

COMPETITIVE RESPONSE TO RADICAL PRODUCT INNOVATIONS

Khaled Aboulnasr

Om Narasimhan

Edward Blair

Rajesh Chandy

Final Revision, *Journal of Marketing*

Khaled Aboulnasr (kaboulna@fgcu.edu) is Assistant Professor of Marketing at the Lutgert College of Business, Florida Gulf Coast University. Om Narasimhan (onarasimhan@csom.umn.edu) is Associate Professor of Marketing at the Carlson School of Management, University of Minnesota. Edward Blair (blair@uh.edu) is Professor of Marketing at C.T Bauer College of Business, University of Houston. Rajesh Chandy (rchandy@umn.edu) is James D. Watkins Professor of Marketing at the Carlson School of Management, University of Minnesota. The authors thank Akshay Rao for valuable suggestions on an earlier draft of this paper.

COMPETITIVE RESPONSE TO RADICAL PRODUCT INNOVATIONS

ABSTRACT

Radical product innovations often are agents of creative destruction: they threaten to destroy existing market positions, and yet they often yield vast new market opportunities. This paper examines how competitors respond to the introduction of radical product innovations. The authors argue that competitive response to radical product innovations is inherently different from response to the incremental innovations that are typically studied in existing research. They introduce the dual concepts of market expansion and entry thresholds to develop new hypotheses about competitive response. Some of these hypotheses contradict prior literature. Using objective data from the U.S. pharmaceutical industry between 1997 and 2001, they estimate a shared-frailty hazard model to explain the competitive response to radical product innovations. Results show that the likelihood of competitive response is substantially higher when the introducing firm is large or market dependent. Moreover, the response is highest when the innovation is introduced in a small market by a large firm. These results contradict those from much prior research on competitive response to product innovation.

COMPETITIVE RESPONSE TO RADICAL PRODUCT INNOVATIONS

The specter of competition looms large in all product introductions. Introducers try to predict which competitors will respond, and when. Some competitors scramble to introduce products of their own. Others refrain from action, perhaps from a fear of retaliation, lack of financial resources, sloth induced by inertia, or a fear of cannibalizing existing products (Kuester, Homburg, and Robertson 1999; Rhoades 1973; Tellis and Golder 2001).

Given the central role of competition in our economic system, the study of competitive response is essential for any understanding of business actions. Managers have to incorporate competitive response into their financial projections as they decide how much to invest in new products, or their dreams of riches could easily turn into dust. Researchers have to ensure that the reaction functions in their models of competitive interaction are accurate, or their insights could mislead (Bowman and Gatignon 1995; Moorthy 1985; Weitz 1985). Policy makers have to be able to predict competitive response, or their interventions could be unwise.

This study examines competitive response to radical product innovations. Radical product innovations differ from other new products in that they have substantially different technology and substantially higher benefits compared with existing products (e.g., Chandy and Tellis 1998). As such, radical product innovations are riskier than other product introductions, and demand more resources (Sorescu, Chandy, and Prabhu 2003). They are also more likely to destabilize markets and cause customers to reconsider existing purchase patterns. They thus threaten existing competitive positions, but also offer new market opportunities. Yet the growing literature on radical product innovation is largely silent on the issue of competitive response, and the large and established literature on competitive response to product introductions often overlooks the introduction of

radical product innovations (see Bowman and Gatignon 1995; Kuester, Homburg, and Robertson 1999; Min, Kalwani, and Robinson 2006; Robinson 1988; Sheremata 2004).

In this paper, we seek to extend and connect these two important streams of research in marketing strategy – on competitive response and radical product innovation – and add to the literature both theoretically and empirically. From a theoretical perspective, we use signaling arguments (e.g., Heil and Langvardt 1994; Heil and Robertson 1991; Porter 1980; Prabhu and Stewart 2001; Robertson, Eliashberg, and Rymon 1995), and introduce the dual concepts of market expansion and entry thresholds to develop new hypotheses about competitive response. In our terms, market expansion refers to an increase in the size of a market, and an entry threshold for any given firm refers to the minimum size of a potential market that would prompt the firm to introduce a new product into the market¹. To the best of our knowledge, no prior research has used these constructs to explain competitive response. We seek to build “home-grown” theory of the type that the editor has called for in a recent editorial (Rust 2006, pp. 1-2) to explore hitherto unexplored issues in competitive response.

Some of the hypotheses we develop contradict prior literature. Prior literature argues that competitors will be less likely to respond to the introduction of new products by larger versus smaller firms because of a fear of retaliatory behavior (Bowman and Gatignon 1995; Shankar 1999). However, in the context of radical product innovations, we argue that competitors are *more* likely to respond to larger versus smaller firms. Indeed we find that radical product introductions by large firms are almost twice as likely to provoke a reaction as those by small firms. Prior literature also argues that competitors will be less likely to respond to product introductions in smaller versus

¹ It is important to note two things here. First, we define entry thresholds at the firm level, unlike authors such as Bresnahan and Reiss (1991), who define entry thresholds at the market level. Second, by entry thresholds we do not imply entry by a firm into a *new* market – we are interested in the introduction of a new product into a market regardless of whether the firm already operates in that market (Chandy and Tellis 1998).

larger markets (Gruca, Kumar, and Sudharshan 1992; Gruca and Sudharshan 1995; Shankar 1999). In contrast, we argue that competitors will be *more* likely to respond to radical product innovations in smaller versus larger markets if the firm introducing the innovation is large. We find empirical support for this hypothesis also. In addition, we examine how response to radical product innovations is influenced by the market dependence of the introducing firm, a variable largely overlooked in prior research (see Montaguti, Kuester, and Robertson 2002). We argue that competitors will be more likely to respond to radical product innovations by firms that are more market dependent, i.e., firms that derive a larger part of their revenues from that particular market. We find that an increase of a standard deviation in the market dependence of the firm introducing the radical innovation makes competitor reaction almost 50% more likely.

From an empirical perspective, we address several method limitations that have been cited in previous research on competitive response. One such limitation has been small sample size, cited as a general limitation by Robinson (1988) and Kuester, Homburg, and Robertson. (1999). For example, Yip (1982) had 37 observations and Shankar (1999) had 23 new product entries and 59 response observations. A second limitation has been completeness of the data, i.e., measuring response for only a limited number of competitors (Robinson 1988; Shankar 1997). A third limitation has been the possibility of self report bias in questionnaire measures (Kuester, Homburg, and Robertson 1999; Robinson 1988). Here, by focusing on the pharmaceutical industry and using data from multiple sources, we seek to address each of these issues. The pharmaceutical industry has been popular in studies of innovation because it is a multi-billion dollar industry that is driven by innovation. Within this important industry, we are able to obtain objective measures of whether new products constitute radical product innovations (Sorescu, Chandy, and Prabhu 2003), as well as objective measures of which competitors responded and when they responded. We develop a

comprehensive database of innovation and response over a five year period, covering more than 50 radical product innovations and more than 700 observations of competitive response, the largest sample obtained to date for this type of research. Our database allows us to develop a richly specified empirical model that accounts for all variables relevant to the testing of our hypotheses, as well as other variables that have been suggested in prior research and variables that address unique features of our empirical context.

The focus of this paper is on competitive responses in the form of product introductions. While competitors can also respond through other elements of the marketing mix, we focus on product responses because prior research suggests that responses to competitive actions tend to be reciprocal, i.e., product responses for product actions, price responses for price actions, etc. (Axelrod 2002; Bowman and Gatignon 1995). Also, Kuester, Homburg, and Robertson (1999) argue that response is especially likely to be on the product dimension when it is prompted by the introduction of highly innovative products.

The balance of this paper is organized as follows. In the next section, we present a conceptual framework and develop our hypotheses. Following this, we describe our research methods, including variable operationalizations, data sources, and analysis procedures. We then present the results of the analysis. Finally, we conclude the paper by identifying possible limitations and discussing several implications for scholarship and practice.

CONCEPTUAL FRAMEWORK

In this paper, we focus on competitive response to radical product innovations: specifically, on the likelihood that competitors will respond to an innovation by introducing products of their own. A *radical product innovation* is a new product that uses significantly different technology and offers significantly greater customer benefits per dollar compared to existing products (Chandy and

Tellis 1998). Radical product innovations are in many ways the “home runs” of product innovation, and have the potential to be extremely lucrative. For example, in the pharmaceutical industry, Sorescu, Chandy, and Prabhu (2003) show that stock market returns to the introduction of radical product innovations can be in the billions of dollars. This said, the effects of radical product innovations are not uniformly positive or straightforward. Such innovations have the potential for three important effects as they relate to existing markets (e.g., Chandy and Tellis 1998; Chen and Miller 1994; Christensen 1997): a) *market expansion*, b) *cannibalization*, and c) *destabilization*.

From the perspective of the market as a whole, radical product innovations imply a high potential for *market expansion*. This is perhaps the most striking difference in outcomes between radical and incremental innovations (Montaguti, Kuester, and Robertson 2002; also see Mahajan, Sharma, and Buzzell 1993). In general, the impact of incremental innovations is to redistribute shares within an existing market. Radical product innovations, on the other hand, provide significantly greater benefits than were previously available, and thus may substantially increase the size of the market (Golder and Tellis 1997; Sorescu, Chandy, and Prabhu 2003). Consider these examples from the US pharmaceutical industry (Source: IMS National Sales Perspectives. All dollar values are inflation adjusted and listed in 1998 dollars).

- The size of the bowel syndrome category was \$377 million in 1999, the year in which GlaxoSmithKline introduced Lotronex. The size of this category became \$1.14 billion by 2003.
- The size of the sexual dysfunction category was \$587 million in 1998, the year in which Pfizer introduced Viagra. The size of the category became \$1.2 billion by 2003.
- The size of the arthritis category was \$1.15 billion in 1998, the year in which Merck introduced Celebrex. The size of the category became \$8.30 billion by 2003.

From the perspective of innovating firms, radical product innovations can result in substantial *cannibalization* of existing business (Chandy and Tellis 1998; Govindarajan and Kopalle 2004). One element of cannibalization is sales cannibalization, whereby innovations take away sales from the firm's existing products in the category. Another element is the cannibalization of specialized investments, whereby innovations reduce the value of investments that are tied to existing products (Nijssen, Hillebrand, and Vermeulen 2005). Innovating firms have to incorporate the potential for cannibalization in their decision-making leading up to the introduction of an innovation (Kerin, Harvey, and Rothe 1978).

From the perspective of incumbent competitors that already have products within the category of an innovation, radical product innovations imply a high potential for market *destabilization* (Schumpeter 1942). By redefining the product category's benefit space, a radical product innovation may not only seize business from existing competitors, but also reposition existing products relative to each other (van Heerde, Mela, and Manchanda 2004). For example, a product that previously held a distinctive performance position may collapse into a generic "old generation" position that places it close to products from which it was previously well differentiated, and may require a "new and improved" model to regain its previous position. The potential for destabilization makes competitive response much more likely for radical product innovations than for many other competitive actions (Chen and Miller 1994).

Given all of this, what factors will influence the likelihood of incumbents' response to a radical product innovation? Various factors might be argued on the basis of the general literature on competitive response (see Bowman and Gatignon 1995; Chen and Miller 1994; Kuester, Homburg, and Robertson 1999; Montaguti, Kuester, and Robertson 2002; Robertson, Eliashberg, and Ryman 1995; Robinson 1988). However, with specific respect to radical product innovations, our research

focuses on the potential for market expansion, and the role of entry thresholds in signaling the extent of market expansion expected. Whatever the other effects of a radical product innovation may be, we argue that competitors will be more likely to respond by introducing their own products when some aspect of the radical product innovation provides them with signals that it will increase the size of the market².

What factors will have these effects? Some of the most credible signals in this context relate to the nature of firms that introduce innovations (Prabhu and Stewart 2001). The very act of product introduction reveals information about the introducer's expectations about the potential of the market it is entering. The introducer reveals this information by virtue of a) who it is, and b) which market it enters. Incumbent competitors incorporate this information into their own decision calculus as they determine when, whether, and how to respond.

We argue that the likelihood of response is higher when potential respondents observe product introduction by firms that have higher entry thresholds (i.e., firms that would only introduce a product if the market has high potential). Moreover, the impact of this signal is highest when such firms introduce products in markets that were previously seen as having low potential.

What is the profile of a firm with high entry thresholds? While factors unique to each firm are likely to play a role, we argue that two factors systematically signal a firm's entry threshold: 1) the firm's size, and 2) its dependence on the market it is entering. Our focus on firm size and market dependence in the context of radical product innovation is consistent with the general literature on radical product innovation, which also highlights the importance of these two factors (see Chandy and Tellis 2000; Chandy, Prabhu, and Antia 2003).

² Note that we are not using the term "signal" in the sense of Spence (1974), where a sender uses signals strategically. In line with a substantial literature in marketing (e.g., Heil and Langvardt 1994; Heil and Robertson 1991; Robertson, Eliashberg, and Rymon 1995) and elsewhere (e.g., Porter 1980), we define a signal as an action by a firm "that conveys information about its intentions and abilities" (Prabhu and Stewart 2001, p. 63).

1. Firm size: Larger firms tend to have higher entry thresholds. This is in part because small markets do not meet the growth needs of large firms (Christensen 1997). As firms get larger, their reference points for what constitute attractive markets also get larger. The prospect of a \$10 million business might cause great excitement in a small firm, but would be met with a shrug in many large firms. As such, the introduction of a radical product innovation by a larger firm is more likely to convey an expectation of market expansion, especially if the current market is relatively small. When confronted with a large firm entering a small market, potential responders are likely to ascribe this otherwise atypical behavior to an expectation of market expansion: the large firm expects that the market will expand substantially as a result of the introduction of the radical product innovation.

2. Market dependence: A market dependent firm derives large parts of its revenue from that particular market. Firms that are highly dependent on a market also tend to have high entry thresholds. This is because by introducing a radical product innovation in the market, the firm is likely to cannibalize the sales of its existing products (Chandy and Tellis 1998). The radical product innovation therefore faces a higher burden of expectations in a market-dependent firm, relative to other firms (Kerin, Harvey, and Rothe 1978). Firms with higher levels of market dependence are most likely to introduce a radical product innovation if they expect enough market expansion to compensate for the cannibalization of existing products.

We next discuss our specific hypotheses.

HYPOTHESES

Effect of introducer size

The existing literature on competitive response to product introductions argues that incumbent competitors will be less likely to respond to the introduction of new products by larger versus smaller firms, due to the deterrent effect of larger resources (Bowman and Gatignon 1995;

Shankar 1999). For instance, Shankar (1999) notes that it may be unwise to respond to large scale entrants because of the fear of a war of attrition. Similarly, Bowman and Gatignon (1995) argue that competitors will be less likely to respond to a new product introduced by a strong firm with large resources because of fear of retaliation. However, in the context of radical product innovation, we argue the opposite. Since radical product innovations are inherently destabilizing (Schumpeter 1942), incumbent firms are much less likely to hold back in an effort to limit competition. Instead, a primary factor in response will be incumbents' assessments of the extent to which the innovation will be successful and the extent to which it will expand the market, as discussed above (also see Tellis and Golder 2001). Incumbents will surmise that a larger firm, given its high entry threshold, will only introduce an innovation if it expects the market potential for the innovation to be large. As such, we posit that competitive response to a radical product innovation will be *more* likely when the introducer is a large firm versus a small firm, because the entry of the former is more likely to signal expected market expansion. In sum, we hypothesize that:

H1: The greater the size of the firm introducing a radical product innovation, the higher the likelihood of competitive response.

Effect of introducer market dependence

We also argue that there will be a greater likelihood of response to radical product innovations introduced by firms with higher levels of market dependence. Market dependent firms introducing a radical product innovation have more to lose by disrupting the market (Heide and Weiss 1995; Montaguti, Kuester, and Robertson 2002). The very notion of 'more to lose' suggests that the entry threshold for such firms is high. For a market dependent firm to introduce a radical product innovation, the new product would have to promise returns that are large enough to compensate for the likely loss of sales and investments associated with existing products on which

the firm depends. The resulting implication of possible market expansion is likely to stimulate competitive response. Thus we hypothesize:

H2: The greater the market dependence of the firm introducing a radical product innovation, the higher the likelihood of competitive response.

Interaction effects of market size

The information on potential for market expansion that is conveyed by the size and market dependence of the introducing firm is likely to be especially valuable when the size of the market in which the radical product innovation is introduced is small. In such a case, the information inherent in the decision of a large or market dependent firm to enter the market takes on even greater significance. The reasoning would be that the large firm clearly sees significant potential in the market that has hitherto not been realized (Christensen 1997). This would motivate competitors to respond. An identical argument applies to the market dependence case (see Chandy and Tellis 1998). Thus we hypothesize:

H3a: The likelihood of competitive response is higher when a large firm introduces a radical product innovation in a small market, than when a large firm does so in a large market.

H3b: The likelihood of competitive response is higher when a market-dependent firm introduces a radical product innovation in a small market, than when a market-dependent firm does so in a large market.

Other variables of interest

Our hypotheses are focused on factors that signal the potential for market expansion, given the entry thresholds of firms that introduce radical product innovations. However, these are not the only variables that might influence competitive response. Other variables that speak to the attractiveness of the market, or the motivation or capabilities of incumbent competitors, may also have an influence. Most of these variables have already been covered in the literature on

competitive response. To avoid repetition, we do not state hypotheses for these variables, but include them as control variables in our analyses and note their likely effects.

Prior literature has considered the market growth rate as an indicator of market attractiveness and hence an antecedent of competitive response (Shankar 1999; Kuester, Homburg, and Robertson 1999; Bowman and Gatignon 1995). Empirical results for this variable have been mixed (Shankar 1999). One scenario is that competitive response will be stronger in growing markets because competitors view the market as highly attractive and will fight for it. Bowman and Gatignon (1995) and Kuester, Homburg, and Robertson (1999) support this view. An alternative is that competitive response will be weaker in growing markets, perhaps because market growth is already taxing the resources of competitors (Tellis and Golder 2001), or perhaps because competitors are already satisfied with their performance (Bowman and Gatignon 1995).

Another market-related factor that has been studied in the literature is market concentration. Here, it could be argued that competitive response is more likely in concentrated markets, partly because competitors can monitor their rivals more carefully (Blundell, Griffith, and Van Reenen 1999; Montaguti, Kuester, and Robertson 2002; Nickell 1996). On the other hand, some research suggests that competitive response may be less likely in concentrated markets, perhaps because of mutual forbearance (see Bernheim and Whinston 1998; Chen and MacMillan 1992). Concentration may also relate to market attractiveness, in that high concentration could indicate that the industry has found only a few solutions to a customer problem, each of which may have limitations, leaving higher upside for new solutions. To the extent that higher concentration indicates higher upside in the market, there should be a higher likelihood of competitive response.

With respect to market attractiveness, another relevant variable is current market size. Apart from the interaction effects that we have hypothesized, it could be argued that larger markets will

motivate stronger competitive response to radical product innovations because competitors are more willing to fight for the market. Alternatively, there could be a lower likelihood of competitive response in larger markets, perhaps because competitors are more likely to be inertia-prone in markets where sales are plenty (see Chandy, Prabhu, and Antia 2003).

A competitor-related variable that is relevant to competitive response is the size of the competitor firm. Prior research has argued that larger competitors are less likely to respond to marketing actions because of bureaucratic inflexibility or inertia (Tornatzky and Fleischer 1990). However, on the other hand, one can argue that larger firms have greater resources and hence greater capabilities for response. In the context of radical product innovations, where the destabilizing potential of the innovation may provide an inherent motivation to respond, these capabilities may result in larger firms being *more* likely to respond.

Another competitor-related variable that is relevant to competitive response is the market dependence of the competitor firm. As with the introducing firm, a competitor's market dependence indicates the importance of the market to that firm. Market dependent competitors have a greater stake in the market, which may motivate a stronger defensive posture and a greater likelihood of response (see Chen and MacMillan 1992).

Finally, it is appropriate to mention two other factors that might potentially affect competitive response. First, competitors might be less likely to respond if they have recently introduced a new product in the same category, either because of commitment to that product or depletion of product development resources. Second, there may be order of response effects, i.e., later firms may be less likely to respond because earlier competitors have claimed pre-emptive market positions, or alternatively, later firms may be more likely to respond because of a bandwagon effect.

The following section discusses how we test each of our arguments. Specifically, it provides details regarding: (a) our considerations in choosing an empirical context, (b) operationalizations and data sources for radical product innovation and competitive response, (c) operationalizations and data sources for other variables, and (d) our model specifications. Figure 1 summarizes the conceptual framework.

METHOD

We test our hypotheses in the context of the pharmaceutical industry. The general method is as follows. We identify all radical product innovations in the pharmaceutical industry over a five year period, from 1997 through 2001; there are 52 such innovations. In the three years following each innovation, we track whether each competitor in the product category responded by introducing its own new product, and if so, when. In total, this gives us 714 observations of whether (and when) competitors responded to radical product innovations. We analyze competitive response with a hazard model formulation that models the likelihood of any given competitor responding in any given time period as a function of various independent variables: those for which we state hypotheses as well as various controls. The goal of a hazard model is to examine longitudinal and cross-sectional effects in duration times and to give probabilistic or expectation-based predictions (DuWors and Haines 1990; Grimshaw et al. 2005).

Empirical context

The model presented in this study describes the likelihood of competitive response to radical product innovations as a function of introducer firm size, introducer market dependence, the interaction of these two variables with market size, and various control variables. In order to test our arguments, we desire an empirical context that has many product categories as well as considerable variety in firm size and market size. It also should be a context in which there are numerous

introductions of radical product innovations that can be objectively identified. The pharmaceutical industry fits all of our requirements.

First, the pharmaceutical industry is a huge industry covering a large number of therapeutic categories with substantial variation in our variables of interest. Second, the pharmaceutical industry offers a substantial number of radical product innovations, which are a driving force behind the growth of the industry (Scherer 2000). Third, the pharmaceutical industry provides an objective, unbiased measure of radical product innovation, as we discuss below.

Operationalizations and data sources for radical product innovation and competitive response

The U.S. Food and Drug Administration (FDA) classifies new drugs on two dimensions: chemical composition and therapeutic potential (see Sorescu, Chandy, and Prabhu 2003 for details). Regarding chemical composition, a drug is classified by the FDA as a *new molecular entity* versus a composition that is a new formulation, new combination or new usage of existing chemistry. New molecular entities (NMEs) represent the most technologically advanced products, with an active ingredient that has never been in the market before. Regarding therapeutic potential, a new drug that represents significant therapeutic benefits in comparison to all existing drugs is given *priority review* by the FDA, while a new drug that has healing features similar to drugs already in the market is given a standard review. These FDA classification dimensions – chemical composition and therapeutic potential – correspond exactly to the technology and benefit dimensions used by Chandy and Tellis (1998) and Sorescu, Chandy, and Prabhu (2003) to define radical product innovations. Thus, a new product introduction is classified as a radical product innovation if it meets the criteria of being a new molecular entity (a distinct advance in technology) and receiving priority review (a distinct advance in customer benefits). This operationalization of radical product

innovation is identical to that used in previous papers on this topic in marketing (Sorescu, Chandy, and Prabhu 2003; Wuyts, Stremersch, and Dutta 2004) and elsewhere (Yeoh and Roth 1999).

Our data contain 52 radical product innovations introduced by 32 different companies in 27 therapeutic categories over a five year period, from 1997 through 2001. On average, each innovation faced 14 incumbent products within its category (high=47; low=2), giving a total of 714 observations for potential response by incumbents. Figure 2 shows the number of radical product innovations introduced by each company and Figure 3 shows the number of radical product innovations per therapeutic category. This information was acquired from the NDA Pipeline. The NDA Pipeline is a comprehensive database that tracks the FDA approval process for new drugs, through all phases of development until product introduction.

Response was measured over the three years following the introduction of a radical product innovation. For example, if a radical product innovation was introduced in March 2001, we measured response through March 2004. Previous research has measured response over windows ranging from six months to two years (Bowman and Gatignon 1995; Kuester, Homburg, and Robertson 1999; Robinson 1988; Shankar 1999). We used three years because it is twice the average period of 1.5 years that competitors took to respond to breakthrough pharmaceutical products in the 1990s (Pharmaceutical Research and Manufacturers of America 2003). A three-year time period allows us to examine responses without causing substantial censoring in the data.

Within the three year observation window, response by each competitor was measured as the number of days after the introduction of the innovation before the competitor introduced a product of its own. Competitors that did not respond by the last date in the window were treated as censored observations in the hazard model. Overall, about half the competitors introduced products

within the three year window. Data on competitive product introductions were also obtained through the NDA Pipeline.

Certain points might be noted about the process of innovation and response in this industry. First, as in most industries, competitors have some awareness of an innovation before it is actually introduced to the market. In most industries, this type of information is available through sources such as industry gossip, personnel movement, trade publications, and company announcements. In pharmaceuticals, this type of information is available through the regulatory process. New drugs in the U.S. go through a multi-stage FDA approval process (Figure 4; FDA 1999). First, the drug sponsor applies for an investigational new drug application (IND) based on pre-clinical animal tests. If approved, the drug proceeds to three phases of clinical trials with humans. If the drug is approved through all three phases of clinical trials, the drug sponsor files a New Drug Application, and if this is approved, the sponsor can introduce the drug. Records of approvals at each stage are public information, so competitors know that a new drug may be coming before it is introduced.

Second, as in most industries, the fact that a company is working on an innovation does not necessarily mean that a successful product will result. This may be particularly true in the pharmaceutical industry. Only 1 in 1,000 new drug compounds makes it as far as the clinical studies phase (www.fda.gov), and according to the Tufts Center for the Study of Drug Development, only 1 in 5 drugs that make it to clinical testing are ultimately approved for introduction (www.fda.gov). Therefore, the various stages of pre-introductory product development have uncertain implications, and competitors who respond to products in the early stages would often be chasing ghosts.

Third, radical product innovations in the pharmaceutical industry are typically protected by patents. This means that competitors cannot easily respond by duplicating the innovation; rather, they must respond from their independent capacities for product development. Some competitors

will have ongoing development programs that provide them with product options to respond to the radical product innovation, and others may initiate such programs, but most commonly, competitors respond with variations or reformulations of their existing products (in our data, only 9.5% of all responding products contain new chemistry and merit priority review).

All of this has implications for the timing of competitive response in the pharmaceutical industry (see Mathieu 2002 for a review). Competitors receive information about radical product innovations before those products are introduced, but the information is not reliable until the later stages of product development. When the information becomes reliable, competitors begin to respond, most commonly with reformulations of existing products. Reformulations have shorter development times than completely new products, but even so, there is some delay (see Mathieu 2002; Keyhani, Diener-West, and Powe 2006; FDA 2005). Overall, some competitive products may appear within months of the introduction of a radical product innovation, but as indicated above, the average response period is about 1.5 years (Pharmaceutical Research and Manufacturers of America 2003), and some responses may even happen after the three-year observation window we use to measure response (see DiMasi and Paquette 2004). In the latter case, the observations are right-censored³, and we account for this in our empirical model.

Operationalizations and data sources for hypothesized variables

Introducer firm size: Sales, assets, and number of employees have all been used as proxies for firm size in prior strategy research, and these variables all tend to be highly correlated with each other (Agarwal 1979). We follow recent research in marketing strategy (Chandy and Tellis 1998) and use a firm's total sales in the year of product introduction to measure firm size.

³ Right censoring refers to a situation where the firm might still be at risk of hazard (in this case, competitive response) at the conclusion of the observation period. It is clearly incorrect to assume that such a firm will never respond, simply because it hasn't responded over the observation period.

One might argue that the effects of introducer's firm size will be relative rather than absolute, i.e., the likelihood of competitive response will depend not so much on the absolute size of the introducing firm as on the relative sizes of introducer and competitors. The use of a relative measure would be consistent with the effects of introducer firm size as discussed in prior literature, where the presumed mechanism for the effect is the competitor's fear of retaliation (Robinson 1988; Shankar 1999). However, it is not consistent with our research, because our signaling arguments depend on the absolute (not relative) size of the introducing firm. Even so, the point is made moot by including competitor firm size in the analysis to capture any effects of the competitor's relative size.

Firm size data are obtained from four sources: (1) Standard & Poor's Compustat database which includes financial information for companies that are publicly traded in the United States, (2) Thomson Datastream, which includes financial data for both U.S. and international companies, (3) Hoovers Online, which also covers some smaller and private companies, and (4) company websites.

Introducer market dependence: Market dependence is used to signify the importance of a particular market to a firm. For the purpose of this study, market dependence is operationalized as the ratio of a firm's sales in a therapeutic product category to the firm's total sales, in the year of introduction (see Chen and Miller 1994 for a similar measure in the airline industry). Virtually all the introducers derived at least some of their sales from the therapeutic categories in which they introduced the innovations; only 3 out of the 52 radical product innovations were introduced by firms that previously derived no sales from the category in question. Data on category sales for each firm are obtained from IMS Health Global Services, which is a source of detailed market research data about the pharmaceutical industry.

Market size: Market size, which is hypothesized to interact with introducer firm size and

introducer market dependence, is operationalized as the total sales for the therapeutic category in which the radical product innovation was introduced, in the year of introduction (Reiffen and Ward 2005). Market size data are obtained from IMS Health Global Services.

Operalizations and data sources for control variables

Control variables used in the analysis included competitor firm size, competitor market dependence, market growth, market size, market concentration, prior product introductions by the competitor, and order of response. These variables are used as controls because they might relate to competitive response for reasons discussed earlier. We also use a control variable for whether or not the product is in the HIV therapeutic category. This variable is used because the FDA provided an automatic expedited review for HIV drugs during the measurement period, which may have affected the dynamics of innovation and response in this category. The operationalization of market size has already been described, and the other control variables are operationalized as follows.

Competitor firm size: Firm size for each competitor is measured in the same fashion and from the same data sources as introducer firm size.

Competitor market dependence: Competitor market dependence is measured in the same fashion and from the same data sources as introducer market dependence.

Market growth: Market growth is operationalized as the rate of change in market size in the year prior to introduction of the radical product innovation (relative to the previous year). Growth rates are calculated from market size data obtained from IMS Health Global Services.

Market concentration: Market concentration is measured using the Herfindahl index, defined as the sum of squared market shares for the largest four competitors in a therapeutic category in the year the radical product innovation was introduced (Sorescu, Chandy, and Prabhu 2003). An alternate measure of market concentration – the sum of market shares of the top four

firms in the market – provides similar results to those reported in this paper. Market concentration data are obtained from IMS Health Global Services.

HIV category: We include a dichotomous dummy variable representing whether or not the radical product introduction belonged to the HIV category. Relevant data are obtained from the NDA Pipeline.

Prior product introductions by the competitor: This variable is operationalized as a dichotomous variable representing whether or not a given competitor introduced a new product in the relevant product category during the three years before the introduction of a radical product innovation. Data are obtained from the NDA Pipeline.

Order of response: Order of response is measured as the number of firms that had already responded to the radical product innovation, prior to response by a particular competitor. Data are obtained from the NDA Pipeline.

Table 1 summarizes the descriptions of variables used in this study, along with the data source for each variable, while Table 2 gives descriptive statistics for the variables. Note that the variables are standardized prior to estimation.

Model specification

We now turn to specification of the model used in our analysis. Our hypotheses deal with competitive response to radical product innovations: specifically, we focus on product introductions made by competitors in the three years following the introduction of a radical product innovation. This suggests three features that any model specification has to account for. First, the response is discrete – a competitor either introduces a product in response or does not. Second, the response follows a temporal sequence – within our sample period, a firm could introduce at any time. Third, the data are right censored – a firm that has not introduced by the end of our sample period could

still do so afterward. All these features suggest the appropriateness of using a hazard model specification to model our phenomenon of interest. Briefly, a hazard specification models the impact of a set of covariates on the probability of a discrete event (such as a product introduction) occurring⁴. Such models account for right censoring and the temporal nature of the data naturally, and have been widely used in marketing (e.g., Jain and Vilcassim 1991; Helsen and Schmittlein 1993; see Li 1995 for an introductory primer).

Having decided on a hazard specification, a number of issues need to be addressed at the outset. Thus, consider a popular basic specification, the proportional hazard model (Greene 2003; Seetharaman and Chintagunta 2003). The hazard function for a firm i can be written as:

$$h(t | x_i) = h_0(t) \exp(\beta_0 + x_i \beta) \quad (1)$$

where $h(t|x_i)$ refers to the instantaneous hazard at time t , given a vector of covariates x , $h_0(t)$ refers to the baseline hazard rate, and β is a vector of unknown regression parameters. The hazard function “simply expresses the instantaneous probability of an event” (DuWors and Haines 1990, p. 487), or the “likelihood that an event that lasted until t will end in the next instance” (Grimshaw et al. 2005, p. 452). The choice of baseline hazard is crucial. One could use a parametric specification and either assume a specific distribution (e.g., exponential, Erlang 2), or choose a flexible specification such as the quadratic Box-Cox (Jain and Vilcassim 1991). Unfortunately, misspecified parametric specifications can lead to inconsistent estimates (Meyer 1995). The alternative, which we adopt, is to use a non-parametric specification (Cox 1972) and make no assumptions about the possible shape of the baseline hazard (if the shape of the baseline hazard is of particular interest, one can compare parametric to non-parametric specifications of the baseline hazard to see which fits the data better,

⁴ Our interest in this paper is on a single outcome – whether or not firms respond with a product introduction. If there are multiple outcomes of interest, one would use a competing risks modeling framework (Lunn and McNeil 1995).

see e.g., Seetharaman and Chintagunta 2003). Since the intercept in the model in Equation 1 above is unidentified from the baseline hazard in the Cox proportional hazard specification, we can rewrite the model as:

$$h(t | x_i) = h_0(t) \exp(x_i \beta) \quad (2)$$

While widely used and quite powerful, the specification above does not account for unobserved heterogeneity (Jain and Vilcassim 1991; Gonul and Srinivasan 1993). It might well be that firms differ in ways that our covariates do not capture; for example, managerial ability is a variable that we do not include, but one could argue that it might influence a firm's competitive response. It is well-known that the exclusion of such factors could lead to a bias towards negative duration dependence (Heckman and Singer 1984). To account for this, we use a random-effects specification, by introducing a new parameter, u , that varies across firms. In the hazard model literature (particularly in the biostatistics field; see, for example, Vaupel, Manton, and Stallard 1979 and more generally Hougaard 2000), this is often referred to as a 'frailty' model, with u being the frailty term. Formally, the specification now is:

$$h(t | x_i) = u_i h_0(t) \exp(x_i \beta) \quad (3)$$

Now, it is important to note that any firm in our data could have multiple incidences of product introductions (the data are thus an unbalanced panel). Suppose each firm i has J_i observations. With some abuse of notation⁵, we can write the hazard rate for the j^{th} observation of the i^{th} firm as (Fan and Li 2002):

$$h_{ij}(t | \mathbf{x}_{ij}, u_i) = h_0(t) u_i \exp(\mathbf{x}_{ij}' \beta), \quad i = 1, \dots, n; \quad j = 1, \dots, J_i$$

⁵ In general, one would use the notation in the case where one had j individuals as part of a group i , sharing a common frailty u_i . In that case, the frailty would be a random term multiplicatively affecting the hazard rate of all members of the group.

where each firm i can be thought to constitute a ‘group’ with j ‘members’. The vector \mathbf{x} contains all the independent variables discussed above, i.e., introducer firm size, introducer market dependence, market size, and other control variables.

It remains to specify the distribution of u . Following common practice in the literature (Clayton 1978; Vaupel, Manton, and Stallard 1979; Hougaard 2000), we specify a Gamma distribution⁶ for this random variable, with mean 1 and variance $1/\theta$, i.e.,

$$g(u) = \frac{u^{\theta-1} \theta^\theta \exp(-u\theta)}{\Gamma(\theta)} \quad (4)$$

The next step is to obtain the likelihood function to be maximized. It is a standard result that the likelihood function is the product of the density function for uncensored observations and the survivor function for censored observations. Applied here this gives us:

$$\prod_{i=1}^n \prod_{j=1}^{J_i} \left[\{h(z_{ij} | \mathbf{x}_{ij}, u_i)\}^{\delta_{ij}} S(z_{ij} | \mathbf{x}_{ij}, u_i) \right] \prod_{i=1}^n g(u_i) \quad (5)$$

where $S(\cdot)$ represents the conditional survivor function, δ is a censoring indicator (i.e., 1 if censored), and z is the observed time (more precisely $z = \min\{t, c\}$, where t and c are the survival and censoring times respectively). Integrating the heterogeneity u out of the above expression gives us the likelihood of the observed data, which is maximized to obtain the parameters θ (capturing frailty) and the vector β .

$$L(\beta, \theta, H) = \exp \left\{ \beta' \left(\sum_{i=1}^n \sum_{j=1}^{J_i} \delta_{ij} \mathbf{x}_{ij} \right) \right\} \times \prod_{i=1}^n \frac{\theta^\theta \prod_{j=1}^{J_i} \{h_0(z_{ij})\}^{\delta_{ij}}}{\Gamma(\theta) \left\{ \sum_{j=1}^{J_i} H_0(z_{ij}) \exp(\mathbf{x}_{ij}' \beta) + \theta \right\}^{(A_i + \theta)}}$$

where $A_i = \sum_{j=1}^{J_i} \delta_{ij}$.

⁶ Use of an Inverse Gaussian distribution for the frailty term (Hougaard 2000) yields similar results in our empirical context.

RESULTS

A Wald test for the overall fit of the model yields a χ^2 value of 363.13, which is significant at the $p < 0.01$ level. Table 3 reports the estimated coefficients. A comparison of the full model (with main effects and interactions) with a model with main effects only indicates that it is appropriate to include the interaction effects in the model. Coefficients for almost all predictor variables are significantly different from zero. Specific results are as follows.

Results of hypothesis tests

H1 suggested that the larger the firm introducing a radical product innovation, the greater the likelihood of competitive response. H1 is supported, with the effect significant and in the expected direction ($\beta = 0.64$; $p < 0.01$). While the magnitude of the coefficient is not immediately interpretable, we can convert it to a hazard ratio, which is the exponential of the coefficient. A hazard ratio of 1 suggests that the variable has no impact on the probability of responding; a ratio greater than 1 suggests it positively influences the probability of response, while a ratio less than 1 suggests a negative influence. The more the ratio departs from 1, the stronger the effect. The hazard ratio for firm size is 1.91, which implies that at any given point of time, a one standard deviation increase in size almost doubles the chance that the firm will respond if it hasn't responded already. In other words, consider firms A and B, with A being exactly one standard deviation bigger than B. Also, suppose neither A nor B have responded to a product introduction by time t . The result above suggests that A is roughly twice as likely as B to respond by period $t+1$.

This finding reverses prior results obtained in the context of incremental innovations, where introducer size has been found to be negatively related to competitive response (Bowman and Gatignon 1995; Shankar 1999). This reversal of effects lends credibility to the idea that competitive

dynamics for radical product innovations may qualitatively differ from those for incremental innovations.

H2 argued that the more market dependent the firm introducing a radical product innovation, the greater the likelihood of competitive response. H2 is supported, with the effect significant and in the hypothesized direction ($\beta=0.52$; $p<0.01$). The hazard ratio is 1.69, which suggests that increasing market dependence by one standard deviation increases the probability of responding 1.69 times.

H3a stated that market size would negatively moderate the influence of introducer size on likelihood of competitive response, such that as the market gets larger, the effect of introducer size gets smaller (and as the market gets smaller, the effect of introducer size gets larger). The hypothesis is supported ($\beta= -0.55$; $p<0.01$). The hazard ratio is 0.57, which suggests that an increase in market size by one standard deviation cuts the effect of introducer size almost by half.

H3b argued that market size would negatively moderate the influence of introducer market dependence on likelihood of competitive response, such that as the market gets smaller, the effect of introducer market dependence gets larger. The observed effect is not significant ($\beta= 0.03$; $p>0.1$), with a hazard ratio of 1.03.

Overall, three of the four hypotheses are confirmed. The results are generally consistent with our argument that competitive response to radical product innovations will be higher when some aspect of the product introduction, such as the introducer firm size, introducer market dependence, and the interaction of market size and introducer firm size provide competitors with signals that the innovation is likely to increase the size of the market.

Other results

Most of the control variables are significant, with interesting and generally intuitive effects.

Competitor firm size: Competitor firm size has a significant positive impact on the likelihood of response ($\beta= 1.15$; $p<0.01$). This is a strong effect – the hazard ratio of 3.17 suggests that a one standard deviation increase in the competitor’s size produces an almost three-fold increase in the probability of reacting, at any given time. This result contradicts prior findings in the context of incremental innovations that either found a negative impact (Kuester, Homburg, and Robertson 1999; Shankar 1999) or no impact (Robinson 1988) of competitor firm size on response. The general explanation for prior findings has been that larger competitors are less likely to respond because of bureaucratic inflexibility or inertia (Tornatzky and Fleischer 1990). However, one also can argue that larger firms have greater resources and hence greater capabilities for response (Sorescu, Chandy, and Prabhu 2003; Chandy and Tellis 1998; Chandy, Prabhu, and Antia 2003), and in the context of radical product innovations, where the destabilizing potential of the innovation may provide an inherent motivation to respond, these capabilities may result in larger firms being more likely to respond. Our findings are consistent with this latter argument, which again suggests that there may be qualitative differences in competitive dynamics for radical and incremental innovations.

Competitor market dependence: Competitor market dependence is also found to have a significant positive impact on response ($\beta= 0.44$; $p<0.01$). The hazard ratio is 1.55. This finding is what one would expect: market dependent competitors have a greater stake in the market, which motivates a stronger defensive posture and a greater likelihood of response.

Market size: A larger category is found to elicit a higher likelihood of response ($\beta= 0.24$; $p<0.01$). The hazard ratio is 1.27. This finding supports the idea that competitors will respond more aggressively in larger markets.

Market growth rate: A faster growing category is found to elicit a higher likelihood of response ($\beta= 0.01$; $p<0.01$). The effect is weak, as is shown by a hazard ratio of 1.01. Prior empirical results for this variable have been mixed (Shankar 1999). This result, combined with the positive result for market size, supports prior studies that suggest that competitive response will be stronger in growing markets because competitors view the market as more attractive and are willing to fight for it (Bowman and Gatignon 1995; Kuester, Homburg, and Robertson 1999).

Market concentration: Market concentration is found to have no significant impact on the likelihood of response ($\beta= 0.08$; $p>0.1$); the hazard ratio is 1.08.

HIV Category: The fact that a product introduction is in the HIV category has no significant impact on the likelihood of response ($\beta= 0.06$; $p>0.1$); the hazard ratio is 1.06.

Prior Product Introductions: Competitors who introduced a new product in the same product category within the previous three years are significantly less likely to respond to a radical product introduction ($\beta= -0.18$; $p<0.01$); the hazard ratio is 0.32.

Order of Response: The greater the number of competitors who have already responded to a radical product introduction, the less likely is it that a given firm will respond with a product introduction ($\beta= -1.13$; $p<0.01$); the hazard ratio is 0.83.

Robustness checks

We conduct a number of robustness checks. First, we examine if our results are sensitive to the cut-off date in our sample, i.e., if changing the extent of right censoring affects the results. To do this, we estimated a Cox hazard model with the cut-off date in our sample changed from 3 years to 2 years. Table 4a reports the results of this change in the degree of right censoring. The results are qualitatively unchanged. In the same vein, we estimate a discrete choice probit model that does not account for right censoring at all (and treats the dependent variable purely as occurrence of response

without regard to time). Table 4b reports the results of this analysis; the results are qualitatively unchanged.

Second, we check the robustness of our specification by trying alternative parametric specifications of the hazard - specifically, a Weibull hazard with Gamma frailty and a log-logistic model with Gamma frailty. The results are very similar in both cases, and are similar to the Cox proportional hazard model reported in the paper.

Third, we examine robustness to the particular sample used, by conducting a bootstrapping analysis with 50 repetitions (Table 5). Again, the results are largely unchanged.

Fourth, we check the predictive validity of our specification (Srinivasan, Lilien, and Rangaswamy 2006). To do this, we randomly pick 2/3 of our sample as the estimation sample and the remaining 1/3 as the holdout sample. Using estimates from the estimation sample, we calculate the hazard ratio for each observation in the holdout sample. If the hazard ratio exceeds the baseline rate, we count that observation as having experienced the hazard (i.e., responded to the product introduction). We then compare this to the actual response to see if the model predicted correctly, and compute the 'hit rate' over all observations. The hit rate on the hold-out sample is 83.35%; this high figure provides reassurance regarding the predictive validity of our model. Delving further, we find that of a total holdout sample of 245, the model predicts a response in 149 cases, 113 of which indeed responded, and no response in 96 cases, 94 of which indeed did not respond. This implies a false positive rate of 0.22 and a false negative rate of 0.02. Using the approach suggested by Morrison (1969) for evaluating the predictive validity of a discriminant classifying function, we find that our 0.83 hit rate compares favorably to 0.49, the hit rate one would have obtained by chance (which is given as: $c_{pro} = \alpha p + (1-\alpha)(1-p)$, where p = true proportion of responders, and α = proportion of responders predicted by model).

DISCUSSION

In this paper, we seek to build a middle-range theory (Bourgeois 1979) of competitive responses to radical product innovation. We introduce the concepts of market expansion and entry thresholds to develop and test new hypotheses about competitive response to radical product innovation. Our analyses reveal some novel findings. Innovations introduced by large firms and by market dependent firms are especially likely to witness a greater likelihood of competitive response. The likelihood of competitive response is highest when large firms enter small markets. The paragraphs below discuss the implications of this research for research and practice.

Know thyself to predict thy opponent. Modern marketing science provides managers with sophisticated techniques to predict the likely outcomes of product introduction. The richness of the consumer response models used in these projections contrasts sharply with the sketchiness of the competitor response models used in them. While consumer response models are often calibrated via detailed empirical analyses of responses from current and future customers, competitor response models are often ad-hoc and based on subjective judgments (see Hauser, Tellis, and Griffin 2006).

The results from this research suggest a need for greater care and more careful anticipation when calibrating the likelihood of competitor response. For firms introducing radical product innovations, these results highlight the usefulness of looking in the mirror for clues regarding the likely responses of their competitors. By examining the signals that they send about their entry thresholds, firms can assess the likelihood and speed of competitive response to their radical product innovations. Large size and market dependence tend to signal high entry thresholds; as such, large and market dependent firms should anticipate and account for greater competitive response to their radical product innovations.

Watch for trickles that can turn into gushers. Most analyses of the likelihood of competitive response to a particular market take the size of the market as a given. Naturally, therefore, many current analyses imply that competitive response is likely to be limited when the market being entered is small (see Montaguti, Kuester, and Robertson 2002). The results from this paper suggest a need to rethink this conclusion.

Our results emphasize the need to examine markets dynamically – not just by looking at them as they are today, but as they could be tomorrow. Radical product innovations can cause hitherto small markets to explode in size. Visions of explosive growth inevitably attract competitive response, even before such growth has actually taken place. Our results indicate that competitors use the entry threshold of the firm that introduces the radical product innovation in a market as signals of the eventual size of the market.

Do not assume that entry by giants will dissuade others from entering. Conventional wisdom suggests that entry into a market by large firms will lead to lower entry by competitors, due to fears of retaliation (Robinson 1988; Shankar 1999). This logic would lead one to conclude that large firms can be sanguine about competition in such cases.

Our results suggest that in the context of radical product innovation, this conclusion should be turned on its head. Indeed, our results suggest that the introduction of a radical product innovation by a large firm is likely to lead to a surge – not a reduction - in competitive response. Visions of market growth that are triggered by the introduction of a radical product innovation by a large firm may swamp any threats of retaliatory behavior. The surge in competitive response is especially prominent in cases where the large firm enters a small market, since the signal regarding market growth is especially powerful in such cases. Our results caution managers of large and

market dependent firms against being overly optimistic about sustaining monopoly profits from radical product innovation.

Limitations and future research

This research has a number of limitations, and some of these can provide avenues for further research. Even though testing our model within the context of a single industry and using the U.S. pharmaceutical industry in particular has advantages, we acknowledge the specific characteristics of this industry, including heavy regulation, pre-announcement of innovation research, the particular speed of innovation cycles, and a mix of firm sizes ranging from extremely large multinationals down to small companies. We believe that one can place confidence in the direction of effects observed in this research, because most of the effects are predicted by our hypotheses or replicate prior research (see Blair and Zinkhan 2006 regarding the role of theory and replication in research generalization). However, industry specific effects might limit the generalizability of effect sizes, so it would be useful to extend this line of research to include other industries that vary in regulatory processes (e.g., international pharmaceutical markets, non-prescription drug markets, or various unregulated markets), innovation cycles (e.g., semiconductors, electronics, paint), or concentration (e.g., aircraft manufacture).

Also, we have only looked at one dimension of response, which is product response. Response can also occur on other dimensions of the marketing mix variables. For example, firms can respond with advertising increases or price cuts. Although existing research (e.g., Kuester, Homburg, and Robertson 1999) suggests that responses to actions on the product dimension are highly likely to also be on the product dimension (and especially so for radical product innovations), it would nevertheless be interesting to see, for example, how large versus small firms

behave on other marketing mix dimensions when reacting to the introduction of a radical product innovation.

It also would be an interesting extension to examine how well products introduced as responses to radical innovations fare in the market – are they more or less likely to succeed than other product introductions? Finally, in common with most studies using secondary data, we have inferred firm decision making from observed outcomes. It would be very useful to supplement our study with primary data obtained from managers, to see how decision-making is influenced by the variables we have suggested, and to examine if there are any important variables our study has omitted.

Table 1: Variables, Measures, and Sources

Variable	Operationalization	Source
Competitive response	Number of days till a focal competitor introduces a new product, starting from the day the radical innovation was introduced.	NDA Pipeline
Introducer size _{<i>t</i>}	Total dollar sales of the firm introducing the radical product innovation, in year <i>t</i> .	Standard & Poor's Compustat Thomson Datastream Hoovers Online Company websites
Introducer market dependence _{<i>t</i>}	Ratio of sales in a therapeutic category divided by the total sales for the introducing firm, in year <i>t</i> .	IMS Health Global Services
Market size _{<i>t</i>}	Total dollar sales of the therapeutic category in which the radical product innovation was introduced, in year <i>t</i> .	IMS Health Global Services
Competitor firm size _{<i>t</i>}	Total dollar sales of focal competitor, in year <i>t</i> .	Standard & Poor's Compustat Thomson Datastream Hoovers Online Company websites
Competitor market dependence _{<i>t</i>}	Ratio of focal competitor's sales in a therapeutic category to the firm's total sales, in year <i>t</i> .	IMS Health Global Services
Market growth _{<i>t</i>}	Percentage change in the size of the market, in year <i>t</i> -1, relative to sales in year <i>t</i> -2.	IMS Health Global Services
Market concentration _{<i>t</i>}	Sum of squared market shares for the largest four competitors in a therapeutic category in the year the radical product innovation was introduced	IMS Health Global Services
HIV category	A dichotomous variable representing whether or not the radical product innovation was introduced in the HIV therapeutic category.	NDA Pipeline
Prior product introductions	A dichotomous variable representing whether or not a focal competitor introduced a new product in the three years preceding the introduction of a radical product innovation.	NDA Pipeline
Order of response	Number of firms that responded to the radical product innovation prior to response by focal firm.	NDA Pipeline

Table 2: Descriptive Statistics

Variable	Mean	Minimum	Maximum
Competitive response (days)	790.68	0.00	1096.00
Introducer size (million \$)	1949.85	<0.01	43651.58
Introducer market dependence (%)	0.20	<0.01	1.00
Market size (million \$)	4989.07	28.89	16000.00
Competitor firm size (million \$)	2041.74	<0.01	43651.58
Competitor market dependence (%)	0.16	<0.01	1.00
Market growth (%)	28.57	3.34	86.13
Market concentration (%)	0.61	0.30	1.00
Order of response (count)	4.38	0.00	22.00

TABLE 3:				
HAZARD MODEL RESULTS				
	<i>Main Effects Only Model</i>		<i>Main + Interaction Effects Model</i>	
<i>Hypothesized Variables</i>	Coeff.	Std. Error	Coeff.	Std. Error
Introducer firm size	0.55**	0.08	0.64**	0.11
Introducer market dependence	0.34**	0.05	0.52**	0.07
Introducer firm size* Market size	-	-	-0.55**	0.16
Introducer market dependence* Market size	-	-	0.03	0.09
<i>Control Variables</i>				
Competitor firm size	1.18**	0.14	1.15**	0.14
Competitor market dependence	0.43**	0.05	0.44**	0.05
Market size	0.09	0.06	0.24**	0.06
Market growth	0.01**	2.69 x 10 ⁻³	0.01**	2.69 x 10 ⁻³
Market concentration	0.10	0.06	0.70	0.49
HIV category	0.08	0.16	0.06	0.16
Prior product introductions	-0.19**	0.06	-0.18**	0.06
Order of response	-1.04**	0.10	-1.13**	0.10
Frailty Parameter	0.23**	0.08	0.19**	0.073
Log Likelihood Value	-1908.58		-1896.49	
Wald χ^2 statistic	340.11**		348.91**	
AIC	3839.16		3818.98	
BIC	-1924.28		-1915.04	
** : p<0.01				

Note: The Akaike Information Criterion (AIC) is given as $-2L + 2k$, where L is the log-likelihood function, and k is the number of parameters. Models with lower values of AIC are preferred. The Bayesian Information Criterion (BIC) is given as $L - 0.5*k*\ln(n)$ where n is the number of observations. Models with lower values of BIC are preferred.

TABLE 4a: Robustness to Degree of Right Censoring

<i>Hypothesized Variables</i>	Estimate	Std. Error
Introducer firm size	0.18**	0.05
Introducer market dependence	0.26**	0.05
Introducer firm size* Market size	-0.21*	0.09
Introducer market dependence* Market size	0.03	0.06
<i>Control Variables</i>		
Competitor firm size	0.26**	0.05
Competitor market dependence	0.14**	0.04
Market size	0.11*	0.04
Market growth	0.01**	0.002
Market concentration	0.03	0.04
HIV category	-0.04	0.13
Prior product introductions	-0.25**	0.08
Order of response	-0.10**	0.01
Frailty Parameter	0.04**	0.02
Log Likelihood Value	-3650.81	
Wald χ^2 statistic	210.90**	
**: p<0.01; *: p<0.05		

Table 4b: Probit Model Estimates (Dependent Variable: Response)

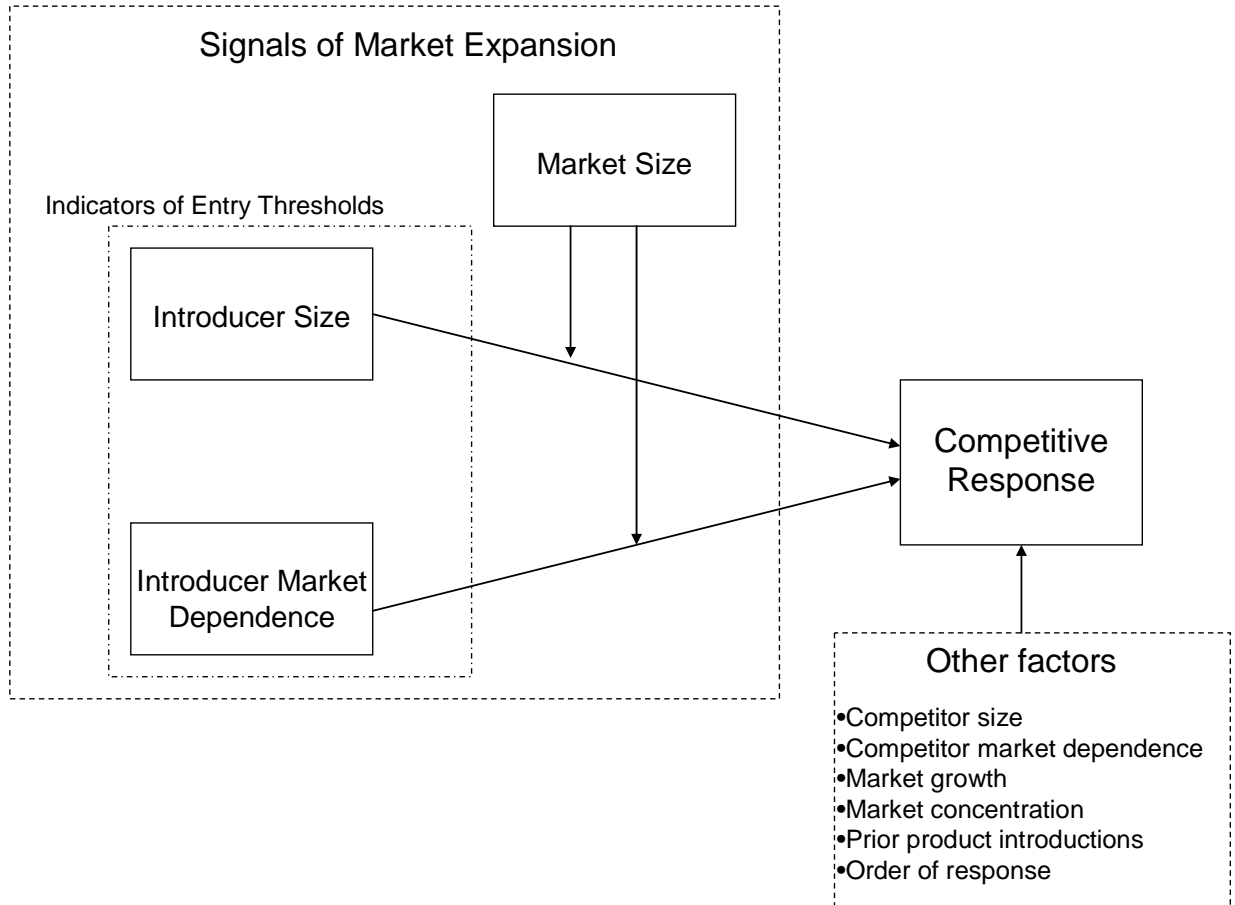
Variable	Estimate	Std. Error
Introducer firm size	0.486**	0.121
Introducer market dependence	0.492**	0.120
Introducer firm size* Market size	-0.744**	0.229
Introducer market dependence* Market size	0.182	0.143
Competitor firm size	1.635**	0.187
Competitor market dependence	1.137**	0.124
Market size	0.210*	0.104
Market growth	0.017**	0.004
Market concentration	0.035	0.086
Prior product introductions	-0.418**	0.093
Order of response	-0.588**	0.115
HIV Category	0.106	0.266
Intercept	-0.956**	0.227

Note: **: Significant at p<.01; *: Significant at p<.05

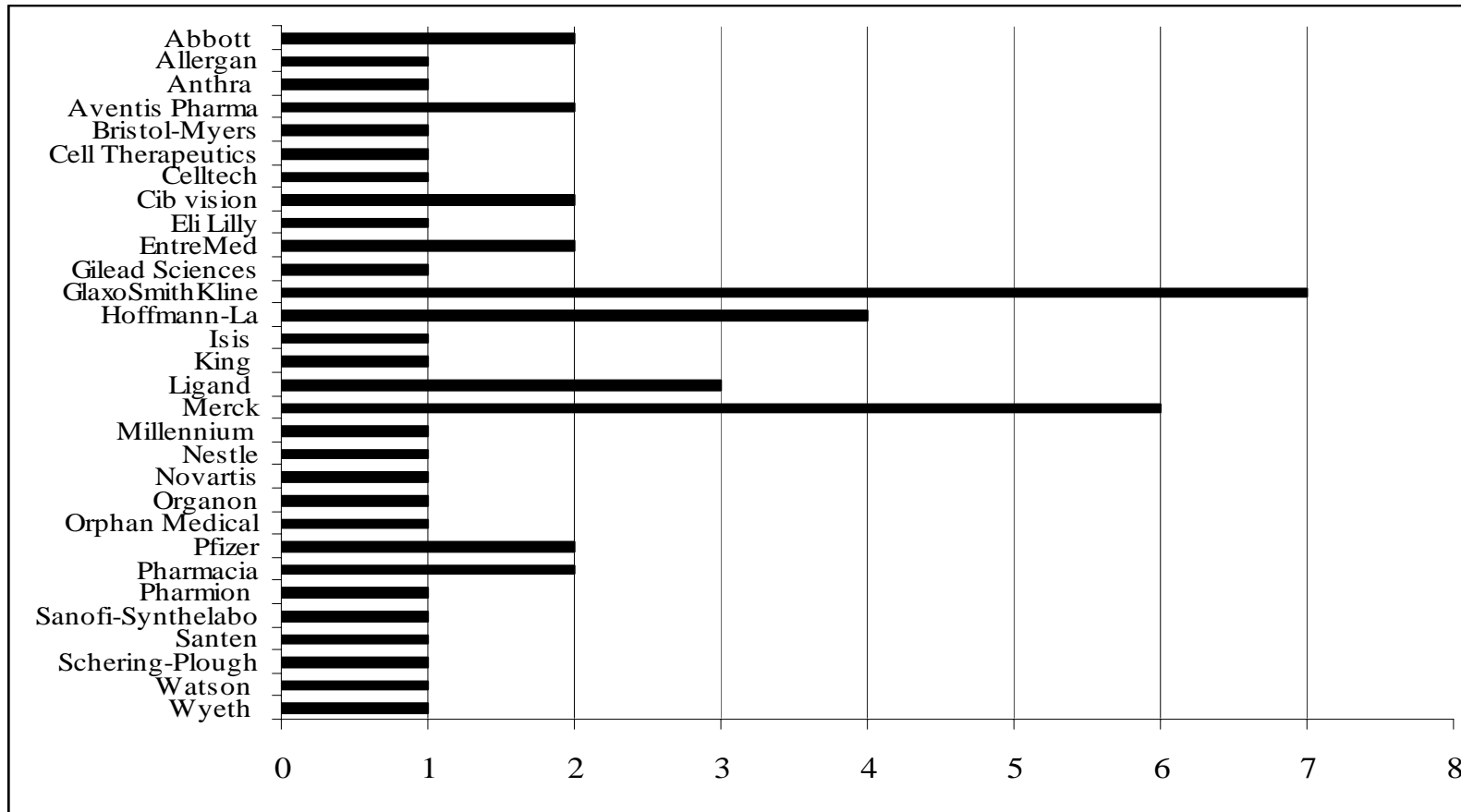
TABLE 5: Bootstrap Analysis

<i>Hypothesized Variables</i>	Estimate	Std. Error
Introducer firm size	0.65**	0.11
Introducer market dependence	0.53**	0.076
Introducer firm size* Market size	-0.56**	0.21
Introducer market dependence* Market size	0.01	0.12
<i>Control Variables</i>		
Competitor firm size	1.15**	0.13
Competitor market dependence	0.43**	0.08
Market size	0.25**	0.10
Market growth	0.01**	0.004
Market concentration	0.08	0.06
HIV category	0.06	0.14
Prior product introductions	-0.37*	0.16
Order of response	-0.20**	0.03
Frailty Parameter	0.04**	0.02
Log Likelihood Value	-3650.81	
Wald χ^2 statistic	338.98**	
**.: p<0.01; *.: p<0.05		

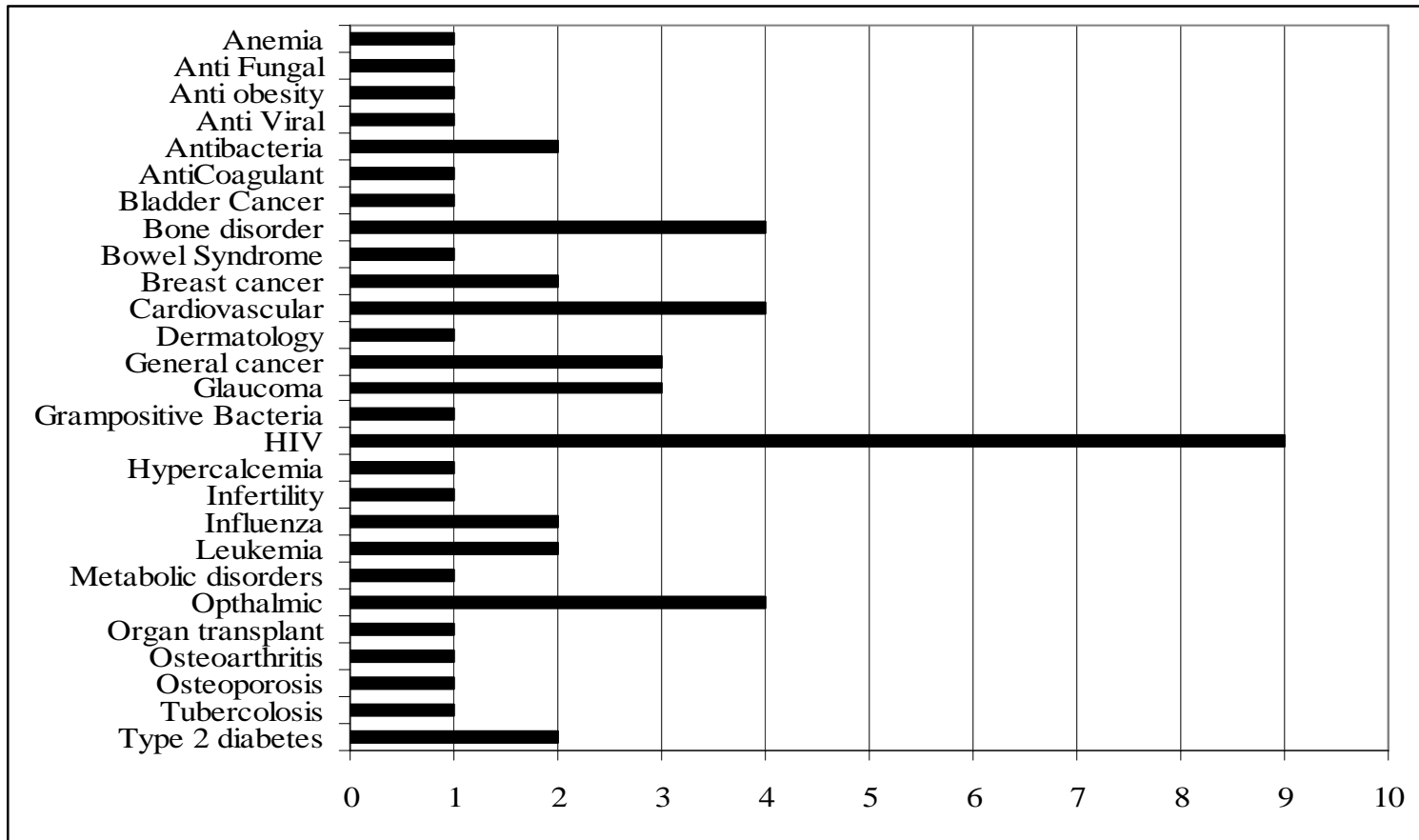
**FIGURE 1:
A CONCEPTUAL MODEL OF COMPETITIVE RESPONSE TO RADICAL
PRODUCT INNOVATION**



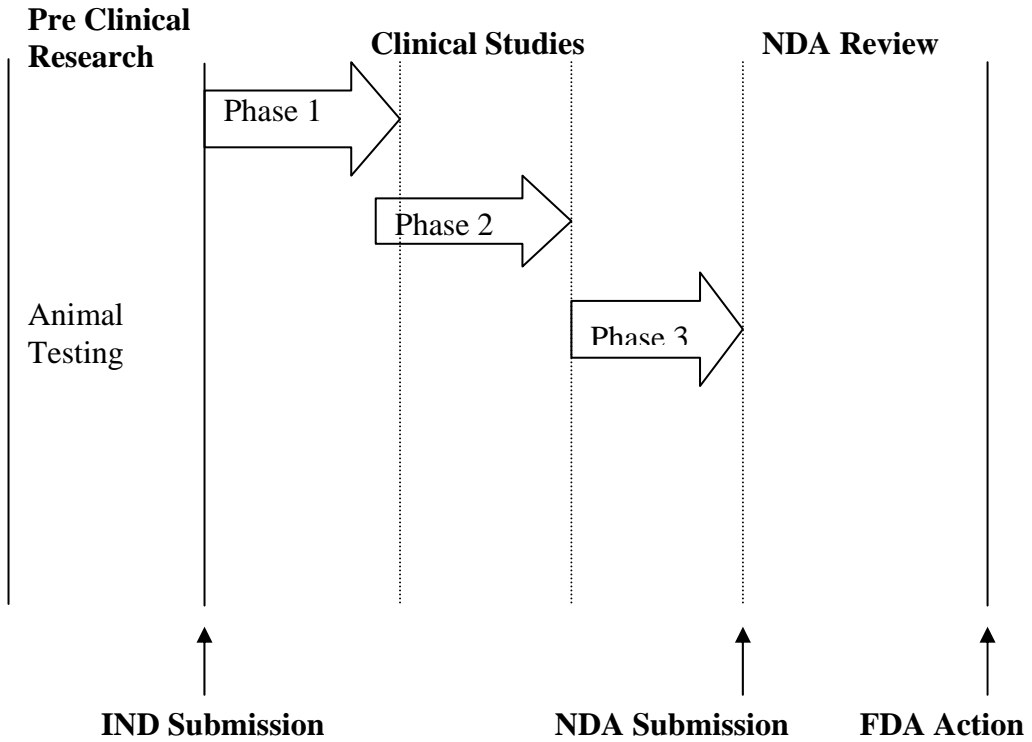
**FIGURE 2:
OF RADICAL PRODUCT INNOVATIONS PER INTRODUCING FIRM**



**FIGURE 3:
OF RADICAL PRODUCT INNOVATIONS PER CATEGORY**



**FIGURE 4:
NEW DRUG DEVELOPMENT PROCESS**



Source: www.fda.gov

REFERENCES

- Agarwal, N. C. (1979), "On the Interchangeability of Size Measures," *Academy of Management Journal*, 22, 404-409.
- Axelrod, Robert (2002), *The Evolution of Cooperation*, New York: HarperCollins.
- Bernheim B. Douglas and Michael D. Whinston (1998), "Incomplete Contracts and Strategic Ambiguity," *American Economic Review*, 88 (4), 902-33.
- Blair, Ed and George Zinkhan (2006), "Nonresponse and Generalizability in Academic Research," *Journal of the Academy of Marketing Science*, 34 (1), 4-7.
- Blundell, Richard, Rachel Griffith, and John Van Reenen (1999), "Market Share, Market Value, and Innovation in a Panel of British Manufacturing Firms," *Review of Economic Studies*, 66 (228), 529-554.
- Bourgeois, L. J (1979), "Toward a Method of Middle-Range Theorizing," *Academy of Management Review*, 4 (3), 443-447.
- Bowman, Douglas and Hubert Gatignon (1995), "Determinants of Competitor Response Time to a New Product Introduction," *Journal of Marketing Research*, 32 (February), 42-53.
- Bresnahan, T.F. and P.C. Reiss (1991), "Entry and competition in concentrated markets," *Journal of Political Economy* 99, 977-1009.
- Chandy, Rajesh K., Jaideep C. Prabhu, and Kersi D. Antia (2003), "What Will the Future Bring? Technology Expectations, Dominance, and Radical Product Innovation," *Journal of Marketing*, 66 (July), 1-18.
- and Gerard J. Tellis (2000), "The Incumbent's Curse? Incumbency, Size and Radical Product Innovation," *Journal of Marketing*, 64 (July), 1-17.
- and Gerard J. Tellis (1998), "Organizing for Radical Product Innovation: The Overlooked Role of Willingness to Cannibalize," *Journal of Marketing Research*, 35 (November) 474-87.
- Chen, Ming-Jer and Danny Miller (1994), "Competitive Attack, Retaliation and Performance: An Exploratory-Valence Framework," *Strategic Management Journal*, 15 (February), 85-102.
- and Ian C. MacMillan (1992), "Nonresponse and Delayed Response to Competitive Moves: The Roles of Competitor Dependence and Action Irreversibility," *Academy of Management Journal*, 35 (3), 539-70.
- Christensen, Clayton M. (1997), *The Innovator's Dilemma*, New York, NY: Harper Business.

- Clayton, D.G. (1978), "A Model for Association in Bivariate Life Tables and its Application in Epidemiological Studies of Familial Tendency in Chronic Disease Incidence," *Biometrika*, 65, 141-151.
- Cox, David R. (1972), "Regression Models and Life-Tables," *Journal of the Royal Statistical Society*," B, 34, 187-200.
- DiMasi, Joseph A. and Cherie Paquette (2004), "The Economics of Follow-on Drug Research and Development," *Pharmacoeconomics*, 22 (2), 1-14.
- DuWors Jr., Richard E. and George H. Haines Jr. (1990), "Even History Analysis Measures of Brand Loyalty," *Journal of Marketing Research*, 27 (November), 485-493.
- FDA (1999), *From Test Tube to Patient: Improving Health Through Human Drugs*, Washington, DC: U.S. Government Printing Office.
- FDA (2005), *FY 2005 Performance Report To The President And The Congress for the Prescription Drug User Fee Act*, Washington, DC: U.S. Government Printing Office.
- Fan, Jianqing and Runze Li (2002), "Variable Selection for Cox's Proportional Hazards Model and Frailty Model," *Annals of Statistics*, 30 (1), 74-99.
- Golder, Peter N. and Gerard J. Tellis (1997), "Will It Ever Fly? Modeling the Takeoff of New Consumer Durables," *Marketing Science*, 16 (3), 256-70.
- Gönül, Füsün and Kannan Srinivasan (1993), "Consumer Purchase Behavior in a Frequently Bought Product Category: Estimation Issues and Managerial Insights From a Hazard Function Model with Heterogeneity," *Journal of the American Statistical Association*, 88, 1219-1227.
- Govindarajan, Vijay and Praveen K. Kopalle (2004), "How Incumbents Can Introduce Radical and Disruptive Innovations: Theoretical and Empirical Analyses," *Working Paper*, Dartmouth College.
- Greene, William (2003), *Econometric Analysis*, New Jersey: Prentice-Hall.
- Grimshaw, Scott D., James McDonald, Grant R. McQueen, and Steven Thorley (2005), "Estimating Hazard Functions for Discrete Lifetimes," *Communications in Statistics-Simulation and Computation*, 34, 451-463.
- Gruca, Thomas S., K. Ravi Kumar, and D. Sudharshan (1992), "An Equilibrium-Analysis of Defensive, Response to Entry Using a Coupled Response Function Model," *Marketing Science*, 11(4), 348-58.
- and D. Sudharshan (1995), "A Framework for Entry Deterrence Strategy: The Competitive Environment, Choices, and Consequences," *Journal of Marketing*, 59 (July), 44-55.

- Hauser, John, Gerard Tellis, and Abbie Griffin (2006), "Research on Innovation: A Review and Agenda for *Marketing Science*," *Marketing Science*, 25 (6), 687-717.
- Heckman, James and Burton Singer (1984), "A Method for Minimizing the Impact of Distributional Assumptions in Econometric Models of Duration Data," *Econometrica*, 51, 271-320.
- Heide, Jan B. and Allen M. Weiss (1995), "Vendor Consideration and Switching Behavior in High-Technology Markets," *Journal of Marketing*, 59 (3), 30-43.
- Heil, Oliver and Thomas S. Robertson (1991), "Toward A Theory of Competitive Market Signaling: A Research Agenda," *Strategic Management Journal*, 12, 403-18.
- and Arien W. Langvardt (1994), "The Interface Between Competitive Market Signaling and Antitrust Law," *Journal of Marketing*, 58 (July), 81-96.
- Helsen, Kristiaan and David Schmittlein (1993), "Analyzing Duration Times in Marketing: Evidence for the Effectiveness of Hazard Rate Models," *Marketing Science*, 12 (4), 395-414.
- Hougaard P. (2000), *Analysis of Multivariate Survival Data*, Springer, New York.
- Jain, Deepak and Naufel Vilcassim (1991), "Modeling Purchase-Timing and Brand-Switching Behavior Incorporating Explanatory Variables and Unobserved Heterogeneity," *Journal of Marketing Research*, 28 (1), 29-41.
- Kerin, Roger A, Michael G. Harvey, and James T. Rothe (1978), "Cannibalism and New Product Development," *Business Horizons*, (October), 25-31.
- Keyhani, Salomeh, Marie Diener-West, and Neil Powe (2006), "Are Development Times for Pharmaceuticals Increasing or Decreasing?" *Health Affairs*, 25 (2), 461-468.
- Kuester, Sabine, Christian Homburg, and Thomas S. Robertson (1999), "Retaliatory Behavior to New Product Entry," *Journal of Marketing*, 63 (October), 90-106.
- Li, Shaomin (1995), "Survival Analysis," *Marketing Research*, 7 (4), 17-23.
- Lunn, Mary and Don McNeil (1995), "Applying Cox Regression to Competing Risks," *Biometrics*, 51 (2), 524-532.
- Mahajan, Vijay, Subhash Sharma, and Robert D. Buzzell (1993), "Assessing the Impact of Competitive Entry on Market Expansion and Incumbent Sales," *Journal of Marketing*, 57 (July), 39-52.
- Mathieu, Mark P. (2002), *New Drug Development: A Regulatory Overview*, Waltham, MA: Parexel International Corporation.

- Meyer, Bruce (1995), "Semiparametric Estimation of Hazard Models," *Working Paper*, Northwestern University and NBER.
- Min, Sungwook, Manohar U. Kalwani, and William T. Robinson (2006), "Market Pioneer and Early Follower Survival Risks: A Contingency Analysis of Really New Versus Incrementally New Product-Markets," *Journal of Marketing Research*, 70 (1), 15-33.
- Montaguti, Elisa, Sabine Kuester, and Thomas Robertson (2002), "Entry Strategy for Radical Product Innovations: A Conceptual Model and Propositional Inventory," *International Journal of Research in Marketing*, 19 (1), 21-42.
- Moorthy, Sridhar (1985), "Using Game Theory to Model Competition," *Journal of Marketing Research*, 22 (3), 262-282.
- Morrison, Donald (1969), "On the Interpretation of Discriminant Analysis," *Journal of Marketing Research*, 6 (May), 153-163.
- Nickell, Steven (1996), "Competition and Corporate Performance," *Journal of Political Economy*, 54 (4), 724-746.
- Nijssen, Edwin, Bas Hillebrand, and P.A.M. Vermeulen (2005), "Unraveling Willingness to Cannibalize: A Closer Look at the Barrier to Radical Innovation," *Technovation*, 25 (12), 1400-1409.
- Pharmaceutical Research and Manufacturers of America (2003), *Industry Profile*, World Wide Web Publication, www.phrma.org.
- Porter, Michael E. (1980), *Competitive Strategy*, New York: The Free Press.
- Prabhu, Jaideep and David W. Stewart (2001), "Signaling Strategies in Competitive Interaction: Building Reputations and Hiding the Truth," *Journal of Marketing Research*, 38 (February), 62-72.
- Reiffen, David and Michael R. Ward (2005), "Generic Drug Industry Dynamics," *Review of Economics and Statistics*, 87 (1), 37-49.
- Rhoades, Stephen (1973). "The Impact of Diversification on Industry Profit Performance in 241 Manufacturing Industries: 1963," *Review of Economics and Statistics*, 55, 146-155.
- Robertson, Thomas, Jehoshua Eliashberg, and Talia Rymon (1995), "New Product Announcement Signals and Incumbent Reactions," *Journal of Marketing*, 59 (July), 1-15.
- Robinson, William T. (1988), "Marketing Mix Reactions to Entry," *Marketing Science*, 7 (Fall), 368-92.
- Rust, Roland (2006), "The Maturation of Marketing as an Academic Discipline," *Journal of Marketing*, 70 (3), 1-2.

- Scherer, F. M (2000), "The Pharmaceutical Industry and World Intellectual Property Standards," *Vanderbilt Law Review*, 53 (6), 2245-54.
- Schumpeter, J. A. (1942), *Capitalism, Socialism, and Democracy*. New York: Harper.
- Seetharaman, P.B. and Pradeep K. Chintagunta (2003), "The Proportional Hazard Model for Purchase Timing: A Comparison of Alternative Specifications," *Journal of Business and Economic Statistics*, 21(3), 368-383.
- Shankar, Venkatesh (1997), "Pioneers' Marketing Mix Reaction to Entry in Different Competitive Game Structures: Theoretical Analysis and Empirical Illustration," *Marketing Science*, 16 (3), 271-93.
- (1999), "New Product Introduction and Incumbent Response Strategies: Their Interrelationship and the Role of Multimarket Contact," *Journal of Marketing Research*, 36 (August), 327-344.
- Sheremata, Willow (2004), "Competing Through Innovation in Network Markets: Strategies for Challengers," *Academy of Management Review*, 29 (3), 359-377.
- Sorescu, Alina, Rajesh Chandy, and Jaideep Prabhu (2003), "Sources and Financial Consequences of Radical Innovation: Insights from Pharmaceuticals," *Journal of Marketing*, 66 (October), 82-102.
- Spence, A. Michael (1974), *Market Signaling*. Cambridge, MA: Harvard University Press.
- Srinivasan, Raji, Gary Lilien, and Arvind Rangaswamy (2006), "The Emergence of Dominant Designs," *Journal of Marketing*, 70 (April), 1-17.
- Tellis, Gerard J. and Peter N. Golder (2001), *Will and Vision: How Latecomers Grow To Dominate Markets*, New York, NY: McGraw Hill.
- The FDA's Drug Review Process: Ensuring Drugs are Safe and Effective, (2004). World Wide Web Publication, www.fda.gov/fdac/features/2002/402_drug.html
- Tornatzky, Louis G. and Mitchell Fleischer (1990), *The Process of Technological Innovation*, Lexington, MA: Lexington Books.
- van Heerde, Harald, Carl Mela, and Puneet Manchanda (2004), "The Dynamic Effect of Innovation on Market Structure," *Journal of Marketing Research*, 41 (May), 166-183.
- Vaupel, J.W., K.G. Manton, and E. Stallard (1979), "The Impact of Heterogeneity in Individual Frailty on the Dynamics of Mortality," *Demography*, 16, 439-454.
- Weitz, Bart (1985), "Introduction to the Special Issue on Competition in Marketing," *Journal of Marketing Research*, 22 (August), 229-36.

- Wuyts, Stefan, Stefan Stremersch, and Shantanu Dutta (2004), "Portfolios of Interfirm Agreements in Technology-Intensive Markets: Consequences for Innovation and Profitability," *Journal of Marketing*, 68 (2), 88-100.
- Yeoh, Poh-Lin and Kendall Roth (1999), "An Empirical Analysis of Sustained Advantage in the U.S. Pharmaceutical Industry: Impact of Firm Resources and Capabilities," *Strategic Management Journal*, 20 (7), 637-653.
- Yip, G. S. (1982), *Barriers to Entry: A Corporate-Strategy Perspective*, Lexington, Mass: D.C. Heath and Company.