Strategic Management Journal
Strat. Mgmt. J., **33**: 88–106 (2012)
Published online EarlyView in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/smj.941
Received 1 September 2009; *Final revision received 25 May 2011*

ENTRY INTO PLATFORM-BASED MARKETS

FENG ZHU[1]* and MARCO IANSITI[2]
[1] *Marshall School of Business, University of Southern California, Los Angeles, California, U.S.A.*
[2] *Harvard Business School, Harvard University, Boston, Massachusetts, U.S.A.*

This paper examines the relative importance of platform quality, indirect network effects, and consumer expectations on the success of entrants in platform-based markets. We develop a theoretical model and find that an entrant's success depends on the strength of indirect network effects and on the consumers' discount factor for future applications. We then illustrate the model's applicability by examining Xbox's entry into the video game industry. We find that Xbox had a small quality advantage over the incumbent, PlayStation 2, and the strength of indirect network effects and the consumers' discount factor, while statistically significant, fall in the region where PlayStation 2's position is unsustainable. Copyright © 2011 John Wiley & Sons, Ltd.

INTRODUCTION

Much of the literature on entry focuses on understanding the order-of-entry effect (e.g., Mitchell, 1991; Robinson, Fornell, and Sullivan, 1992; Fuentelsaz, Gomez, and Polo, 2002; Dowell and Swaminathan, 2006) and how the resources and capabilities possessed by an entrant affect its post-entry performance (e.g., Schoenecker and Cooper, 1998; Klepper and Simons, 2000; Helfat and Lieberman, 2002; Lee, 2008). While several studies have found that pioneers enjoy enduring competitive advantages over late entrants (e.g., Yip, 1982; Urban *et al*., 1986; Lambkin, 1988; Lieberman, 1989; Makadok, 1998), other studies have found various situations in which pioneers could fail or lose their market leadership to late entrants (e.g., Schnaars, 1994; Christensen and Bower, 1996; Christensen, 1997; Freeman, 1997; Cho, Kim, and Rhee, 1998; Shankar, Carpenter, and Krishnamurthi, 1998; Dowell and Swaminathan, 2006). An implication of these studies is that whether a late entrant can be successful depends critically on whether first-mover advantages of early movers, or incumbents, are sustainable (Lieberman and Montgomery, 1988).

This study contributes to this stream of literature by examining when a late entrant can take over market leadership in a platform-based market. Increasingly, a larger number of industries today are organized around platforms via which multiple parties conduct transactions (Iansiti and Levien, 2004; Eisenmann, Parker, and Alstyne, 2006; Boudreau, 2010). Different from traditional, non-platform-based markets, these platform-based markets are often viewed as two-sided, because platform providers must get both consumers and developers of complementary applications on board in order to succeed. An example of such a market is video game consoles. Platform providers include Sony, Nintendo, and Microsoft, each of

Keywords: platform-based markets; winner-take-all; first-mover advantage; indirect network effects; video game industry
* Correspondence to: Feng Zhu, Marshall School of Business, University of Southern California, 3670 Trousdale Parkway, BRI 306, Los Angeles, CA 90089-0808, U.S.A.
E-mail: fzhu@marshall.usc.edu

Table 1. Examples of platform-based markets

Market	Side 1	Platform(s)	Side 2
PC operating systems	Computer users	Windows, Macintosh, Linux	Application developers
Web browsers	Internet surfers	Internet Explorer, Firefox	Plugin developers
Portable documents	Document readers	Adobe	Document writers
Online auction houses	Buyers	eBay	Sellers
Video sharing	Clip makers	YouTube	Clip watchers
Online dating clubs	Men	Match.com, AmericanSingles.com	Women
Credit cards	Cardholders	Diners Club, Visa, MasterCard	Merchants
Streaming audio/video	Content users	Windows media player, Real audio	Content creators
Search advertising	Searchers	Google, MSN, Yahoo	Advertisers
Stock exchanges	Equity purchasers	NYSE, NASDAQ	Listed companies
Home video games	Game players	Xbox, PlayStation, Wii	Game developers
Recruitment sites	Job seekers	Monster.com, Hotjobs.com	Employers

which produces (incompatible) game consoles, with each console having its own associated developer and player communities. Table 1 provides additional examples. As these examples illustrate, market dynamics often vary significantly across different markets: early movers in some markets, such as eBay and YouTube, successfully defended their market leadership from later entrants (e.g., Yahoo auction site and Google Video); in other markets, later entrants, such as Google and Visa, took over market leadership from early movers (e.g., Overture and Diners Club).

Researchers disagree about whether an entrant platform can gain or retain market share when it competes with an incumbent platform. The debate centers on the relative importance of indirect network effects, platform quality, and consumer expectations in such markets. Platform-based markets are often characterized by indirect network effects because of the interdependence between consumer demands for platforms and demands for their associated applications: more applications on a platform leads to greater demand for that platform; at the same time, a larger installed base of consumers leads to a larger supply of applications.[1] Some scholars argue that because of indirect network effects, a platform that has a small lead on both sides of the market is likely to attract more consumers and more application developers, and thus over time, it could take over the entire market even if its quality is inferior to its rivals' (e.g., Wade, 1995; Schilling, 1999, 2003; Shapiro and Varian, 1999; Park, 2004; Sheremata, 2004; Lieberman, 2007).

In contrast, several scholars argue that quality in such markets is still important and, just as in traditional markets, innovative late entrants can outsell incumbents (Liebowitz and Margolis, 1994, 1999; Rangan and Adner, 2001; Liebowitz, 2002; Suárez and Lanzolla, 2007; Tellis, Yin, and Niraj, 2009). Indeed, Evans (2003) finds that many early entrants in platform-based markets ultimately do not retain their leadership positions.

Finally, a few scholars argue that consumer expectations of the future market share of the entrant platform play critical roles in its success. Static models of indirect network effects in the economic literature largely support this expectation-driven view (e.g., Katz and Shapiro, 1994; Farrell and Klemperer, 2007). In these models, consumers often form rational expectations with respect to each platform's market size. There often exist 'monopoly equilibria,' in which all consumers and application developers adopt one platform. The monopoly outcome occurs when consumers and developers hold favorable expectations of one platform with respect to its future market size—they believe that everyone else will adopt the same platform. As entrants lack installed bases, consumers tend to hold favorable expectations of established platforms.

Understanding the relative importance of indirect network effects, product quality, and consumer expectations is of critical importance for platform providers to formulate entry strategies. In contrast to previous studies that typically look at each individual factor, we consider all three factors in a unified framework. We explicitly model the

[1] In different contexts, indirect network effects are also referred to as a 'positive feedback loop,' a 'virtuous cycle,' or 'cross-market network effects' (e.g., Lieberman, 2007; Chen and Xie, 2007).

DOI: 10.1002/smj

competition between an entrant with superior quality and an incumbent platform with an installed-base advantage, and examine market dynamics.

Our analysis suggests that whether an entrant can successfully enter a platform-based market depends critically on two parameters: the strength of indirect network effects, which measures how much consumers care about application variety, and consumers' discount factor of future applications, which measures how much consumers care about applications to be released in the future. In particular, we find that when the strength of indirect network effects and the consumers' discount factor are less than certain thresholds, an entrant with any quality advantage can gain market share over time, even when it competes with an incumbent with a very large installed-base advantage.

To demonstrate the applicability of our theoretical model, we empirically examine the competition in the video game industry between an entrant with a small quality advantage, the Xbox console, and an incumbent with a large installed-base advantage, the PlayStation 2 console. We find that consistent with our theoretical prediction, the strength of indirect network effects and the discount factor in this market, while statistically significant, are within the range in which PlayStation 2's huge installed-base advantage is unsustainable.

Our unified theoretical framework provides a positive reconciliation of the mixed views on the success of late entrants in such markets and shows that whether installed bases can deliver sustainable first-mover advantages depends critically on market conditions. The finding is consistent with other studies that find that industry contexts affect firms' entry decisions (e.g., Schoenecker and Cooper, 1998).

Our study also suggests that one cannot make an *a priori* statement for market outcomes for a given market without an empirical investigation. While previous empirical studies that examine indirect network effects in platform-based markets (Shankar and Bayus, 2003; Rysman, 2004; Venkatraman and Lee, 2004; Clements and Ohashi, 2005; Boudreau and Jeppesen, 2011) focus almost exclusively on detecting the presence of indirect network effects in specific markets, we show that statistical significance alone is insufficient, and it is important to combine theoretical frameworks with empirical analyses to understand market dynamics.

The rest of the paper is organized as follows. We first describe the model and derive equilibrium market outcomes. We then discuss our empirical strategy and report results. We conclude by discussing the study's theoretical and empirical implications as well as its limitations.

THE MODEL

We develop a formal model to examine conditions under which an entrant platform can survive the competition with an incumbent platform. In our model, two platforms, an entrant E and an incumbent I, compete head-to-head for the same consumer population. Each platform is associated with a group of consumers and application developers on each respective side of the market. The two platforms are incompatible with each other: Applications developed for one platform cannot be used on the other platform. Each application developer supplies one application. Each consumer adopts one platform.

In each time period, (1) a group of new consumers chooses platforms and purchases available applications, and (2) a group of new application developers chooses platforms, incurs fixed costs, and sells their applications to the installed base of consumers. The two sets of actions occur simultaneously. When we move to the next period, the same sets of actions are repeated. We assume, for simplicity, that each consumer allocates a fixed budget to purchase applications in each period.

We assume that in each period, the two platforms are priced at the same level. While platform providers could strategically use prices to differentiate their platforms, this assumption allows us to focus on the interactions of indirect network effects, platform quality, and consumer expectations. In addition, this assumption is valid for many platforms that are based on nonproprietary technologies or sponsored by advertisers. Even for platforms based on proprietary technologies, as in our empirical application, platform providers may choose to match each other's prices.

We first consider the interaction between the two sides of the market in each period. Our objective is to characterize how consumer demand for a platform changes with application availability, and how the supply of applications for a platform changes with its installed base of consumers. Table 2 provides definitions of all variables in our model.

Table 2. Variable definitions

E, I	Entrant and incumbent platform, respectively
Q_j	Quality of platform j, $j \in \{E, I\}$
Q	Quality ratio of the two platforms on the consumer side, $Q = Q_E/Q_I$
T	Platform's life expectancy
V_{jt}	Utility that the representative consumer receives from platform j in period t
e	Strength of indirect network effects
φ	Discount factor of consumers' future utility from applications
n_{jt}	Number of applications associated with platform j in period t
Δn_{jt}	Number of new applications released for platform j in period t
N_{jt}	Discounted total number of applications on platform j in period t
s_{jt}	Percentage of new consumers choosing platform j in period t
β_j, α_t	Console-specific and time-specific constants
b_{jt}	Installed base of platform j in period t
Δb_{jt}	Number of new consumers adopting platform j in period t
F_{jt}	Fixed cost of supporting platform j in period t
F	Ratio of fixed costs of supporting the two platforms, $F = F_{It}/F_{Et}$
δ_b, δ_d	Decay rates of the installed base and associated applications, respectively
M_t	Total number of consumers making adoption decisions in period t
$\dot{b}_{jt}$, $\dot{n}_{Et}$	Changes in the installed base and the number of applications associated with platform j in period t, respectively
e^*	Threshold for e

Consumer adoption

We use b_{jt} and n_{jt}, respectively, to denote the installed base of consumers and the total number of applications (equivalently, the total number of developers) associated with platform $j \in \{E, I\}$ at the beginning of period t. We use Q_j to denote the quality of platform j and assume that Q_j is constant over the platform's life cycle.[2] Let $T > 0$ be the platform's life expectancy. Consumers are forward-looking: they make decisions after they consider applications available today and those to be released in the future.

Following the literature (e.g., Church and Gandal, 1992; Nair, Chintagunta, and Dubé, 2004), we use a representative consumer approach to model consumer preferences. The approach provides an aggregate description of an underlying consumer population.[3] We solve the representative consumer's utility maximization problem and derive the utility the consumer receives from adopting platform j in period t, V_{jt}, as

$$V_{jt} = \beta_j + \ln Q_j + e(\ln n_{jt} + \sum_{s=t+1}^{T} \varphi^{s-t} \ln \Delta n_{js}),$$

where β_j is a constant, $e > 0$ is a constant, $\varphi \in [0, 1]$ is the discount factor of consumers' future utility from applications, n_{jt} is the current number of applications associated with platform j in period t, and Δn_{js} is the number of new applications released in period s for platform j. Hence, e here measures the extent to which consumers care about application variety. We thus use e as our measure for the strength of indirect network effects. When $\varphi = 0$, consumers place no value on future applications and they are essentially myopic. As φ approaches 1, consumers are patient and value future applications as much as those currently available. Consumer expectations of future application availability in this case could play an important role in shaping market dynamics. As we use a representative consumer approach, such parameters as Q_j, e, and φ capture the average valuation or characteristics of all consumers.

[2] Consumers may also take application quality into consideration. We do not use a separate measure for application quality for two reasons. First, platform quality is often more important. The purchase experience on an auction site, for example, depends critically on the site's design and security protection. Second, platform quality is often highly correlated with application quality. For example, applications written for a more powerful platform tend to run faster. Therefore, we use a single measure, Q_j, to capture overall quality. In addition to the technical capability of the platform, Q_j captures other factors that may affect consumers' perception of platform quality, such as brand image and effectiveness in the management of distribution channels.

[3] See the working paper version of this paper for all derivations and proofs in this paper (Zhu and Iansiti, 2010).

The valuation of platform quality, the degree to which consumers care about application variety, and the level of patience may vary in the underlying population.

Denote $N_{jt} = \exp\left(\ln n_{jt} + \sum_{s=t+1}^{T} \varphi^{s-t} \ln \Delta n_{js}\right)$. We can rewrite the above utility function as:

$$V_{jt} = \beta_j + \ln Q_j + e \ln N_{jt}. \quad (1)$$

Here N_{jt} is the discounted total number of applications and $e \ln N_{jt}$ measures a consumer's valuation of applications available today and those to be released in the future. Equation (1) suggests that the consumer's utility increases with platform quality, Q_j, and number of applications, N_{jt}, and the marginal benefit decreases as Q_j and N_{jt} increase. The functional form is consistent with Boudreau (2011), who finds that the benefit of complementary applications diminishes in the mobile computing industry. Similar functional forms are also used in empirical studies of indirect network effects, such as Ohashi (2003).

We follow the literature (e.g., Nair *et al.*, 2004; Clements and Ohashi, 2005), and use a standard logit model to capture heterogeneity in consumer tastes in platforms. The logit model, however, may raise the concern of 'independence of irrelevant alternatives,' which in this context means that we can add irrelevant platforms and they will be assigned a nonzero market share. This concern is alleviated by the fact that our analysis focuses on two platforms that compete head-to-head. The introduction of irrelevant alternatives may exert a similar effect on both platforms and, hence, may not change their market share ratio, which is the focus of our theoretical and empirical analyses. In addition, the logit model yields close form solutions for platform market shares, and, thus, provides convenience for both theoretical analysis and empirical estimation.

The percentage of new consumers who choose platform j in period t, s_{jt}, is (McFadden, 1973):

$$s_{jt} = \frac{\exp(V_{jt})}{\exp(V_{Et}) + \exp(V_{It})}. \quad (2)$$

If we substitute the expression for V_{jt} into Equation (2), we have

$$s_{Et} = \frac{QN_{Et}^e}{QN_{Et}^e + N_{It}^e} \text{ and } s_{It} = \frac{N_{It}^e}{QN_{Et}^e + N_{It}^e}, \quad (3)$$

where $Q = Q_E/Q_I$. We refer to Q as the quality ratio of the two platforms on the consumer side. It measures the entrant's quality advantage over the incumbent.

Developer entry

Developers choose platforms to maximize their profits from the sale of applications. Using the free-entry condition on the developer side, we can obtain the number of new developers supporting platform j in period t,Δn_{jt}, as:

$$\Delta n_{jt} = \alpha_t \frac{b_{jt}}{F_{jt}}, \quad (4)$$

where α_t is a function of t, and F_{jt} is the fixed cost of supporting platform j in period t. The equation suggests that an exogenous reduction in the fixed cost (F_{jt}), or an increase in the installed base of consumers (b_{jt}) could induce more application developers to enter the market.

We assume that the fixed cost drops at the same rate for both platforms and let $F = F_{It}/F_{Et}$ be the ratio of the two fixed costs. F measures the cost advantage of platform E over platform I on the developer side.

We are particularly interested in the case where an entrant with superior quality competes with an incumbent with an installed-base advantage. Therefore, in the following discussion, we assume $Q > 1$ and $QF > 1$ (i.e., the entrant's combined quality advantage and cost advantage is greater than that of the incumbent), and $b_{E,\,0} < b_{I,\,0}$ and $n_{E,\,0} < n_{I,\,0}$.[4] We now proceed to illustrate how successive adoption choices made by consumers and developers in each period eventually aggregate into a collective choice of platforms.

EVOLUTION OF MARKET STRUCTURE

We now extend the one-period model to multiple periods to examine how market shares of the two platforms change over time. As consumers may cease to use platforms or switch to other ones and application popularity tends to decrease over time,

[4] As the incumbent typically has larger installed bases on both the consumer side and application side, we use the term 'installed-base advantage' to refer to advantages in both the installed base of consumers and the application supply.

it is important to take decay in the installed base of consumers and applications over time into account.

We use $\delta_b \in (0, 1)$ and $\delta_d \in (0, 1)$ to denote the 'rate of decay' of the installed base and associated applications. Let M_t be the total number of new consumers who make adoption decisions in period t. The change of the installed base of platform E is

$$\dot{b}_{Et} = \Delta b_{Et} - \delta_b b_{Et} = M_t s_{Et} - \delta_b b_{Et} = M_t \frac{QN_{Et}^e}{QN_{Et}^e + N_{It}^e} - \delta_b b_{Et}. \quad (5)$$

Equation (5) is intuitive: the change in the installed base of platform E is the number of new consumers who adopt platform E less the number of existing consumers who exit the installed base in a given period. By incorporating δ_b, we are essentially allowing consumers to exit the market or to reconsider their platform choices. We expect δ_b to decrease with the switching cost: the more costly it is to switch, the lower is the installed base's rate of decay.

We apply the same approach to the developer side and obtain a system of four equations:

$$\dot{b}_{Et} = M_t \frac{QN_{Et}^e}{QN_{Et}^e + N_{It}^e} - \delta_b b_{Et},$$

$$\dot{b}_{It} = M_t \frac{N_{It}^e}{QN_{Et}^e + N_{It}^e} - \delta_b b_{It},$$

$$\dot{n}_{Et} = \alpha_t \frac{b_{Et}}{F_{Et}} - \delta_d n_{Et},$$

$$\dot{n}_{It} = \alpha_t \frac{b_{It}}{F_{It}} - \delta_d n_{It}.$$

As our objective is to understand when an entrant will retain or gain market share over time, we take t from 0 to T to examine market evolution.

We first examine the simple case in which consumers are myopic, i.e., $\varphi = 0$, and then discuss the forward-looking case, as many properties of the myopic case remain in the forward-looking case.

Figure 1 shows the long-run market outcomes for markets with different levels of e. We plot platform E's long-run market share on the consumer side for different values of e. The figure for the developer side is similar and thus omitted.

We find there exists a threshold e^*. When the strength of indirect network effects is above e^* (that is, when consumers care a lot about application variety), the incumbent platform evolves toward a monopoly. When the strength is lower than e^*, however, regardless of the magnitude of the incumbent's installed-base advantage, the entrant platform will take over the leadership, because its market share is above 50 percent. In particular, when e is between 0 and 1, the two platforms will coexist in the long run, each with a fixed market share. When e is between 1 and e^*, the entrant platform evolves toward a monopoly.

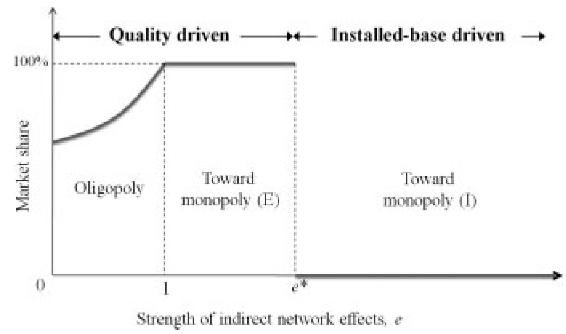


Figure 1. Long-run market share of platform E on the consumer side

There are two interesting observations. First, we observe a phase transition at e^*: When e is right below e^*, the entrant market share approaches 100 percent, but when e exceeds e^*, the incumbent market share approaches 100 percent. Second, if we focus on the oligopoly region, we find that the entrant's market share increases with e. When e approaches 1, the entrant's market share approaches 100 percent on each side. This finding suggests that the incumbent does not necessarily gain greater market share with stronger indirect network effects.

The intuition for these two observations is that in order for the incumbent to sustain or increase its installed-base advantage, the strength of indirect network effects, e, must be sufficiently strong. When e is greater than e^*, the network effects are so strong that the incumbent will always be able to protect its market share. But when e is less than e^*, the better quality platform will always win in the long run. The incumbent's installed-base advantage will erode over time, and the entrant will eventually take over market leadership, as consumers attracted by quality will outweigh consumers attracted by the number of available applications.[5] Once the entrant reaches

[5] As an example, consider the situation where the incumbent has a 95 percent market share on each side of the market and

DOI: 10.1002/smj

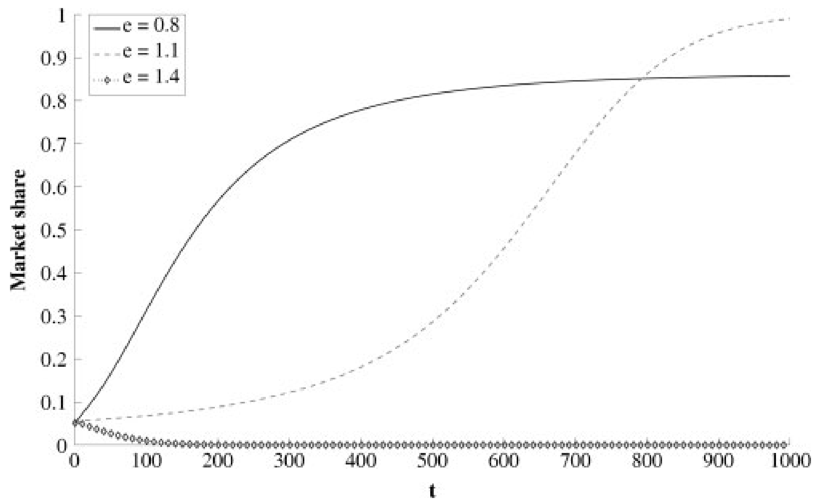


Figure 2. Evolution of platform E's market share on the consumer side for different values of e

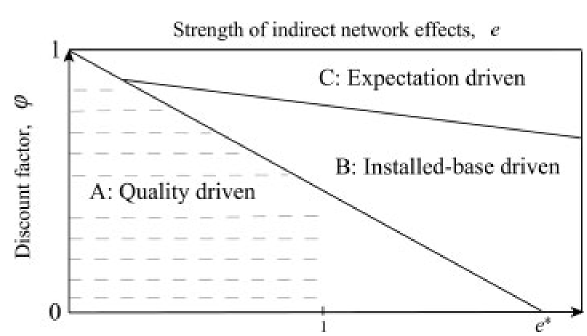
50 percent market share, the combination of quality and installed-base advantage will rapidly help the entrant take over the rest of the market. Therefore, stronger network effects can actually increase platform E's market share when $e < e^*$. Thus, an entrant with even a small quality advantage can be very successful when $e < e^*$. The threshold e^* increases with the entrant's quality advantage and decreases with the incumbent's installed-base advantage.

We refer to the left portion of the diagram, where e is less than e^*, as the quality-driven region because, in this case, quality advantage dominates installed-base advantage, and we refer to the right portion of the diagram, where e is greater than e^* as the installed-based driven region.

Figure 2 shows the evolution of platform E's market share on the consumer side for different values of e. In this example, $e = 0.8$, $e = 1.1$, and $e = 1.4$ correspond to the regions where two platforms coexist, the entrant platform evolves toward a monopoly, and the incumbent platform evolves toward a monopoly, respectively. It is important to note that in reality, a platform may exit the market well before its market share approaches zero. Hence, the market may tip much faster than illustrated here. If platforms' are short-lived, however, the market shares will be different, but they will evolve along the same trajectories.

We now extend the analysis to consider forward-looking consumers, i.e., $\varphi > 0$. When $\varphi > 0$, consumers' adoption behavior in each period influences, and at the same time is influenced by, application provision in future periods. The complexity of the model makes analytical solutions intractable, and we solve the model numerically.[6]

We summarize market outcomes in Figure 3. The horizontal axis is again the strength of indirect network effects, e, and the vertical axis is the



We use straight lines to segment the area for simplicity.

Figure 3. Summary of theoretical results

the entrant has a five percent market share. To maintain or grow its market share, the incumbent needs to attract at least 95 percent of new adopters on each side. This in turn requires the strength of indirect network effects, e, to be large enough so that at least 95 percent of new consumers will adopt the incumbent platform and as a result, at least 95 percent of new developers will also choose the incumbent platform. Otherwise, the incumbent's market share drops below 95 percent in the next period. The same logic applies for all future periods. Therefore, if e is not sufficiently large (i.e., $e < e^*$), eventually the incumbent will lose its installed-base advantage to the entrant.

[6] See the working paper version of this paper for the simulation results (Zhu and Iansiti, 2010).

discount factor, φ. There are three regions segmented by two curves. The positions of the two curves are determined jointly by the magnitudes of quality advantage and installed-base advantage, and the platform's life expectancy.[7] When the values of e and φ lie in region A of Figure 3, the market dynamics are driven by quality advantage. Similar to the myopic case, the entrant can successfully enter the market regardless of the incumbent's installed-base advantage. In terms of market structure, when $e < 1$, two platforms can coexist and the entrant has a larger market share on each side in the long run; when $e > 1$, the entrant will evolve toward a monopoly. The same intuition from the myopic case applies here. In region B, indirect network effects are strong enough that installed-base advantage dominates quality advantage, and the incumbent platform will evolve toward a monopoly. In region C, the discount factor, φ, is large. That is, consumers are sufficiently patient, and they place a large value on future applications. Hence, their utilities become similar to those of future adopters, and they are more likely to take the same actions as future adopters. As a result, the platform with favorable consumer expectations will evolve toward a monopoly.

We similarly refer to region A as the quality driven region, region B as the installed-base driven region, and region C as the expectations driven region.[8]

Figure 3 also suggests that consumers' forward-looking behavior does not necessarily benefit an entrant. When the strength of indirect network effects is below e^*, an entrant can successfully enter the market when φ is low, or when φ is high and the entrant has favorable expectations. When φ is moderate, forward-looking behavior hurts the entrant. The intuition is that when φ is moderate, consumers care about new applications to be released in the near future in addition to the currently available ones. Because of its installed-base advantage, the incumbent will have more new applications in the near future. Hence, when consumers have a moderate level of patience, the incumbent becomes more attractive. Therefore, if an entrant cannot encourage consumers to be sufficiently patient, it will be better off with myopic consumers.

EMPIRICAL ANALYSIS

To illustrate the applicability of our framework (e.g., Figure 3), we apply it to the setting of the video game market. We first discuss the industry background and then provide the hypothesis for our empirical investigation.

The video game market is two-sided in that console providers need to attract both game players and game developers. The industry is becoming increasingly important today: more than 41 percent of U.S. households owned video game consoles in 2006 (Arendt, 2007; Zhu and Zhang, 2010). The growth of the industry far outpaces that of other entertainment industries, such as movies and music (Zeidler, 2008). According to a study conducted on behalf of the Entertainment Software Association, 'the U.S. computer and video game software industry's annual growth rate from 2003 to 2006 exceeded 17 percent' (ESA, 2008: 25).

Entry of the Xbox console

We study the competition between an incumbent, Sony's PlayStation 2, and a new entrant, Microsoft's Xbox console, between November 2001 and October 2005. PlayStation 2 was introduced in October 2000 and is backward compatible with PlayStation 1. Xbox was introduced in November 2001. While previous entrants into this market often came with next generation technology, Xbox technology belongs to the same generation as PlayStation 2 (128 bits generation).[9] Xbox came with a faster clock speed and more memory.

[7] Region B becomes smaller (i.e., the entrant is more likely to survive for a given strength of network effects) when its quality advantage increases, the incumbent's installed-base advantage decreases or the platforms' life expectancy increases.

[8] Our modeling approach follows the tradition of evolutionary models of dynamic competition and technological changes (e.g., Nelson and Winter, 1982). Several studies extended their approach to study technology adoption under direct network effects (e.g., Arthur, 1989; Auriol and Benaïm, 2000; Cabral, 1990, 2006; Loch and Huberman, 1999; Mitchell and Skrzypacz, 2006). Although these studies focus only on direct network effects and do not allow consumers to look forward, many find that network effects may cause sudden shifts in market dynamics even with heterogeneous adopters, because adopters focus not only on matching a product to their own tastes, but also on joining the expected winner (e.g., Loch and Huberman, 1999; Cabral, 2006).

[9] Bit value refers to the word length of a console's processor and is often considered the most important measure of a console's graphical performance. As a result, the number of bits is used to classify different generations of consoles.

DOI: 10.1002/smj

Table 3. Summary statistics on console sales and game releases for PlayStation 2 and Xbox consoles

	PlayStation 2				Xbox			
	2002	2003	2004	2005	2002	2003	2004	2005
% of installed base	0.81	0.76	0.72	0.69	0.19	0.24	0.28	0.31
% of total games	0.84	0.80	0.71	0.65	0.16	0.20	0.29	0.35
% of new console units sold	0.73	0.67	0.53	0.68	0.27	0.33	0.47	0.32
% of new games released	0.68	0.60	0.60	0.55	0.32	0.40	0.40	0.45
% of new games by console provider	0.09	0.09	0.07	0.08	0.08	0.10	0.07	0.05

PlayStation 2 had a significant lead in installed base and availability of games: by the time Xbox was introduced, more than 4.5 million PlayStation 2 consoles had been sold in the United States and more than 1,000 compatible game titles were available for PlayStation 2.

Many industry experts and scholars cast doubt on Xbox's ability to seize a large market share for several reasons. First, Microsoft did not succeed in its first foray into the video game market when it worked with Sega to design Windows CE as a software operating system for the Dreamcast system in mid-1996.[10] Second, many industry experts viewed Microsoft's success in the personal computer (PC) industry itself as evidence that installed-base advantage is a strong indicator of success in such markets. For example, an article in *The Economist* predicted, 'Yet Microsoft might lose, for the same reason that no software maker has succeeded in dethroning Windows. Like the market for PC operating systems, the video-game market exhibits strong network effects that protect incumbents. The more games there are for a console, the more attractive it is for consumers, making it even more appealing to game developers. And here, Sony has a huge lead' (*Economist*, 2001). Finally, many experts were concerned about Microsoft's lack of understanding of the video game industry. As Brandon Justice, a video-game analyst at IGN.com, commented: 'They're trying to approach this like any other sector of business, but the gaming world doesn't necessarily work that way. They seem to be extremely confident when they have no right to be' (Acohido, 2001). Indeed, Microsoft's attempt to import its PC business model into the video game business—free and open access to all developers, and licensing manufacturers to third-party hardware makers, such as Dell—was unsuccessful (Hagiu, 2007).

Despite the skepticism, Xbox made a successful entry into this market. Table 3 shows the market shares of the installed base, the total number of games, the new console sales, and the number of new game releases for each console over time. We compute these market shares by dividing the number for each console by the sum of the two consoles in each year. As the numbers indicate, Xbox has been very successful in growing its market shares on both sides: its shares of installed base and associated games increased over the years. In 2004, Xbox had more than 40 percent shares in both new console sales and new game releases. While its share of new game releases increased to 45 percent in 2005, Xbox sales slowed down in 2005, most likely because of the anticipated release of the next generation system, Xbox 360.[11] We also compute the percentage of PlayStation 2 games provided by Sony and the percentage of Xbox games supplied by Microsoft. The data suggest that console providers produced only a very small number of game titles and that third-party game developers are the major game suppliers.

The competition between the two consoles provides an ideal setting for our empirical analysis for two reasons. First, as both consoles target adults between 18 and 34 and most players own only one console,[12] they position themselves in direct competition with each other. Second, in our model, we have assumed that platforms are priced at the

[10] Windows CE turned out to be unsuitable for video games. Thus, of the 40-odd games scheduled to be available within the first six months of Dreamcast's launch, only one used the joint Sega-Microsoft toolkit.

[11] Xbox 360 was released in November 2005. Microsoft officially announced its release date in May 2005.

[12] According to a survey by the market research company the NPD Group, among all consumers with a video game console, less than five percent own both Xbox and PlayStation 2 consoles. Source: The NPD Group. 'Video Games Cross-Platform Study,' August, 2003. Thus, this empirical setting fits well with our theoretical assumption that consumers adopt one platform only.

same level. The pricing strategies of Microsoft and Sony fit this assumption well. At the release of Xbox, both consoles were priced at $299. Since then, the two console providers quickly matched each other's price over time. Their price differences were less than $10 in all months except March 2004 ($12.10) and April 2004 ($30.95).[13] As the consoles were offered at similar prices in each period, we expect that consumers made their purchase decisions based on the quality of the consoles and the variety of associated games available at the time of purchase and those to be released in the future rather than prices.

In the video game market, consumer utility may also directly depend on the size of the installed base if *direct* network effects are significant.[14] As both Xbox and PlayStation 2 consoles have online capability, direct network effects could exist. Online console-based games did not take off until 2006, however (Bdnews24, 2006). In addition, only 5.2 percent of games released for the two consoles could be played online, and even games with heralded online features are often played alone. Thus, we believe that indirect effects are of far greater significance for the period we study. Direct network effects may also arise when friends, who own the same console, exchange games. As Clements and Ohashi (2005) suggest, in the video game industry, such effects are often limited to local regions, and with the country-level data, indirect network effects are far more significant.

Given that Xbox successfully entered the market and did not seem to have favorable expectations over PlayStation 2, according to our theoretical framework in Figure 3, we hypothesize that:

> *Hypothesis 1: In the video game market, the strength of indirect network effects and consumers' discount factor are within the range where the market dynamics are quality driven.*[15]

[13] Console prices are computed by dividing the monthly dollar value of the sales by the volume of units sold for each console.

[14] With direct network effects, a consumer's valuation of a product increases as the number of other consumers who adopt the same product increases, and hence direct network effects arise from the same side of the market, while indirect network effects operate through a complementary side (Clements, 2004).

[15] Our empirical analysis also serves as a test to check whether expectations matters and if so, whether Xbox has favorable expectations.

Data

We obtain data on console and game sales from the NPD Group, a leading market-research firm that tracks this industry. NPD collects data from approximately 17 leading U.S. retail chains that account for 80 percent of the U.S. market. From these data, NPD formulates estimates of sales figures for the entire U.S. market. We obtain monthly sales and price data for PlayStation 2 and Xbox consoles, and their associated games, from October 2000 to October 2005. For each console, we compute the average monthly price by dividing the monthly revenue by the volume of units sold. Game publishers continued to release new games for the two consoles after October 2005. We collect data on the number of new games released for each console in each month after October 2005 from GameSpot.com.[16]

Empirical specifications

Our empirical analysis consists of two steps. First, we measure the strength of indirect network effects, e, the discount factor, φ, the two quality ratios, Q and F, and the installed-base advantage of PlayStation 2 on each side of the market, $b_{I,0}$ and $n_{I,0}$. The values of $b_{I,0}$ and $n_{I,0}$ can be observed directly from the data, and we estimate the rest of the parameters in a regression framework. In addition, as Q and F are ratios, we only need to use console dummies in regressions to estimate the quality ratios, rather than to develop metrics to explicitly measure the actual quality levels. Then, we use these estimated parameter values to determine whether the video game industry is located in the quality-driven region of our theoretical framework (i.e., Figure 3), as we have hypothesized.

We first discuss our regression framework for estimating the parameters. We transform Equation (3) to yield the following specification (Berry, 1994):

$$\ln s_{Et} - \ln s_{It} = \beta_Q + e(\ln N_{Et} - \ln N_{It}) + \beta_{2005} Dummy_{2005} + \xi_t, \quad (6)$$

[16] GameSpot.com is also known as VideoGames.com. According to Ranking.com, which tracks the popularity of the top one million Web domains, GameSpot.com is the 172th most visited site of all Web domains and is the most visited one on video games. Source: http://www.ranking.com, accessed April 2009.

DOI: 10.1002/smj

where the entrant, E, is Xbox and the incumbent, I, is PlayStation 2. β_Q captures the quality advantage of Xbox over PlayStation 2. The quality ratio, Q, can be obtained as $\exp(\beta_Q)$.[17] While the log difference specification takes away time-specific effects that are common to both consoles, we include a dummy for year 2005 to control for potential cannibalization effects from the planned release of Xbox 360.[18] N_{jt} measures game variety, which includes both available games at time t and discounted games from future releases. Similar to other empirical work related to forward-looking consumers, we adopt an 'errors-in-variables' approach (e.g., Wickens, 1982: 55). That is, as we assume consumer expectations are fulfilled, we use the actual game release data in the future and express N_{jt} as a function of φ.

We now consider the developer side. Using Equation (4), we obtain the following specification:

$$\ln \Delta n_{jt} = \beta_0 + \beta_1 \ln b_{jt} + \beta_2 Dummy_E + \sum_{i=3}^{5} \beta_i Dummy_{2000+i} + \beta_6 Dummy_{Holiday} + \xi_{jt}, \quad (7)$$

where the dependent variable, $\ln \Delta n_{jt}$, is the logarithm of the number of new games released for console j in period t, and b_{jt} is the installed base of console j in period t. The size of the installed base by console and by month is obtained from cumulative console sales up to the current month, subject to a constant rate of decay. We experiment with different decay rates and compare our data on the console market share with survey results from other sources. We find that the annual decay rate of 10 percent, which corresponds to a monthly decay rate of 0.87 percent, provides the best match. According to our theoretical model, we expect β_1 to be 1. The cost ratio, F, can be obtained as $\exp(\beta_2)$.[19] As we are not taking differences across the two consoles in each period, we need to control for time-specific effects. We thus include year dummies, and a holiday dummy that equals 1 when the month is November or December and 0 otherwise, as control variables.[20]

RESULTS

Table 4 presents our regression results. Panel A reports results for console adoption on the consumer side. Equation (6) is our empirical specification. In Model I, we assume myopic consumers (i.e., $\varphi = 0$). In Model II, we relax this myopia assumption and employ a nonlinear least squares (NLS) estimation, as the discount factor, φ, enters Equation (6) nonlinearly. The time period starts from the introduction of Xbox into the U.S. market, November 2001, to October 2005. Our results indicate significant indirect network effects in this market. The estimated strength of indirect network effects is 0.69 and 0.62 in the two models, respectively, which suggest that myopic models may overestimate the strength. We also find that the discount factor is small (0.31). In addition, we find that Xbox has a small quality advantage over PlayStation 2. The quality ratio Q is $\exp(\beta_Q) = 1.35$. Finally, the significant, negative coefficients of the dummy for year 2005 suggest that the anticipated release of Xbox 360 significantly slowed down the adoption of Xbox.

We conduct several robustness checks. First, we include the price difference between the two consoles as an additional control variable to test our assumption that price difference does not have a significant impact on relative console sales. The results from Model III suggest that price difference, indeed, does not affect consumer choices and are consistent with the observation that the two console providers matched each other's price quickly.

[17] We could derive this expression by taking the ratio of s_{Et} and s_{It} from Equation (3) and obtain: $s_{Et}/s_{Et} = Q(N_{Et}/N_{It})^e$. Taking the logarithm of both sides, we have: $\ln s_{Et} - \ln s_{It} = \ln Q + e(\ln N_{Et} - \ln N_{It})$. Hence, $\beta_Q = \ln Q$ and Q can be obtained as $\exp(\beta_Q)$. Although we do not have monthly data on marketing expenditure for the two consoles, as reported in Derdenger (2009), the marketing support by Microsoft and Sony for their consoles is similar: the monthly average marketing expenditure for Xbox and PlayStation 2 from January 2002 and November 2004 is US$252,030 and US$295,260, respectively. Our log difference specification eliminates their effects.

[18] Although Microsoft announced the official release date in May 2005, the release had been widely expected since early 2005.

[19] We can see this by taking the logarithm of the both sides of Equation (4) and have: $\ln \Delta n_{jt} = \ln \alpha_t + \ln b_{jt} - \ln F_{jt}$. Comparing this expression to Equation (7), we have $\beta_0 = \ln \alpha_t$ and we expect $\beta_1 = 1$. The coefficient of the platform dummy, β_2, captures the difference in the fixed costs, $\ln F_{It} - \ln F_{Et}$ (i.e., $\ln F$). Thus, we can compute F as $\exp(\beta_2)$.

[20] Although we have monthly observations, we could not obtain meaningful estimates by including dummies for each month, largely because of a lack of cross-sectional variation with only two consoles.

Table 4. Regression results for console adoption and game supply

Model	Panel A: Console adoption						
	I	II	III	IV	V	VI	VII
β_Q	0.28*	0.30**	0.32	0.28**	0.30**	0.27*	0.30**
	(0.14)	(0.14)	(0.26)	(0.13)	(0.14)	(0.13)	(0.13)
$\ln N_{Et} - \ln N_{It}$	0.69***	0.62***	0.64***	0.59***	0.64***	0.52**	0.63***
	(0.10)	(0.11)	(0.12)	(0.11)	(0.10)	(0.09)	(0.10)
φ		0.31*	0.34*	0.36**	0.31*	0.32*	0.33**
		(0.18)	(0.18)	(0.16)	(0.18)	(0.16)	(0.17)
$Dummy_{2005}$	−0.60***	−0.61***	−0.62***	−0.60***	−0.61***	−0.64**	−0.61***
	(0.12)	(0.12)	(0.12)	(0.11)	(0.11)	(0.11)	(0.11)
$p_{Et} - p_{It}$			−0.00				
			(0.04)				
Observations	47	47	45	47	47	47	47
R-squared	0.53	0.54	0.53	0.57	0.56	0.59	0.56

Model	Panel B: Game supply						
	I	II	III	IV	V	VI	VII
$\ln b_{jt}$	0.90***	0.84***	0.87***	0.94***	0.80***	0.78**	0.86**
	(0.32)	(0.27)	(0.30)	(0.36)	(0.29)	(0.31)	(0.39)
$Dummy_E$	0.54	0.47	0.52	0.55	0.47	0.18	0.17
	(0.38)	(0.33)	(0.38)	(0.44)	(0.38)	(0.39)	(5.62)
$Dummy_{Holiday}$		0.36*	0.36*	0.36*	0.33	0.39**	0.46**
		(0.21)	(0.21)	(0.21)	(0.21)	(0.19)	(0.24)
$Dummy_E \times Dummy_{2005}$			−0.07	−0.03	−0.09	0.07	0.00
			(0.35)	(0.41)	(0.36)	(0.35)	(0.00)
$Dummy_{2003}$	−0.63**	−0.56*	−0.58*	−0.79**	−0.52*	−0.56*	−0.53
	(0.31)	(0.29)	(0.31)	(0.35)	(0.31)	(0.31)	(0.43)
$Dummy_{2004}$	−1.02**	−0.93**	−0.96**	−1.07**	−0.89**	−0.93**	−1.02*
	(0.40)	(0.37)	(0.40)	(0.43)	(0.40)	(0.40)	(0.59)
$Dummy_{2005}$	−1.22**	−1.06**	−1.06**	−1.30**	−0.97**	−1.14**	−1.13**
	(0.47)	(0.43)	(0.43)	(0.50)	(0.44)	(0.43)	(0.50)
Observations	94	94	94	94	94	94	94
R-squared	0.22	0.25	0.25	0.24	0.22	0.35	0.20

Panel A reports regression results for console adoption on the consumer side. Panel B reports regression results for game supply on the developer side. Standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

We are also concerned that game players may value games with high quality only when making purchase decisions. We therefore collect professional ratings for these games from GameSpot.com. We count only games with ratings greater than 7.0 on a 10.0-point scale. Games with scores above 7.0 are considered good according to GameSpot's rating system. We repeat our analysis with only these good games and obtain similar results (Model IV).

Alternatively, instead of only counting the good games, we weight each game by its quality. We use the professional ratings at GameSpot.com as measures for game quality. If a game is rated *x* out of 10.0, we assign a value of *x/10* to this game. We then sum these values for each platform in each month to create a quality-adjusted game-availability measure. We repeat our analysis with this new measure in Model V. The results are similar.

Finally, about 12 percent of games that are available on PlayStation 2 can also be played on Xbox. It is possible that consumers may not pay attention to these nonexclusive game titles when they choose consoles. We thus repeat the analysis after removing these nonexclusive titles and report the results in Model VI. We obtain similar results.

Panel B reports results for game supply on the developer side. We use Equation (7) as the empirical specification. We first estimate the equation

DOI: 10.1002/smj

without the holiday dummy in Model I and then include the holiday dummy in Model II. In Model III, we add an interaction variable between the dummy for Xbox and the dummy for year 2005 to control for potential negative effects from the release of Xbox 360. In Model IV, we count only games with ratings greater than 7.0 on a 10.0 scale at GameSpot.com. In Model V, we use the quality-adjusted measure in place of the simple count of new game titles. In Model VI, we consider only exclusive game titles on each console. Results are similar in all six models. We find that the coefficients of $\ln b_{jt}$, β_1, are above 0.78 in all models. T-tests cannot reject the hypothesis that β_1 is 1 in any model, which suggests that our empirical approach is consistent with the model. We also find that the difference in development costs between the two consoles is statistically indistinguishable from zero. The negative coefficients of the year dummies and the positive coefficients of the holiday dummy suggest that controlling for the installed base, fewer games are released over time, but more games are released during holiday seasons. One possible reason is that game players allocate smaller budgets for game purchases over time and larger budgets during holiday seasons. Finally, we do not detect a significant negative impact from the release of Xbox 360 on the Xbox game supply. This result is most likely because Xbox 360 is partially backward compatible: it can play most of Xbox games.

As we estimate the two equations using the same data, the error terms of the two equations are likely to be correlated. To improve the efficiency of our estimation, we employ a nonlinear seemingly unrelated regression (SUR) to estimate the two equations jointly (Model II of Panel A and Model III of Panel B). We report the results in Model VII of each panel. The results are similar.

As Model VI has the highest r-squared values in both regressions, we now use the parameter values from this model (i.e., $Q = 1.31$, $F = 1$, $e = 0.52$, and $\varphi = 0.32$) to examine whether the market is located in region A of the theoretical framework, as we have hypothesized. We conduct counterfactual experiments to determine the market's location. If we are in region A of the framework, for example, when we keep φ constant and increase e, at some point, we should reach region B, the installed-base driven scenario. In that case, PlayStation 2 should have pushed Xbox out of the market. We use January 2002 as the initial period and simulate market dynamics by holding one factor at the estimated level and changing the other factor. We find that consistent with our theoretical framework, given $\varphi = 0.32$, e needs to be greater than 1.48 for PlayStation 2 to drive Xbox out of the market. We also find that given $e = 0.52$, the market dynamics are driven by the installed base when φ increases to 0.59. These results provide evidence that the market is indeed located in region A.

DISCUSSION AND CONCLUSION

Our paper makes several contributions to the literature on platform-based markets. First, we present a dynamic model on platform competition. Platforms have been studied extensively, mostly in the context of static models (Church and Gandal, 1992; Park, 2002; Armstrong, 2006), which often lead to multiple equilibria as a result of indirect network effects in these markets. As industries characterized by indirect network effects are among the most dynamic industries, there is a need to develop dynamic models to address the equilibrium selection problem and understand market evolution.

Our work also contributes to the empirical literature on indirect network effects. Researchers have examined indirect network effects in the context of home videocassette recorders (VCRs), DVD players, personal digital assistants, and home video games (Gandal, Kende, and Rob, 2000; Ohashi, 2003; Shankar and Bayus, 2003; Park, 2004; Venkatraman and Lee, 2004; Clements and Ohashi, 2005, Stremersch *et al*., 2007). Table 5 lists the empirical setting of each study, whether the study considers both sides of the platform, and whether the study uses dynamic models. All of these studies, with the exception of Gandal *et al.* (2000) and Park (2004), rely on static frameworks. An implicit assumption of these static approaches is that consumers are myopic. Gandal *et al.* (2000) analyze dynamic demand for a market with a single standard (DVD players), while we study a market with two competing platforms. Park (2004) analyzes the competition between VHS and Betamax. As Park does not have data on the number of movie titles available for each technology, he essentially models indirect network effects as if they were direct: consumer utility is a function of the installed base of consumers rather than movie variety. Our empirical analysis considers dynamics on

DOI: 10.1002/smj

Table 5. Prior empirical studies of platform-based markets

Study	Market	Consumer or application side	Dynamic
Shurmer (1993)	PC software	Consumer	No
Basu, Mazumdar, and Raj (2003)	CD	Consumer	No
Clements and Ohashi (2005)	Video game console	Both	No
Corts and Lederman (2009)	Video game console	Both	No
Cottrell and Koput (1998)	Microcomputer	Consumer	No
Dranove and Gandal (2003)	DVD and DIVX players	Consumer	No
Gandal, Greenstein, and Salant (1999)	CP/M and DOS	Both	No
Gandal *et al*. (2000)	CD	Both	Yes
Gupta, Jain, and Sawhney (1999)	Digital television	Both	No
Nair *et al*. (2004)	PDA	Both	No
Ohashi (2003)	VCR	Consumer	No
Park (2004)	VCR	Consumer	Yes
Rysman (2004)	Yellow page	Both	No
Shankar and Bayus (2003)	Video game console	Consumer	No
Stremersch *et al*. (2007)	9 different markets	Both	No
Venkatraman and Lee (2004)	Video game console	Both	No

both sides of the platforms in a setting with competing platforms and forward-looking consumers.

In addition, these existing empirical studies focus almost exclusively on the statistical significance of indirect network effects in their empirical settings, and often pay little attention to the magnitude of indirect network effects. Several studies (e.g., Ohashi, 2003) take this statistical significance as evidence that indirect network effects protect the incumbents and, thus, argue that it is critical to be the first mover. Our research shows that statistical significance alone is insufficient for understanding market dynamics. We provide a framework to illustrate how one could use the magnitudes of indirect network effects and other market factors jointly to determine market dynamics. The framework shows that in markets with significant indirect network effects, an installed-base advantage does not provide a safety shield for the first mover if the market is in the quality-driven region. In this region, to defend its leadership position, the incumbent needs to achieve quality levels at least comparable to those of the entrant. When market dynamics are driven by installed-base advantages or consumer expectations, however, first movers may indeed drive out new entrants even if their quality is inferior. Therefore, our study suggests that even in markets with statistically significant indirect network effects, no single strategy will work across them and explains why findings from previous work in one setting often fail to explain market dynamics in other settings.

Managerial Implications

Our study suggests that despite the complexity of platform-based markets, it is possible to model the dynamics of such markets and predict an entrant's likelihood of success by combining empirical estimates with a theoretical foundation. Although our empirical analysis focuses on one console generation in the video game industry, our results help identify the driver of platform success in this market, and platform providers can thus design strategies accordingly when they compete in future generations. In addition, our theoretical framework and empirical results can help to understand the dynamics in other platform-based markets.

Different industries offer different industry dynamics, which influence the relative strength of network effects. In the video game industry, each console owner buys only eight games on average (Eisenmann *et al*., 2006). Therefore, we expect game players to place a relatively small value on game variety, which explains the relative weak indirect network effects we observed, and the entrant's success.

In the case of the VCR market and the high-definition video market, consumers watch an average of several movie titles each month.[21] In addition, in the video game market, most gamers are teenagers or young adults, who are not known for their forward-looking behavior. We thus expect consumers to be more sensitive to the current and

[21] For example, it has been reported that, on average, consumers watch almost six movies a month on DVD (Netherby, 2006).

future movie titles associated with each standard. Therefore, we expect both the strength of indirect network effects and the consumers' discount factor of future applications to be high.[22] It is, thus, not surprising that the VCR and high-definition video markets tipped to favor market leaders. The standards with small, early leads in market share, VHS and Blu-ray DVD, quickly emerged as dominant platforms.

In the search advertising market (e.g., Chen, Liu, and Whinston, 2009; Xu, Chen, and Whinston, 2011), indirect network effects between users and advertisers are likely to be low, because most users are not attracted to search engines by their ads. In addition, users are less likely to be forward-looking, as the switching cost in this market is low. Hence, market dynamics are likely to be quality driven. Indeed, Google was able to take over market leadership from Yahoo and drive out many of the early entrants, such as Infoseek and Inktomi, using its superior search algorithm.

As another example, we can look at the operating systems market. In the 1990s, consumers' reliance on third-party software was much higher than it is today. Consumers had to install many software packages such as music players, CD makers, and zip utilities. Today, most of these functionalities are provided by the operating system platform or are accessible over the Web through a Web browser. As a result, consumers are less sensitive to application variety. The market may have thus shifted from the installed-base driven region to the quality-driven region. Indeed, Apple's market share in PCs had been around two to three percent for almost 10 years, but recently it has increased to more than 10 percent and continues to rise (Palmer, 2009).

The Web browser market experienced similar dynamics. In the 1990s, because of a lack of standards, Web pages created for one browser might be displayed differently in another browser. Indirect networks effects were, thus, large, as users preferred browsers that could display most Web pages correctly and content publishers wanted to design their pages for browsers with a large number of users. In addition, users were less likely to be forward-looking, as the switching cost across different browsers is low (partly because they all have similar interfaces). Our framework suggests that we would expect one browser to dominate the market. Microsoft, as the second mover in this market, increased its installed base by bundling Internet Explorer (IE) with its operating systems and paying top Internet sites to design their Web pages for IE. It also successfully closed the quality gap with the market leader, Netscape, by embracing and extending Netscape's features (Yoffie and Kwak, 2001). These practices helped IE assume the leadership and drive Netscape out of the market. Today, indirect network effects are significantly weaker, because only rarely is it the case that Web pages designed for one browser cannot be displayed correctly in different browsers because of increased standardization. New entrants, such as Mozilla's Firefox, Apple's Safari, and Google's Chrome, all successfully entered the market. The dynamics are consistent with our framework, as the market shifts toward the lower-left corner of region A.

Limitations and future research

Our study has several limitations. First, our model and empirical analysis only apply to markets in which two platforms compete head-to-head for the same consumer population and price at similar levels (e.g., Xbox vs. PlayStation 2 and Google's search engine vs. Microsoft's Bing). In some platform-based markets, entrants can strategically cater to different populations to avoid such head-to-head competition. The recent success of Nintendo's Wii, for example, is largely because Nintendo differentiates its console from Xbox 360 and PlayStation 3 and targets casual game players (Anthony, 2008). These casual game players may value certain aspects of console quality, such as motion sensors, more than other aspects, such as processing power and graphics, and may also value game variety much less than hardcore game players. These factors contribute to Wii's rapid adoption despite Nintendo's small game library. Our framework does not apply to platforms with different positioning strategies. Future research

[22] Indeed, empirical findings in Ohashi (2003) support our reasoning. Ohashi studies user adoption of the VHS and Betamax standards in this market. While he does not consider forward-looking behavior and hence might overestimate the strength of indirect network effects, we compute our measure, e, from his regression results (Table IV, Ohashi, 2003) to be above 3 during 1978–1982. The indirect network effects in this market were mostly driven by the video rental business. Video rental shops began to expand in the early 1980s and grew exponentially. Therefore, the strength of indirect network effects increased over the years.

could examine how new entrants can differentiate themselves by exploiting different dimensions of platform quality and successfully enter platform-based markets.

Second, we use market share as our measure for platform success. Although market share captures market dynamics, it does not explicitly measure the platforms' profitability. In addition, our study implicitly assumes that entry will occur and an entrant will always obtain some market share in the first period. If an entrant needs to incur a large fixed cost to enter a market and expects to be driven out of the market shortly, it may choose not to enter the market. Future research could gather cost data to endogenize an entrant's entry decision by measuring its expected profitability.

Third, although we allow consumers to look forward, we assume that application developers care only about current installed bases. In markets where the popularity of applications declines rapidly after their releases, this assumption of myopic developers provides a good approximation (Nair *et al.*, 2004; Clements and Ohashi, 2005; Prieger and Hu, 2006). In our empirical setting of the video game industry, a typical game title makes more than 50 percent, sometimes as much as 80 percent, of its total sales in the first three months after its release. Although the sales of popular games may last longer, game publishers often release their sequels (e.g., Halo vs. Halo 2), which significantly reduces the popularity of older versions. As a result, game developers tend to make decisions based on the current installed bases of the consoles and heavily discount their revenues from future game players. In markets where application popularity declines slowly, developers' forward-looking behavior could affect market dynamics significantly. We leave this extension for future research.

Fourth, our study does not examine market segmentation, largely because we only have aggregate industry-level data. As a result, our estimated parameters capture the average characteristics of the consumer population. Our forward-looking parameter, for example, captures the degree of patience of a representative consumer. It is possible that one segment of the market consists of myopic consumers and another segment consists of patient consumers. Understanding market segmentation is important for platforms to formulate their targeting and promotion strategies. Future research could gather individual-level data to examine different market segments.

Finally, our empirical analysis looks at only one empirical setting, which is found to be in the quality-driven region of our theoretical framework. Future research could take our approach to test the framework using data from other platform-based markets.

ACKNOWLEDGEMENTS

This paper was previously circulated under the title 'Dynamics of platform competition: exploring the role of installed base, platform quality, and consumer expectations.' We thank Constance Helfat and two anonymous reviewers for their generous input that greatly improved the quality of this manuscript. We also thank Paul Adler, Carliss Baldwin, Ramon Casadesus-Masanell, Mian Dai, Ben Edelman, April Franco, Andrei Hagiu, Chun-Yu Ho, Mark Kennedy, Chi-Hyon Lee, Deishin Lee, Josh Lerner, Sunil Mithas, Yongwook Paik, Monic Sun, Michael Zhang, as well as participants of the *O&S* workshop at the University of Southern California, and seminar participants at Harvard University, Boston College, Carnegie Mellon University, Georgia Institute of Technology, HEC Paris, INSEAD, University of California at Irvine, Singapore Management University, Stanford University, and the Sixth Annual Atlanta Competitive Advantage Conference for helpful comments.

REFERENCES

Acohido B. 2001. Microsoft bets on Xbox success, but some skeptical video-game console has tough rivals. *USA Today*, 24 April, 6B.

Anthony S. 2008. Nintendo Wii's growing market of 'nonconsumers.' *Harvard Business Review* (blog), 30 April. http://bit.ly/cJFq2O (1 August 2010).

Arendt S. 2007. Game consoles in 41% of homes. *Wired,* 5 March. http://www.wired.com/gamelife/2007/03/game_consoles_i/ (1 August, 2010).

Armstrong M. 2006. Competition in two-sided markets. *RAND Journal of Economics* **37**(3): 668–691.

Arthur BW. 1989. Competing technologies, increasing returns, and lock-in by historical events. *Economic Journal* **99**: 116–131.

Auriol E, Benaïm M. 2000. Standardization in decentralized economics. *American Economic Review* **90**(3): 550–570.

Basu A, Mazumdar T, Raj SP. 2003. Indirect network externality effects on product attributes. *Marketing Science* **22**(2): 209–221.

Bdnews24. 2006. Xbox Live challenge is to reach masses, bdnews24.com (Bangladesh online newspaper), 21 December. http://www.bdnews24.com/details.php?id=46695&cid=8 (1 December 2009).

Berry S. 1994. Estimating discrete-choice models of product differentiation. *RAND Journal of Economics* **25**(2): 242–262.

Boudreau KJ. 2010. Open platform strategies and innovation: granting access vs. devolving control. *Management Science* **56**(10): 1849–1872.

Boudreau KJ. 2011. Let a thousand flowers bloom? An early look at large numbers of software 'apps' developers and patterns of innovation. Available at SSRN: http://ssrn.com/abstract=1826702 (15 May 2011).

Boudreau KJ, Jeppesen LB. 2011. Unpaid complementors and platform network effects? Evidence from on-line multi-player games. Working paper, London Business School: London. Available at http://ssrn.com/abstract=1812084 (15 May 2011).

Cabral L. 1990. On the adoption of innovations with 'network' externalities. *Mathematical Social Sciences* **19**(3): 299–308.

Cabral L. 2006. Equilibrium, epidemic and catastrophe: diffusion of innovations with network effects. In *New Frontiers in the Economics of Innovation and New Technology: Essays in Honor of Paul David*, Antonelli C, Foray D, Hall BH, Steinmueller E (eds). Edward Elgar: London, UK; 427–437.

Chen J, Liu D, Whinston AB. 2009. Auctioning keywords in online search. *Journal of Marketing* **73**(4): 125–141.

Chen Y, Xie J. 2007. Cross-market network effect with asymmetric customer loyalty: implications for competitive advantage. *Marketing Science* **26**(1): 52–66.

Cho DS, Kim DJ, Rhee DK. 1998. Latecomer strategies: evidence from the semiconductor industry in Japan and Korea. *Organization Science* **9**(4): 489–505.

Christensen CM. 1997. *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*. Harvard Business School Press: Boston, MA.

Christensen CM, Bower JL. 1996. Customer power, strategic investment, and the failure of leading firms. *Strategic Management Journal* **17**(3): 197–218.

Church J, Gandal N. 1992. Network effects, software provision and standardization. *Journal of Industrial Economics* **40**(1): 85–104.

Clements MT. 2004. Direct and indirect network effects: are they equivalent? *International Journal of Industrial Organization* **22**(5): 633–645.

Clements MT, Ohashi H. 2005. Indirect network effects and the product cycle: video games in the U.S., 1994–2002. *Journal of Industrial Economics* **53**(4): 515–542.

Corts KS, Lederman M. 2009. Software exclusivity and the scope of indirect network effects in the U.S. home video game market. *International Journal of Industrial Organization* **27**(2): 121–136.

Cottrell T, Koput K. 1998. Software variety and hardware value: a case study of complementary network externalities in the microcomputer software industry. *Journal of Engineering and Technology Management* **15**(4): 309–338.

Derdenger T. 2009. 'Vertical' integration and foreclosure of complementary products. Working paper, Carnegie Mellon University: Pittsburgh, PA.

Dowell G, Swaminathan A. 2006. Entry timing, exploration, and firm survival in the early U.S. bicycle industry. *Strategic Management Journal* **27**(12): 1159–1182.

Dranove D, Gandal N. 2003. The DVD vs. DVIX standard war: network effects and empirical evidence of preannouncement effects. *Journal of Economics & Management Strategy* **12**(3): 363–386.

Economist. 2001. Let the games begin. Business & finance: consumer electronics, 17 May.

Eisenmann TR, Parker G, Alstyne MWV. 2006. Strategies for two-sided markets. *Harvard Business Review* **84**(10): 92–101.

ESA. 2008. *Annual Report*. Entertainment Software Association: Washington, DC. http://www.theesa.com/about/ESA_2008_AR.pdf (1 August 2009).

Evans DS. 2003. Some empirical aspects of multi-sided platform industries. *Review of Network Economics* **2**(3): 191–209.

Farrell J, Klemperer P. 2007. Coordination and lock-in: competition with switching costs and network effects. In *Handbook of Industrial Organization (Volume 3)*, Armstrong M, Porter RH (eds). North-Holland: Amsterdam, the Netherlands; 1967–2072.

Freeman C. 1997. *The Economics of Industrial Innovation* (3rd edn). MIT Press: Cambridge, MA.

Fuentelsaz L, Gomez J, Polo Y. 2002. Followers' entry timing: evidence from the Spanish banking sector after deregulation. *Strategic Management Journal* **23**(3): 245–264.

Gandal N, Greenstein S, Salant D. 1999. Adoptions and orphans in the early microcomputer market. *Journal of Industrial Economics* **47**(1): 87–105.

Gandal N, Kende M, Rob R. 2000. The dynamics of technological adoption in hardware/software systems: the case of compact disc players. *RAND Journal of Economics* **31**(1): 43–61.

Gupta S, Jain DC, Sawhney MS. 1999. Modeling the evolution of markets with indirect network externalities: an application to digital television. *Marketing Science* **18**(3): 396–416.

Hagiu A. 2007. *Microsoft Xbox: Changing the game?* HBS Case 5-709-480. Harvard Business School: Boston, MA.

Helfat CE, Lieberman MB. 2002. The birth of capabilities: market entry and the importance of pre-history. *Industrial and Corporate Change* **11**(4): 725–760.

Iansiti M, Levien R. 2004. *The Keystone Advantage: What the New Dynamics of Business Ecosystems Mean for Strategy, Innovation, and Sustainability*. Harvard Business School Press: Boston, MA.

Katz ML, Shapiro C. 1994. Systems competition and network effects. *Journal of Economic Perspectives* **8**(2): 93–115.

Klepper S, Simons KL. 2000. Dominance by birthright: entry of prior radio producers and competitive ramifications in the U.S. television receiver industry.

Strategic Management Journal, October–November Special Issue **21**: 997–1016.

Lambkin M. 1988. Order of entry and performance in new markets. *Strategic Management Journal*, Summer Special Issue **9**: 127–140.

Lee GK. 2008. Relevance of organizational capabilities and its dynamics: what to learn from entrants' product portfolios about the determinants of entry timing. *Strategic Management Journal* **29**(12): 1257–1280.

Lieberman MB. 1989. The learning curve, technological barriers to entry, and competitive survival in the chemical processing industries. *Strategic Management Journal* **10**(5): 431–447.

Lieberman MB. 2007. Did first-mover advantage survive the dot-com crash? Working paper, UCLA Anderson School of Management, Los Angeles, CA.

Lieberman MB, Montgomery DB. 1988. First-mover advantages. *Strategic Management Journal*, Summer Special Issue **9**: 41–58.

Liebowitz SJ. 2002. *Re-Thinking the Network Economy: The True Forces That Drive the Digital Marketplace*. AMACOM: New York.

Liebowitz SJ, Margolis SE. 1994. Network externality: an uncommon tragedy. *Journal of Economic Perspectives* **8**(2): 133–150.

Liebowitz SJ, Margolis SE. 1999. *Winners, Losers & Microsoft: Competition and Antitrust in High Technology*. The Independent Institute: Oakland, CA.

Loch CH, Huberman BA. 1999. A punctuated-equilibrium model of technology diffusion. *Management Science* **45**(2): 160–177.

Makadok R. 1998. Can first-mover and early-mover advantages be sustained in an industry with low barriers to entry/imitation? *Strategic Management Journal* **19**(7): 683–696.

McFadden DS. 1973. Conditional logit analysis of qualitative choice behavior. In *Frontiers in Econometrics (Economic Theory and Mathematical Economics)*, Zarembka P (ed). Academic Press: New York; Chapt. 4.

Mitchell MF, Skrzypacz A. 2006. Network externalities and long-run market shares. *Economic Theory* **29**(3): 621–648.

Mitchell W. 1991. Dual clocks: entry order influences on incumbent and newcomer market share and survival when specialized assets retain their value. *Strategic Management Journal* **12**(2): 85–100.

Nair H, Chintagunta P, Dubé JP. 2004. Empirical analysis of indirect network effects in the market for personal digital assistants. *Quantitative Marketing and Economics* **2**(1): 23–58.

Nelson RR, Winter SG. 1982. *An Evolutionary Theory of Economic Change*. Harvard University Press: Cambridge, MA.

Netherby J. 2006. DVD holds share of leisure time. *Video Business Magazine,* 12 July.

Ohashi H. 2003. The role of network effects in the U.S. VCR market, 1978–1986. *Journal of Economics & Management Strategy* **12**(4): 447–496.

Palmer R. 2009. Apple market share tops 10%, Windows share lowest since tracking began. Tauw (the unofficial Apple Weblog) 2 January. http://www.tuaw.com/2009/01/02/apple-market-share-tops-10-windows-share-lowest-since-tracking [20 October 2010].

Park S. 2002. Network benefit function in the presence of indirect network externalities. Working paper, Department of Economics, SUNY at Stony Brook: Stony Brook, NY.

Park S. 2004. Quantitative analysis of network externalities in competing technologies: the VCR case. *Review of Economics and Statistics* **86**(4): 937–945.

Prieger JE, Hu WM. 2006. An empirical analysis of indirect network effects in the home video game market. NET Institute Working paper no. 06–25. Available at http://ssrn.com/abstract=941223 (1 December 2009).

Rangan S, Adner R. 2001. Profits and the Internet: seven misconceptions. *MIT Sloan Management Review* **44**(4): 44–53.

Robinson WT, Fornell C, Sullivan M. 1992. Are market pioneers intrinsically stronger than later entrants? *Strategic Management Journal* **13**(8): 609–624.

Rysman M. 2004. Competition between networks: a study of the market for yellow pages. *Review of Economic Studies* **71**(2): 483–512.

Schilling MA. 1999. Winning the standards race: building installed base and the availability of complementary goods. *European Management Journal* **17**(3): 265–274.

Schilling MA. 2003. Technological leapfrogging: lessons from the U.S. video game console industry. *California Management Review* **45**(3): 6–33.

Schnaars SP. 1994. *Managing Imitation Strategies: How Later Entrants Seize Markets from Pioneers*. Free Press: New York.

Schoenecker TS, Cooper AC. 1998. The role of firm resources and organizational attributes in determining entry timing: a cross-industry study. *Strategic Management Journal* **19**(12): 1127–1143.

Shankar V, Bayus BL. 2003. Network effects and competition: an empirical analysis of the home video game industry. *Strategic Management Journal* **24**(4): 375–384.

Shankar V, Carpenter GS, Krishnamurthi L. 1998. Late mover advantage: how innovative late entrants outsell pioneers. *Journal of Marketing Research* **35**(1): 54–70.

Shapiro C, Varian HR. 1999. *Information Rules: A Strategic Guide to the Network Economy*. Harvard Business School Press: Boston, MA.

Sheremata WA. 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.

Stremersch S, Tellis GJ, Franses PH, Binken JLG. 2007. Indirect network effects in new product growth. *Journal of Marketing* **71**(3): 52–74.

Suárez F, Lanzolla G. 2007. The role of environmental dynamics in building a theory of first-mover advantages. *Academy of Management Review* **32**(2): 377–392.

Tellis GJ, Yin E, Niraj R. 2009. Does quality win? Network effects versus quality in high-tech markets. *Journal of Marketing Research* **46**(2): 135–149.

Urban GL, Carter T, Gaskin S, Mucha Z. 1986. Market share rewards to pioneering brands: an empirical analysis and strategic implications. *Management Science* **32**(6): 645–659.

Venkatraman N, Lee CH. 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.

Wade J. 1995. Dynamics of organizational communities and technological bandwagons: an empirical investigation of community evolution in the microprocessor market. *Strategic Management Journal*, Summer Special Issue **16**: 111–133.

Wickens MR. 1982. The effcient estimation of econometric models with rational expectations. *Review of Economic Studies* **49**(1): 55–67.

Xu L, Chen J, Whinston AB. 2011. Price competition and endogenous valuation in search advertising. *Journal of Marketing Research* **48**(3): 566–586.

Yip GS. 1982. *Barriers to Entry: A Corporate Strategy Perspective*. Lexington Books: Lexington, MA.

Yoffie DB, Kwak M. 2001. *The browser wars 1994–1998*. HBS Case 9-798-094. Harvard Business School: Boston, MA.

Zeidler S. 2008. U.S. movie box office hits record in '07: MPAA. Reuters.com, 5 March. http://www.reuters.com/article/entertainmentNews/idUSN0536665220080305 (1 August 2010).

Zhu F, Iansiti M. 2010. Entry into platform-based markets. Working paper, University of Southern California: Los Angeles, CA. Available at http://www-bcf.usc.edu/~fzhu/PlatformEntry_WorkingPaper.pdf

Zhu F, Zhang M. 2010. Impact of online consumer reviews on sales: the moderating role of product and consumer characteristics. *Journal of Marketing* **74**(2): 133–148.