PROBABILITY AND TIMING OF EXPANSION BY INDUSTRY INCUMBENTS FOLLOWING EVOLUTIONARY MAJOR PRODUCT INNOVATION

Will Mitchell

ABSTRACT

This paper distinguishes between two types of major product innovation within an industry—paradigmatic innovation as represented by the birth of new technical subfields, and evolutionary major product innovation as represented by introduction of new products that require new material technology and lead to new uses while drawing on existing scientific principles. The study predicts that industry incumbents will react somewhat differently to major innovation within a technical subfield than they do to the emergence of new technical subfields.
During the past decade, the study of industry incumbents' actions in the wake of the creative destruction (Schumpeter, 1942) of innovation has become a key issue in the fields of strategy, economics, and organizations. Much of the analysis has focused on a firm's specialized capabilities, the competitiveness of its industrial environment, or interactions between internal and environment factors (Dosi, 1982; Freeman, 1982; Katz & Shapiro, 1987; Nelson & Winter 1982; Sahal, 1981; Teece, 1986; Tushman & Anderson, 1986; von Hippel, 1988; Williamson, 1985). Mitchell (1989) found that an industry incumbent's reaction to the introduction of goods that draw on new knowledge bases, and so represent the birth of a new technical subfields, is affected by product, firm, and industry-level factors. However, creative destruction is not limited to cases in which the challenge comes from products that rely on new knowledge bases. In addition, and more frequently, the challenges arise as new products evolve from existing knowledge bases.

This paper extends findings reported in Mitchell (1989) to the case of evolutionary major product innovation within a technical subfield. The concepts of technical subfields and evolutionary major innovation nest within Dosi's (1988, p. 1127) definition of a technological paradigm, that is, "the need which are meant to be fulfilled, the scientific principles utilized for the task [and] the material technology to be used." The emergence of a new technical subfield is likely to require significant changes along each of the three dimensions of a paradigm, and so represents the emergence of a new technological paradigm.

Within-subfield evolutionary major product innovation, meanwhile, is subparadigmatic concept, involving the use of existing scientific principles to support new material technology and new applications. Such innovation is major in the sense that product cost, quality, and applications are significant altered, but evolutionary in the sense that the changes grow out of an existing base of knowledge. Both subfield birth and evolutionary major product innovation are consistent with most definitions of radical innovation (e.g. Abernathy & Utterback, 1978), but only subfield birth represents a new technological paradigm.

The analysis uses logistic and accelerated event-time regression to examine expansion probability and timing in five product areas of the nuclear medical imaging subfield of the diagnostic imaging industry. The study, expansion between the early 1950s and the late 1980s, identifies significant differences in the expansion probability and timing of 103 imaging industry and nuclear subfield incumbents, following the introduction of five types of nuclear medical devices. Much of the difference in expansion probability and timing is explained by differences in product, firm, and industry factors.
INFLUENCES ON EXPANSION PROBABILITY AND TIMING

The central point of this research is to identify influences on the probability and timing of expansion by industry incumbents following subparadigmatic major innovation, and compare the influences to those following paradigmatic innovation. It is generally accepted that industry incumbents are likely to react differently to radical innovations than to minor incremental adjustments to existing principles, material technology, and usage. Incumbents are the sources of most incremental changes to existing goods, and other firms are usually able to evaluate and respond to minor innovations quickly and effectively, drawing mainly on their existing stock of knowledge and routines (Nelson & Winter, 1982).

Radical departures from established goods, involving new technical skills (Abernathy & Utterback, 1978; Utterback & Kim, 1983), however, are typically introduced by industry newcomers (Jewkes, Sawyers, & Stillerman, 1958; Tushman & Anderson, 1986) and create major competitive challenges to incumbents. Yet, whether the product, firm, and industry-level influences that affect entry choice and timing strategies of current competitors following the emergence of a new technical subfield will produce the same reactions following evolutionary major product innovation is an open question. This paper predicts that some expansion choice and timing responses will differ.

Consider, for instance, innovation in the consumer electronics industry. The emergence of color television represented evolution within the TV technical subfield of the industry, while the introduction of VCRs marked the birth of a new technical subfield. A TV manufacturer will need to react differently to a television innovation than to introduction of VCRs. The first represents an immediate substitutive threat. The latter is more likely to be a long term complementary challenge, in the sense that television design and production will need to provide interfaces to VCRs and VCR marketing will affect television sales. Thus, a current manufacturer has more time and flexibility in responding to the introduction of VCRs than to color television.

Yet, in neither case can the television manufacturer ignore the emerging innovation, if there are technical or marketing complementarities that spill back from the new product area to the older field—an established firm which does not react to a substitutive or complementary innovation is likely to lose its position in its established business (Mitchell & Singh, 1990). If consumers buy TVs based on their satisfactory experience with VCRs, for instance, a television manufacturer which does not also manufacture video cassette recorders will be at a competitive disadvantage.

In general, an industry incumbent's reaction to product innovation within a technical subfield of an industry is likely to vary, depending on whether the
firm’s specialized assets have primary value within the subfield, or within the broader industry. For a leader within a subfield, evolutionary major product innovation is an immediate threat to its existing position in the subfield. It must react quickly, or risk being surpassed, in terms of existing market share, profitability, and survival. To a more broadly established incumbent, however, innovation represents a long-term opportunity—the chance to extend its position into the evolving product area. The firm with a broad base across several technical subfields in the industry can afford to wait longer while technical and market uncertainties subside, and to compare the new products to other opportunities, because a change in any one subfield will affect only part of its industry-specific operations. A follower within a subfield also has more reaction flexibility than a subfield leader, because it is likely to target a focused niche within the subfield and may be unaffected by the innovation.

HYPOTHESES

Several bodies of research touch on the two key questions of this paper: whether an incumbent will expand and when it will do so. In the diversification literature, there is general agreement that expansion into related businesses often produces positive net results, while unrelated expansion is likely to be neutral or negative (Montgomery, 1985; Rumelt, 1982). Although there is less agreement about what constitutes appropriate relatedness, there is little doubt that both entry into new technical subfields and introduction of evolutionary major product innovations represent related expansion on the part of industry incumbents. Hence, we would expect that some incumbents would expand, but there is no clear prediction of which incumbents will be most likely to undertake the related expansion.

Entry timing, meanwhile, has been the subject of several taxonomies in the fields of marketing and strategy (see Miller, 1988; Lieberman & Montgomery, 1988). Although there is no consensus regarding the causes of variations in the time of new product introduction, the general trend of the analyses is that early entry often leads to greater long-term market share (Robinson, 1988). In addition, the greater a firm’s chances of locking out followers, the greater its incentive to enter early (Lieberman & Montgomery, 1988).

Mitchell (forthcoming), however, reports that early entry also may be associated with early exit, while Mitchell and Singh (1990) show that failed expansion had significant negative effects on a firm’s existing related business. Thus, choosing to expand into a new product area and timing the expansion require a trade-off between potential gains from the new products, on the one hand, and potential investment losses and damage to existing operations, on the other.

Mitchell (1989) predicted that three sets of factors would affect the trade-off and so influence the probability and timing of entry by industry incumbents
into emerging technical subfields: the degree to which products in a new subfield substituted for existing goods, the strength of an incumbent’s industry-specialized supporting assets, and the competitiveness of the industry when the new subfield emerged. The logic of the predictions was threefold. First, when products in a new subfield represent a directly substitutive threat, a producer must react and must react quickly, or fail. Second, the emergence of products drawing on new technical knowledge does not eliminate the value of many specialized assets required to successfully commercialize the new goods. Such assets include distribution systems, incremental R&D capabilities, service systems, and established reputations. The possession of specialized supporting assets required to successfully commercialize core products is the base of an incumbent’s strength. It is likely to attempt to use that strength, and so realize the value of the assets, by entering the new subfield. Third, the more competitive the industrial environment, the sooner a firm must act, or risk being locked out or knocked out by capable rivals that acted before it. At the same time, however, increased competition will reduce the likelihood that a firm will succeed in an emerging subfield and so reduce the probability that it will enter. Using five technical subfields of the diagnostic imaging industry as the empirical base, the analysis found the predicted effects.

A similar, but not identical, logic applies when major innovation occurs within a technical subfield. The following hypotheses address influences on industry incumbents’ expansion choice and timing following evolutionary major product innovation. The first set of hypotheses predicts that the product substitution effects will be found. The second and third set of hypotheses predict that effects of subfield-level competition and firm subfield-relevant strength will hold.

**Hypothesis 1a.** The more the new type of product substitutes for an industry incumbent’s existing products, the more likely the incumbent will expand into a new product area within a technical subfield.

**Hypothesis 1b.** The more the new type of product substitutes for an industry incumbent’s existing products, the earlier the incumbent will expand into a new product area within a technical subfield.

**Hypothesis 2a.** The more competitive a subfield when the new product area emerges, the less likely an industry incumbent will expand into a new product area.

**Hypothesis 2b.** The more competitive a subfield when the new product area emerges, the earlier an industry incumbent will expand into a new product area.
Hypothesis 3a. The stronger an industry incumbent’s position within a technical subfield when a major new product area emerges within the subfield, the more likely it will expand into the major new product area.

Hypothesis 3b. The stronger an industry incumbent’s position within a technical subfield when a major new product area emerges within the subfield, the earlier it will expand into the major new product area.

Most influences that relate to an incumbent’s strength and the degree of competition at the broader industry level are also likely to be similar to the influences on entry probability and timing following subfield emergence.

Hypothesis 4a. The more competitive the industry when a new product area emerges within a technical subfield, the less likely an industry incumbent will expand into a new product area.

Hypothesis 4b. The more competitive the industry when a new product area emerges within a technical subfield, the earlier an industry incumbent will expand into a new product area.

Hypothesis 5a. The stronger an industry incumbent’s position within the entire industry when a major new product area emerges within a technical subfield, the more likely it will expand into a major new product area.

One key influence, though, is likely to differ between the subfield and evolutionary major product innovation cases. Firms with strength at the general industry level, such as large market share, will be able to wait for technical and market uncertainties to subside before introducing a new product within an existing subfield, knowing that their overall strength will allow them to successfully expand late.

Hypothesis 5b. The stronger an industry incumbent’s position within the entire industry when a major new product area emerges within a technical subfield, the later it will expand into a major new product area.

DATA

Nuclear Medical Imaging Product Areas

The hypotheses were tested by identifying influences on expansion probability and incidence in five major product areas of the nuclear medical imaging subfield of the diagnostic imaging industry. Nuclear medical devices comprise one class of medical diagnostic imaging instruments. Earlier tools
included conventional x-ray and electrodiagnostic instruments, while more recent diagnostic imaging technical subfields include ultrasonic and x-ray computed tomographic (CT) imaging systems. All the devices allow physicians and other health care workers to obtain information about physical structures and physiological activity within the body. The relevant subfields of the diagnostic imaging industry and the five product areas of the nuclear medical subfield are listed in Table 1.

Nuclear medical techniques involve administering a small amount of radioactive material to a patient, detecting the gamma rays that are emitted, and calculating the position of the rays within the body. A nuclear medical instrument then produces either an image on film or physiological information that can be interpreted by a researcher or clinician. By labeling substances that accumulate in specific organs and lesions with the radioactive materials, static and dynamic images of individual body systems can be produced (Kaufman, 1979). A radiopharmaceutical that is created by labeling human serum albumin

<table>
<thead>
<tr>
<th>Year introduced</th>
<th>No. of industry incumbents, year before introduction (No. expanded)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional x-ray</td>
<td>1896</td>
</tr>
<tr>
<td>Electrodiagnostic</td>
<td>1911</td>
</tr>
<tr>
<td>Nuclear medicine</td>
<td>1954</td>
</tr>
<tr>
<td>Ultrasound</td>
<td>1957</td>
</tr>
<tr>
<td>Computed tomography (CT)</td>
<td>1973</td>
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</tbody>
</table>

**Table 1. Diagnostic Imaging Industry Technical Subfields and Major Nuclear Medical Product Areas**

**Industry Technical Subfields**

**Nuclear Medical Product Areas**

<table>
<thead>
<tr>
<th>Product Area</th>
<th>Year introduced</th>
<th>No. of industry incumbents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moving Scanners</td>
<td>1954</td>
<td>9</td>
</tr>
<tr>
<td>Stationary cameras</td>
<td>1962</td>
<td>13</td>
</tr>
<tr>
<td>Image data processing</td>
<td>1968</td>
<td>15</td>
</tr>
<tr>
<td>Single photon emission (SPECT)</td>
<td>1976</td>
<td>33</td>
</tr>
<tr>
<td>Positron emission (PET)</td>
<td>1976</td>
<td>33</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>103</strong></td>
<td>(29)</td>
</tr>
</tbody>
</table>
with radioactive iodine-131, for example, is trapped in the pulmonary capillaries and so enables lung scans to be obtained (Lindeman & Quinn, 1976).

The first nuclear medical imaging devices to be introduced commercially were scanners for obtaining images of thyroid glands, introduced about 1954. Scanner sales grew slowly until the late 1960s, when a stationary camera introduced about 1962 became the dominant instrument. Commercial nuclear medical image data processing systems were introduced about 1968, complementing other product areas, and by the late 1970s had become part of most nuclear medical imaging systems. Commercial single-photon emission computed tomographic (SPECT) competed with cameras and positron emission tomographic (PET) instruments were introduced in 1976. SPECT competed with cameras and enjoyed steady sales growth, while PET largely created new diagnostic applications and has diffused slowly.

All nuclear medical imaging products draw on the scientific principles of radioactive physics and chemistry. As each new product class has emerged, however, new material technology has been required, including new crystals, collimators, radiopharmaceuticals, and devices to create useful radioactive substances. In addition, new uses of the devices have become possible. Thus, each product class represents a evolutionary major product innovation within the nuclear medical subfield.

Nuclear medicine substitutes for some other diagnostic imaging methods. The techniques produces higher contrast images than conventional x-ray methods and some nuclear medical techniques provide information about organ function as well as structure. Because it requires lower levels of ionizing radiation, nuclear medicine is safer than conventional x-ray methods. In addition, the images can often be obtained more cheaply than pictures produced with x-ray computed tomographic and magnetic resonance imaging instruments. However, it is only a partial substitute because the spatial resolution of nuclear medical images, that is, the minimum separation required to distinguish two points, is poorer than can be obtained with the more expensive methods.

Sales of nuclear medical equipment grew slowly during the 1950s and 1960s. The combination of technical advances and market expansion induced by the establishment of the American Medicare and Medicaid programs in 1966 and 1967 led to diffusion of the diagnostic equipment (Russell, 1977), and sales grew from $50 million during the late 1960s to $200 million in 1981. Shipments then fell to about $160 in 1987, however, as nuclear medical equipment was supplanted by other imaging advances. Overall American sales of diagnostic imaging systems, meanwhile, grew from about $40 million in the late 1950s to almost $3 billion in 1988.
Sources And Concepts

The information for this study is drawn from a search of the business, academic, and government press. In order to corroborate and extend the archival data, a series of about 50 interviews was conducted with individuals who worked in nuclear medical research and licensing positions within academic and corporate organizations. The study includes manufacturers that sold diagnostic nuclear medical systems in the U.S. market, omitting component suppliers and firms that only distributed another manufacturer’s products. Expansion into a product area, which was recorded at the parent-firm level of analysis, was defined to have taken place when a manufacturer placed its first unit in a clinical site outside its own plant.

The study includes all industry incumbents that participated in the nuclear subfield during the year before the introduction of the new types of nuclear medical devices. It also includes imaging industry incumbents which were not members of the nuclear subfield and held at least 1% industry market share. These criteria identified 103 incumbents, 29 of which expanded into the new product areas.¹

Variables

The dependent variable for the analysis of expansion probability was defined as a 0-1 dummy variable that recorded whether an incumbent had expanded into the nuclear medical product area by 1989, the end of the study. This also identified right-censoring status for the expansion timing dependent variable, in order to distinguish between waiting periods that ended with an expansion and waiting periods that did not end. The expansion time was defined as the number of years following the introduction of a nuclear medical device that an incumbent expanded into the product area. The waits were capped at 1989 or, if it had exited by the end of the study, the year the firm left the imaging industry. The minimum was set at one year, for firms that expanded during the first year of product life, while the maximum possible wait was 36 years (1953-1989).

Independent variables were defined to estimate the predicted product substitution, firm strength, and competitiveness effects. Product substitution was defined as a dummy variable, set equal to 1 if a firm produced scanners before the introduction of cameras, or manufactured cameras before the introduction of SPECT instruments. Because possession of specialized assets, such as distribution and service systems, is associated with market share, firm industry and subfield-relevant strength were defined as industry and subfield market shares held during the year before the introduction of a new nuclear medical product type. Competitiveness was defined as one minus the sum of the squared industry and subfield market shares during the year before the introduction of the new products (one minus the Hirschman-Herfindahl Index
of industry concentration). The nuclear subfield competitiveness measure for the year prior to the introduction of scanners was set equal to 1, the maximum possible competitiveness value.

In addition, control variables were defined for corporate size, nationality of ownership, and product-type sales levels. The size effect might be in either direction. Greater size may be associated with bureaucratic inertia (Crozier, 1964) and, hence, both lower probability of expansion and slower expansion. Conversely, greater size may provide more resources with which to undertake the risk of earlier expansion (Wernerfelt & Karnani, 1987). Size was recorded as the square root of an incumbent’s corporate sales during the year before the introduction ($ million, deflated by the 1967 Producer Price Index).

The nationality effect is likely to be associated with lower probability of expansion and later expansion by American firms (Mitchell, 1989). American firms are sometimes viewed as being less responsive than their foreign competitors and thus may be later and less likely to introduce new product-types. Also, because the focus of the study is the American market, foreign-owned incumbents have already shown that they are capable of expanding across international boundaries and so may be more likely than many American-owned firms to expand. Nationality was defined as a dummy variable with value equal to 1 if the majority ownership was American and 0 otherwise.

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| Table 2. Product-Moment Correlations and Summary Statistics |
| (N = 103) |

<table>
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<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<tr>
<td>Industry market share</td>
<td>1.0</td>
<td>0.26</td>
<td>−0.38</td>
<td>−0.08</td>
<td>0.10</td>
<td>0.02</td>
<td>0.35</td>
<td>0.08</td>
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<td>2.</td>
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<tr>
<td>Subfield market share</td>
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<td>−0.00</td>
<td>−0.20</td>
<td>0.29</td>
<td>0.10</td>
<td>−0.01</td>
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<td>3.</td>
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<td>Industry competition</td>
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<td>−0.00</td>
<td>−0.09</td>
<td>0.26</td>
<td>−0.11</td>
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<td>4.</td>
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<td>Subfield competition</td>
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<td>−0.06</td>
<td>−0.50</td>
<td>−0.60</td>
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<td>5.</td>
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<tr>
<td>Product substitution</td>
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<td>0.15</td>
<td>−0.20</td>
<td></td>
<td></td>
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<td>6.</td>
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</tr>
<tr>
<td>Product 10-year sales</td>
<td>1.0</td>
<td>0.00</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>7.</td>
<td></td>
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<tr>
<td>Corporate size</td>
<td>1.0</td>
<td>−1.2</td>
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<tr>
<td>8.</td>
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<td>American firm</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
</tr>
</tbody>
</table>

Minimum value

| 0  | 0  | .82 | .50 | 0  | 1  | 0  | 0  |

Maximum value

| 23 | 60 | .90 | 1.00 | 1  | 4  | 91.5 | 1  |

Mean value

| 4.6 | 3.9 | .89 | .75 | .10 | 2.2 | 18.1 | .68 |

Standard deviation

| 6.4 | 10.7 | .02 | .15 | .30 | 1.1 | 23.8 | .47 |
Product areas that enjoy greater sales are more likely to attract expanding incumbents and, if the sales strength is apparent soon after product introduction, earlier expansion. The prediction of greater expansion probability assumes similar returns to scale across the product areas, which appears to be a reasonable assumption for the nuclear medical equipment subfield where minimum efficient scale is generally low. Product-type sales effects were estimated with a 10-year relative sales index (scanners and PET = 1, computers = 2, SPECT = 3, cameras = 4). Descriptive statistics and product-moment correlations among the covariates are reported in Table 2.

STATISTICAL METHODS

Two statistical methods, logistic and accelerated event-time regression, were used to test the hypotheses. The logit and the gamma distribution accelerated event-time estimates were obtained with the LOGIT and SURV procedure of LIMDEP (Greene, 1990), while the Weibull distribution accelerated event-time estimates were obtained with the LIFEREG procedure of SAS (SAS Institute Inc., 1985). Tests of the expansion probability hypotheses were carried out by calculating a logistic regression equation with the following functional form:

\[
\ln \frac{P_i}{(1 - P_i)} = a + Bx_i
\]

\(P_i\) is the probability that the \(i\)th unit will experience an event (in this study, the probability that an incumbent will expand into a particular product area). The log odds of the probability is held to be linearly affected by a vector of covariates \(x_i\) with coefficient vector \(B\) and intercept \(a\). The effect of a one-unit change of the \(j\)th covariate \(x_{ij}\) on the probability of observation \(i\) expanding into a product area is \(B_j(P - P_i)\). The estimates were obtained with ungrouped maximum likelihood methods (Hanushek & Jackson, 1977; Maddala, 1983).

Logistic regression is suited to testing predictions regarding expansion probability. To investigate expansion timing, however, one must examine the length of the wait as well as whether an expansion occurred. The accelerated event-time method provides a means of estimating influences on the length of waiting periods.

The principal advantage of the accelerated event-time method over more-conventional regression techniques is its use of right-censored cases, which in this case means that an incumbent had not expanded into a nuclear medical product area by the end of the study. If censored cases are discarded or treated as if the event had occurred, the results often will be seriously biased (Tuma & Hannan, 1984). In this study, the ability to use such observations is crucial; over 80 percent of the incumbents had not expanded into the new product.
areas by 1989. Moreover, with different observation periods for each of the five product areas (14 to 36 years) incumbents had longer to expand into the older product areas. If the only firms included were those that expanded, the larger populations of incumbents in the later cases would produce downward-biased estimates of expansion waiting periods. Event-time analysis controls for variation across product areas because it incorporates the information that some incumbents had not expanded.

The accelerated event-time method assumes that the event times (expansion waiting periods, in this study) are distributed according to a parametric baseline distribution that would hold if all independent variables were zero (Kalbfleisch and Prentice, 1980; Cox and Oakes, 1984). The effects of covariates are then estimated as exponentially multiplicative accelerations or decelerations of the baseline distribution. The additive logarithmic form of the model takes the following functional form:

\[ \ln T_i = a + B X_i + se_i \]

\( T_i \) is the observed event-time of the \( i \)th case; \( X_i \) is a vector of covariates associated with the \( i \)th case; \( a \) and \( B \) are an intercept and a vector of coefficients associated with the independent variables. A positive \( B \) coefficient accelerates the baseline distribution of event times and a negative coefficient decelerates the distribution. The error vector \( e \) is distributed according to the assumed parametric distribution and is scaled by a variance-related factor \( s \). A shape parameter \( k \) is also associated with some distributions.

Accelerated event-time analysis requires that an underlying distribution be specified. In this analysis, the best fit was provided by the Weibull distribution, a fat-tailed distribution that has previously been found to fit entry waiting periods (Mitchell, 1989). The Weibull is appropriate for monotonically decreasing rates. The Weibull is nested within the three-parameter generalized gamma distribution, which can be used to test and control for the effects of omitted independent variables. If such heterogeneity were not controlled, the estimations could produce either inconsistent parameter estimates or inappropriate standard errors, with the second being the most common problem (Gourieroux, Montfort, & Trognon, 1984). If the gamma collapses to the Weibull, that is, if the third parameter of the gamma distribution is not significant, the effect of such influences can be judged to be small (Greene, 1990). The Weibull in turn collapses to the constant rate exponential distribution if the Weibull scale parameter equals 1.

**RESULTS**

Most hypotheses were supported, as reported in Table 3, although some counter-findings emerged. Overall, both the logistic and accelerated event-time
(N = 103, 29 expanded; t-statistic probability in parentheses)

<table>
<thead>
<tr>
<th></th>
<th>Probability</th>
<th>Timing</th>
</tr>
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<tbody>
<tr>
<td>Intercept</td>
<td>30.056 (.03)</td>
<td>0.674 (.92)</td>
</tr>
<tr>
<td>Incumbent strength</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry market share</td>
<td>-0.064 (.33)</td>
<td>0.053 (.06)</td>
</tr>
<tr>
<td>Subfield market share</td>
<td>0.094 (.03)</td>
<td>-0.031 (.00)</td>
</tr>
<tr>
<td>Competitiveness</td>
<td></td>
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<tr>
<td>Industry</td>
<td>-33.677 (.03)</td>
<td>3.119 (.68)</td>
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<tr>
<td>Subfield</td>
<td>-2.635 (.23)</td>
<td>0.476 (.60)</td>
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<td>Substitute product</td>
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<td>Corporate size</td>
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<td>-0.015 (.02)</td>
</tr>
<tr>
<td>American firm</td>
<td>-1.329 (.04)</td>
<td>0.020 (.94)</td>
</tr>
<tr>
<td>Product 10-year sales</td>
<td>0.156 (.63)</td>
<td>-0.150 (.30)</td>
</tr>
<tr>
<td>Weibull scale</td>
<td></td>
<td>0.563 (.00)</td>
</tr>
<tr>
<td>Loglikelihood (df = 93)</td>
<td>-40.0</td>
<td>-56.1</td>
</tr>
<tr>
<td>LL₀ (df = 101)</td>
<td>-61.2</td>
<td>-73.1</td>
</tr>
<tr>
<td>Gamma LL₀ (df = 100)</td>
<td></td>
<td>-72.5</td>
</tr>
<tr>
<td>Logistic fit</td>
<td>Expansion</td>
<td>17/29</td>
</tr>
<tr>
<td></td>
<td>No expansion</td>
<td>70/74</td>
</tr>
</tbody>
</table>

Notes: Positive logistic regression coefficients in column 1 indicate greater entry likelihoods; negative accelerated event-time regression coefficients in column 2 indicate earlier entry. LL₀ is the loglikelihood of a model containing no independent variables.

models provided reasonable explanatory power. The logistic equation predicted 87 of 103 cases. In addition, the independent variables in each model produced significant increases in the loglikelihood, relative to models containing only intercept and scale terms (the LL₀ statistics).² The baseline Weibull accelerated event-time model (LL₀) fit the data about as well as a more complicated gamma distribution (Gamma LL₀). Thus, given the interpretation of the third parameter of the gamma distribution as a test for the effects of unobserved heterogeneity, there is reasonable assurance that the effects of omitted variables would not wash out the estimated influences.

Product substitution, as predicted in Hypotheses 1a and 1b, was associated with both greater expansion probability and earlier expansion. Two of four competitiveness hypotheses were supported. (Analyses using the number of industry leaders, rather than the concentration indices, produced similar results.) Increased subfield and industry competitiveness was associated with
lower expansion probability, as predicted in Hypotheses 2a and 4a, although only the industry competitiveness result was statistically significant at conventional levels. Counter to Hypotheses 2b and 4b, however, neither increased subfield nor industry competitiveness was associated with earlier expansion. Indeed, the coefficients of the competitiveness measures were associated with later expansion, although at insignificant statistical levels.

Three of the four firm-strength coefficients, meanwhile, had the expected sign at statistically significant levels. Greater market share within the nuclear subfield was associated with both higher expansion probability and earlier expansion, as predicted in Hypotheses 3a and 3b. Also as predicted, by Hypothesis 5b, greater industry-level market share was associated with later expansion into the nuclear medical product areas. Hypothesis 5a, however, which predicted that industry strength would lead to greater expansion probability, was rejected, with a nonsignificant negative effect being estimated. This counter finding, along with the earlier competitiveness findings, will be discussed in the following section.

The control variables provided intriguing influences. Opposite to the paradigmatic innovation results in Mitchell (1989), corporate size was associated with higher and earlier expansion probability. Larger firms appear better able to overcome inertia when innovation is evolutionary than when it requires paradigmatic changes, consistent with Hannan and Freeman's (1984) prediction that structural inertia will be more of a factor for core changes than for peripheral changes. In this case, entry into a new subfield represents a core change, while expansion within a subfield represents a peripheral change. American ownership had no significant influence on expansion timing, but was associated with lower expansion probability. Product sales growth, meanwhile, was nonsignificantly associated with higher probability and earlier timing of expansion.

**DISCUSSION AND CONCLUSIONS**

The results of this study are largely consistent with those expected. Differences in product, firm, and competitive factors produced differences in expansion strategy following evolutionary major product innovation within technical subfields. A few of the effects were unexpected, however, producing insight to differences in strategy following evolutionary rather than paradigmatic change.

In part, the subfield-level influences on responses to evolutionary innovation are consistent with the industry-level influences on strategy following paradigmatic changes reported in Mitchell (1989). Product substitution was unequivocally associated with quick response and high probability of response. Firm strength within a subfield, measured by prior market share, was associated with quicker response.
Evolutionary Major Product Innovation

Subfield competitiveness, however, was not associated with quick expansion, nor did it have a significant effect on the probability of expansion. A subfield incumbent's response to major evolutionary change, therefore, appears to be driven more by a firm's subfield-relevant position and the threat that a new product will directly undercut that position, than by subfield-level competitiveness. If a new product that draws on related knowledge will substitute for its existing core goods, a subfield leader will usually expand quickly, no matter what the degree of competition.

These results indicate that a paradigmatic change may represent an opportunity to be weighed, while an evolutionary change represents a threat that must be countered. That is, when deciding whether and when to seek new sales by entering a new technical subfield, incumbents appear to take into account the competitiveness of an industry, with its impact on the likelihood of success in a new subfield. When existing sales must be protected, however, as in the case of evolutionary major product innovation, the degree of competitiveness has little effect on the decisions.

The second level of influences, at the level of the broader industry, run only partly parallel to the subfield level factors. Changes in industry-level competitiveness have similar effects to changes in subfield competitiveness, and are felt more strongly. A lowering of industry concentration, in particular, is associated with lower expansion probability. One possible explanation is that as the industry becomes more competitive, an incumbent must spend more effort protecting its existing operations, rather than coping with the uncertainty of expansion into new areas. A parallel explanation is that decision makers in more competitive industries may be distracted by the number of competitors and competitive options, and so have a more difficult time securing the information and political support necessary for expansion.

Industry-level market share, meanwhile, has effects opposite to subfield leadership. If a firm possesses market strength at the level of the broader industry, it can afford to wait to expand into a new product-area within any given subfield, rather than be forced to rush in to protect its core operations. Indeed, the industry-level leader may not even expand into the new product area, choosing instead to use its resources elsewhere. This finding is consistent with the proposition that organizational slack available to firms that pursue a broad set of activities may temporarily insulate industry leaders from competitive pressures (Hannan and Freeman, 1977; Thompson, 1967).

The expansion probability results have important implications for industries which are becoming more competitive due to growing numbers of internationally-based competitors. As an industry becomes more competitive, incumbents become less likely to counter new product innovations. At the same time, American-owned firms are less likely to expand than their foreign-owned competitors. Hence, in markets where firms based outside the United States have become major players, the relative number American-owned firms will
tend to decline and leadership positions will be assumed by European and Japanese manufacturers.

Firms must constantly revise and refine the strategies they use to survive in changing industries. Understanding differences in how firms react to evolutionary and paradigmatic product innovation is an important part of understanding why and how the strategies vary. At the root of the differences in strategy are differences in the products offered, the specialized capabilities of individual firms, and the competitive industrial environment within which the firms operate. Strategic decisions, including expansion choice and timing decisions, must be undertaken in the midst of a complex web of business, corporate, industry, and national environments.

There will be cases where the best strategy is to stay at home, particularly when new products have little technical or market relationship to older goods or to the complementary assets which support the development, manufacture, and sale of the established goods. In other instances, it will be possible to wait until most technical and market uncertainties have subsided before introducing new products. Frequently, however, firms must expand, and must expand before major uncertainties have subsided, or suffer in their established businesses. Firms that fail to successfully obtain the visas necessary to cross the environmental borders, that is, that do not acquire the knowledge and perspective required to integrate information from different environments, will risk spending time arguing with immigration service personnel while their competitors are selling goods to their customers.

NOTES

1. Of the 103 incumbents included in the study, 21 participated (4 expanded) only in the nuclear subfield, 41 (11 expanded) only in one or more other subfields of the imaging industry, and 41 (14 expanded) in both the nuclear and at least one other subfield.

2. Twice the difference in the loglikelihoods of two nested models is distributed as a chi-squared statistic, with degrees of freedom equal to the difference in the number of variables. With a difference of 8 variables, a chi-squared statistic of 15.6 (loglikelihood increase of 7.8) is significant at the .05 level, as is a chi-squared statistic of 4.0 (loglikelihood increase of 2) with a difference of 1 variable.

REFERENCES


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———. (forthcoming). Dual clocks: Entry order influences on incumbent and newcomer market share and survival when specialized assets retain their value. Strategic Management Journal, 12.


