *International Journal of Research in Marketing*, 21 (4), 421-438.

Stremersch, S., A.M. Weiss, B.G.C. Dellaert and R.T. Frambach (2003), "Buying Modular Systems in Technology-Intensive Markets," *Journal of Marketing Research*, 40 (3), 335-350.

Stremersch, S., E. Muller and R. Peres (2010), "Does New Product Growth Accelerate Across Technology Generations?," *Marketing Letters*, forthcoming.

Stremersch, S., G.J. Tellis, P.H. Franses and J.L.G. Binken (2007), "Indirect Network Effects in New Product Growth," *Journal of Marketing,* 71 (3), 52-74.

Sun, B., J. Xie and H.H. Cao (2004), "Product Strategy for Innovators in Markets with Network Effects," *Marketing Science*, 23 (2), 243-254.

Sutton, J. (1991), *Sunk Costs and Market Structure*, Cambridge, MA: MIT Press.

Tam, P-W. (2000), "Army of Programmers Helps Palm Keep Its Edge – Loyal Independent Designers Decline to Adapt Software for Rival Microsoft System," *Wall Street Journal*, June 1, B1.

Teece, D. (1986), "Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing, and Public Policy," *Research Policy*, 15(6), 285–305.

Tellis, G.J., S. Stremersch and E. Yin (2003), "The International Takeoff of New Products: The Role of Economics, Culture, and Country Innovativeness," *Marketing Science*, 22 (2), 188-208.

Thomas, L.A. (1995), "Brand Capital and Incumbent Firms' Positions in Evolving Markets," *Review of Economics and Statistics*, 77 (3), 522–34.

Thum, M. (1994), "Network Externalities, Technological Progress, and the Competition of Market Contracts," *International Journal of Industrial Organization*, 12 (2), 269-289.

Tucker, C. (2006), "Interactive, Option-Value and Domino Network Effects in Technology Adoption," *working paper*, Sloan School of Management, Massachusetts institute of technology.

Tushman, M.L. and P. Anderson (1986), "Technological Discontinuities and Organizational Environment," *Administrative Science Quarterly*, 31 (3), 439-456.

Utterback, J.M. (1994), *Mastering the Dynamics of Innovation*, Boston, MA: Harvard Business School Press.

Utterback, J.M. and F.F. Suarez (1993), "Innovation, Competition and Industry Structure," *Research Policy,* 22 (1), 1-21.

Valente, T.W. (1995), *Network Models of the Diffusion of Innovations.* Cresskill, NJ: Hampton Press.

Van den Bulte, C. (2000), "New Product Diffusion Acceleration: Measurement and Analysis," *Marketing Science*, 19 (4), 366-80.

Van den Bulte, C. and G.L. Lilien (2001), "Medical Innovation Revisited: Social Contagion versus Marketing Effort," *American Journal of Sociology*, 106 (5), 1409-1435.

Van den Bulte, C. and S. Stremersch (2004), "Social Contagion and Income Heterogeneity in New Product Diffusion: A Meta-Analytic Test," *Marketing Science*, 23 (4), 530-544.

Varian, H.R., J. Farrell and C. Shapiro (2004), *The Economics of Information Technology; An Introduction,* New York, NY: Cambridge University Press.

Venkatraman, N. and C. Lee (2004), "Preferential Linkage and Network Evolution: A Conceptual Model and Empirical Test in the U.S. Video Game Sector," *Academy of Management Journal,* 47 (6), 876–892.

Viswanathan, S. (2005), "Competing Across Technology-Differentiated Channels: The Impact of Network Externalities and Switching Costs," *Management Science*, 51 (3), 483-496.

Wade, J. (1995), "Dynamics of Organizational Communities and Technological Bandwagons: An Empirical Investigation of Community Evolution in the Microprocessor Market," *Strategic Management Journal*, 16 (6), 111-133.

Wheelwright, S.C. and K.B. Clark (1992), *Revolutionizing Product Development: Quantum Leaps in Speed, Efficiency, and Quality*, New York, NY: Free Press.

Williams, D. (2002), "Structure and Competition in the U.S. Home Video Game Industry," *International Journal of Media Management,* 4 (1), 41-54.

Witt, U. (1997) ""Lock-in" vs. "Critical Masses" - Industrial Change under Network Externalities," *International Journal of Industrial Organization*, 15 (6), 753-773.

Wooldridge, J.M. (2002), *Econometric Analysis of Cross Section and Panel Data.* Cambridge, MA: MIT Press.

Wuyts, S., S. Stremersch, C. Van den Bulte, and P.H. Franses (2004), "Vertical Marketing Systems for Complex Products: A Triadic Perspective," *Journal of Marketing Research*, 41 (4), 479-487.

Xie, J. and M. Sirbu (1995), “Price Competition and Compatibility in the Presence of Positive Demand Externalities,” *Management Science*, 41 (5), 909-926.

Yoder, S.K. (1990), “Sony to Market Digital Tape Decks in U.S.,” *Wall Street Journal*, June 5, B4.

Yoffie, D.B. (1997), *Competing in the Age of Digital Convergence*, Boston, MA: Harvard Business School Press.

Ziegler, B. (1994), “IBM to Spend $100 Million on Ad Blitz to Launch Two PC Lines, New Image,” *Wall Street Journal*, September 19, B9.

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# SYSTEM MARKETS
## INDIRECT NETWORK EFFECTS IN ACTION, OR INACTION?

In this dissertation, I empirically examine system markets up close. More specifically I examine indirect network effects, both demand-side and supply-side indirect network effects. Indirect network effects are the source of positive feedback in system markets, or so network effect theory tells us. Systems are composed of complementary and interdependent products, such as hardware and software. For instance, a video game system is composed of the video game console, on the one hand, and video games, on the other hand.

Surprisingly, I find that the positive feedback cycle of indirect network effects is less pervasive, or at least more complex, than "current wisdom" would have us believe. Supply-side and/or demand-side indirect network effects, as traditionally operationalized, are often not present. When present, they display strong heterogeneity. There is often no positive feedback cycle present in the initial stage of the system's life cycle. Software quantity is of little importance, while software products of exceptional high quality (i.e., superstars) play an important role. Our empirical studies identify numerous factors marketing manager can manipulate to influence the positive feedback cycle. Subsequently marketing managers can incorporate our findings in their marketing strategy, and outmaneuver competitors (i.e., competing systems, fellow complementors).

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P.O. Box 1738, 3000 DR Rotterdam
The Netherlands

Tel. +31 10 408 11 82
Fax +31 10 408 96 40
E-mail info@erim.eur.nl
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