First in, First out? The Effects of Network Externalities on Pioneer Survival

Network externalities are playing an increasingly important role in the economy, and they have significant implications for firms' marketing strategies. The authors study the effects of network externalities in conjunction with other product and firm characteristics on the survival of pioneers. They apply an accelerated failure time model to data on 45 office products and consumer durables. The authors find evidence that network externalities have a negative main effect on the survival duration of pioneers. However, for more radical products and for technologically intense products, increases in network externalities are associated with increased survival duration. The larger the pioneer, the more network externalities increase its survival duration, whereas incumbent pioneers experience a decrease in survival duration compared with nonincumbents. The findings of this article contribute to theory in marketing strategy and have important implications for firms that are developing market entry strategies for products with network externalities.

As the economy becomes more interconnected, more products in computing, consumer electronics, and telecommunications industries exhibit network externalities (Yoffie 1997). Positive network externalities exist when a customer's utility for a product increases as the number of customers who use identical or compatible products increases. Some examples of products with network externalities include digital videodisc players, digital cameras, instant messaging systems, interactive televisions, and MP3 players. Given the increasing importance of network externalities in the economy, extensive literature in economics has examined the strategic and welfare implications of network externalities (e.g., Economides 1989; Farrell and Saloner 1986; Katz and Shapiro 1986). A consistent finding in the literature is that network externalities alter customer behavior (e.g., before adopting the product, it is rational for people to wait for others to adopt the product) and have important implications for marketing strategy.

Previous studies have explored the implications of network externalities on several aspects of marketing, including (1) customer behavior and market structure (Frels, Shervani, and Srivastava 2003; Goldenberg, Libai, and Muller 2002a; Shankar and Bayus 2003); (2) product-related decisions such as preannouncements (Nagard-Assayag and Manceau 2001), timing of product introductions (Padmanabhan, Rajiv, and Srinivasan 1997), and product differentiation (Esser and Leruth 1989); and (3) market entry (Gupta, Jain, and Sawhney 1999; Xie and Sirbu 1995). The effects of network externalities are acutely experienced in the high-technology sector, which constituted 14.7% of gross domestic output in 1999, up from 9.6% in 1980 (U.S. Department of Commerce 2000), and has been growing four times as fast as the rest of the economy (Milken Institute 2000). Although there are valuable insights on marketing in high-technology markets (e.g., Heide and Weiss 1995; Weiss and Heide 1993), the area remains underresearched (John, Weiss, and Dutta 1999, p. 78).

There is a rich and diverse stream of research on the rewards of pioneering. Although some of the literature points to an advantage for pioneers (e.g., Carpenter and Nakamoto 1989; Kalyanaram and Urban 1992; Robinson and Fornell 1985; Urban et al.1986), other research sug-
gests that later entrants may also enjoy advantages (e.g., Bayus, Jain, and Rao 1997; Golder and Tellis 1993; Lilien and Yoon 1990; Narasimhan and Zhang 2000; Shankar, Carpenter, and Krishnamurthi 1998). Thus, the mechanisms that generate pioneering rewards appear to be complex. We next summarize the specific findings in previous research that motivate our article.

First, the detection of pioneering advantage depends on the performance metric used (e.g., market share, profitability, survival duration). VanderWerf and Mahon’s (1997) meta-analysis of 22 studies on pioneering indicates that studies that use market share are more likely to find a pioneering advantage than are studies that use other metrics. Indeed, most of the previous research that has detected a pioneering advantage (e.g., Kalyanaram and Urban 1992; Robinson and Fornell 1985; Urban et al. 1986) has used market share as the performance metric. There is now a need for studies that explore pioneering advantages in other performance metrics (Lieberman and Montgomery 1998).

Second, pioneering advantages may be specific to a product class or industry (Kerin, Varadarajan, and Peterson 1992; Szymanski, Troy, and Bharadwaj 1995; VanderWerf and Mahon 1997). In particular, network externalities, a characteristic of many high-technology products, may influence the rewards of pioneering. Network externalities tend to create winner-take-all markets, in which one firm emerges as a dominant player and other firms, which sometimes have superior products, are locked out (Schilling 2002). If the pioneer does not survive, its market share and profitability are moot issues. Thus, survival is a primary performance metric for pioneers in networked markets.

Third, previous research on the survival of pioneers provides mixed results. Across 36 product categories, Golder and Tellis (1993) report a long-term survival rate of 53% for pioneers. Whitten (1979) reports that pioneers in seven cigarette markets survived. Several studies report no difference in survival rates between pioneers and later entrants, including 18 markets for Iowa newspapers (Glazer 1985), 39 markets for chemical products (Lieberman 1989), and 11 markets for consumer nondurables (Sullivan 1992). In contrast, Mitchell (1991) and Christensen, Suarez, and Utterback (1998) find lower survival rates for pioneers in the medical diagnostic-imaging and rigid-disk-drive industries, respectively. Kalyanaram, Robinson, and Urban (1995, pp. G218–19) suggest an emerging empirical generalization “that order of market entry is not related to long-term survival rates,” with the caveat that more research is needed to clarify the issue.

In this article, we address the following two questions: (1) How do network externalities influence the survival duration of pioneers (main effect)? and (2) What factors moderate the effects of network externalities on the survival duration of pioneers (moderating effects)? We develop a model of pioneer survival that incorporates the main effect of network externalities, the moderating effects of two product characteristics (radicalness and technological intensity), and two firm characteristics (size of the pioneering firm and its incumbency with respect to a previous product generation) on the effects of network externalities on the survival duration of pioneers.

We estimate our model by using data on 45 office and consumer durables products and an accelerated failure time (AFT) specification (Cox and Oakes 1984; Kalbfleisch and Prentice 1980). Our results indicate that (1) survival duration of pioneers decreases as the network externalities of a product increases; (2) radicalness and technological intensity of the product moderate the effect of network externalities to increase the survival duration of pioneers; and (3) firm size and the pioneer’s incumbency moderate the effect of network externalities to increase and decrease, respectively, the survival duration of pioneers.

In the next section, we define network externalities and present our conceptual arguments. We then describe the data collection and model estimation procedures and the results of our empirical analysis. We conclude by discussing the implications of our results for marketing theory and practice, summarizing the limitations of our work and identifying directions for further research.

Conceptual Development

Characteristics of both the product and the pioneering firm influence the rewards of pioneering in a complex manner, which involves several possible contingencies (Kalyanaram, Robinson, and Urban 1995; Lieberman and Montgomery 1998). On the basis of previous research on organizational innovation, we consider both product and organizational factors moderators of the effect of network externalities on the duration of pioneer survival. We include two product factors: radicalness (Chandy and Tellis 2000) and technological intensity (Agarwal 1996). We also include two organizational factors: firm size (Audretsch 1995) and incumbency (Henderson 1993; Mitchell 1991). The literature on network externalities provides conflicting indications about the main effects of network externalities and the moderating effects of product and firm characteristics on the effect of network externalities on pioneer survival. Thus, we present arguments for both positive and negative effects of product and firm characteristics on pioneer survival (see P1 and P2; for such an approach for theory development in the presence of opposing arguments, see Armstrong, Brodie, and Parsons 2001; Bettman, Capon, and Lutz 1975).

Definitions

When the utility of a product to each user in a network depends on the number of users, the product exhibits direct network externalities (Katz and Shapiro 1986). For example, the utility of a fax machine is nil if no one else has one. As the number of people (n) who own fax machines increases, the utility of the fax machine to each user increases in proportion to the number of possible two-way connections, n (n – 1). Indirect or complementary network externalities arise when there is a positive link between the utility to a customer and the number of other users of the product because of complementary products (Katz and Shapiro 1986). Increases in the number of users of the focal hardware product increases the availability of complementary products, which in turn increases the utility that customers derive from the focal product. Videocassette recorders, compact disc [CD] players, MP3 players, and digital videodisc
players exhibit indirect network externalities. To be consistent with previous research (Golder and Tellis 1993; Urban et al. 1986), we define a pioneer as the first firm to commercialize a new product. We focus on the pioneer’s survival in the product market it pioneered, and we measure its survival at time \( t \) on the basis of whether the pioneer still maintained a presence in the product market.

**Effects of Network Externalities on Survival Duration**

*Positive effects of network externalities.* Given the important role of the installed base for products with network externalities, a pioneer’s product may achieve market power through positive feedback (Arthur 1989). A large installed base attracts more developers of complementary and compatible products, thereby enhancing the utility of a pioneer’s product and speeding adoption (Choi 1994). Adopters invest in learning to use the product (e.g., videogames, software) and/or in complementary products (e.g., CD music titles for CD audio players), which results in lock-in and prevents defections to offerings of later entrants (Shapiro and Varian 1998). In addition, products with network externalities are sometimes characterized by a standard (e.g., CD audio standard). The emergence of a standard reduces uncertainty about the eventual size of the network, thereby inducing earlier adoption by customers (Chakravarti and Xie 2002) and spurring the development of complementary products. Thus, the pioneer may be able to set the standard and draw customers to its network, resulting in long-term survival. Thus:

\[
P_1: \text{The greater the network externalities of a product, the longer is the survival duration of the product pioneer.}
\]

*Negative effects of network externalities.* Other aspects of network externalities suggest negative effects. First, some innovations (e.g., communication devices) initially diffuse slowly because of uncertainties associated with their potential utility when few adopters exist (Rogers 1995). Prospective customers may adopt a “wait-and-see” attitude, delaying adoption until uncertainties are reduced so that the market exhibits “excess inertia” (Farrell and Saloner 1986). This excess inertia also exists in products with indirect network externalities. Hardware firms want complementors to offer a wide selection of software, but complementors wait until the new hardware has achieved significant market penetration before committing to the hardware platform. Gupta, Jain, and Sawhney (1999) investigate this “chicken-and-egg” coordination problem between producers of hardware and software in the digital television market. Goldenberg, Libai, and Muller’s (2002b) study of fax machine adoption shows that network externalities slow the growth of fax machine adoption, thus revealing a “hockey-stick” pattern of slow growth over a long period followed by rapid takeoff. The initial slow sales over a long period may provide a window of opportunity for later entrants.

Second, because of excess inertia, the pioneer’s development costs may outpace its revenue, which negatively affects its short-term performance. Thus, the pioneer may curtail its early marketing investments, which hurts its long-term survival. As customer expectations become more certain and complementary goods are developed, later entrants benefit from lower developmental costs as a result of vicarious learning from the pioneer.

Third, when network externalities are sufficiently strong, as additional customers adopt the product, the marginal customer’s utility of adoption increases. The increasing utility of the product to customers enables later entrants to have a greater chance of success than the pioneer because of the larger network that exists at their later entry time. Thus:

\[
P_2: \text{The greater the network externalities of a product, the shorter is the survival duration of the product pioneer.}
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2Network externalities can be positive or negative (e.g., congestion in telecommunications networks) and tangible or intangible (intangible externalities pertain to the equity of well-established brands whose customers perceive benefits of reduced product uncertainty and peer approval through their large customer bases). To provide focus, we consider only positive and tangible network externalities here.

3We use the terms “pioneer,” “pioneering firm,” and “market pioneer” interchangeably.

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marketing challenge that makes it more difficult to succeed: managing product innovation as the product evolves into a market-ready form and overcoming excess market inertia in developing the product’s network. Thus:

\[ P_6: \text{As radicalness of the product increases, the relationship between network externalities and pioneer survival becomes more negative.} \]

**Moderating Effect of Technological Intensity of Product**

We define *technologically intensive products* as ones that have significant depth and breadth of technical and scientific knowledge embedded in their creation and functionality (Capon and Glazer 1987; John, Weiss, and Dutta 1999; Rosenberg 1976, 1994). A product’s technological intensity is distinct from its radicalness. For example, the microwave oven is high in radicalness but low in technological intensity (it draws primarily from one technology domain: radar technology), whereas the projection television is low in radicalness but high in technological intensity (it draws from multiple technology domains: audio, optical, and computing technologies). As does radicalness, technological intensity may have opposing moderating effects on the effect of network externalities on the survival of pioneers in networked markets, which we describe next.

Higher levels of technological intensity imply greater complexity in product design and commercialization (John, Weiss, and Dutta 1999). Technologically intensive products often involve interdisciplinary, diverse technologies embedded across firms, industries, and users (Iansiti and West 1997). In such a situation, competitors face serious challenges to ensure that the diverse technologies work together well. As a result, the pioneer may have a window of opportunity to establish an installed base before competitive entry, enabling it to secure its long-term survival (Lieberman 1989). Thus:

\[ P_5: \text{As technological intensity of the product increases, the relationship between network externalities and pioneer survival becomes more positive.} \]

Technological intensity of products may also hurt the pioneer’s survival in networked markets. Technologically intense products are characterized by rapid changes in the early stages of market development (John, Weiss, and Dutta 1999; Utterback 1994). The pioneer may be forced to keep a rudimentary design that is rendered obsolete by later designs. Technologically intense products are also characterized by heterogeneity in adopter cohorts as the market evolves from introduction to maturity (Moore 1991; Rogers 1995). To appeal to later cohorts, the pioneer must redesign its product often, perhaps relying on disruptive technologies that can make previous investments obsolete (Christensen 1997). The subsequent product designs, based on new technologies introduced by later entrants, may find rapid market acceptance, thereby reducing the chances of the pioneer’s survival. Thus:

\[ P_6: \text{As technological intensity of the product increases, the relationship between network externalities and pioneer survival becomes more negative.} \]

**Moderating Effect of Incumbency of Pioneer**

Consistent with previous research (Chandy and Tellis 2000; Henderson 1993; Mitchell 1991), we define an *incumbent* as a firm that markets a product belonging to the previous product generation that satisfied the same customer need. Some aspects of incumbency can aid survival, whereas others can hurt it. Having marketed products from the preceding generation, incumbent firms have access to assets such as market knowledge, brand equity, and customer relationships (Thomas 1995). Incumbents are likely to have access to existing customer networks, which may ensure backward compatibility of the pioneering innovation with the product from the previous generation and reduce switching costs for potential adopters. Compatibility advantages may also operate with respect to producers of suppliers’ goods and complementary goods. In networked markets, incumbent pioneers can leverage their existing networks and offer greater

\[ P_7: \text{As the size of the pioneer increases, the relationship between network externalities and pioneer survival becomes more positive.} \]

Second, a large firm has several layers of staff (Blau and Schoenherr 1971), which can delay response to new technologies and market opportunities (Kimberly 1976; Tornatzky and Fleischer 1990). In addition, the structure of large organizations can reduce incentives for individual innovators (Cohen 1995). In networked markets, such bureaucratic inertia provides an opportunity for a later entrant to establish a network and attract customers to its network. Thus:

\[ P_8: \text{As the size of the pioneer increases, the relationship between network externalities and pioneer survival becomes more negative.} \]

\[ 4\text{Although the effects of firm characteristics may apply to all pioneers to some extent, the effects of firm size and incumbency are particularly important in products with network externalities, which are characterized by considerable uncertainty about the potential size of the network, the standard, and the availability of complementary and compatible goods.} \]
utility to customers than nonincumbent pioneers, thus securing their long-term survival. Thus:

P9: The relationship between network externalities and pioneer survival is more positive for incumbent pioneers than for nonincumbent pioneers.

In contrast, incumbents are prone to technological inertia (Foster 1986; Ghemawat 1991), and their efforts in new product marketing are often characterized by underinvestment (Henderson 1993). Thus, incumbent pioneers may be reluctant to make the large investments that are necessary to support the new technology, which may threaten the firm’s existing product (Christensen 1997). Such inertia may be intensified in networked markets because of the cannibalizing potential of the new product’s network. Thus:

P10: The relationship between network externalities and pioneer survival is more negative for incumbent pioneers than for nonincumbent pioneers.

In summary, our conceptual arguments suggest that network externalities and the moderating effects of product and firm characteristics exert countervailing forces on the effect of network externalities on the survival of pioneers. Table 1 summarizes these arguments. Figure 1 illustrates how product radicalness can have a positive moderating effect (P3) on the relationship between network externalities and firm survival, resulting in a counterclockwise rotation of the main effect relationship. We next describe the data collection procedure, the measures, and the model we estimate to investigate the effects of network externalities on pioneer survival.

### Method

**Data**

We used three criteria to collect data for this study. First, to provide the necessary variance in network externalities, we identified two classes of products: office products and consumer durables that exhibit various degrees of network externalities. The two product classes have been studied in previous research on innovation diffusion and pioneering (Chandy and Tellis 2000; Golder and Tellis 1993, 1997; Sultan, Farley, and Lehmann 1990), which we build on in this...
article. Second, we limit our focus to products introduced after World War II, because World War II altered the business environment and the postwar period witnessed the emergence of new technologies (e.g., computing, electronics, telecommunications) that were different in scope and character from those (e.g., mechanical, electromechanical) introduced previously (Teitelman 1994). Third, because of our interest in the survival of pioneers and not the survival of products, we excluded products that did not succeed (e.g., minidisc players). This criterion is consistent with our focus on the survival of pioneers in products demonstrated to be viable, substantive, and managerially relevant. On the basis of these three criteria, we identified 63 office products and consumer durables.

We used the historical method (Golder 2000) to collect data on the pioneer’s time of entry, survival, characteristics, and technological intensity of the product. For each product, we obtained information about the pioneer from articles published in scholarly journals, company histories, and online business databases. When it was possible, we used multiple sources to increase the reliability of our data. We were able to collect reliable information about the product, the dates of pioneering, and the survival of pioneers for 45 of the 63 product categories (Table 2). The products we studied span more than 50 years and include all major innovations in office products and consumer durables during this period.

Our 45 products compare favorably in terms of number with those used in recent studies (Chandy and Tellis 2000; Golder and Tellis 1993, 1997; Sultan, Farley, and Lehmann 1990). In addition, the set of products in our study overlaps with 12 of the 16 new (introduced after 1945) consumer durables studied by Golder and Tellis (1997), 9 of the 10 new durables and office products studied by Golder and Tellis (1993), and 20 of the 25 new consumer durables and office products studied by Chandy and Tellis (2000). All the data are from publicly available data sources.

**Measures**

**Pioneer survival.** Our dependent variable is the survival duration of a pioneer in the product market it pioneered, which is measured in number of years. We used 2001 as the cutoff year for measuring pioneering survival. Because several pioneers (n = 21) were in existence in 2001, our survival data are right-censored at 2001.5

**Network externalities.** There are no established measures for our key construct of network externalities. Thus, using two independent sets of raters to assess the reliability of the measures, we developed a new measure. A review of previous research (e.g., Frels, Shervani, and Srivastava 2003; Shankar and Bayus 2003), case studies (e.g., Gachan, Vadasz, and Yoffie 1997), and our discussions with managers indicated that network externalities are a matter of degree and are not dichotomous (i.e., present or absent) and that a product can have direct network externalities, indirect network externalities, or both. We conceptualize the degree of network externalities as a continuous variable that represents both direct and indirect externalities. We used two groups of raters to measure the degree of network externalities: (1) academic experts (12 professors at nine business schools who are recognized experts on organizational innovation or high-technology products or network externalities) and (2) MBA students (a class of 26 MBA students who had recently completed an elective course on high-technology marketing strategy). We provided the raters with a definition of direct and indirect network externalities and then asked them to rate separately the degree of direct and indirect network externalities associated with each product on a 1 (no network externalities) to 7 (very high network externalities) scale. We computed the degree of network externalities for each product from each rater by adding the scores for direct and indirect network externalities. We computed the reliability of the raters by computing reliability coefficients and eliminating raters (3 academic experts and 5 MBA students) who had item-to-total correlations of less than .40. The intraclass reliability coefficient (Shrout and Fleiss 1979) for the ratings provided by each group of raters (academic experts = .91; MBA students = .95) showed that the measures provided by both the retained academic experts and the students are internally consistent. The average measures of degree of network externalities the two groups of raters provided are highly correlated (.86, p < .01). To assess discriminant validity, we followed the procedure that Campbell and Fiske (1959) suggest. Specifically, we compared the correlations for the network externalities measure across raters (for the same product) with the interrater correlations across products (for the same rater); we found the latter correlations to be small (ranging from .15 to .35).

To bolster our confidence in the ratings measure of network externalities, we also obtained ratings from eight marketing managers, and we found that the ratings provided by the managers were internally consistent (intraclass reliability coefficient = .89) and correlated well with the ratings provided by the academic raters (.83, p < .01). We subsequently used the ratings data from students and managers separately to estimate our model, and, because we found consistent results, we report results based on the data from the academic experts.

**Radicalness of product.** We used Chandy and Tellis’s (2000) radical scale, which has two dimensions: (1) whether a new product incorporates a substantially different core technology (technology radicalness 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 (benefits radicalness on a scale from 1 to 9). We developed a radicalness measure by adding the two scores. We followed a similar procedure for radicalness as we did for network externalities, using both academic and graduate student raters. Our academic raters were 10 professors who are experts on organizational innovation (a different group from that used to rate network externalities); the student raters were 19 midlevel engineer executives enrolled in a master’s of technology management
<table>
<thead>
<tr>
<th>Product</th>
<th>Network Externalities</th>
<th>Previous Product Generation</th>
<th>Market Pioneer (Year of Entry)</th>
<th>Status of Pioneer (Year of Exit)</th>
<th>Current Market Leader (Year of Entry)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antivirus software</td>
<td>6.8</td>
<td>-</td>
<td>Symantec (1982)</td>
<td>Survived</td>
<td>Symantec</td>
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<tr>
<td>Audiocassette player</td>
<td>9.3</td>
<td>Spool audio player</td>
<td>Philips (1962)</td>
<td>Survived</td>
<td>Panasonic</td>
</tr>
<tr>
<td>CD player</td>
<td>9.3</td>
<td>Audiocassette player</td>
<td>Sony (1982)</td>
<td>Survived</td>
<td>Sony</td>
</tr>
<tr>
<td>Cellular telephone</td>
<td>10.0</td>
<td>Telephone</td>
<td>AT&amp;T (1979)</td>
<td>Survived</td>
<td>Verizon</td>
</tr>
<tr>
<td>Color television</td>
<td>8.4</td>
<td>Black-and-white television</td>
<td>RCA (1963)</td>
<td>Survived</td>
<td>RCA</td>
</tr>
<tr>
<td>Dot matrix printer</td>
<td>6.0</td>
<td>-</td>
<td>Seikosha (1964)</td>
<td>Failed (1979)</td>
<td>Okidata (1972)</td>
</tr>
<tr>
<td>Fax machine</td>
<td>10.6</td>
<td>Telegraph</td>
<td>Magnavox (1960)</td>
<td>Failed (1965)</td>
<td>Sharp (early 1980s)</td>
</tr>
<tr>
<td>Flat-bed scanner</td>
<td>6.6</td>
<td>-</td>
<td>Kurzwell Technologies (1978)</td>
<td>Taken over by Visioneer (1994)</td>
<td>Xerox (1979)</td>
</tr>
<tr>
<td>Food processor</td>
<td>4.1</td>
<td>Mixer</td>
<td>Cuisinart (1972)</td>
<td>Survived</td>
<td>Hamilton-Beach (1955)</td>
</tr>
<tr>
<td>High-definition television</td>
<td>8.4</td>
<td>Color television</td>
<td>Zenith (1998)</td>
<td>Survived</td>
<td>Zenith</td>
</tr>
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<td>Home VCR</td>
<td>9.4</td>
<td>16 mm home projection system</td>
<td>Sony (1975)</td>
<td>Survived</td>
<td>RCA/Matsushita (1977)</td>
</tr>
<tr>
<td>Ink-jet printer</td>
<td>6.2</td>
<td>Dot matrix printer</td>
<td>Hewlett-Packard (1984)</td>
<td>Survived</td>
<td>Hewlett-Packard</td>
</tr>
<tr>
<td>Instant photography</td>
<td>5.4</td>
<td>35 mm camera</td>
<td>Polaroid (1948)</td>
<td>Survived</td>
<td>Polaroid</td>
</tr>
<tr>
<td>Mainframe computer</td>
<td>9.3</td>
<td>Punched card machine</td>
<td>Univac (1946)</td>
<td>Failed (1986)</td>
<td>IBM (1953)</td>
</tr>
<tr>
<td>Pager</td>
<td>7.4</td>
<td>Telephone</td>
<td>Motorola (1974)</td>
<td>Survived</td>
<td>Cobra</td>
</tr>
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<td>Product</td>
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<tr>
<td>Single-use camera</td>
<td>4.4</td>
<td>35 mm camera</td>
<td>Fuji (1986)</td>
<td>Survived</td>
<td>Fuji</td>
</tr>
</tbody>
</table>

*Network externalities ratings are provided by academic expert raters; scale ranges from 2 to 14.

Notes: If the pioneering firm did not survive and exited the market, the figure in parentheses in Column 5 denotes the year the pioneer exited the market. If the pioneer has survived and was a market leader in its category in 2001, it is depicted in bold in Column 6.
program at a leading university. We computed the reliability of the raters by computing reliability coefficients and eliminating raters (1 academic expert and 2 graduate students) who had item-to-total correlations of less than .40. Our retained academic experts had intragroup reliability ratings of .76, and the graduate students had intragroup reliability ratings of .84, which indicates acceptable internal consistency. As occurred previously, the average ratings from the two groups were highly correlated (.88, p < .01). We estimated the model with ratings from both groups of raters, we found consistent results, and we again report results based on data from the academic raters.

Technological intensity of product. To measure the technological intensity of products, we follow Hadlock, Hecker, and Gannon (1991) and use a categorical variable that classifies a product as technical or nontechnical on the basis of the ratio of the number of research and development employees to total personnel of the firms in the product category (for examples of the use of this measure, see Agarwal 1996; Agarwal and Bayus 2002). Of the 45 products, we classified 28 as technologically intensive.

Size of pioneer. Although a firm’s size can be measured in several ways, including number of employees, sales volume, and total assets, the most common measure used in the innovation literature is number of employees (Cohen 1995). Because alternative definitions usually yield similar results (Agarwal 1979), we measured size by the number of firm employees at the time of pioneering, and we investigate two such measures: the actual number of employees and a dichotomous variable (small–large) split at the median firm size of 100 employees. For publicly traded firms, we obtained the size information from the COMPUSTAT database. For privately held firms, we obtained the size information from company directories and news archives. Using this method, we classified 25 of the 45 firms as small. We estimated the model with both the dichotomous and the continuous measure of size, and we found similar results. We report results based on the categorical measure because it is more robust and less subject to the influence of extreme values.

Incumbency of the pioneer. We follow the definition of incumbent that has been used in previous research (Chandy and Tellis 2000; Mitchell 1991; Mitchell and Singh 1993) and define a pioneer as an incumbent if it also markets a product belonging to the previous generation of products that satisfied the same customer need. We determined the previous product generation by using historical methods and academic experts. In six cases, the experts determined that there was no previous product generation that satisfied the particular customer need. The third column of Table 2 provides the previous product generation that we used to determine incumbency of the pioneer. We coded an incumbent pioneer as 1 and a nonincumbent pioneer as 0. Of the pioneers we studied, 19 were incumbents.

Model

Pioneer survival times cannot be analyzed by standard regression approaches because such data are typically right-censored (i.e., not all pioneers have failed by the time of the study). In 2001, the cutoff time for our study, 21 of the 45 pioneers continued to be in business. We used the AFT model, which accommodates right-censoring, to investigate the effects of network externalities and the moderation effects of product and firm characteristics on the effect of network externalities on the survival duration of pioneers (Cox and Oakes 1984; Helsen and Schmittlein 1993; Kalbfleisch and Prentice 1980). We provide an outline of AFT models, based on which we specify the following estimation equation, in the Appendix:

\[
\ln(T_i) = \mu + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_k X_{ik} + \sigma \varepsilon_i,
\]

where \(T_i\) is the number of years firm \(i\) has been in existence in the product category as of 2001, and \(X_i\) is the vector of the covariates associated with the pioneering product introduced by firm \(i\). The covariates used in the model are time invariant and include network externalities and the moderation effects of the two product and the two firm characteristics on the effect of network externalities on pioneer survival, which we described previously. If the results indicate that a particular sign is significant (e.g., a negative sign for incumbency \(\times\) network externalities), our data support the corresponding form of the proposition (in this case, negative).

Results

Descriptive Statistics of Products

Table 2 contains the network externalities ratings, and Figure 2 contains the histograms of the network externalities and radicalness ratings for the products in our study. The dispersion of the rating scales for network externalities and radicalness suggests that the raters view the two constructs as continuous rather than dichotomous. Although possible values for the network externalities measure range from 2 (no network externalities) to 14 (high network externalities), the ratings of the products we studied ranged from 3.4 (electric toothbrush) to 12.1 (operating system for personal computers), with a mean of 7.7 and a standard deviation of 2.2. The radicalness ratings, with possible scale values from 2 to 18, ranged from 8.9 (electric toothbrush) to 15.3 (photocopiers), with a mean of 12.8 and a standard deviation of 2.4, which indicates moderate to substantial innovativeness for the products in the study.

Performance of Pioneers and Current Market Leaders

Of the 45 pioneers, 24 (53%) exited the market by 2001, which compares well with the 50% failure rate for the digital/high-technology products reported by Tellis and Golder.
FIGURE 2
Histograms of Network Externalities and Radicalness Ratings

Notes: For network externalities ratings, the scale ranges from 2 to 14, with a mean of 7.7 and a standard deviation of 2.2. For radicalness ratings, the scale ranges from 2 to 18, with a mean of 12.8 and a standard deviation of 1.4.

(2000, p. 43). The average survival duration for the pioneers studied was 11 years. The average market share for the surviving pioneers is 25%, and only 18% (n = 8) of the pioneers were leaders in the products they pioneered, with an average market share of 47%. The average market share of 25% for surviving pioneers is much higher in our study than that (8%) obtained by Tellis and Golder (2001, p. 44) for digital and high-technology products. We examined the correlations between market shares of all pioneers and the degree of network externalities and found a nonsignificant, negative relationship (p = –.14, not significant), but we found a positive relationship between the market shares of current market leaders that are not pioneers and the degree of network externalities (p = .30, p < .10). When we performed a median split of the network externalities scale, we found that the 10 surviving pioneers of the products with high network externalities had a market share of 19% compared with the 31% market share of the 11 surviving pioneers that introduced products with low network externalities. The average market share for the 24 later entrants that are current market leaders is 41%, compared with 25% for the surviving pioneers. The average lag in time of entry between the pioneer and the later-entry current market leaders is 8 years. In summary, an aggregate level analysis of the data suggests that there is a negative effect of network externalities on the performance of pioneers and that later entrants are not disadvantaged in relation to pioneers in terms of either survival duration or market share.

Model Estimation Results

We were interested in determining whether the base hazard rate (i.e., the instantaneous probability that the pioneer will fail at time t) was constant, increasing, or decreasing with time, so that we could investigate a pioneer’s risk of failure over time. We considered alternative base hazard functions, including the exponential, gamma, log-normal, log-logistic, and Weibull, for which the AFT method allows, and we used a multistep approach to determine the distribution that best represents the survival times of pioneers in networked markets. We were unable to estimate the gamma model with our data because of convergence problems that were partly due to the small sample size. However, the gamma model often displays convergence problems; even if it is estimable, it is difficult to judge the shape of the hazard function from the estimated parameters (Allison 1995, p. 74). We estimated the exponential model, which assumes a constant hazard rate (a special case of the Weibull model, with scale parameter set to 1), and we found that this model can be rejected (p < .001). Therefore, using three distribution functions (log-normal, log-logistic, and Weibull) that accommodate a changing hazard rate, we estimated the model in Equation 1 with the results reported in Columns 1–3 of Table 3.

Although the general pattern of results is similar across the models, based on the Akaike information criterion (AIC), the model estimated with the Weibull hazard function fits the data slightly better than those estimated with the log-normal and the log-logistic functions. The Weibull model can be interpreted as both a (parametric) proportional hazards model and an AFT model (see the Appendix). We also present the results of the Cox proportional hazards model in Column 4 of Table 3. The sign reversals of the estimates for this model compared with the AFT models occur because the proportional hazards model estimates the effects on hazard rate, whereas the AFT model estimates the effects on survival times. By multiplying the Weibull parameter estimates for the AFT model in Table 3 by (–1/σ), we obtained the estimates of the proportional hazards model with a Weibull distribution of survival times. With this transformation, the general pattern of results from the Weibull and the Cox proportional hazards models is similar. However, in terms of the AIC, the overall fit of the proportional hazards model is inferior to that of the Weibull AFT model; therefore, we discuss only the results of the AFT model.

The model χ² statistic is significant (χ² = 24.74, degrees of freedom [d.f.] = 10, p < .01), and the scale parameter of the model is .62, which indicates that the hazard rate for pioneer survival decreases over time (i.e., the longer the pioneer has survived, the greater are its chances of continued survival). Our results indicate that network externalities have a negative effect on the survival duration of pioneers (b = –2.38, p < .01), suggesting that the higher the level of network externalities, the shorter is the survival duration of the pioneer (in support of P2). Both for more radical products (b = .14, p < .01) and for more technologically intensive products (b = .42, p < .05), network externalities increase the
TABLE 3
Results of Model Estimation of Effect of Network Externalities on Pioneer Survival

<table>
<thead>
<tr>
<th>Variable</th>
<th>Log-Normal Distribution (1)</th>
<th>Log-Logistic Distribution (2)</th>
<th>Weibull Distribution (3)</th>
<th>Proportional Hazards (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>19.71 (6.05)***</td>
<td>19.52 (6.63)***</td>
<td>23.12 (5.68)***</td>
<td>—</td>
</tr>
<tr>
<td><strong>Product-Level effects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Network externalities</td>
<td>−1.94 (.84)*</td>
<td>−1.94 (.95)**</td>
<td>−2.38 (.83)***</td>
<td>3.25 (1.42)**</td>
</tr>
<tr>
<td>Radicalness of product × network externalities</td>
<td>.11 (.06)*</td>
<td>.11 (.05)*</td>
<td>.14 (.05)***</td>
<td>−18 (.09)***</td>
</tr>
<tr>
<td>Technological intensity of product × network externalities</td>
<td>.42 (.19)*</td>
<td>.39 (.20)*</td>
<td>.42 (.18)**</td>
<td>−62 (.30)**</td>
</tr>
<tr>
<td><strong>Firm-Level Effects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size of pioneer × network externalities</td>
<td>.70 (.30)**</td>
<td>.70 (.37)**</td>
<td>.89 (.29)***</td>
<td>−1.20 (.48)**</td>
</tr>
<tr>
<td>Incumbency of pioneer × network externalities</td>
<td>−.90 (.33)</td>
<td>−.94 (.34)***</td>
<td>−1.03 (.33)***</td>
<td>1.35 (.55)***</td>
</tr>
<tr>
<td><strong>Controls</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radicalness of product</td>
<td>−.80 (.36)**</td>
<td>−.82 (.37)**</td>
<td>−1.00 (.31)***</td>
<td>1.35 (.55)***</td>
</tr>
<tr>
<td>Technological intensity of product</td>
<td>−2.89 (1.32)**</td>
<td>−2.67 (1.44)*</td>
<td>−3.10 (1.23)***</td>
<td>4.49 (2.06)**</td>
</tr>
<tr>
<td>Size of pioneer</td>
<td>−4.34 (1.86)**</td>
<td>−4.34 (1.96)**</td>
<td>−5.67 (1.78)**</td>
<td>7.14 (3.02)**</td>
</tr>
<tr>
<td>Incumbency of pioneer</td>
<td>6.31 (2.16)**</td>
<td>6.68 (2.29)**</td>
<td>7.36 (2.33)**</td>
<td>−9.91 (3.88)**</td>
</tr>
<tr>
<td>Log (introduction year)</td>
<td>−.82 (.28)</td>
<td>−.83 (.29)***</td>
<td>−.81 (.26)***</td>
<td>1.03 (.49)**</td>
</tr>
<tr>
<td>Scale parameter</td>
<td>.86</td>
<td>.51</td>
<td>.62</td>
<td>—</td>
</tr>
<tr>
<td>Model $\chi^2$ (d.f. = 10)</td>
<td>18.80 ($p = .05$)</td>
<td>19.54 ($p = .05$)</td>
<td>24.74 ($p = .01$)</td>
<td>18.13 ($p = .05$)</td>
</tr>
<tr>
<td>AIC</td>
<td>104.42</td>
<td>105.48</td>
<td>103.46</td>
<td>157.26</td>
</tr>
</tbody>
</table>

* $p < .10$.
** $p < .05$.
*** $p < .01$. 

survival duration of pioneers (in support of P3 and P5). For larger firms, network externalities increase survival duration ($b = .89$, $p < .01$, in support of P3), whereas for incumbent pioneers, network externalities decrease survival duration ($b = −.03$, $p < .01$, in support of P10). In our model, we also observed several unhypothesized main effects for radicalness, technological intensity, size, and incumbency. Table 1 links these empirical findings to our conceptual arguments.

Although the magnitudes of the coefficients are not directly informative, a simple transformation provides an intuitive interpretation. For a continuous variable such as network externalities, the transformation $100(e^{b} − 1)$ gives the percentage change in the expected survival time for each unit increase in the variable. Thus, $100(e^{−2.38} − 1) = −91\%$ indicates the percentage decrease in the expected survival time for each one-unit increase in the degree of network externalities, when other covariates are held constant. The order of magnitude for the effects is similar to those obtained in other AFT studies of firm survival. For example, Mitchell and Singh’s (1993) study of the effects of expansion into new technical subfields on survival in a firm’s base business reports similar effect sizes ($b = 1.78$) for the expansion effect. Note that the coefficient value is a statistical estimate, and given its 95% confidence interval (i.e., −.75 to −4.01), the corresponding change in survival duration ranges from −53% to −98%. Note that in the presence of statistically significant moderation effects in the model, the main effect does not represent the full impact of changes to survival duration associated with a change in the degree of network externalities.

By excluding network externalities and only retaining the main effects of the two products, the two firm characteristics, and time, we also examined the power of network externalities in explaining the survival duration of pioneers ($\chi^2 = 9.78$, d.f. = 5, $p < .10$). The difference in the model $\chi^2$ statistic between the reduced model and the complete model (Column 3, Table 3), which includes network externalities and all the moderating effects, is significant ($\chi^2 = 14.96$, d.f. = 5, $p = .01$). We also estimated a model that retained only the main effects of all explanatory variables, excluding all the moderating effects, and we found that the difference in the model $\chi^2$ statistic between the reduced model and the complete model (Column 3, Table 3), which includes network externalities and all the moderating terms, is significant ($\chi^2 = 14.34$, d.f. = 4, $p < .01$). The results suggest that a model that includes network externalities and the moderating effects of product and firm characteristics provides a significantly improved explanation of pioneer survival over models that exclude network externalities and the moderating effects.
Robustness of Results

Definition of exit. Not all pioneer failures we studied were unambiguous exits from the product market. In two cases (Aldus’s desktop publishing software and Kurzweil Technology’s flat-bed scanner), other firms (Adobe and Xerox, respectively) acquired the pioneer. In both cases, we treated the exit as a censored exit. In eight other cases (e.g., mainframe computers, database software), the pioneer failed in the market in which it pioneered, but another firm took over the related assets. The appropriate approach is to estimate a model of competing risks to determine the effects of covariates on the multiple types of exits (Allison 1995, p. 185). However, the small number (ten) of ambiguous exits precludes such an approach. Thus, we reestimated the model, excluding the ten pioneers (n = 35) with ambiguous exits (Column 1, Table 4). The model $\chi^2$ statistic is significant ($\chi^2 = 23.40$, d.f. = 10, $p < .01$), and the scale parameter of the model is .65. The general pattern of results with this smaller sample is consistent with the ones we obtained with the inclusion of the ambiguous exits.

Censoring date. An assumption of duration models is that censoring is conditionally independent of the event and the covariates. For our analysis, we used the full information in the data set and censored the survival of the pioneers in 2001. To explore whether the results were sensitive to the use of 2001 as the censoring date, we reestimated the model with three different censoring dates: 1998, 1995, and 1992 (Table 4). From the results in Columns 2–4 of Table 4, it is evident that the general pattern of results with the different cutoff years is similar to those we reported in Table 3.

Sample. Even though our sample size compares well with those of previous research (e.g., Chandy and Tellis 2000; Golder and Tellis 1993, 1997), it is small, and thus we performed a bootstrap analysis to examine sensitivity of our results to sampling variations (Efron 1979). We generated a list of 50 random numbers (with replacements) from 1 to 45. We then estimated Equation 1 50 times, each time with 44 observations, and we eliminated one observation that corresponded to the random number generated. The results of the bootstrapping analysis (Column 5, Table 4) indicate that our results are robust to sampling variations.

Differential effects of direct and indirect network externalities. We conducted an exploratory investigation by estimating a model that includes direct and indirect network externalities separately and their interactions (not reported herein). Although the overall pattern of results was similar to the results we obtained with the combined measure of network externalities, the effect of direct network externalities in that model was significant at $p < .10$, whereas the effect of indirect network externalities was not significant. The lack of statistical significance may be because neither direct nor indirect network externalities independently explain pioneering survival.

Academic expert ratings. To cross-validate our estimation results with the ratings of network externalities and radicalness from academic raters, we reestimated Equation 1 with the network externalities and radicalness ratings obtained from student raters and managers; we found results consistent with those we report herein. In summary, our results are robust to different definitions of exit, censoring dates, and other threats to validity, including sampling variations and the use of raters.

Conclusions

First-mover advantages can be powerful and long-lasting in lock-in markets, especially those in information industries where scale economies are substantial. If you can establish an installed base before the competition arrives on the scene, you may make it difficult for later entrants to achieve the scale economies necessary to compete. —Shapiro and Varian 1998

In the networked market, whoever gets a small, early advantage in a market may soon have a large, insuperable edge of increasing returns to scale due to the networked effects. —Industry Standard, September 19, 1999

Contrary to traditional wisdom about pioneering advantages in networked markets, our results indicate that network externalities significantly decrease the survival duration of pioneers. Increases in the marginal customer’s utility over time and the excess inertia of customers adopting new products, both of which shorten pioneer survival, appear to outweigh the advantages associated with an installed base of customers that may prolong pioneer survival. In addition, the results of our analysis support a contingency-based framework of product and firm characteristics that moderate the effect of network externalities on the survival duration of pioneers.

Theoretical Contributions

The results of our study contribute to research in marketing strategy that explores market entry, network externalities, and high-technology markets.

Market entry. Our study adds to the limited research on the survival of pioneers (e.g., Golder and Tellis 1993; Mitchell 1991). In particular, our finding that network externalities reduce the survival duration of pioneers challenges the proposed empirical generalization that “order of market entry is not related to long-term survival rates” (Kalyanaram, Robinson, and Urban 1995, p. G218). By including network externalities and two product characteristics, we clarify the role of product characteristics in the performance of pioneers and address calls for research on this issue (Kerin, Varadarajan, and Peterson 1992; VanderWerf and Mahon 1997). By including network externalities and two product characteristics, we clarify the role of product characteristics in the performance of pioneers and address calls for research on this issue (Kerin, Varadarajan, and Peterson 1992; VanderWerf and Mahon 1997). In addition, by studying office products and consumer durables, we address the calls to extend pioneering research beyond the traditional contexts of packaged goods, pharmaceuticals, and the PIMS databases (Kalyanaram, Robinson, and Urban 1995; Lieberman and Montgomery 1998).

Network externalities. Extant theoretical economics literature on network externalities suggests that there are opposing processes of lock-in that result in market power potentially aiding the survival of the pioneer (Choi 1994) and in excess inertia that can hurt the pioneer’s quest for survival (Farrell and Saloner 1986). The results of the negative main effect of network externalities on survival duration
<table>
<thead>
<tr>
<th>Variable</th>
<th>Parameter Estimates</th>
<th>Standard Error</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td></td>
<td></td>
<td>29.59 (6.60)***</td>
<td>21.51 (4.85)***</td>
<td>17.86 (4.78)***</td>
<td>15.87 (3.84)***</td>
<td>22.94 (5.82)***</td>
</tr>
<tr>
<td>Product-Level Effects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Network externalities</td>
<td></td>
<td></td>
<td>-3.51 (0.96)***</td>
<td>-2.33 (0.72)***</td>
<td>-1.99 (0.71)***</td>
<td>-1.44 (0.58)**</td>
<td>-2.36 (0.85)***</td>
</tr>
<tr>
<td>Radicalness of product (\times) network externalities</td>
<td>.19 (.06)***</td>
<td>.14 (.04)***</td>
<td>.13 (.04)**</td>
<td>.10 (.05)**</td>
<td>.17 (1.14) (N.S.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technological intensity of product (\times) network externalities</td>
<td>.62 (.21)***</td>
<td>.41 (0.16)**</td>
<td>.32 (0.16)**</td>
<td>.17 (.14) (N.S.)</td>
<td>.42 (.19)**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Firm-Level Effects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size of pioneer (\times) network externalities</td>
<td>.10 (.03)***</td>
<td>.09 (.03)***</td>
<td>.04 (.03)**</td>
<td>.10 (.04)**</td>
<td>.14 (.05)**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incumbency of pioneer (\times) network externalities</td>
<td>-1.22 (0.45)**</td>
<td>-1.54 (0.45)**</td>
<td>-1.35 (0.45)**</td>
<td>-1.03 (0.45)**</td>
<td>-1.32 (0.45)**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radicalness of product</td>
<td>-1.23 (0.36)**</td>
<td>-3.03 (1.12)**</td>
<td>-2.08 (1.08)*</td>
<td>-1.33 (1.28)**</td>
<td>-3.08 (1.27)**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technological intensity of product</td>
<td>-4.66 (1.58)**</td>
<td>-8.86 (1.90)**</td>
<td>-6.52 (1.94)**</td>
<td>-5.36 (1.28)**</td>
<td>-7.62 (2.14)**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size of pioneer</td>
<td>-6.80 (1.90)**</td>
<td>-4.84 (1.47)**</td>
<td>-7.49 (2.22)**</td>
<td>-6.74 (2.22)**</td>
<td>-8.88 (2.22)**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incumbency of pioneer</td>
<td>9.58 (3.54)**</td>
<td>6.52 (1.94)**</td>
<td>9.58 (3.54)**</td>
<td>9.58 (3.54)**</td>
<td>9.58 (3.54)**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log (introduction year)</td>
<td>.65 (.10)**</td>
<td>.52 (.10)**</td>
<td>.51 (.10)**</td>
<td>.42 (.10)**</td>
<td>.30 (.10)**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scale parameter</td>
<td>23.40 (26.08) (p &lt; 0.01)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model (\chi^2) (d.f. = 10)</td>
<td></td>
<td></td>
<td>23.40 (26.08) (p &lt; 0.01)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: N.S. = not significant.

aSample excludes ten products for which the pioneering exit is ambiguous.
of pioneers indicate that the negative excess inertia effects of network externalities outweigh the positive lock-in effects on the pioneer’s survival duration.

However, the moderating effects of product and firm characteristics on the effect of network externalities on the survival of pioneers qualify the previous case. Pioneers of more radical and technologically intensive products in networked markets survive longer than pioneers in less radical and less technologically intense products. Thus, it appears that though radical and technologically intensive product categories are risky for pioneers in networked markets (as evinced by the unhypothesized negative main effects for radicalness and technological intensity in Column 3, Table 3), the characteristics also provide entry barriers that mitigate that risk, thereby enabling the pioneer to establish an installed base, wield market power, and secure long-term survival.

Large pioneering firms have access to complementary resources that enable them to establish an installed base and lock in customers to their product’s network, positively influencing firms’ long-term survival. For incumbent pioneers, increases in network externalities decrease the duration of pioneer survival, a finding that is consistent with previous research on incumbents’ inertia to invading innovations (e.g., Ghemawat 1991; Henderson 1993; Mitchell 1991).

In summary, our findings indicate a notable and complex interplay of product and firm characteristics that determine the effect of network externalities on pioneer survival. In our empirical analysis, we were able to elucidate the interplay of factors and explain the relationship between network externalities and market entry strategy (i.e., pioneering), thereby extending the literature on marketing strategy for firms in networked markets (Gupta, Jain, and Sawhney 1999; Padmanabhan, Rajiv, and Srivnasan 1997).

High-technology markets. As the first reported empirical investigation of market entry in high-technology markets, our study addresses a call for more research on marketing strategy issues in such markets (John, Weiss, and Dutta 1999, p. 78). The unhypothesized negative main effects of products’ radicalness and technological intensity on pioneer survival indicate that though pioneers of radical and technologically intensive products face considerable risks, the risks are mitigated by the presence of network externalities. These findings point to the role of product characteristics in determining the rewards of pioneering in such markets and suggest that strategy researchers should consider these variables in future theory development in the domain.

Managerial Contributions

Our findings provide several specific managerial insights. First, network externalities have a strong negative effect on the survival duration of pioneers. This finding suggests that firms contemplating entry into such markets should consider taking a wait-and-see approach to launch, allowing other firms to pioneer but readying to enter quickly if the market begins to take off. Thus, it pays to be patient but watchful in those markets. Indeed, for 12 of the 45 products we studied, the later entrant adopted standards set by the pioneer or an earlier entrant, piggybacking on the technological developments. The later entrant firm thus learns vicariously about the product market before market entry, which is consistent with recent evidence for delaying new product entry (Narasimhan and Zhang 2000).

However, not all pioneers in networked markets failed; the surviving pioneers had average market shares of 25%. Why do some pioneers survive and thrive while others fail? Our case histories suggest a possible explanation: a focus on marketing the networked utility of the product. The utility of a networked product to a customer derives from two sources: (1) the intrinsic, or the stand-alone, utility of the product, independent of the number of other users of the product (e.g., using a personal computer as a stand-alone computing device), and (2) the networked utility that results from other users in the physical (e.g., fax machine) or virtual (e.g., personal computer, CD player) network. Pioneers of products with network externalities must not only market their products but also develop and market the product’s network. Firms can build network utility in different ways, including licensing of the product to other manufacturers to build a large installed base quickly to reduce customer uncertainty, promotion of the development of complementary goods (e.g., CD music titles for CD players), and/or ensuring of backward compatibility with existing networks to reduce switching costs to the new network. Pioneers that focused on promoting and delivering network utility to customers survived, but firms (whether pioneers or later entrants) that focused on only the stand-alone utility tended to fail.

Consider Sony, which pioneered the CD player in 1982. Sony worked extensively to develop the CD format accepted by the music industry and entered into extensive licensing agreements for other firms to manufacture the CD player. Sony also recognized that the availability of music titles on CDs was crucial for delivering utility to customers of the CD player, so it leveraged its Columbia Records label and its collaboration with Philips’s PolyGram Records, two of the world’s largest music producers at the time, to ensure the availability of music titles on CDs. When Sony introduced its first CD player, Columbia Records simultaneously released the world’s first 50 music CD titles (for other examples, see Liebowitz and Margolis 2001; Varian and Shapiro 1998).

Second, radicalness and technological intensity of the product moderate the effect of network externalities to increase the survival duration of pioneers. Although radical and technologically intensive product markets are risky, these product characteristics actually strengthen the pioneer’s survival. Consider again the CD player pioneered by Sony. Because of its laser-based, computerized technology, the CD player offered virtually noiseless sound quality that was impossible to achieve with the prevalent audiocassette player, thereby providing a breakthrough in sound reproduction. Not affected by the scratches, smudges, and heat warping that afflict audiocassettes, CDs maintained their original sound quality for a long time. The CD player was revolutionary and, as an industry analyst (San Diego Tribune 1987, p. B1) notes, was “the most dramatic development in sound reproduction since Edison.” Thus, the radicalness of CD players resulted in formidable entry barriers for
subsequent entrants, ensuring Sony’s long-term market dominance.

Third, firm size moderates the effect of network externalities to increase the survival duration of pioneers, and incumbency moderates the effect of network externalities to decrease the survival duration of pioneers. Large firms can be assured that their size and attendant resources aid their pioneering efforts in networked markets, whereas it might be beneficial for small firms to partner with other firms that have the necessary resources for market development. For example, Philips’s large size and plentiful resource base proved useful in pioneering the audionicassette player market. With respect to incumbency, incumbent pioneers in networked markets must guard against technological inertia, which hurts their survival.

Limitations and Further Research

This study has some limitations that present opportunities for further research. We focused on the survival duration of pioneers. In some situations, pioneers may survive for a long period but not realize large market share or high profits. We used firm size as a surrogate for organizational resources, and we did not measure the impact of specific resources (e.g., size of the business unit, marketing mix) on the survival duration of pioneers. Further research should investigate the effects of network externalities on other measures of pioneer performance, such as market share and financial performance, and incorporate the effects of the pioneers’ other resource characteristics.

We focused on the survival duration of pioneers, not on the survival of products. Therefore, we restricted our attention to products that had mass-market acceptance. We were unable to collect data for 18 products in smaller product markets (e.g., radar detector) for which historical records were sparse. Other researchers might extend our study to identify the pioneering rewards in a broader set of product categories.

Given the lack of objective measures for network externalities and radicalness, we used retrospective, subjective measures. Because of improved record keeping and contemporaneous accounts of new product innovations, future researchers can use measures that might not be subject to the possible hindsight biases of our subjective measures.

In addition, we focused on two product and two firm characteristics as moderators of the effect of network externalities on pioneer survival. A product characteristic that we did not consider is the appropriability of the innovation (Teece 1986), or the ability of the firm to collect rents for its innovation efforts. In general, appropriability in the product categories we studied is low, because few firms appeared to rely on the protection afforded by patents. Further research should investigate the effects of appropriability and other product and firm factors on the rewards to pioneers for products with network externalities.

In summary, we view this study as a useful base for further investigation of the effects of network externalities on the performance of pioneering firms. We hope our research stimulates additional work in the area.

Appendix

Outline of AFT Models

A pioneer’s time of failure, T (from time of product introduction), is a random variable that has a probability density function \( f(T = t) \), denoted as \( f(t) \), where cumulative density is represented by \( F(t) \). The likelihood that a pioneer fails at time \( T = t \), given that it has not failed in the time interval \([0, t)\), is \( h(t) > 0 \). The hazard function is \( h(t) \) (i.e., the risk of a firm failing at any given time \( t \) and is equal to \( f(t)/(1 – F(t)) \). All pioneers face a base hazard that represents the risk of failure in homogeneous (average) conditions. Various covariates specific to each pioneering product (e.g., firm size, type of product, moderation effects on network externalities) can increase or decrease the hazard (and, consequently, the survival duration) of pioneers.

There are two main ways to estimate the effects of covariates on survival: (1) use of nonparametric models to model their effect on the hazard (e.g., Cox proportional hazards model) and (2) use of parametric models to model their effect on the duration time (e.g., AFT models). The AFT models can accommodate several distributions (gamma, log-normal, log-logistic, Weibull, or exponential [a special case of Weibull]) for the hazard function. Because we wanted to explore the specific form and shape of the hazard function that underlies the survival of pioneers, we used the AFT model. The AFT method is well accepted in the fields of statistics, engineering, and sociology (see Allison 1995; Kalbfleisch and Prentice 1980; Lawless 1982) but has been used infrequently in marketing (e.g., Bayus 1998; Manchanda et al. 2002).

We illustrate the AFT model with an example. Suppose that there are two firms that are identical in all respects except for group membership \((0\) and \(i)\); A firm in Group 0 with survival time \( t \) will have a survival time \( \phi t \) in Group \( i \) (i.e., \( S_0[t] = S_i[\phi t] \)). For example, if Group 0 consists of large firms and Group 1 consists of small firms, it might be expected that \( \phi < 1 \) (i.e., pioneers in Group 1 have an accelerated failure time). The hazard functions for the two groups then share the following relationship: \( h(t) = \phi h_0(t) \). When incorporating the effects of covariates, we denote the hazard function as \( h(t,X) \), where \( X \) is a set of covariates. Furthermore, if we specify that \( \phi \) is determined by a set of covariates \( (\phi = e^{\alpha X}) \), the hazard function for firms in Group \( i \) (compared with that of firms in Group 0) for the AFT model is:

\[
(A1) \quad h(t,X) = e^{\alpha X} h_0(t e^{\alpha X}).
\]

If firms in Group 0 have a Weibull distribution of survival times, \( W(a, b) \), the distribution of survival times of firms in Group \( i \) is also Weibull, \( W(a e^{\alpha X}, b) \), so that firms have the same duration distribution conditional on \( X \). Likewise, if firms in Group 0 have a log-logistic distribution of survival times, \( LL(\mu, \sigma) \), or a log-normal distribution, \( LN(\mu, \sigma) \), the survival times of firms in Group \( i \) are given by \( LL(\mu - \alpha X, \sigma) \) and \( LN(\mu - \alpha X, \sigma) \), respectively. For estimation of the parameters of the previous distributions, it is easier to work with the distribution of \( Ln(T) \) rather than \( T \). Therefore, we specify an estimation model as follows:

\[
(A2) \quad Ln(T_i) = \beta_1 X_{i1} + \beta_2 X_{i2} + ... + \beta_k X_{ik} + \sigma e_i,
\]

where the terms are described in the text.
To determine the relationship between Equation A2 and the survival distribution, if it is assumed that $T_i$ has a Weibull distribution, the correspondence between the parameters of $W(\alpha, \beta, \gamma)$ and the parameters of Equation A2 is as follows: $b = 1/\sigma$; $\alpha = e^{-1/\sigma}$; and $\alpha = -\beta$. In contrast, if it is assumed that $T_i$ has a log-logistic distribution (equivalently, $\ln(T_i)$ has a logistic distribution), the correspondence between the parameters of $LL(\mu - \alpha X_i, \sigma)$ and Equation 2 is as follows: $\mu = \mu_i$; $\sigma = \sigma_i$; and $\alpha = -\beta$. The correspondence between the survival time distribution and Equation 2 for log-normal is analogous to that of log-logistic.

We also note that the Weibull model can be interpreted as both a proportional hazards model and an AFT model. For Weibull $W(\alpha, \beta, \gamma)$, the base hazard function is given by $h_0(t) = \alpha t^{\beta-1}$. The hazard function for the AFT model per Equation A1 is $h(t, X_i) = e^{\alpha X_i h_0(t)} = e^{\alpha X_i (\alpha t^{\beta-1})} = (e^{\alpha X_i} h_0(t))$. The last equation in this sequence of identities is the proportional hazards representation; the proportionality constant is equal to $e^{\alpha X_i}$. Note also that $e^{\alpha X_i} = e^{-(1/\sigma)\beta X_i}$ when it is represented in terms of the parameters of Equation A2, because $b = 1/\sigma$ and $\alpha = -\beta$.

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