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Arati Srinivasan

Boston University, arati@bu.edu

N. Venkatraman

Boston University, venkat@bu.edu

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THE ROLE OF INDIRECT NETWORK EFFECTS IN EXPLAINING PLATFORM DOMINANCE IN THE VIDEO GAME INDUSTRY (2002-2006): A NETWORK PERSPECTIVE

*Le rôle des effets de réseau indirects pour expliquer la dominance des plateformes dans
l'industrie du jeu vidéo (2002-2006) : une perspective centrée sur le réseau*

Completed Research Paper

Arati Srinivasan
School of Management
Boston University
arati@bu.edu

N.Venkatraman
School of Management
Boston University
venkat@bu.edu

Abstract

Going beyond the traditional operationalization of indirect network effects as the number of complements available, this study focuses on the network positions of platforms and complementors to explain platform dominance. We use data from the U.S. home video game industry between 2002 and 2006 to test our model. While the impact of degree of linkages with complementors is not significant, our findings support that platform dominance is positively influenced by a greater variety of links with complementors and lesser degree of overlap with other platforms. We find support for the impact of complementor dominance on platform dominance and that this impact decreases with platform age. Our results have important implications for research in indirect network effects and also important managerial implications. Platform providers need to focus on making their platforms more heterogeneous and providing the third party developers with toolkits that encourage them to develop titles exclusively for a platform.

Keywords: Indirect network effects, platforms, video game industry, variety, overlap, complementor dominance

Résumé

Le but de cette étude est d'aller au-delà de la définition traditionnelle des effets indirects du réseau comme fonction du nombre de biens complémentaires disponibles, en mettant l'accent sur les positions de réseau des plates-formes et des fournisseurs de biens complémentaires pour expliquer la domination des plates-formes dans l'industrie du jeu vidéo.

Introduction

The high-tech industry is an example of an industry characterized by system-based competition where a single firm does not have all the resources to meet the end customers' requirements (Shapiro and Varian 1998). Such firms, hence, rely on third-party developers to provide complementary products that jointly appeal to end customers (Baldwin and Clark 2000; Garud et al. 2003). Under such settings, software and hardware together form a system and competition is platform-based rather than product-based where a particular standard may not become dominant because of inadequate support from the developer network (Katz and Shapiro 1994; Schilling 2002). Therefore, the ability of firms to attract and manage a network of complementors to develop products in line with their platform architecture becomes more crucial to their success than merely providing superior technological features (Cusumano and Gawer 2002). As a result, there is a growing stream of research to understand the role of complements in driving hardware adoption.

Most prior research on indirect network effects has, however, treated the relationship between complementors and firms as a black box and focused on understanding the impact of the number of complementors and hence, the number of complementary goods available, on hardware sales. For instance, Gandal et al. (2000) in their study of the compact disc industry analyzed the impact of the number of CD titles available on the diffusion of CD players. Similarly, Nair et al. (2004) used the number of software titles available for different PDAs as a measure of complementary network effects. In the video game industry, Clements and Ohashi (2005) and Prieger and Hu (2006) studied the impact of the number of game titles available on hardware sales. While all these studies used the same operationalization of complementary network effects, the results obtained were conflicting. While Gandal et al. (2000) and Nair et al. (2004) found a positive impact of software availability on hardware sales, Clements and Ohashi (2005) found that the impact of software availability increased over time. On the other hand, Prieger and Hu (2006) found that the impact of software availability was more crucial in the early stages of the platform which directly contradicted the findings of Clements and Ohashi (2005).

In addition to such conflicting results, Stremersch et al. (2007) found in their review that most prior research has been inconsistent and incomplete in their definition and operationalization of indirect network effects. They underscored the need for newer and better conceptualizations of indirect network effects that goes beyond the mere availability of a large amount of software on hardware sales. Our study, therefore, is a response to move beyond the 'black box' view of indirect network effects and understand what aspects of the relationship between platform providers and complementors are most likely to help achieve platform dominance. We adopt a network perspective to understand the impact of indirect network effects on platform dominance.

The network perspective has been used extensively to understand inter-organizational alliances across multiple industries (Ahuja 2000; Dyer and Singh 1998; Gulati 1995). Firms have typically relied on collaborative alliances to access resources and knowledge not already available inside the firm (Powell et al. 1996). Studies have focused on understanding how firms choose alliance partners and the impact of such partnerships on firm performance (Ahuja 2000; Kogut et al. 1995).

Within system-based competition, although no formal agreements exist between platform providers and complementors, a network perspective is still useful in understanding the impact of indirect network effects. Relationships with complementors, although implicit, provide resources critical to the success of many high-technology systems due to inherent mutual dependency between the parties within the system (Venkataraman and Lee 2004). Platform providers invest significant resources to attract developers to their platform and in turn, third-party developers commit resources to develop software for a platform over time. Platform providers attract developers to their platforms not just by creating hardware of superior quality but also by providing them with toolkits that simplify the software development process. Such toolkits in addition to providing basic training to the developers also contain libraries of commonly used modules that the developer can incorporate into their design

(von Hippel and Katz, 2002). For instance, the Windows operating system simplifies the software development process by providing access to APIs (Application Programming Interfaces) which are interfaces that are ‘exposed’ and ‘documented’. These APIs allow more flexibility and control to software developers in designing their applications. The software developers, on the other hand, invest significant resources in understanding the APIs and customizing their applications to a specific platform. As a result, platforms that are able to derive the maximum benefits from such relationships are more likely to achieve dominant positions than those that do not.

Our main contribution in this paper is, therefore, to go beyond prior operationalization of indirect network effects as the number of complements available to include other characteristics of the network in which the complementors and platforms are embedded. We argue that those platforms that are supported by a more diverse set of complementors and those platforms that have the exclusive commitment of developers are likely to be in a more advantageous position than those platforms that merely have a large network of complementors. Also, studies on the impact of network structure on firm performance have found that a firm’s position in the network and the position of its network partners, impacts its ability to access resources. For instance, firms that are connected to dominant partners or partners with more linkages themselves are more likely to have access to superior resources (Ahuja 2000) and are also more likely to signal legitimacy and stability (Oliver 1990). Therefore, in this study we attempt to understand the impact of the preferential attachment decisions of dominant developers on platform sales. Finally, we further extend this research by including platform age as a contingency and arguing that the impact of complementor dominance on platform sales diminishes with platform age.

Our study is an attempt to link direct network effects with indirect network effects by explicitly recognizing the characteristics of the network of complementors and platform manufacturers that drive platform dominance. Thus, our study is in the spirit of recent network studies that have focused on understanding the impact of network positions of firms in explaining firm performance.

Background: Network Effects in the Video Game Industry

We chose the video game industry as the context of our study because of the importance of network effects in the industry. Two types of network effects operate here: (a) direct or consumer network effects where value to the customer accrues directly from increased network size and (b) indirect or complementary network effects where value accrues due to the availability of more complements for a platform (Stremersch et al. 2007).

In the context of the video game industry, a videogame system consists of a videogame console (or the hardware platform) and game titles (or the software). The success of a videogame console depends on the availability of game titles for it resulting in the importance of indirect network effects. For example, the success of Playstation 2 is attributed largely to the strength of video game titles available on it.

The U.S. home video game industry has witnessed a rapid growth over the past few years. This growth can be partly attributed to rapid improvements in console quality as a result of which console manufacturers introduce newer generations of their consoles approximately every five years. Since the emergence of the home video game industry in 1976, there have been seven video game generations each with significant improvements in transistor and microprocessor and graphics capabilities (Gallagher and Park 2002). In addition, each of these generations has seen the emergence of new dominant platforms with firms developing the dominant platform in one generation unable to retain dominance in the next generation.

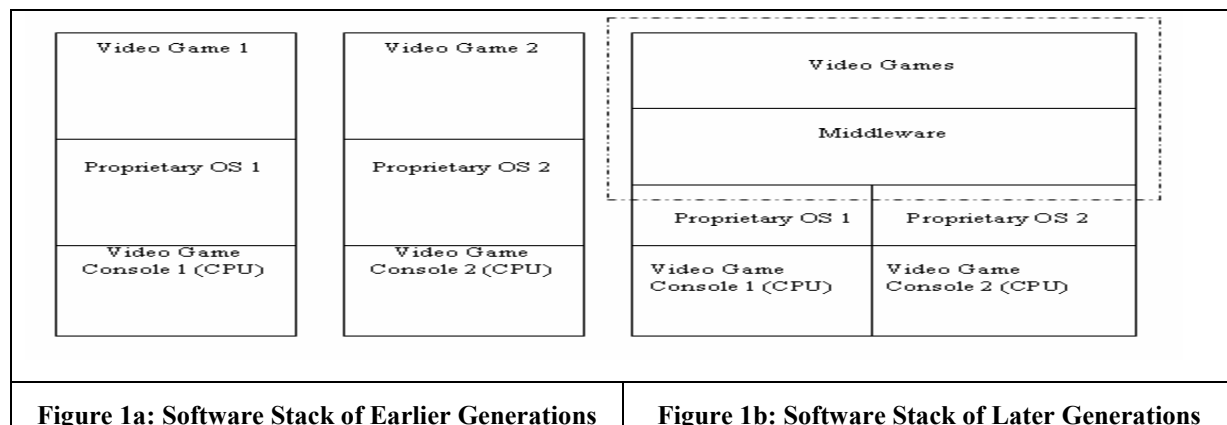
The first generation of home video games came into being with the introduction of the cartridge-based systems by Magnavox and Atari. The use of replaceable cartridges offered customers a wide variety of games. This also marked the beginning of licensing of games from third party developers. Atari’s success in licensing home versions of popular arcade games resulted in its dominance in the early history of the video game industry. However, Atari’s dominance was threatened in the 1980s with the introduction of a second generation video game system by Coleco called the Colecovision. Coleco was also able to succeed by licensing popular arcade games and by also marketing an adapter that allowed Colecovision to play Atari games. The third generation began with the introduction of the Nintendo Entertainment System (NES) which had superior graphic capabilities than earlier systems. In order to maintain dominance, Nintendo controlled which third party developers could license its system and also maintained its own in-house game development. In addition, it also made exclusive deals with game developers which meant that a game developed for NES could not be built for a rival system for two years. To challenge the dominance of Nintendo, firms like Sega and NEC introduced the Sega Genesis and the Turbo Grafix -16 systems respectively which were based on 16-bit graphic processors. This marked the creation of the fourth generation. The growing

popularity of the Sega Genesis meant that Nintendo no longer able to retain exclusive deals with its licensees and games were now allowed to be developed for multiple competing platforms. The fifth generation of video games was created with the introduction of 32-bit video game systems by 3DO and Sega (Saturn). This generation also saw the entry of Sony into the industry with its popular Playstation video game system followed by the introduction of the popular N64 by Nintendo. The success of the Playstation and the N64 could also be attributed to their strong support from complementary game developers. The sixth generation was introduced with the Sega Dreamcast which was a 128-bit system. This was followed by the introduction of the popular Playstation 2, the Microsoft Xbox and the Nintendo GameCube. Microsoft attempted to establish its presence in this industry by attracting third party developers by providing extensive support in the form of toolkits and also by offering non-preferential licensing schemes (Gallagher and Park 2002). Finally, the seventh generation of video game systems is underway with Sony Playstation 3, Microsoft Xbox 360 and the Nintendo Wii vying for dominance.

This historical overview of the video game demonstrates the importance of the role played by third party developers in driving platform dominance. It is also interesting to note that due to changes in the nature of licensing agreements and also improvements in technology there has been a growing increase in the number of non-exclusive game titles developed on a platform. In the early days of the video game industry, the consoles were incompatible with each other and developers needed to spend a considerable amount of time and effort in redesigning, rewriting and retesting games for different consoles making it cumbersome to develop similar game titles for multiple platforms. However, over time, while the hardware has remained incompatible, the rise of sophisticated middleware has reduces the costs associated with porting games across platforms. This implies that software code, designs and components developed for one console can be ported within minimum modifications to other consoles (Baldwin and Clark 2000). We present a stylized software stack of the video game industry in Figures 1a and 1b that demonstrate the evolution of video game systems across generations. Figure 1a shows the stack when there was no middleware and it was cumbersome to develop games across multiple platforms. Figure 1b demonstrates the use of middleware for easy porting of games. The ability to port games across consoles has resulted in a greater overlap of game titles across platforms. This implies that platforms have fewer unique offerings as opposed to their competitors and therefore, need to re-focus their attention on building exclusive deals with complementors. Finally, over time, game publishers have become larger in size and dominance. They are, therefore, investing a lot of resources in the advertising and promotion of their games which means that platform providers may benefit more from establishing relationships with larger and more prominent publishers. Given these characteristics of the video game industry, we believe that it is an ideal setting for our study.

In addition, the characteristics of the video game industry also make it an appropriate setting to apply the network-based perspective to understand the impact of indirect network effects. As mentioned previously, the success of a video game console depends upon the availability of software titles. However, there is significant heterogeneity in the quality of games with a only a small percentage of games becoming hits (Corts and Lederman 2007) and thereby, driving platform sales. This implies that the number of game titles may not be the only aspect of the indirect network effect in explaining platform sales. Moreover, games belong to multiple genres and platform providers need the support of developers across different genres to cater to different markets.

As a result of these changing characteristics of the dynamic video game industry, our study focuses on the sixth and seventh generation video game consoles where the battle for dominance has been largely shaped by the characteristics of the complementors that the console manufacturers have partnered with.



| with no Porting Capabilities | with Porting Capabilities |
|------------------------------|---------------------------|
|------------------------------|---------------------------|

Theory and Hypotheses

Our study is motivated by the need to go beyond an understanding of the impact of the number of complementors and hence, the number complements on platform dominance, to also look at the impact of the differential network positions of complementors and platform providers. Prior research on indirect network effects has so far implicitly treated all complementors as equal and has therefore, assumed that building a large network of complementors and hence, complements is sufficient to achieve platform dominance. While having a large base of complementors may be one important strategy employed by firms, there is also a need to recognize that there is a degree of differentiation between complementors and firms may indeed be deriving the most benefit from their relationships with only a few important complementors. A network perspective, therefore, would provide insight into what aspects of the relationship between complementors and platform providers are crucial in achieving platform dominance. Therefore, before we discuss our hypothesis, in the following section we present an overview of the important network concepts that we will be using for this research.

Network Concepts

Networks have become an important area of focus in management research and a number of conceptualizations and constructs have been used to understand firms' positions in the network and the consequences of those positions. In its broadest conceptualization, a network is a set of nodes and relationships that link two nodes together (Barabasi 2002). The nodes are actors and can be individuals, groups of people or organizations depending upon the context of the study. A tie, also known as a link connects two actors together and multiple ties combine to form the network (de Nooy et al 2005). In the context of the video game industry, the actors are console manufacturers and game developers and the ties are the games that are developed by game developers for a console. The constructs that we are interested in for this research are degree centrality, tie variety and degree of overlap. Centrality is perhaps the most commonly analyzed network measure. Degree centrality of a node reflects the number of ties/linkages an actor has to other actors. Centrality of an actor is important as it reflects the power/status of an actor (Oliver, 1990) and also implies that actors with more ties have access to more knowledge resources and hence more likely to succeed (Ahuja 2000; Gulati, 1995). Ties can be of different types such as friendship ties, alliances, trade ties between countries etc. An actor with a more diverse set of ties is likely to have access to a greater variety of resources. In the context of the video game industry, the variety of ties is reflected in the genres of video games developed for a console. Each game genre is coded as a unique type of tie between a console manufacturer and a game developer. A greater variety of game genres is more likely to appeal to a broader customer base. Finally, another important network measure that we use in this study is the degree of overlap. Two actors are said to have a high degree of overlap when they have ties to the same set of actors (Podolny and Stuart 1995). A high degree of overlap between actors reduces the competitive position of the actors as they have access to the same resources and also have nothing to unique to offer as opposed to their competitors. In the video game industry, the degree of overlap is the extent to which two console manufacturers have the same games developed on their respective platforms. Therefore, consistent with the network perspective, our conceptual model is based on treating indirect network effects as not just accruing from the number of complements, but also from the variety of complements, the exclusivity of complements and the dominance of complementors.

With this review of key network concepts, we present our hypotheses below.

Hypothesis 1. Degree of ties with complementors and platform sales

Our first question is how the number of complementary products influences platform sales. From a network perspective, the number of complementary game titles released for a console represents the degree of ties between the complementors and platform providers. Several network studies in the past have studied the relationship between a firms' degree in its network of relationships on outcomes such as a firms' innovation output (Ahuja 2000) and performance (Kogut et al. 1995; Powell et al. 1996; Rowley et al. 2000). For instance, Ahuja's (2000) study of the chemical industry found that a firm's degree centrality positively influenced its innovation output. Powell et al (1996), similarly, found that centrality of firms in their network of relationships in the biotechnology industry resulted in more rapid subsequent growth.

While the above studies analyze the impact of a firm's degree of ties in a network of formal relationships or alliances between firms, in industries characterized by system-based competition, there are no formal agreements between the focal firm and its set of complementors. Therefore, each tie between a firm and its complementors represents a commitment by a complementor to lend its support to a particular platform.

The ability to garner the commitment of a larger set of complementors implies a greater availability of complementary products. The availability of complementary products in turn influences users' choices among platforms and hence, the size of the installed base of that platform (Schilling 2002). As a result, platform developers expend considerable amount of resources in trying to build a large ecosystem of complementors. Most prior studies on indirect network effects have analyzed the impact of the number of complementary products available for a platform on platform sales (Gandal et al. 1999, Nair et al., 2004, Ohashi 2003).

In the video game industry, Clements and Ohashi (2005) empirically assessed the impact of the number of game titles available on hardware sales. They used data from video game industry from 1994-2002 and found that as the number of game titles available on any given console increases, it becomes more attractive to the consumer and hence results in an increase in hardware sales. More recently, Prieger and Hu (2006) also empirically assessed the impact of the availability of game titles on hardware sales and found that while there was a positive influence of software availability on hardware sales, this effect became weaker over time. They used data from 2002-2006 which is the same time period of our study. Therefore, our hypothesis is a direct replication of prior work on indirect network effects in the video game industry. We hypothesize that:

H1: Degree of ties with complementors will have a positive impact on platform sales

Hypothesis 2. Variety of ties with complementors and platform sales

Our second question is how the variety of complementors' offerings influences platform dominance. While degree typically measures the presence or absence of ties and treats them all as the same, ties differ on a number of dimensions such as their strength and also the type that exist between the partners in the network. Firms dealing with heterogeneous market segments benefit from a greater variety of partners (Gulati and Garguilo 1999). Powell et al (1996) in their study of the biotechnology industry found that firms with access to a more diverse set of activities were in more information-rich positions which subsequently influenced how well connected a firm became. In another study of the biotechnology industry, Baum et al. (2000) found a positive influence of the impact of partners' resources on firm performance. Similarly, Beckman and Haunschild (2002) found a positive relation between firm performance and its ties to heterogeneous partners as this diversity resulted in diverse information and knowledge.

In industries characterized by system-based competition, the diversity in the offerings of a firm's complementary products can influence its performance. A platform that can support a larger variety of software will be able to reach out to different markets and hence improve its sales. In their study of the microcomputer software industry, Cottrell and Nault (2004) found that platforms that covered more application categories (such as spreadsheets, word processors and databases) performed better as their experienced economies of scope in consumption. In addition, they argued that customers preferred to purchase a variety of software from the same vendor. This implies that having ties to developers who produce a variety of software titles may be more beneficial than linking to developers who produce niche applications.

In the video game industry, the variety of the complementary products can be understood in terms of the video game genres available. Video games typically belong to different genres such as action, action-adventure, role-playing, party games etc. Different genres of games may be attractive to different demographics of the video gaming population. As a result, a video game console manufacturer who is able to attract a larger variety of game developers that produce games of different genres may be able to attract a wider range of video gamers and hence improve its sales. We, therefore hypothesize that:

H2: The variety of ties with complementors will have a positive impact on platform sales

Hypothesis 3. Degree of overlap of software complements and platform sales

We, next, focus on the question of how the degree of overlap of software complements (i.e., game titles) between two or more consoles influences platform sales. The resource based view of firm states that firms that have rare, inimitable and valuable resources enjoy competitive advantage (Penrose 1959). Population ecology extends this

view to understand the dynamics of competition by taking into consideration the impact of the overlap of the resource positions of organizations. Baum and Singh (1994) in their study of day care centers found that high levels of niche crowding increased the potential for competition of resources, which in turn had a positive influence on organizational mortality.

Podolny and Stuart (1995) extended this stream of research to develop the concept of technological niches which is based on the idea that organizations compete on multiple dimensions and hence occupy niches in multiple domains. In the context of their paper they defined niche overlap between two organizations in a technological network as a function of the degree of common dependence on prior inventions. They used the idea of niche overlap in the network as a measure of competition and argued that greater crowding (sum of niche overlaps) negatively influenced a firm's chances of survival.

In industries characterized by system-based competition, a high degree of overlap between platforms suggests that platforms are competing for the same third-party developers and their offerings. Having the same third-party developers develop similar applications on multiple platforms results in a lack of differentiation between platforms and hence reduces the relative attractiveness of a particular platform. Tanriverdi and Lee (2008) in their study of the software industry found that firms that pursued a platform relatedness strategy (by making their operating system APIs similar to those of other operating systems) experienced lower market share than firms that did not pursue such a strategy.

Specifically, in the video game industry there is competition among the console manufacturers to attract developers to develop games for their platforms. Therefore, a platform's niche can be conceptualized as the game titles that have been released for that platform (Venkataraman and Lee 2004). There is an overlap of platform niches when a title is released for more than one platform. A video game platform that has a high degree of overlap with another platform is less likely to provide anything unique to the customer and is more unattractive than a platform with a low degree of niche overlap. Our argument is supported by Corts and Lederman (2007) who in their study of the video game industry found that the presence of exclusive or non-exclusive titles affected the relative utility of the different alternatives and thereby, which console a consumer ultimately chose. However, while they studied the impact of software exclusivity on an individual consumer's choice of a console, we studied the impact of the extent of overlap at the level of platform sales. As a result, our hypothesis is:

***H3:** High degree of overlap of software complements will have a negative impact on platform sales*

Hypothesis 4: Complementor dominance and platform sales

Finally, we address the question of how the position of a game developer in the network of game developers and platform providers influences platform sales. A large stream of research on alliances and networks has focused on how firms choose alliance partners and its implications for performance. For instance, Gulati (1995) found that firms tended to partner with firms that they had linked to in the past which in turn determined alliance success. In addition, Oliver (1990) found that firms were attracted to more dominant actors in the network for reasons of stability and legitimacy. By developing ties to larger and well-known companies, a firm was able to attain prestige and hence greater legitimacy. Baum and Oliver (1992) in their study found that day cares were able to increase their legitimacy by partnering with prominent organizations in the community.

Similarly, Podolny (2001) also found that the value of connecting to high status partners increased when there was high altercentric uncertainty i.e. when there is a high amount of uncertainty regarding the quality of the output of the product brought to the market. This argument is especially relevant under system-based competition where the design and launch of complementary software is based on formal and informal agreements between third party developers and platform providers (Venkataraman and Lee 2004). Specifically, in the case of the video game industry, the ability of a console manufacturer to attract the most dominant publishers to publish games on their platform acts as a signal to the end customer about the quality of the console and the games developed for it. Moreover, the ability of the console manufacturer to attract the most dominant developers may also mean that some of the most popular games are built for their platform. This is because some of the best selling games have been developed by the top video game publishing houses. For instance, the Madden NFL Series, one of the best selling games of all times is developed by Electronic Arts, one of the largest and most well known video game developers.

Therefore, while the presence of dominant complementors serves as a signal of status and legitimacy, there may be other benefits to having dominant complementors as well. Developing relationships with dominant complementors

often provides access to superior resources (Ahuja 2000). As a result, there will be greater benefit to link to partners that are well positioned in the network. In the case of the videogame industry, developing ties to dominant publishers who have the most resources to invest in the advertising and promotion of their games, could translate into greater visibility and popularity of the video game console itself. Therefore, we hypothesize that:

H4a: *Dominance of complementors will have a positive impact on platform sales*

We further argue that the impact of the dominance of complementors will be moderated by the age of the platform. Firms that are newer are likely to have higher mortality rates since they are yet to develop strong ties to customers and suppliers (Stinchcombe 1965). As a result, younger firms are likely to have lower levels of legitimation than older firms and hence firm age acts as a signal of the quality of firm (Sorenson and Stuart 2000). Rothaermel and Boeker (2008) also used the case of the biotechnology industry to argue that as firms became older and evolved, they were more likely to gain legitimacy and credibility, were more likely to have a dense web of relationships with partners and thus, had increased status.

Similarly, in the case of technology platforms, the quality of the new technology is unknown to the end customer and hence they need to rely on other signals of legitimacy and quality. Under such situations, the presence or absence of a tie acts as an information cue upon which the end customers base their quality assessments (Podolny 2001). The need for such informational cues may decrease over time as users gain experience with the technology and also as platform providers have had the time to establish strong ties with their end customers.

In the video game industry, as a new game console is introduced there is uncertainty regarding the quality of the console and the hence the console manufacturers may benefit from having a games developed by larger and more prominent game developers. On the other hand, as the console becomes older, there is less uncertainty surrounding it and the importance of having games developed by larger game developers may diminish. We, therefore, hypothesize that:

H4b: *The impact of dominance of complementors on platform sales will decrease with platform age.*

The research model is shown in Figure 2.

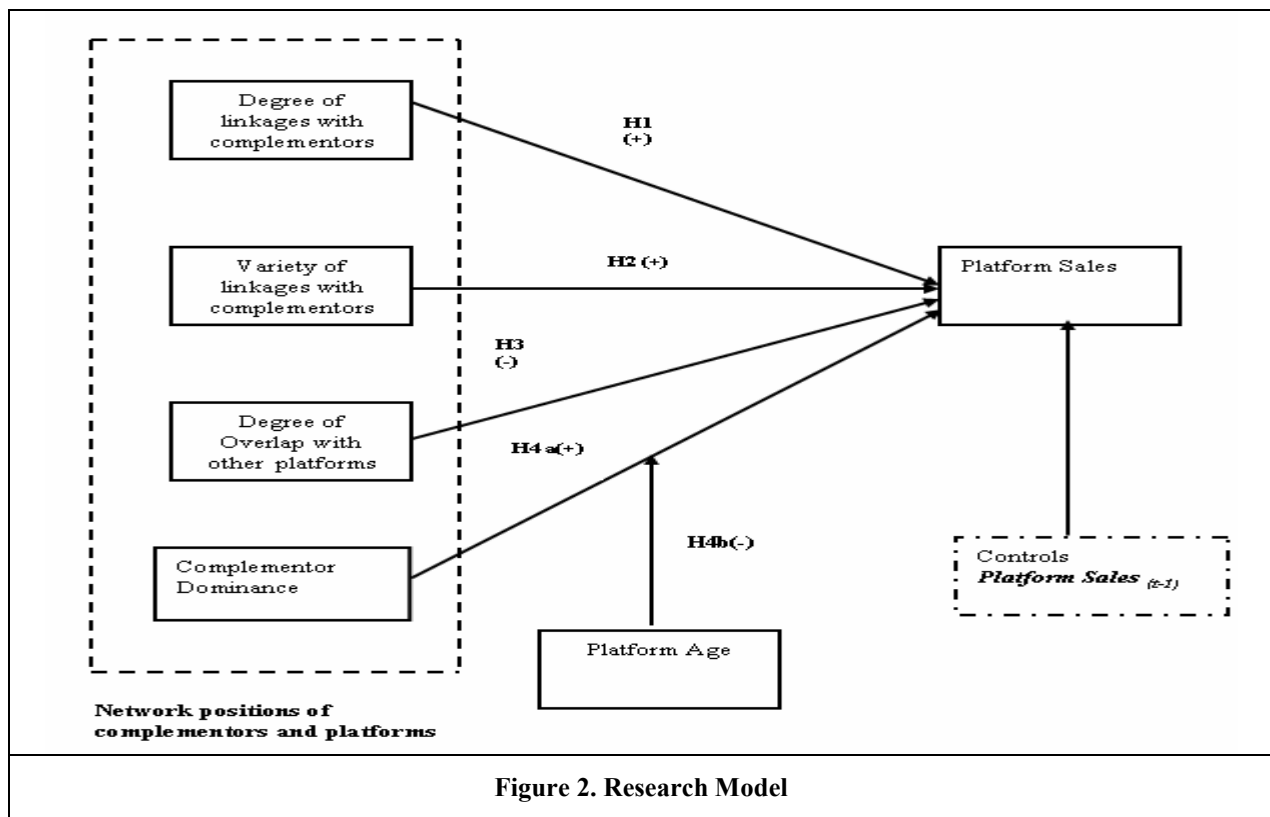


Figure 2. Research Model

Methods

Research Setting and Data

The setting for our study is the US home video game industry with data from 2002-2006 that includes the sixth and seventh generation video game consoles and the games launched on them during that time period. We assembled a unique database by collecting data from multiple sources. We first obtained monthly sales data for each console from 2002-2006 from the website www.PCvsConsole.com. This data was further validated using press releases of the NPD Group. The NPD group collects this data from the largest game retailers in the US (Clements and Ohashi 2005). We then obtained data on the games released for each console, the date of release, the game genre and the publisher of the game. This data was assembled from the website www.gamespot.com. Given the short lifecycle of both the hardware and the software titles we used monthly rather than quarterly or annual data. As a result, we have a panel data set of a total of six consoles and 2622 games titles. Since we are interested in indirect network effects accruing due to relationships with third party developers we excluded all games that were developed in-house for any console.

Construct Operationalization

Platform Sales_{i, t}. Our dependent variable is platform sales and is operationalized as the number of units sold in month t for each console i . Platform sales in this case is an indication of platform dominance. Our operationalization is in line with prior studies that have used sales as a proxy for performance (Ohashi, 2003; Shankar and Bayus, 2003).

Degree of ties_{i, t}. Each game title launched by a game developer for platform i is coded as a unique tie. We define degree of ties with complementary software providers as the proportion of software titles available for platform i in time period t . In our computation of the number of software titles available we used a three month moving window to account for aging. Therefore, for every month t , we included all the games developed between time periods $[t-2, t]$, inclusive. This is because given the short lifecycle of game titles we assume that customers will be interested only in the most recent games. A similar operationalization of availability of video game titles has been used in prior studies of the video game industry (Prieger and Hu 2006), based on evidence that often more than 50% of the sales of a video game occur during the three months after its release (Coughlan 2001).

Variety of ties_{i, t}. Variety of complementary software covers the number of video game genres spanned by a platform. We operationalize it as the proportion of genres released on a platform i in time period t . Like our operationalization of complementary software degree, we include genres introduced in the current month and the previous two months. Based on the classification scheme used in the website www.gamespot.com, video game genres were classified into eighteen categories. Since each month did not see the release of games of all genres, we computed the proportion of genres with respect to the number of genres released in month t across all platforms. For instance, if in January 2002, the number of genres of games released was 10 and Playstation 2 had games that belonged to five different genres, then the variety of links for Playstation 2 for January 2002 was 0.5.

Complementary Software Overlap_{i, t}. Overlap is a measure of the sum of the proportion of titles released on platform i that are released on platform j as well. We use the formula developed by Podolny and Stuart (Podolny and Stuart 1995) in our measurement of overlap which is as follows:

α_{ij} = proportion of i 's niches simultaneously occupied by j .

$$A_{ij} = \sum \alpha_{ij}$$

The degree of overlap is measured for game titles released in the current time period and the previous two time periods.

Complementor Dominance_{i, t}. Our measure of complementor dominance includes two components. We first measure the centrality of the game developers as the proportion of game titles released by a developer in time period t . We then measure the proportion of game titles released by game developer j for platform i in time period t . Our measure of complementor dominance is then the product of these two components. Thus, we define complementor dominance as $\sum \sum X_{ij, t} C_j$ where $X_{ij, t}$ is the proportion of game titles released by game publisher j for platform i in time period t and C_j is the centrality of publisher j .

Such a measure not only accounts for the average centrality of the complementors but also assigns a weight that captures the preferential attachment choices of the larger developers, that is, the proportion of games for a platform that are developed by the largest developers. As we did for the previous measures, we compute complementor dominance using a three month moving window.

Moderator: Platform Age_{i,t}. Platform age is defined in months as the difference between date t and console i's launch date.

Control : Platform Sales_{i,t-1}. This variable captures the impact of the previous month's sales of each console on the current month's sales. We included this as a control to avoid autocorrelation problems that are common in time series statistical models.

Descriptive Statistics

Table 1 presents the descriptive statistics that summarizes the means, standard deviations and correlations among the variables.

| Table 1. Descriptive Statistics | | | | | | | |
|---------------------------------|---------------------------|---------|---------|--------|---------|---------|-----------|
| Variables | Ln(Sales _{t-1}) | Ln(Age) | Sq(Age) | Degree | Variety | Overlap | Dominance |
| Ln(Sales _{t-1}) | 1.0 | | | | | | |
| Ln(Age) | 0.14* | 1.0 | | | | | |
| Sq(Age) | 0.02 | .77* | 1.0 | | | | |
| Degree | 0.06 | 0.25* | 0.02 | 1.0 | | | |
| Variety | 0.30* | 0.40* | 0.14 | 0.30* | 1.0 | | |
| Overlap | 0.13 | 0.37* | 0.12 | 0.36* | 0.35* | 1.0 | |
| Dominance | 0.31* | 0.31* | 0.25* | 0.08 | 0.50* | 0.22* | 1.0 |
| Mean | 11.98 | 3.18 | 1374.5 | 0.31 | 1.75 | 1.15 | 3.1 |
| S.D. | 1.79 | 0.92 | 1240.54 | 0.13 | 0.52 | 0.54 | 1.4 |

< 0.05, N = 198

Model Specification and Testing

Our dataset consists of videogame consoles that entered at different time periods, thereby requiring an unbalanced panel design. When dealing with panel data, a fixed or random effects model may be determined to be the appropriate model. Our hypotheses were tested using a cross-sectional time series fixed effects model of the following form:

$$Sales_{i,t} = \alpha \ln(Sales_{i,t-1}) + \beta \ln(age_{i,t}) + \gamma sq(age_{i,t}) + \delta degree_{i,t} + \zeta variety_{i,t} + \eta overlap_{i,t} + \theta dominance_{i,t} + \lambda (dominance_{i,t} * \ln(age_{i,t})) + \epsilon_{i,t} + v_{i,t}$$

Here $\epsilon_{i,t}$ and $v_{i,t}$ are the specific residuals and panel dummies respectively. Age and the previous month's sales (DE) were specified as logarithmic functions to allow standardization of results, consistent with prior research (Hannon and Carroll 1992). The square of age is also included in the model to detect non-monotonicity. The model was tested using Stata 9.2. Since our dependent variable was a count of the number of console units sold, a negative binomial fixed effects model was used. We also ran the analysis with the random effects model and our results were similar to those obtained from the fixed effects model.

In addition, the Hausman test was conducted to determine whether the fixed or the random effects model was the appropriate model to use. The Hausman test tests the null hypothesis that the coefficients estimated by the random effects estimator are the same as the coefficients estimated by the fixed effects estimator. Therefore, a significant p-value indicates that a fixed effects model should be used. The chi-square value of the Hausman test was 22.71 (p<

0.001) indicating that the fixed effects model was the appropriate model to use. We, therefore, present results obtained from the fixed effects model.

Results

Table 2 presents a summary of the Stata estimations of our model. We build through a series of five models. In the first model we only include the control variable. In Model 2 we introduce the direct effect of the moderator variable age. In Model 3, the degree of linkage is introduced and in Model 4 all the other network characteristics are included. Finally in Model 5 we introduce the interaction variable. All models except Model 3 are individually significant. In addition, the between model change in chi-square is also significant for all the four models except between models 2 and 3 as can be seen from Table 2. The results that we discuss below are drawn from Model 5.

| Table 2. Estimation of Model | | | | | |
|-----------------------------------------|--------------------|-------------------------|-------------------------|---------------------------|--------------------------|
| Predictor | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
| <i>Sales_{t-1}</i> | 0.31*** (0.04) | 0.26*** (0.05) | 0.27*** (0.05) | 0.22*** (0.06) | 0.22*** (0.06) |
| <i>Ln(Age)</i> | | 0.13 (0.1) | 0.12 (0.1) | 0.05 (0.09) | 0.23† (0.14) |
| <i>Sq(Age)</i> | | -1.7e-04** (6.9e-06) | -1.7e-04** (7.3e-06) | -3.8e-04*** (1.05e-04) | -2.9e-04** (1.01e-04) |
| <i>Degree</i> | | | 0.08 (.38) | 0.03 (0.38) | 0.02 (0.38) |
| <i>Variety</i> | | | | 0.04*** (0.014) | 0.04*** (0.014) |
| <i>Overlap</i> | | | | -0.03† (0.02) | -0.03† (0.02) |
| <i>Dominance</i> | | | | 0.23*** (0.03) | 0.52*** (0.15) |
| <i>Dominance* ln(Age)</i> | | | | | -0.08* (0.042) |
| <i>Constant</i> | -3.07*** (0.53) | -2.62*** (0.62) | -2.62*** (0.60) | -2.29** (0.77) | -2.97*** (0.83) |
| <i>df</i> | 1 | 3 | 4 | 7 | 8 |
| <i>Likelihood ratio</i> | -2538.56 | -2534.35 | -2534.33 | -2505.43 | -2503.41 |
| <i>Model comparison logic</i> | | (2) – (1) | (3) – (2) | (3) – (2) | (4) – (3) |
| <i>-2LL</i> | 5077.12 | 5068.7 | 5068.66 | 5010.86 | 5006.82 |
| <i>Likelihood ratio chi-squared</i> | | 8.42** | 0.04 | 57.85*** | 4.02** |

*** < 0.001, ** < 0.01, * < 0.05, † < 0.1 Std. errors in parentheses

Hypothesis 1 predicts a positive relationship between degree of ties with complementary software providers and platform sales. The coefficient is 0.02 (not significant) indicating that our hypothesis is not supported. This implies that firms with a larger set of complements do not necessarily achieve platform dominance using such a strategy. One explanation for the lack of significance of degree of ties on sales could be related specifically to the characteristics of the video game industry. For instance, only a small percentage of games turn out to be successes and as a result may be the only games that largely drive platform sales. The other explanation could be due to the fact that we only included third-party titles that may have under-represented the true level of support for the platforms. Before we discount the importance of degree of linkage, we need to rule out that rival explanation. Therefore, we ran our analysis including the games developed in-house. While the effect of degree of linkages was significant for Model 3 ($p < 0.01$), the impact did not continue to remain significant in Models 4 and 5 as additional variables were introduced.

Hypothesis 2 predicts a positive relationship between variety of ties with complementary software providers and platform share. The coefficient is 0.04 ($p < 0.001$) which is consistent with our theoretical prediction that a video game console manufacturer who is able to attract game developers that produce games of different genres may be able to attract a wider range of video gamers and hence improve its sales.

Hypothesis 3 is a test of the impact of overlap of complementary software on platform share. We predicted that high degree of overlap would negatively influence sales due to a lack of unique offerings on the platform. The coefficient is -0.03 ($p < 0.1$) indicating support for our hypothesis that operating in more crowded niches results in increased competition for resources and hence poor performance.

Finally, Hypothesis 4a tests the impact of partnering with dominant developers. We predicted a positive relationship between complementor dominance and platform sales. The coefficient is 0.52 ($p < 0.001$). This finding is consistent with research on preferential attachment that states that firms are more likely to attach to more dominant partners for reasons of status and legitimation and to have access to superior resources. Hypothesis 4b tests the impact of platform age as a moderator. The interaction term between platform age and complementor dominance is -0.08 ($p < 0.05$) which is negative and significant indicating support for our hypothesis that for older platforms the impact of platform dominance on platform sales diminishes.

The direct effect of age (the moderating variable) also presents some interesting findings. As has been done in prior studies in population ecology, we included both $\ln(\text{age})$ and the square of age in our specification. The effect of the square of age is negative and significant ($-2.9e-04$, $p < 0.01$) which indicates an inverted U-shaped relationship between platform age and platform dominance. When a platform is new there is uncertainty regarding the quality of a platform. Once users gain familiarity with the platform the uncertainty regarding the platform quality gets resolved and platform sales take-off. However, beyond a certain threshold, as platforms become older, their technical characteristics and functionality diminish relative to newer platforms, making them less attractive to game developers and end users.

Further Validation

Most prior studies on indirect networks effects in the video game industry (Shankar and Bayus 2003; Venkataraman and Lee 2004; Clements and Ohashi 2005) have computed the availability of game titles for a platform as the total number of games accumulated on a platform since its introduction. However, for our study, we acknowledged that there is an effect of aging of game titles and therefore, included only games available in the current and previous two periods. Since, to our knowledge, only one other study (Prieger and Hu 2006), included such an impact of aging, we attempted to further increase the robustness of our analysis. We, therefore, re-ran our analysis using without controlling for an aging effect. We compare the results obtained from this model with the results shown in Table 2 in Table 3. As can be noted from Table 3, including the total number of games accumulated since platform introduction, did not alter our results significantly, lending further support to the robustness of our analysis.

Table 3: Comparison of Results for Model with Three Month Moving Window for Aging with Model without Controlling for Aging Effect

| | 3-Month Aging | No Aging Effect |
|-------------------------|---------------|-----------------|
| DE | Sig. (+) *** | Sig. (+) *** |
| Ln(Age) | Sig. (+) † | Sig. (+) * |
| Sq(Age) | Sig. (-) ** | Non (-) |
| Degree | Non (+) | Non (-) |
| Variety | Sig. (+) *** | Non (+) |
| Overlap | Sig. (-) † | Sig. (-) * |
| Dominance | Sig. (+) *** | Sig. (+) *** |
| Dominance*ln_Age | Sig. (-) † | Sig. (-) † |

*** < 0.001, ** < 0.01, * < 0.05, † < 0.1

Discussion

The main contribution of this paper is to extend our understanding of factors that influence platform dominance in industries associated with strong indirect network effects. Extant research has emphasized the need for building larger networks of complementors as one strategy to achieve success. Our study highlighted the importance of platforms to develop networks that have a greater diversity of complementors, that emphasize exclusive relationships with their complementors and that most importantly, also focus on forming relationships with the most dominant complementors. Our contribution is to extend the existing research on indirect network effects by going beyond the simple operationalization of indirect network effects as the number of available complements to include the impact of relative network positions of the platforms and complementors.

The lack of significance of the degree of links with complementors reinforces the need to open the black box of indirect network effects to understand what factors beyond the number of complements influences platform dominance. Prior studies of indirect network in the video game industry have also found conflicting results. For instance, Clements and Ohashi (2005) found that the impact of software availability on hardware sales increased over time while Prieger and Hu (2006) found that the impact of software availability was more crucial in the early stages of the platform, thereby, contradicted the findings of Clements and Ohashi (2005). The reasons for inconsistencies in the results obtained could be specific to the video game industry. One possible explanation is that only a few highly popular videogame titles account for a major share of sales. Previous studies have shown that the top 100 video game titles accounted for more than 50% of the video game titles sold (Venkataraman and Lee 2004). Another potential explanation is the growing number of non-exclusive titles across consoles because of the reduced costs associated with porting. The presence of non-exclusive titles reduces the differentiation between platforms and thereby, the impact of complements on platform sales. This argument is supported by our finding that a higher degree of overlap of game titles across platforms has a negative impact on platform sales.

These findings have important managerial implications as well. They provide firms with a deeper understanding of what aspects of the complementary product are more crucial for them and hence more important to focus on. While focusing on increasing the number of games being developed for their platforms may not help console manufacturers, they need to focus on attempting to reduce the overlap of game titles with other platforms. This could translate into the development of licensing agreements that secure exclusive rights to the most popular game titles.

However, while console manufacturers prefer a lower degree of overlap of game titles with other consoles, game developers may actually benefit from being able to develop non-exclusive game titles. As a result, a possible extension to our study could be to study the ability of game developers to port games across consoles and the impact of that on both game developer and platform dominance. Future research could also focus on how platform providers can increase the heterogeneity of their platforms in the form of toolkits they provide to make them more attractive for third party developers to develop exclusive game titles. The impact of other forms of support such as tools and documentation for modding on games popularity and hence, platform sales can also be studied. In

addition, it would be interesting to analyze the differential impact of overlap on platform sales when there is a higher degree of overlap of larger developers as compared smaller or less significant developers.

While these findings are specific to the video game industry, depending upon the context of the industry and the technology itself, different aspects of the relationship with complementors could have a more significant effect than the others.

Another important contribution of this paper is to extend the research on preferential attachment to understand how the choice of developers influences platform dominance. We found that console manufacturers who were able to attract the most dominant developers to build games for their platform were more successful in increasing their own dominance. We also extended this line of reasoning by introducing platform age as a moderator. Our findings indicated that as platforms become older the impact of complementor dominance on platform sales decreases. This is an important first step in the understanding of the evolution and dynamics of complementary network effects. It is also an important contribution to existing research, as to our knowledge, no prior research has attempted to understand at what stages certain aspects of the relationship become more important than others.

The managerial implications of these findings are that firms should pay attention to the kind of complementors they are attracting to their platform. We also found a significant effect of attracting dominant developers to their platform in the video game industry. This implies that platform providers should focus their resources in trying to attract larger and more popular developers as it signals to the end users that the quality of the games on that particular platform are likely to be better. Other industries could also benefit from attracting the most dominant developers. For instance, operating systems that are able to support Microsoft applications are more likely to be successful than those that are not. Finally, our finding that platform age acts as a moderator on the influence of complementor dominance on platform sales has important managerial implications as well. It provides insight into the strategies that firms need to follow in order to achieve platform dominance. When a new platform is introduced, firms need to focus on creating legitimacy by building relationships with larger and more prominent third party developers while this may become less important as platforms become older. At this point, the focus of firms may shift to competitive differentiation and providing customers with more innovative offerings. Therefore, one strategy for older firms could be then to focus on building larger networks of complementors that allow them to focus on exploration (March 1991).

This paper also makes a contribution to network studies that have attempted to understand the impact of network characteristics on network performance (Kogut et al. 1995; Dyer and Singh 1998; Ahuja 2000). While most of these studies have analyzed formal relationships between firms, in this study we analyze the relationship that exists between a platform provider and its complementors in industries characterized by system-based competition where there are no formal or contractual agreements (beyond simple licensing deals) between the parties.

Finally, we believe that IS research community has an important role to play in advancing our understanding of the role and impacts of indirect network effects. While this paper made initial inroads into opening up the black-box of indirect network effects by adopting a network perspective, a promising area of extension is to understand the degree of overlap in terms of commonality of development architecture and similarity of development tools. Such operationalizations allow us to understand how the technical architecture impacts the choices made by videogame developers to provide the requisite games that give rise to the network effects. Fine-grained approaches that elaborate on the schematic proposed in Figure 1 would go further to link concepts of IS architecture to strategies under network-based competition.

Conclusions

Our study sought to introduce a network perspective of the pattern of links between videogame platforms and complementors to provide deeper insights into the relationship between direct and indirect network effects. Our results provide insights that go beyond simply looking at the number of complements and urge researchers dealing in settings characterized by high-tech, system-based competition to embrace concepts and approaches from network perspectives.

Our results, however, need to be seen against the backdrop of some limitations that point directions for further refinement and extensions. One: our work did not include the impact of other factors such as the pricing strategies of console manufacturers and the technological characteristics of the platform (although using a fixed effect model allowed us to control for platform specific effects). Future extensions could include these factors in addition to the

different aspects of complementarity to develop a comprehensive model of platform adoption. In addition, other next steps could be to include a time element and observe at what stages the different aspects of complementarities, installed base and pricing become important.

Two: we took steps to enhance the validity and accuracy of the data that were collected from multiple sources. While some of these sources have been used in prior published academic research, our primary database relies on data from multiple sources. We sought to validate some data elements from multiple sources wherever possible (such as with industry-standard data source of NPD Group). Overall, we are confident with the quality and accuracy of the data for estimation of the models.

Three: given our results that showed the importance of network perspective in system-based competition, it will be useful to further extend and refine the operationalization of complementor dominance and variety of links. Interesting extensions could be to derive more fine-grained measures of dominance using top-rated titles and variety of links beyond simple classification of genres towards more weighted schemes.

In all such extensions, we believe that IS research community has an important role to play by bringing insights of software architecture that enables and constrains how complementors support different platforms.

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