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# Survival in Markets with Network Effects: Product Compatibility and Order-of-Entry Effects

**Qi Wang, Yubo Chen, and Jinhong Xie**

*While pioneers fail more frequently than early followers in markets with network effects, this study finds that there are opportunities for pioneers to enjoy a survival advantage. The findings offer useful insights into a firm's entry decision in markets with network effects.*


## Report Summary

Firms competing in markets with network effects often encounter overwhelmingly high market uncertainty and innovation risk, so survival is a crucial performance concern for new products in these markets. In this study, the authors suggest that a pioneer's survival (dis)advantage is jointly affected by network effects and two different types of product compatibility: cross-generation (compatibility with previous-generation products) and within-generation (compatibility with other products in the same generation).

Using data from 45 markets, they find systematic patterns of pioneer survival advantage based on these two types of compatibility. Despite the lower average survival duration of pioneers compared to their early followers in these markets, the study finds that pioneers can have a survival advantage in markets with both strong and weak network effects; however, the two cases require opposite compatibility conditions.

Specifically, when the products are cross-generation compatible but within-generation incompatible, a pioneer has a survival *disadvantage* relative to early followers in markets with very weak network effects; however, a pioneer has a survival *advantage* in markets with very strong network effects. When the products are cross-generation incompatible but within-generation compatible, the results are reversed: A pioneer has a survival *advantage* in markets where there are weak network effects, but a *disadvantage* in markets where there are strong network effects.

These findings provide some useful insights into a firm's entry decision in markets with network effects. Conventional wisdom has emphasized the importance of being first in markets influenced by network effects in order to benefit from a positive installed base. These findings reveal a lower average survival duration of pioneers compared to their early followers in such markets. More importantly, these results show that, although on average pioneers have a higher failure rate than their early followers in markets with network effects, opportunities exist for pioneers to enjoy a survival advantage in markets with both strong and weak network effects. ■


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## Introduction

A network effect (also called a network externality) is the market phenomenon in which the value of a product or service to consumers depends on the number of users of that product or service (see Katz and Shapiro 1985 and 1994 for detailed discussion). With rapid advances in information technology and the digital revolution, the network effect is becoming an important characteristic of an increasing number of industries and product/service categories (e.g., computers, communications, consumer electronics, software, financial exchanges, home networking, online auctions/gaming/dating, and social network websites). Due to the unique characteristics of markets with network effects, firms competing in these markets often encounter overwhelmingly high market uncertainty and innovation risk. Consequently, survival has become a primary performance concern in these markets (Srinivasan, Lilien, and Rangaswamy 2004). However, many important strategic questions about survival under network effects remain unanswered. For example, does the strong positive feedback from installed base convey a survival advantage to the first mover? Or are the up-front costs of securing a self-propagating base so large that these markets are largely "first in, first out"? What specific market/product characteristics facilitate or impede pioneer survival? Given the conflicting views presented in the popular press and the mixed evidence from the marketplace, more academic research is needed to answer these questions. This paper advances our understanding of the pioneer's survival (dis)advantage in markets with network effects by conducting a systematic and rigorous empirical analysis based on data collected in 45 product categories from 1950 to 2007. Our results reveal that two factors jointly determine a pioneer's survival relative to its early followers in markets with network effects: (1) product compatibility (both cross-generation and within-generation), and (2) the strength of network effects of the underlying market. Surprisingly, we find that pioneers can have a survival advantage both in markets with strong and weak network effects; however, the two cases require opposite compatibility conditions.

Markets with network effects have some unique characteristics, which often increase market uncertainty and innovation risk (e.g., Chakravarti and Xie 2006; Farrell and Saloner 1985). For example, unlike traditional markets, consumer adoption utility in the markets with network effects depends not only on the quality of the underlying product/service, but also on the size of the user base (Katz and Shapiro 1994). This installed-base effect creates a unique "start-up" difficulty for innovating firms, because the new product may offer little value to early adopters at the time of product launch due to its limited user base (Katz and Shapiro 1986). Furthermore, standards competition resulting from product incompatibility is common in the presence of network effects (Shapiro and Varian 1998). Over the past two decades, we have observed many fierce standards battles between incompatible technologies, such as the famous battle between Betamax and VHS in the home VCR market; the recently resolved battle between the Blu-ray and HD-DVD formats in the high-definition DVD player market; ongoing competition between Microsoft Windows and Apple Macintosh operating systems in the personal computer market; the growing competition between Apple's iPhone, RIM's Blackberry, and Palm in the smartphone markets, to name but a few. Brutal standards battles not only reduce competing firms' profits, but also make a "winner-take-all" market outcome, under which the loser has no choice but to exit the market, more likely to occur (Schilling 2002; Shapiro and Varian 1998).

A growing number of researchers have addressed the implications of network effects on emerging issues such as pricing (e.g., Xie and Sirbu 1995), product line decision (Sun, Xie, and Cao 2004), software piracy (Haruvy, Mahajan, and Prasad 2004), advertising

(Chakravarti and Xie 2006), cross-market network effects (Chen and Xie 2007), indirect network effects (Stremersch et al. 2007), and the roles of quality and network effects in the new product success (Tellis, Yin, and Niraj 2009). Recent research on network effects in the marketing literature has also provided empirical evidence of such effects in various industries, including HDTVs (Gupta, Jain, and Sawhney 1999), video games (Shankar and Bayus 2003), CD players (Basu, Mazumdar, and Raj 2003), PDAs (Nair, Chintagunta, and Dube 2004), and floppy disk drives (Wang, 2005). To date, however, few studies have been undertaken on the ability of different firms to survive in such markets.

The survival literature has suggested that firms' market entry order can play an important role in their ability to survive (e.g., Golder and Tellis 1993). Various studies have provided empirical evidence for pioneer survival (dis)advantage under different conditions (e.g., Lilien and Yoon 1990; Min, Kalwani, and Robinson 2006; Robinson and Min 2002). Since the installed-base effect exhibited in markets with network effects implies both a higher first-mover risk and a higher first-mover benefit compared with traditional markets, the order-of-entry effect on survival in markets with network effects can be even more complicated and critical. Despite the importance of survival in markets with network effects, however, pioneer survival (dis)advantage in such markets has received scant academic attention. Recently, Srinivasan, Lilien, and Rangaswamy (2004) took the first step toward empirically investigating firm survival in markets with network effects based on data from 45 product categories. Their work greatly advances our theoretical understanding of this underexplored research area and their results provide the first empirical evidence for the negative impact of network effects on the survival duration of a pioneer's product. However, their research focuses on pioneers' products only and does not directly address the order-of-entry effect.

Our paper aims to fill this gap in the literature by investigating the order-of-entry effect on survival in markets with network effects. We propose that the pioneers' survival (dis)advantage compared with their early followers is contingent on product compatibility (incompatibility), which is an essential product characteristic in these markets (e.g., Katz and Shapiro 1985; Xie and Sirbu 1995; Chakravarti and Xie 2006). Specifically, we consider two fundamentally different types of incompatibility: (1) *cross-generation incompatibility* (i.e., if the underlying product is incompatible with previous generation products) and (2) *within-generation incompatibility* (i.e., if the product is incompatible with other products in the same generation). For example, current-generation DVD players are cross-generation incompatible with the previous generation of VCR players, but are within-generation compatible with each other. We first develop a theoretical contingency framework on how a pioneer's survival (dis)advantage is jointly affected by network effects and the two types of incompatibility. We then empirically test our theoretical hypotheses using data from 45 markets with different degrees of network effects.

Our results reveal some intriguing systematic patterns of contingency. First, we find a significant interaction effect between network effects and the two types of incompatibility. Specifically in markets with very weak network effects, the two types of product incompatibility affect the pioneer's survival advantage in *opposite* directions: Cross-generation incompatibility strengthens, but within-generation incompatibility weakens the pioneer's survival advantage. However, as network effects increase, the impact of both types of incompatibility becomes weaker in their original directions, and eventually their directions are reversed; that is, when network effects are very strong, cross-generation incompatibility becomes harmful, but within-generation incompatibility becomes helpful to the pioneer's survival advantage. Second, although our data reveal a lower average survival duration faced by pioneers than their early followers in markets with network effects, we find some conditions under which pioneers can experience a survival advantage relative to their early followers. It is striking that (a) such a pioneer survival advantage can occur in markets with both strong and weak network effects, and (b) the two cases require opposite compatibility conditions. Specifically, we find that pioneers have a longer survival duration than their early followers (a) in markets with strong network effects if the pioneer is cross-generation compatible but not within-generation compatible, and (b) in markets with weak network effects if the pioneer is within-generation compatible but not cross-generation compatible. These findings provide important insights for both theory and practice.

The remainder of the paper is organized as follows: In the next section, we present our conceptual framework and develop our hypotheses. We then describe our data and estimation method, and present our empirical results. Finally, we discuss the contributions of this paper and the managerial implications of our results.

## Conceptual Development

Previous research has developed and tested hypotheses concerning the main effect of entry order on survival as well as the impact of some moderators, such as the pioneer's lead time (e.g., Robinson and Min 2002). A recent study (Srinivasan, Lilien, and Rangaswamy 2004) has also presented and tested hypotheses regarding the main effect of network effects on pioneer's survival as well as the impact of some moderators, such as product radicalness. Although we include many factors identified in previous studies, our conceptual development focuses on a new dimension; that is, how product (in)compatibility and network effects jointly impact a pioneer's survival advantage. Below, we define product (in)compatibility and develop four hypotheses. The first two hypotheses focus on the interaction of network effects and the two types of incompatibility (across- and within-generation) on pioneer survival advantage, and the last two hypotheses focus on conditions under which pioneers are more likely to survive longer compared with their early followers in markets with network effects.

### Product compatibility

Product compatibility is a fundamental issue in markets with network effects (e.g., Farrell and Saloner 1985; Katz and Shapiro 1985; Xie and Sirbu 1995), although the technical definition of "compatibility" may be product-specific. For communications networks, "compatibility" implies that subscribers to different networks can communicate with each other. For durable goods, such as modems, facsimile machines, or videoconferencing equipment, it implies that equipment produced by different vendors can interconnect. For complementary goods (e.g., ATM cards and game discs/cartridges for video players), it implies that the complementary goods of a brand can also be used with different brands (e.g., ATM cards issued by one bank can operate on other banks' ATMs). We believe product compatibility is a potentially crucial survival factor for firms competing in markets with network effects because, with incompatible products, firms engage in a standards war. Such a specific form of competition can significantly increase market uncertainty and affect firms' marketing strategies and profits. Furthermore, standards competition also affects consumer behavior since it imposes additional adoption risks (Chakravarti and Xie 2006). For example, adopting a product that utilizes a losing standard incurs significant costs for consumers. Therefore, firm competition and survival rates among different market players differ greatly as a result of product incompatibility.

The extant literature has considered two specific types of product incompatibility: (1) cross-generation (e.g., Choi 1994; Dhebar

1995; Postrel 1990), and (2) within-generation (e.g., Farrell and Saloner 1985; Xie and Sirbu 1995). Cross-generation incompatibility occurs between products in different generations (e.g., the facsimile (fax) machine versus the telegraph transmitter, DVD players versus VCR players). Within-generation incompatibility applies to products developed within the same generation (e.g., VHS versus Betamax VCR players). Although the literature has examined the impact of product compatibility on some important firm strategies such as pricing and advertising (e.g., Farrell and Saloner 1985; Xie and Sirbu 1995; Chakravarti and Xie 2006) or consumer behavior (Chakravarti and Xie 2006), the impact of product compatibility on firms' survival ability has not been investigated. Also, previous studies of product compatibility have focused on one specific type of product incompatibility; that is, cross- or within-generation incompatibility. It is important to understand whether or not these two types of incompatibility influence product survival differently. In the following discussion, we examine how each type of product incompatibility may influence a firm's pioneering survival (dis)advantage, and how these impacts might vary with the strength of network effects.

### Impacts of cross-generation incompatibility

Previous research has shown that one major source of pioneering advantage arises from consumer preference formation. Carpenter and Nakamoto (1989) argue that, when a new category is introduced and consumer category preference is not well defined, consumers tend to form their preferences based on the market pioneer's product and consider its product as the category stereotype. When later entrants arrive, their products will be compared with the pioneer's product, the market stereotype, and hence may be perceived disadvantageously. In markets with network effects, it appears reasonable that cross-generation incompatibility strengthens such a pioneer advantage because cross-generation compatibility implies similarity between the new generation product and that of the existing generation. As a result, introducing cross-generation compatible products limits the pioneer's ability to redefine consumer preferences. In contrast, cross-generation incompatible products usually feature very different technologies from those of the previous generation. For example, the DVD player was created as a result of the development of digital technology, and cannot be made compatible with its precursor, the video cassette recorder (VCR), which was dependent on analog technology. Significant product differentiation due to cross-generation incompatibility creates a high level of uncertainty for consumers when evaluating products and forming their product preferences (Dehbar 1995), which provides an opportunity for the pioneer to redefine consumer preferences. Accordingly, it is more likely for the pioneer to enjoy a "first mover" advantage arising from consumer preference formation when its product is incompatible than when it is compatible with previous-generation products. Therefore, cross-generation product incompatibility can create a positive impact on the product pioneering advantage in markets with network effects.

Cross-generation product incompatibility may also have a negative effect on product pioneering advantage, however, because compatible new-generation products can take advantage of the existing installed base of previous-generation products, but cross-generation-incompatible products enter the market with a small or nonexistent installed base. In markets subject to network effects, the consumption benefit to a consumer increases with the number of users of the compatible products (Katz and Shapiro 1985; Xie and Sirbu 1995). With such a positive interdependence among consumers, when a new product is incompatible with its previous generation, potential consumers tend to wait until the uncertainty regarding the future customer base is reduced (Farrell and Saloner 1985). That is, cross-generation incompatibility increases consumers' uncertainty concerning the future installed base and also the value of the new-generation products. Many studies argue that consumer uncertainty regarding the new product category can create a greater survival risk to market pioneers than to their followers (e.g., Golder and Tellis 1993; Lilien and Yoon 1990). Because consumer expectations become more well defined as more information becomes available as a result of the market pioneer's early marketing investment, later entrants can "free ride" this information-diffusion process and thus have a greater chance of success. Therefore, cross-generation product incompatibility can further exacerbate a pioneer's disadvantage from consumer uncertainty, and consequently have a negative impact on product pioneering advantage in markets with network effects.

How cross-generation product incompatibility ultimately influences the order-of-entry effect and in turn product survival duration depends on the net effect of these two opposite impacts, which is affected by the strength of network effects. Although the *positive* impact of cross-generation incompatibility on market pioneer advantage arising from *consumer preference formation* is not influenced by network effects, the *negative* impact of cross-generation incompatibility on market pioneer advantage arising from *market uncertainty* due to the installed base effect is significantly affected by the strength of network effects. Srinivasan, Lilien, and Rangaswamy (2004) show that, as a result of such a negative consumer installed-base effect, the survival duration of pioneer products decreases with the strength of network effects. Therefore, although the positive impact of cross-generation incompatibility on product pioneering advantage remains the same with an increase in the strength of network effects, its negative impact on pioneer advantage increases. Hence, in general, the impact of cross-generation product incompatibility on pioneering advantage (the order-of-entry effect) decreases with the strength of network effects.

We now consider two specific cases, markets with very strong and very weak network effects. When network effects are very weak (zero in the extreme case), the "start-up" problem for market pioneers in establishing an installed base is very low. As a result, the positive impact of cross-generation incompatibility on pioneer advantage from high differentiation may dominate its negative impact from consumer uncertainty concerning product installed base. Thus, the net effect associated with cross-generation incompatibility on pioneering advantage is positive. In contrast, as discussed previously, when network effects are very strong, cross-generation incompatibility makes it very difficult for market pioneers to establish their installed bases. The negative impact of cross-generation incompatibility from consumer uncertainty regarding product installed base could dominate its positive impact from high differentiation. Thus, cross-generation incompatibility could have a negative impact on pioneering survival advantage.

The previous discussion leads to the following two hypotheses on the joint effect of cross-generation incompatibility and network effects on pioneer survival advantage:

H1: Generally, the impact of cross-generation incompatibility on pioneer survival advantage *decreases* with the strength of network effects.

H2: Specifically, cross-generation incompatibility has

a. a *positive* impact on pioneer survival advantage in markets with very weak network effects;

b. a *negative* impact on pioneer survival advantage in markets with very strong network effects.

### Impacts of within-generation incompatibility

When products within a generation are incompatible, this incompatibility creates two opposite impacts on the order-of-entry effect and, in turn, on pioneer advantage in survival duration. On the one hand, extant research suggests that one of the major advantages of later entry is the opportunity to outperform the pioneers by introducing distinctive products (Carpenter and Nakamoto 1989). In markets with network effects, introducing a within-generation incompatible product creates a high level of product differentiation by late entrants (e.g., Besen and Farrell 1994; Kim 2002). Incompatibility can thus help a firm distance its product from existing products, meet consumers' demand heterogeneity, and thus reduce long-term price competition (Katz and Shapiro 1986 and 1994). As a result, product incompatibility can create a positive product differentiation effect for later entrants (Katz and Shapiro 1994), which can help them overcome the pioneer advantage in networked markets. In other words, within-generation product incompatibility may generate a *negative product differentiation effect* on pioneering advantage in markets with network effects.

On the other hand, the existing literature has also shown that market pioneers can benefit from preempting the market and setting a high entry barrier for followers (e.g., Lieberman and Montgomery 1988). In markets with network effects, the most important entry barrier for followers is the consumer installed base. With within-generation incompatibility, the consumers of a late entrant can only derive the benefits from its own installed base rather than the combined installed bases of all compatible products. As a result, the potential benefits that consumers can gain from followers can be very limited compared to those they can gain from the pioneer because of its large existing installed base. Moreover, within-generation incompatibility also creates a huge switching cost to consumers of existing products (Farrell and Klemperer 2007). As a result, incompatibility can discourage product adoption by potential consumers and can impose a negative installed-base effect on late entrants (Chakravarti and Xie 2006). In other words, within-generation product incompatibility can generate a *positive installed-base effect* on pioneering advantage in relation to followers in markets with network effects.

The overall impact of within-generation incompatibility thus depends on the magnitude of these two opposing influences, which can be determined by the strength of network effects. Note that the negative impact of within-generation incompatibility arising from the followers' product-differentiation effect is independent of network effects. However, the positive impact of within-generation incompatibility arising from the pioneer's installed-base advantage is more significant in markets with stronger network effects. As a result, the impact of within-generation product incompatibility on pioneer advantage (the order-of-entry effect) generally increases with the strength of network effects.

When the network effect is very weak (zero in the extreme case), the "start-up" problem for market followers in establishing an installed base is very low. The negative impact of within-generation incompatibility from high differentiation for pioneers dominates its positive installed-base impact. Thus, the within-generation incompatibility has an overall negative impact on pioneering advantage. In contrast, when the network effect is very strong, within-generation incompatibility imposes significant difficulties on followers in establishing their installed bases. For market pioneers, the positive installed-base effect of within-generation incompatibility can completely dominate the negative product differentiation effect. Thus, within-generation incompatibility has a net positive impact on pioneering advantage.

We have formalized the following two hypotheses on the joint effect of within-generation incompatibility and network effects on pioneer survival advantage:

H3: Generally, the impact of within-generation incompatibility on pioneer survival advantage *increases* with the strength of the network effects.

H4: Specifically, within-generation incompatibility has

a. a *negative* impact on pioneer survival advantage in markets with very weak network effects;

b. a *positive* impact on pioneer survival advantage in markets with very strong network effects.

### Overall order-of-entry effects

We now discuss the conditions under which pioneers are likely to have survival (dis)advantage in markets with network effects. The previous discussion suggests that the impact of the two types of product (in)compatibility on pioneer survival advantage is moderated by the strength of network effects. Specifically, in markets with very weak network effects, cross-generation incompatibility has a positive impact (H2a), whereas within-generation incompatibility has a negative impact (H4a) on pioneers' survival advantage. These hypotheses suggest that when products are cross-generation compatible but within-generation incompatible, pioneers are at a disadvantage compared to early followers. In contrast, when products are cross-generation incompatible but within-generation compatible, pioneers are more likely to have an advantage in survival duration than are their early followers. Thus, we formalize the following hypothesis on the overall order-of-entry effects when the network effects are very weak.

H5: In markets with very weak network effects,

a. Market pioneers have a lower survival duration than early followers when their products are cross-generation compatible but within-generation incompatible;

b. Market pioneers have a higher survival duration than early followers when their products are cross-generation incompatible but within-generation compatible.

On the contrary, in markets with very strong network effects, hypotheses 2b and 4b suggest that cross-generation incompatibility has a negative impact but within-generation incompatibility has a positive impact on firm pioneer advantage. Therefore, when products are cross-generation compatible but within-generation incompatible, pioneers can gain a strong survival advantage; when the products are cross-generation incompatible but within-generation compatible, however, pioneers are at a disadvantage compared to early followers. Thus, we formalize the following hypothesis on the overall order-of-entry effects when the network effects are very strong.

H6: In markets with very strong network effects,

a. Market pioneers have a higher survival duration than early followers when their products are cross-generation compatible but within-generation incompatible;

b. Market pioneers have a lower survival duration than early followers when their products are cross-generation incompatible but within-generation compatible.

When products are both cross-generation and within-generation compatible or incompatible, the two types of (in)compatibility have opposite impacts on pioneering survival advantage. Thus, the overall order-of-entry effects are ambiguous, depending on the magnitude of the two types of product (in)compatibility. There is, thus, no clear theoretical prediction in these cases, and the result is purely empirical.

In summary, our conceptual development suggests that two types of product (in)compatibility have opposite impacts on order-of-entry effects. When the strength of network effects increases, the direction of these impacts reverses. The overall order-of-entry effect is contingent on the specific type of product compatibility and the strength of network effects. Pioneers can have a survival advantage in markets with both strong and weak network effects; however, the two cases require opposite compatibility conditions. We summarize all our theoretical hypotheses in Table 1.

Table 1
**Summary of Theoretical Hypotheses**

**Joint Effects of Product Compatibility and Network Effects on Pioneer Survival Advantage (H1–H4)**

| | | Specific Cases | |
|---|---|---|---|
| | **General Pattern** | **Markets with Weak Network Effects** | **Markets with Strong Network Effects** |
| Impact of Cross-Generation Incompatibility (CGIC) on Pioneer Survival Advantage | *Decrease with Network Effects* (H1) | *Positive* (H2a) | *Negative* (H2b) |
| Impact of Within-Generation Incompatibility (WGIC) on Pioneer Survival Advantage | *Increase with Network Effects* (H3) | *Negative* (H4a) | *Positive* (H4b) |

**Overall Order-of-Entry Effects on Product Survival Duration (H5 and H6)**

| **Products** | **Markets with Weak Network Effects** | **Markets with Strong Network Effects** |
|---|---|---|
| Cross-Generation Compatible/ Within-Generation Incompatible (CGC/WGIC) | *Pioneer Disadvantage* (H5a) | *Pioneer Advantage* (H6a) |
| Cross-Generation Incompatible/ Within-Generation Compatible (CGIC/WGC) | *Pioneer Advantage* (H5b) | *Pioneer Disadvantage* (H6b) |

## Data and Estimation Methods

This section describes our data collection procedure, the measurement of the variables, and our empirical estimation method.

### Data and variables

Srinivasan, Lilien, and Rangaswamy (2004) examine 45 categories impacted by network effects. Using the historical method (e.g., Golder and Tellis 1993; Sood and Tellis 2005), they identify the pioneer in each selected category from 1950 to 2001. These products range from computer hardware (e.g., mainframe computers, notebook computers, workstations), computer software (e.g., antivirus, database, desktop publishing), consumer electronics (e.g., home VCRs, DVD players, TVs), to telecommunication equipment (e.g., cordless telephones, fax machines, wireless telephones) and office supplies (e.g., photocopiers, scanners, printers). Our empirical analysis focuses on the same 45 categories. We collect information not only on the pioneer but also on early followers in each selected category from 1950 to 2007.

First, following the same method used in Srinivasan, Lilien, and Rangaswamy (2004), we independently identify pioneers in these 45 product categories. In 42 of the 45 categories, the pioneers we identified are consistent with those in the 2004 study.[1] Such a high degree of result consistency suggests strong method validity. Second, using the pioneer in each category as the starting point, we trace forward, on a yearly basis, the news archives, articles published in scholarly journals, company histories, and online databases until we identify the early followers. Following Robinson and Min (2002), when multiple entrants are identified in the same year, we include them all in our database as early followers. Overall, our data set includes 45 pioneers and 55 early followers in 45 categories from 1950 to 2007. Variables used in our empirical examination are defined as follows.

Table 2
**Product Compatibility Distribution**

**Pioneers (*N* = 45)**

| | | Within-Generation | |
|---|---|---|---|
| | | Incompatible (WGIC) | Compatible (WGC) |
| Cross-Generation | Incompatible (CGIC) | 20 | 13 |
| | Compatible (CGC) | 5 | 7 |

**Early Followers (*N* = 55)**

| | | Within-Generation | |
|---|---|---|---|
| | | Incompatible (WGIC) | Compatible (WGC) |
| Cross-Generation | Incompatible (CGIC) | 22 | 20 |
| | Compatible (CGC) | 6 | 7 |

**Survival Duration and Order-of-Entry**
Following Srinivasan, Lilien, and Rangaswamy (2004), we determine survival durations for pioneers and early followers by the length of time from year of entry to year of exit. Note that the 2004 study data collection ends in 2001. For those pioneers who were reported under "exit" in their study, we use that measure of survival duration. For those pioneers reported under "survival" in their study, however, we continue to identify their survival status until 2007 (i.e., the endpoint of our data collection). For the early followers, our starting point is the year 2007. We then trace backward, on a yearly basis, the news archives, articles published in scholarly journals, company histories, and online databases until we identify each firm's exit year. If a firm is still in market by 2007, its survival duration is the length of time from the year it entered a market to the year 2007 and right-censored. Overall, among the 45 pioneers and 55 early followers we identify, 18 pioneers and 42 early followers are still in the market by 2007. We use a variable, PIONEER, to measure the order-of-entry (PIONEER = 1 for market pioneers, PIONEER = 0, otherwise).

**Product Incompatibility.** We conduct extensive research and consult experts to understand the compatibility issues for each product category. We code product compatibility for the three product categories in our database. For telecommunications networks (e.g., telephone and cellular phone service network), compatibility means that subscribers to one telecommunication network can communicate with others. For durable goods (e.g., modems, facsimile machines, disk drive, and food processor), it is said to be compatible when equipment (or components) produced by different vendors are interchangeable (i.e., can interconnect to each other). For complementary goods (e.g., hardware/software; operation systems/application programs; video game consoles/game cartridges; and VCRs, CD, DVD players/video tapes, CDs, DVDs), a product is compatible if its complementary goods can also be used by other different brands of the same products. We use the historical method to determine the two types of (in)compatibility for each firm's product at the time when it was introduced. Two dummy variables, CGIC and WGIC, are used to measure cross-generation and within-generation incompatibility, respectively. Specifically, if a product was incompatible with its previous generation when it was introduced, the CGIC = 1; otherwise, the CGIC = 0.[2] The same previous generation product used in Srinivasan, Lilien, and Rangaswamy (2004) is adopted for each of the 45 product categories. Similarly, if a product was incompatible with other products in its generation when it was introduced, then WGIC = 1; otherwise, the WGIC = 0.
Of the 45 pioneers' products, 33 were cross-generation incompatible and 25 were within-generation incompatible. Of the 55 early followers' products, 42 were cross-generation incompatible and 28 were within-generation incompatible.[3] Table 2 summarizes the number of products with the two types of incompatibility for pioneers and early followers.

**Network Effects.** We adopt the same measure of network effects used in Srinivasan, Lilien, and Rangaswamy (2004). Specifically, they measure the network effects of the pioneer in each of the 45 categories based on the sum of two ratings provided by nine academic raters: degree of direct network effects and degree of indirect network effects. We use the same measure of network effects for the pioneer and its followers in the same category. Therefore, as in Srinivasan, Lilien, and Rangaswamy (2004), the network effects measured in our dataset vary from 3.4 (weakest) to 12.1 (strongest).

**Control Variables.** We collect data on a set of control variables. To control for product radicalness, we follow the procedure described in Chandy and Tellis (2000) and Srinivasan, Lilien, and Rangaswamy (2004) to obtain the radicalness measurement for each product. Specifically, 18 engineering master's degree students were asked to rate each product category in two dimensions (each with a scale from 1 to 9): (1) whether a new product incorporates a substantially different core technology relative to the previous-generation product, and (2) whether a new product provides substantially higher customer benefits relative to the previous generation. The radicalness of a product category is then measured by adding together the ratings from these two dimensions. To facilitate the evaluation, we provide students descriptions of each product category, such as the time of product introduction and the basic features and functions offered at that time. Our radicalness measure has an average of 13.9 with a standard deviation 1.72 for the pioneers and an average of 13.62 with a standard deviation 1.87 for the early followers, which is close to the mean of 12.8 and standard deviation of 1.4 reported in Srinivasan, Lilien, and Rangaswamy (2004).

To control for potential impacts of firm incumbency on product survival, we collect data on the incumbency status of a firm. In the literature (e.g., Chandy and Tellis 2000; Mitchell 1991; Mitchell and Singh 1993; Srinivasan, Lilien, and Rangaswamy 2004), a firm is defined as incumbent if it also produces a product that belonged to the previous generation. Following this definition, we use the historical method to identify the incumbency status of each firm. Among the 45 pioneers and 55 early followers in our dataset, 19 of the pioneers and 27 of the early followers were incumbent. A dummy variable is used such that INCUMB = 1 indicates that the firm is an incumbent, and INCUMB = 0, otherwise.

To control for firm size, following Srinivasan, Lilien, and Rangaswamy (2004), we collect data on the number of employees in each firm at the time of its market entry, and sort all firms into two categories based on whether or not they employed at least 100 people at the time of entry. A dummy variable Size is measured as 1 if a firm has at least 100 employees; 0 otherwise.

Finally, we collect the product market entry time for each firm. Following Robinson and Min (2002), we define two variables related to entry time: (1) *lead time* as the number of lead years of a pioneer over its early followers, and (2) *delay time* as the number of years the entry of an early follower was delayed after the pioneer's entry. The average lead time for 45 pioneers is 4.82 years and the average delay time for 55 early followers is 3.13 years. Note that, the average lead time for the pioneers is different from the average delay time for early followers simply due to their different sample size. Again following Robinson and Min (2002), the natural logarithm of the lead time and delay time are used in the estimation. We also control the effect of product age by adding the natural logarithm of the product introduction year in the estimation.

We summarize the definitions of all variables in Table 3.

### Estimation method

Following Srinivasan, Lilien, and Rangaswamy (2004), we use the accelerated failure time

Table 3
**Variables: Definitions**

| Variable (Abbr.) | Definition |
|---|---|
| PIONEER | 1 if the firm is market pioneer; 0 otherwise |
| Network Effects (NE) | We adopt the measurement published in Srinivasan, Lilien, and Rangaswamy (2004), in a scale from 2 to 14: 2 if the product has no network effects; 14 if the product has extremely large network effects. |
| Cross-Generation Incompatibility (CGIC) | 1 if a product was incompatible with its previous generation; 0 otherwise |
| Within-Generation Incompatibility (WGIC) | 1 if a product was incompatible with other products in its generation; 0 otherwise |
| Incumbency (INCUMB) | 1 if the firm also markets a product belonging to the previous generation of products that satisfied same customer needs; 0 otherwise |
| Radicalness (RDC) | We adopt the measurement in Srinivasan, Lilien, and Rangaswamy (2004) and Chandy and Tellis (2000) by adding two dimensions: (1) whether a new technology incorporates a substantially different core technology on a scale from 1 to 9 and (2) whether a new product provides substantially higher customer benefits compared with the previous product generation in the category on a scale from 1 to 9. |
| Size | 1 if the number of employers in the firm is equal to or more than 100; 0 otherwise |
| Lead Time (Lead) | For the market pioneers, the natural logarithm of the lead time in years over the early followers; 0 otherwise |
| Delayed Time (Delay) | For the early followers, the natural logarithm of the delay time in years after the pioneer's entry; 0 otherwise |
| Intro. Year | The natural logarithm of the introduction year |

model (AFT) (see Cox and Oakes 1984; Kalbfleisch and Prentice 1980) to estimate the impacts of the two types of incompatibility on the survival durations in markets with network effects. The AFT model incorporates the impact of independent variables on the baseline survival duration of a product multiplicatively. Specifically, the survival duration $t_i$ of product $i$ is assumed to be a multiplicative function of independent variables $X_{ik}(k = 1, \ldots, K)$ and its baseline survival duration $t_{0i}$; that is, $t_i = t_{0i}\exp(\sum_{k=1}^{K} X_{ik}\beta_k)$. In the following empirical estimation, we empirically specify the survival duration function as:

$$\begin{aligned}\mathrm{Ln}t_i = {} & \beta_0 + \beta_1 \mathrm{PIONEER}_i + \beta_2 \mathrm{CGIC}_i + \\ & \beta_3 \mathrm{WGIC}_i + \beta_4 \mathrm{NE}_i + \beta_5 \mathrm{NE}_i{*}\mathrm{CGIC}_i + \beta_6 \mathrm{NE}_i{*}\mathrm{WGIC}_i + \\ & \beta_7 \mathrm{NE}_i{*}\mathrm{PIONEER}_i + \beta_8 \mathrm{CGIC}{*}\mathrm{PIONEER}_i + \\ & \beta_9 \mathrm{NE}_i{*}\mathrm{CGIC}_i{*}\mathrm{PIONEER}_i + \beta_{10} \mathrm{WGIC}_i{*}\mathrm{PIONEER}_i + \\ & \beta_{11} \mathrm{NE}_i{*}\mathrm{WGIC}_i{*}\mathrm{PIONEER}_i + \beta_{12\sim19} \mathrm{CONTROL} + \ln(t_{0i}) \qquad (1)\end{aligned}$$

where the baseline survival time $t_{0i}$ is assumed to be independently and identically distributed as the Weibull distribution, a well-adopted distribution in survival analysis (Cox and Oakes 1984). Given the Weibull distribution assumption, the survival probability of survival duration $t_i$ and the likelihood function can be derived accordingly. The technical details for the survival probability and likelihood function can be found in Appendix A.

As discussed earlier, our research focuses on the joint effect of product compatibility and network effects on pioneer survival advantage. To examine the general patterns of such joint effects (H1 and H3), we need to test the coefficients of the three-way interaction terms of NE*CGIC*PIONEER, $\beta_9$, and NE*WGIC*PIONEER, $\beta_{11}$, in Equation 1. To test their joint effects in specific cases (H2 and H4), we must calculate and test ($\beta_8$ +

Table 4
**Descriptive Statistics**

| | Pioneer (*N* = 45) | | Early Follower (*N* = 55) | |
|---|---|---|---|---|
| **Variable** | **Mean** | **S.D.** | **Mean** | **S.D.** |
| Survival Duration (Years) | 17.36 | 13.23 | 22.15 | 13.70 |
| Network Effects | 7.67 | 2.23 | 7.97 | 2.15 |
| Cross-Generation Incompatibility | .73 | .45 | .76 | .43 |
| Within-Generation Incompatibility | .56 | .50 | .51 | .51 |
| Radicalness | 13.90 | 1.72 | 13.62 | 1.87 |
| Incumbency | .42 | .50 | .49 | .50 |
| Size | .60 | .50 | .82 | .39 |
| Intro. Year | 7.59 | .01 | 7.59 | .01 |
| Lead Time/Delay Time (Years) | 4.82 | 9.04 | 3.13 | 3.32 |

S.D. = standard deviation

$\beta_9$NE) and ($\beta_{10}$ + $\beta_{11}$NE), respectively. Similarly, to test H5 and H6, the overall order-of-entry effect or pioneer advantage, we must calculate and test ($\beta_1$ + $\beta_7$NE + $\beta_8$CGIC + $\beta_9$NE*CGIC + $\beta_{10}$WGIC + $\beta_{11}$NE*WGIC). The vector CONTROL includes control variables such as radicalness ($RDC_i$), incumbency ($INCUMB_i$), firm size ($Size_i$), product introduction year ($Intro.Year_i$), pioneer lead time ($Lead_i$) and follower delay time ($Delay_i$), and their square timers ($Lead_i^2$ and $Delay_i^2$). These variables were discussed previously and defined in Table 3.

## Results

We report the descriptive statistics of all variables in Table 4, and the results of our model estimation in Table 5. As shown in Table 4, for the 45 product categories in our study, the mean survival duration is 17.36 years for pioneers and 22.15 years for early followers ($p < .05$). This suggests that, *on average*, pioneers experience a survival *disadvantage* compared with their earlier followers in these markets. As shown in Table 5, overall, our estimation results show a goodness of fit (i.e., $\chi^2 = 67.40$) at a significant level of $p < .01$. The coefficient of the variable PIONEER is significantly negative ($\beta_1 = -2.086$, $p < .10$), suggesting a negative main effect of entry order on firm survival. The coefficient of variable NE in Table 5 is significantly negative ($\beta_4 = -1.227$, $p < .10$), suggesting a negative main effect of network effects on firm survival. This finding is consistent with that discovered in Srinivasan, Lilien, and Rangaswamy (2004) when only pioneer firms were examined.

In the following, we first present the key results of our model: (1) the general pattern of the joint effects of product compatibility and network effects on pioneer survival advantage (H1 and H3), (2) such joint effects in some specific markets (H2 and H4), and (3) the overall order-of-entry effect on survival in markets with network effects (H5 and H6). We then discuss the robustness of our results.

### General pattern of the joint effects

H1 and H3 predict that network effects influence the impact of the two types of product (in)compatibility on pioneer survival advantage in opposite directions: they decrease the impact of cross-generation incompatibility (H1), but increase the impact of within-generation incompatibility (H3). As shown in Table 5, the coefficient of NE*CGIC*PIONEER is significantly negative ($\beta_9 = -1.541$, $p < .05$), but the coefficient of NE*WGIC*PIONEER is significantly positive ($\beta_{11} = 0.986$, $p < .05$). These results suggest that, as network effects increase, the impact of cross-generation incompatibility on pioneer survival advantage becomes weaker, whereas the impact of within-generation incompatibility becomes stronger. Hence, H1 and H3 are supported.

### Joint effects in specific markets

H2 predicts that cross-generation incompatibility increases pioneer survival advantage in markets with weak network effects (H2a), but decreases such an advantage in markets with strong network effects (H2b). To test these predictions, we rewrite the sum of factors with CGIC*PIONEER in Equation 1 as

Table 5
**Empirical Results of Survival Duration in Markets with Network Effects**

| Variable | Estimate | Standard Error | Hypothesized Effects |
|---|---|---|---|
| Intercept ($\beta_0$) | 3.082** | 1.462 | |
| PIONEER ($\beta_1$) | –2.086* | 1.515 | |
| CGIC ($\beta_2$) | –1.911* | 1.414 | |
| WGIC ($\beta_3$) | 1.598* | 1.043 | |
| NE ($\beta_4$) | –1.227* | .384 | |
| NE*CGIC ($\beta_5$) | 1.354** | .767 | |
| NE*WGIC ($\beta_6$) | –.808** | .420 | |
| NE*PIONEER ($\beta_7$) | 1.214* | .820 | |
| CGIC*PIONEER ($\beta_8$) | 2.667** | 1.474 | |
| NE*CGIC*PIONEER ($\beta_9$) | –1.541** | .798 | – (H1) |
| WGIC*PIONEER ($\beta_{10}$) | –2.216** | 1.152 | |
| NE*WGIC*PIONEER ($\beta_{11}$) | .986** | .497 | + (H3) |
| **Control Variables** | | | |
| RDC ($\beta_{12}$) | .171 | .107 | |
| INCUMB ($\beta_{13}$) | .530* | .397 | |
| Size ($\beta_{14}$) | 1.343*** | .461 | |
| Intro. Year ($\beta_{15}$) | 65.963* | 41.963 | |
| Lead ($\beta_{16}$) | –.559 | .582 | |
| Lead*Lead ($\beta_{17}$) | .612* | .366 | |
| Delay ($\beta_{18}$) | –1.079 | .835 | |
| Delay*Delay ($\beta_{19}$) | 2.588** | 1.159 | |
| Scale Parameter | .933 | | |
| Log-Likelihood Value | –85.540 | | |
| Goodness of Fit (d.f. = 19) | $\chi^2$ = 67.400*** | | |
| Sample Size | 100 | | |

Note: ***$p < .01$; **$p < .05$; *$p < .10$.

$K_{cross}$*CGIC*PIONEER, where $K_{cross} = (\beta_8 + \beta_9 NE)$. The coefficient, $K_{cross}$, represents the net impact of cross-generation incompatibility on pioneer survival advantage at each level of the network effects. As shown in Table 6, in markets with the lowest level of network effects (NE = –6),[4] the coefficient $K_{cross}$ is significantly positive ($K_{cross} = 11.913 > 0$, $p < .05$), which supports H2a. On the other hand, in markets with the highest level of network effects (NE = 6), the coefficient $K_{cross}$ turns out to be significantly negative ($K_{cross} = -6.581$, $p < .05$), which supports H2b.

H4 predicts that within-generation incompatibility decreases pioneer survival advantage in markets with weak network effects (H4a), but increases it in markets with strong network effects (H4b). To test these predictions, we rewrite the sum of factors with WGIC*PIONEER in Equation 1 as $K_{within}$*WGIC*PIONEER, where $K_{within} = (\beta_{10} + \beta_{11} NE)$. The coefficient, $K_{within}$, represents the net impact of within-generation incompatibility on product pioneer advantage at each level of network effects. As shown in Table 6, in markets with the lowest level of network effects (NE = –6), the coefficient $K_{within}$ is significantly negative ($K_{within} = -8.132$, $p < .05$), which supports H4a. However, in markets with the highest level of network effects (NE = 6), the coefficient $K_{within}$ turns out to be positive ($K_{within} = 3.700$, $p < .1$), which supports H4b.

### Overall order-of-entry effects

Our last two hypotheses provide conditions under which pioneers are more likely to have survival (dis)advantage than their early followers (H5 and H6). To test this overall order-of-entry effect, we rewrite the sum of factors with PIONEER in Equation 1 as $K_{overall}$*PIONEER, where $K_{overall} = (\beta_1 + \beta_7 NE + \beta_8 CGIC + \beta_9 NE{*}CGIC + \beta_{10} WGIC + \beta_{11} NE{*}WGIC)$. The coefficient, $K_{overall}$, represents the overall entry-order effects on survival under different product compatibility conditions. Table 7 presents the overall entry-order effects in markets with the lowest level of network effects (NE = –6) and the highest level of network effects (NE = 6), under different combinations of the two types of product compatibility. As shown in Table 7, for NE = –6, the overall entry-of-order effect is significantly *negative* ($K_{overall} = -17.504$, $p < .01$) if the products are cross-generation compatible but within-generation incompatible (CGC/WGIC), which supports H5a.

Table 6

**Hypothesis Test on Joint Effects of Product Incompatibility and Network Effects on Pioneer Survival Advantage**

| Parameter | Estimate | Standard Error | Hypothesized Effects |
|---|---|---|---|
| H1: $\beta_9$ | –1.541** | .798 | – (H1) |
| H2: $K_{cross} = \beta_8 + \beta_9 NE$ | | | |
| NE | | | |
| –6 | 11.913** | 5.966 | + (H2a) |
| –5 | 10.373** | 5.180 | |
| –4 | 8.831** | 4.400 | |
| –3 | 7.290** | 3.627 | |
| –2 | 5.749** | 2.867 | |
| –1 | 4.208** | 2.135 | |
| 0 | 2.667** | 1.474 | |
| 1 | 1.125 | 1.030 | |
| 2 | –.416 | 1.106 | |
| 3 | –1.957 | 1.630 | |
| 4 | –3.498* | 2.316 | |
| 5 | –5.039** | 3.057 | |
| 6 | –6.581** | 3.821 | – (H2b) |
| H3: $\beta_{11}$ | .986** | .497 | + (H3) |
| H4: $K_{within} = \beta_{10} + \beta_{11} NE$ | | | |
| NE | | | |
| –6 | –8.132** | 3.764 | – (H4a) |
| –5 | –7.146** | 3.285 | |
| –4 | –6.160** | 2.813 | |
| –3 | –5.174** | 2.351 | |
| –2 | –4.188** | 1.906 | |
| –1 | –3.202** | 1.494 | |
| 0 | –2.216** | 1.152 | |
| 1 | –1.230 | .956 | |
| 2 | –.244 | .998 | |
| 3 | .742 | 1.253 | |
| 4 | 1.728 | 1.625 | |
| 5 | 2.714* | 2.050 | |
| 6 | 3.700* | 2.501 | + (H4b) |

***$p < .01$; **$p < .05$; *$p < .10$.
NE is mean-centered. The mean value is 8.

The overall entry-of-order effect is significantly *positive* ($K_{overall} = 2.542$, $p < .10$) if the products are cross-generation incompatible but within-generation compatible (CGIC/WGC), which supports H5b. Now consider the case with very strong network effects. As shown in Table 7, for NE = 6, the overall entry-of-order effect is significantly *positive* ($K_{overall} = 8.900$, $p < .05$), if the products are cross-generation compatible but within-generation incompatible, which supports H6a. Finally, the overall entry-of-order effect has the predicted negative sign but is not significant ($K_{overall} = -1.38$, $p > .10$) if the products are cross-generation incompatible but within-generation compatible.

### Robustness of results

We examine the sensitivity of our estimations by two additional analyses. First, instead of assuming the Weibull baseline distribution, as in Equation 1, we estimate our model by assuming two other commonly used baseline distributions: lognormal and log-logistic distributions. Our results, based on these two alternative assumptions (see the estimation results under the assumptions of lognormal and log-logistic distributions in Appendix B), are consistent with those presented in Table 6.

Second, instead of using the accelerated failure model as in Srinivasan, Lilien, and Rangaswamy (2004), we estimate a proportional hazard model (see Cox and Oakes (1984) and Kalbfleisch and Prentice (1980) for references). The signs of our estimates are opposite to the AFT model because the proportional hazard model assumes the impacts of variables on the hazard rate while the AFT model assumes the impacts of variables on the time to survive. The two models lead to the same patterns (see the results in the fourth column of Appendix B).

## General Discussion

### Research contributions

First, this paper contributes to the literature on network effects. Although network effects, as an increasingly important marketing phenomenon, have attracted increasing attention from scholars in marketing, management, and

Table 7
**Hypothesis Test on Overall Order-of-Entry Effects**

| | Product Compatibility | | Overall Order-of-Entry Effects | |
|---|---|---|---|---|
| | Cross-Generation | Within-Generation | (Overall Pioneer Advantage) | Hypothesized Effects |
| **Very Weak Network Effects (NE = –6)** | Compatible | Incompatible | –17.504***<br>(6.568) | – (H5a) |
| | Compatible | Compatible | –9.371*<br>(5.943) | |
| | Incompatible | Incompatible | –5.590**<br>(3.198) | |
| | Incompatible | Compatible | 2.542*<br>(1.663) | + (H5b) |
| **Very Strong Network Effects (NE = 6)** | Compatible | Incompatible | 8.900**<br>(4.171) | + (H6a) |
| | Compatible | Compatible | 5.200<br>(4.198) | |
| | Incompatible | Incompatible | 2.320<br>(1.858) | |
| | Incompatible | Compatible | –1.380<br>(1.882) | – (H6b) |

****p* < .01; ***p* < .05; **p* < .1.
The overall pioneer advantage is estimated as $K_{overall} = (\beta_1 + \beta_7 NE + \beta_8 CGIC + \beta_9 NE*CGIC + \beta_{10} WGIC + \beta_{11} NE*WGIC)$.
Numbers in parentheses are the estimated standard errors.
NE is mean-centered. The mean value is 8.

economics in recent years, there are limited studies on firm survival in such markets. Among the few published studies on this subject, theoretical researchers (e.g., Shapiro and Varian 1998) suggest that firms can have a pioneer advantage in markets with network effects because the positive installed-base effect increases entry barriers and creates a "first-mover" competitive advantage. A recent empirical paper (Srinivasan, Lilien, and Rangaswamy 2004), however, finds that network effects have a negative impact on the survival duration of a pioneer's product. Their work, as the first published empirical work on pioneer survival in the presence of network effects, offers many important insights, but it does not directly address the order-of-entry effect.

Our paper extends the existing research by examining the order-of-entry effect in markets with network effects and, by introducing an unexplored factor—product compatibility—to this research stream. We show that, in markets with network effects, product compatibility plays a critical role in determining the order-of-entry effects on survival. Interestingly, we discover that the two different types of product compatibility, *cross-generation* and *within-generation* compatibility, impact pioneer survival advantage in different ways. We also find that both the *magnitude* and the *direction* of the impacts of the two types of product compatibility are contingent on the strength of network effects in the underlying market. As the result, the overall order-of-entry effect on survival is determined by the specific combination of the two types of product compatibility and the strength of network effects. Our research makes a conceptual contribution by proposing some systematic patterns within these complicated contingency relationships. This is the first study to provide empirical evidence as to how pioneers can have a survival advantage compared with their early followers in markets with both strong and weak network effects and under different product compatibility conditions. Specifically, when the products are cross-generation compatible but within-generation incompatible, a pioneer has a survival *disadvantage* relative to early followers in markets with very weak network effects, but has a survival *advantage* in markets with very strong network effects. However, when the products are cross-generation incompatible but within-generation compatible, the results are reversed: A pioneer has a survival *advantage* in the former markets (i.e., where there are weak network effects) but a *disadvantage* in the latter (i.e., where there are strong network effects).

This paper also contributes to the order-of-entry literature. The extant research has mixed findings regarding the order-of-entry effects on firm survival. Some studies suggest a pioneer advantage (e.g., Carpenter and Nakamoto 1989; Robinson and Min 2002); other studies indicate a pioneer disadvantage (e.g., Lilien and Yoon 1990; Mitchell 1991). We show two important market characteristics—the relative strength of network effects and product compatibility in a market jointly determine the ultimate effects of order-of-entry. This is a very important finding considering the growing importance of network effects throughout the economy.

## Managerial implications

The installed-base effect, a unique characteristic of markets with network effects, is a double-edged sword for a market pioneer's survival: Although it imposes a high first-mover risk due to the unique "start-up" difficulty (zero or small installed base at product launch), it also provides a high first-mover benefit, because the established installed base creates entry barriers and competitive advantages. To be successful in markets with network effects, managers need a deeper understanding of the overall impact of network effects on survival as well as the impact of more specific market/product factors. Our findings provide some useful insights into a firm's entry decision in markets with network effects. Conventional wisdom has emphasized the importance of being first in markets influenced by network effects in order to benefit from a positive installed base (Shapiro and Varian 1998); however, our findings reveal a lower average survival duration of pioneers compared to their early followers in such markets (see Table 4).

More importantly, our results show that, although on average pioneers have a higher failure rate than their early followers in markets with network effects, opportunities exist for pioneers to enjoy a survival advantage in markets with both strong and weak network effects. We identify specific conditions for such opportunities. For example, in markets with strong network effects, when a new technology is compatible with previous-generation technology, our findings suggest that firms have a pioneer advantage if their products are incompatible with their followers' products. In markets with weak network effects, however, when the technology is incompatible with previous-generation technology, firms can gain a pioneer advantage if their products are compatible with those of their competitors. These findings may be helpful to firms facing market-entry decisions.

## Limitations and directions for future research

This paper has several limitations. First, as in other studies using historical methods, our dataset includes only products that we can find in historical records, and those products, especially products of small firms that have existed in markets for only a very short time, may not be identifiable due to their missing archival records. Second, following the study in Srinivasan, Lilien, and Rangaswamy (2004), we use subjective measures for network effects. Future studies, if using objective measures, can provide additional insights into this research. Finally, this paper focuses only on the survival duration of a product. Future research can explicitly examine how the connection between network effects and product compatibility impacts firms' financial performance and predicts their survival risks.

## Appendix A: The Accelerated Failure Model

In our empirical estimation, we use the accelerated failure time model (AFT) (see Cox and Oakes 1984; Kalbfleisch and Prentice 1980) to estimate the impacts of the two types of incompatibility on the survival durations in markets with network effects. Specifically, based on the assumption of the AFT model that independent variables (or covariates) affect the baseline survival duration multiplicatively, we assume:

$$t_i = t_{0i} \exp\left(\sum_{k=1}^{K} X_{ik}\beta_k\right) \quad \text{(A1)}$$

where $t_i$ denotes the survival duration of firm $i$, $X_{ik}$ ($k = 1, \ldots, K$) denotes the $k$th independent variable that might affect the product $i$'s survival duration with its coefficient of $\beta_k$, and $t_{0i}$ is the baseline survival duration without the impacts of independent variables. We assume $t_{0i}$ to be independently and identically distributed with the Weibull distribution (i.e., its survival probability is $S(t_{0i}) = \exp\left\{-[t_{0i}]^{\frac{1}{\sigma}}\right\}$, a well-adopted distribution in survival analysis (Cox and Oakes 1984).

The survival probability and hazard function for $t_i$ are then given by

$$S(t_i) = \exp\left\{-\left[t_i \exp\left(-\sum_{k=1}^{K} X_{ik}\beta_k\right)\right]^{\frac{1}{\sigma}}\right\}, \quad \text{(A2)}$$

$$h(t_i) = \frac{1}{\sigma}\left[\exp\left(-\sum_{k=1}^{K} X_{ik}\beta_k\right)\right]\left[t_i \exp\left(-\sum_{k=1}^{K} X_{ik}\beta_k\right)\right]^{\frac{1}{\sigma}-1}, \quad \text{(A3)}$$

where the scale parameter $\sigma$ determines if the hazard function is monotonically decreasing ($\sigma > 1$), increasing ($\sigma < 1$), or constant ($\sigma = 1$). Given the survival probability function (Equation A2) and the hazard function (Equation A3), the likelihood function can be written as

$$L = \prod_{i=1}^{n} h(t_i)^{\delta_1} S(t_i) \quad \text{(A4)}$$

where the $\delta_1$ indicates whether observations for product $i$ is right censored. Specifically, $\delta_1 = 0$ when the observation for firm $i$ is right censored; otherwise $\delta_1 = 1$. In our empirical estimation, we empirically estimate the likelihood function for all the products by using the maximum likelihood method, where the survival duration function (Equation A1) is empirically specified as Equation 1. To increase the interpretability of the parameter estimates, continuous variables such as network effects, radicalness, lead time, and delay time are mean-centered (Srinivasan, Lilien, and Rangaswamy 2008).

## Appendix B: Parameter Estimation with Different Distribution Assumptions

| Variable | AFT Model (Log-Normal) | AFT Model (Log-Logistic) | Proportional Hazard Model |
|---|---|---|---|
| Intercept ($\beta_0$) | 2.626*** | 2.735** | 1.185* |
| | (1.083) | (1.236) | (.814) |
| PIONEER ($\beta_1$) | –1.858* | –1.889* | 1.909 |
| | (1.120) | (1.325) | (1.589) |
| CGIC ($\beta_2$) | –1.957** | –1.743* | 1.762 |
| | (1.067) | (1.199) | (1.460) |
| WGIC ($\beta_3$) | .834* | 1.168** | –1.554* |
| | (.605) | (.798) | (1.036) |
| NE ($\beta_4$) | –1.085* | –1.085* | 1.185* |
| | (.713) | (.716) | (.814) |

*Continued*

## Appendix B: Continued

| Variable | AFT Model (Log-Normal) | AFT Model (Log-Logistic) | Proportional Hazard Model |
|---|---|---|---|
| NE*CGIC ($\beta_5$) | 1.228** | 1.167** | –1.327** |
| | (.685) | (.683) | (.779) |
| NE*WGIC ($\beta_6$) | –.537** | –.626** | .788** |
| | (.315) | (.338) | (.416) |
| NE*PIONEER ($\beta_7$) | 1.212* | 1.163* | –1.201* |
| | (.739) | (.735) | (.832) |
| CGIC*PIONEER ($\beta_8$) | 2.329** | 2.150** | –2.449** |
| | (1.173) | (1.277) | (1.525) |
| NE*CGIC*PIONEER ($\beta_9$) | –1.437** | –1.334** | 1.515** |
| | (.733) | (.724) | (.810) |
| WGIC*PIONEER ($\beta_{10}$) | –1.267* | –1.587** | 2.090** |
| | (.786) | (.933) | (1.157) |
| NE*WGIC*PIONEER ($\beta_{11}$) | .493 | .586* | –.929** |
| | (.418) | (.438) | (.503) |
| **Control Variable** | | | |
| RDC ($\beta_{12}$) | .199** | .225** | –.195** |
| | (.110) | (.112) | (.111) |
| INCUMB ($\beta_{13}$) | .559* | .451 | –.430 |
| | (.421) | (.418) | (.426) |
| Size ($\beta_{14}$) | 1.239*** | 1.212*** | –1.375*** |
| | (.447) | (.449) | (.480) |
| Intro. Year ($\beta_{15}$) | 45.346 | 60.752* | –65.636* |
| | (41.900) | (43.718) | (44.843) |
| Lead ($\beta_{16}$) | –.833 | –.614 | .669 |
| | (.584) | (.577) | (.607) |
| Lead*Lead ($\beta_{17}$) | .733** | .690** | –.651** |
| | (.390) | (.385) | (.380) |
| Delay ($\beta_{18}$) | –1.260 | –1.005 | 1.126 |
| | (.769) | (.833) | (.882) |
| Delay*Delay ($\beta_{19}$) | 2.631*** | 2.306** | –2.604** |
| | (.916) | (1.014) | (1.176) |
| Scale Parameter | 1.296 | .723 | |
| Log-Likelihood Value | –86.50 | –86.21 | –139.21 |
| Goodness of Fit ($\chi^2$, d.f.=19) | 59.66*** | 63.40*** | 59.62*** |
| Sample Size | 100 | 100 | 100 |

***$p < .01$; **$p < .05$; *$p < .1$.

## Notes

1. The three inconsistent cases are color television, CAD software, and camcorder, for which we found earlier entrants than the pioneers identified in Srinivasan, Lilien, and Rangaswamy (2004).

2. For six product categories without previous generations, we consider these categories conceptually the same as cross-generation incompatible and code CGIC as 1.

3. Since there could be more than one early follower (i.e., more followers enter in the same year) for a pioneer, the number of incompatible products is higher for the followers than the pioneers.

4. The original measure of network effects is between (2, 14) with the average of 8. The mean-centered measure is between (–6, 6).

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