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Competitive Response to Radical Product Innovations

Radical product innovations are often agents of creative destruction. They threaten to destroy existing market positions, and yet they often yield vast new market opportunities. This article 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. The 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.

Keywords: innovation, competition, market expansion, entry thresholds

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 the economic system, the study of competitive response is essential for any understanding of business actions. Managers need 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 need 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 need 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 than 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. Thus, they not only threaten existing competitive positions but also offer new market opportunities. However, 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 article, we 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 market.[1] To the best of our knowledge, no prior research has used these constructs to explain competitive response. We attempt to build a "home-grown" theory of the type that Rust (2006, pp. 1–2) calls for to

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[1]We define entry thresholds at the firm level, unlike authors such as Bresnahan and Reiss (1991), who define entry thresholds at the market level. In addition, 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).

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explore previously unexplored issues in competitive response.

Some of the hypotheses we develop contradict prior literature, which has argued that competitors are less likely to respond to the introduction of new products by larger firms than to that of 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 than to 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 has also argued that competitors are less likely to respond to product introductions in smaller than in larger markets (Gruca, Kumar, and Sudharshan 1992; Gruca and Sudharshan 1995; Shankar 1999). In contrast, we find that competitors are more likely to respond to radical product innovations in smaller than in larger markets if the firm introducing the innovation is large. In addition, we examine how response to radical product innovations is influenced by market dependence, a variable largely overlooked in prior research (see Montaguti, Kuester, and Robertson 2002). We argue that competitors are 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 one 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 methodological limitations that have been cited in previous research on competitive response. One such limitation is small sample size (Kuester, Homburg, and Robertson 1999; Robinson 1988). For example, Yip (1982) uses only 37 observations, and Shankar (1999) uses 23 new product entries and 59 response observations. A second limitation is completeness of the data—namely, measuring response for only a limited number of competitors (Robinson 1988; Shankar 1997). A third limitation is the possibility of self-reporting bias in questionnaire measures (Kuester, Homburg, and Robertson 1999; Robinson 1988). By focusing on the pharmaceutical industry and using data from multiple sources, we attempt to address each of these issues. The pharmaceutical industry has been popular in studies of innovation because it is a multibillion 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 enables 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 article is on competitive responses in the form of product introductions. Although competitors can also respond through other elements of the marketing mix, we focus on product responses because prior research has suggested that responses to competitive actions tend to be reciprocal (e.g., product responses for product actions, price responses for price actions; see Axelrod 2002; Bowman and Gatignon 1995). In addition, 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.

We organize the rest of this article 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 by identifying possible limitations and discussing several implications for scholarship and practice.

Conceptual Framework

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 than existing products (Chandy and Tellis 1998). In many ways, radical product innovations are 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): (1) market expansion, (2) cannibalization, and (3) 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; see also Mahajan, Sharma, and Buzzell 1993). In general, the impact of incremental innovations is to redistribute shares within an existing market. Conversely, radical product innovations 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 the following examples from the U.S. pharmaceutical industry (IMS Health Global Services 2004; 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 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 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 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). An 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 must 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, placing it closer 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).

Market Expansion, Entry Thresholds, and Competitive Response

What factors influence the likelihood of competitors' 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 Rymon 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 are 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 market.[2]

What factors have these effects? Some of the most credible signals in this context are related 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 (1) who it is and (2) 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 greater 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 the greatest when such firms introduce products in markets that were previously viewed as having low potential.

What is the profile of a firm with high entry thresholds? Although 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 literature on radical product innovation, which also emphasizes the importance of these two factors (see Chandy, Prabhu, and Antia 2003; Chandy and Tellis 2000).

First, in terms of 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 become larger, their reference points for what constitutes attractive markets also become larger. The prospect of a $10 million business might cause great excitement in a small firm, but this might 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; that is, the large firm expects that the market will expand substantially as a result of the introduction of the radical product innovation.

Second, in terms of 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). Therefore, the radical product innovation faces a greater burden of expectations in a market-dependent firm than in other firms (Kerin, Harvey, and Rothe 1978). Firms with higher levels of market dependence are most likely to introduce a radical prod-

[2]Note that we do not use the term "signal" as does Spence (1974), who argues that 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).

uct innovation if they expect enough market expansion to compensate for the cannibalization of existing products.

Hypotheses

Effect of Introducer Size

The existing literature on competitive response to product introductions argues that incumbent competitors are less likely to respond to the introduction of new products by larger than by smaller firms because of the deterrent effect of larger resources (Bowman and Gatignon 1995; Shankar 1999). For example, 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 are 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. Because 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 we discussed previously. Incumbents will surmise that a larger firm, given its high entry threshold, will introduce an innovation only 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 than when it is a small firm because the entry of the former is more likely to signal expected market expansion. In summary, we hypothesize the following:

H_1: The greater the size of the firm introducing a radical product innovation, the greater is the likelihood of competitive response.

Effect of Introducer Market Dependence

We also argue that there is 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 must 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 resultant implication of possible market expansion is likely to stimulate competitive response. Thus:

H_2: The greater the market dependence of the firm introducing a radical product innovation, the greater is 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 powerful 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 is that the large firm might detect significant potential in the market that has previously not been realized (Christensen 1997). This will motivate competitors to respond. An identical argument applies to the case of market dependence. Thus:

H_3: The likelihood of competitive response is greater when (a) a large firm introduces a radical product innovation in a small market than when it does so in a large market and (b) a market-dependent firm introduces a radical product innovation in a small market than when it does so in a large market.

Other Variables of Interest

Our hypotheses focus 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 we include them as control variables in our analyses and note their likely effects.

Prior literature has considered the market growth rate an indicator of market attractiveness and, thus, an antecedent of competitive response (Bowman and Gatignon 1995; Kuester, Homburg, and Robertson 1999; Shankar 1999). 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 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. Thus, 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). Concentration may also be related 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 a higher upside for new solutions. To the extent that higher concentration indicates higher upside in the market, there should

be a greater likelihood of competitive response. Conversely, some research indicates that competitive response may be less likely in concentrated markets, perhaps because of mutual forbearance (Bernheim and Whinston 1998; Chen and MacMillan 1992).

With respect to market attractiveness, another relevant variable is current market size. Apart from the interaction effects that we hypothesized, it can 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 in which sales are plenty (Chandy, Prabhu, and Antia 2003).

A competitor-related variable 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). Conversely, it can be argued that larger firms have greater resources and, thus, greater capabilities for response. In the context of radical product innovations, in which 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 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 (Chen and MacMillan 1992).

Finally, two other factors 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 because of either commitment to that product or depletion of product development resources. Second, there may be order-of-response effects; specifically, later firms may be less likely to respond because earlier competitors have claimed preemptive 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 (1) our considerations in choosing an empirical context, (2) operationalizations and data sources for radical product innovation and competitive response, (3) operationalizations and data sources for other variables, and (4) 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. This gives us 714 total 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 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

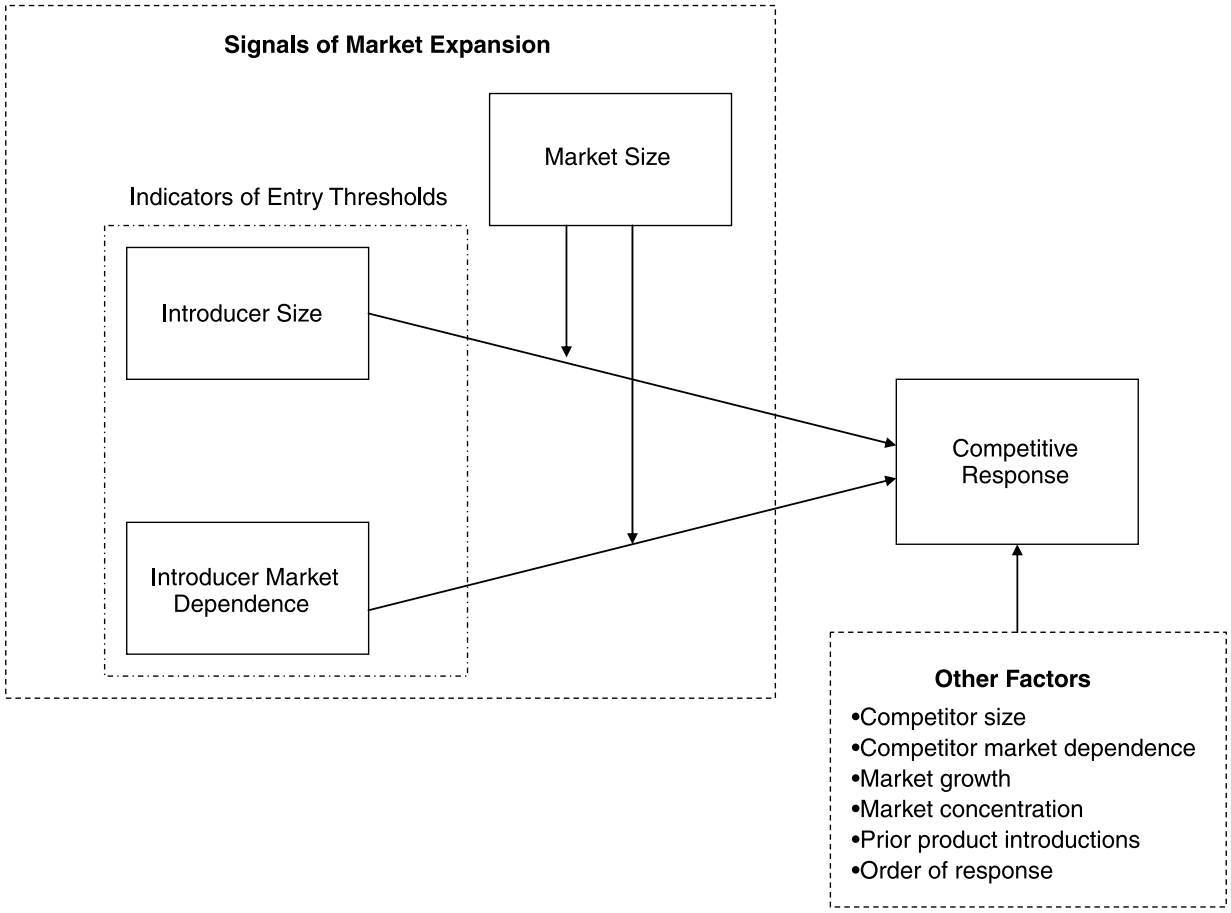
The model presented in this study describes the likelihood of competitive response to radical product innovations as a function of introducer firm size, introducer market dependence, the interaction of these two variables with market size, and various control variables. To test our arguments, we need an empirical context that has many product categories and considerable variety in firm size and market size. It also should be a context in which numerous introductions of radical product innovations can be objectively identified. The pharmaceutical industry fits all 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 subsequently.

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 (for details, see Sorescu, Chandy, and Prabhu 2003). Regarding chemical composition, the FDA classifies a drug as a "new molecular entity" versus a composition that is a new formulation, new combination, or new usage of existing chemistry. New molecular entities 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 compared with all existing drugs is given "priority review" by the FDA, whereas 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 that Chandy and Tellis (1998) and Sorescu, Chandy, and Prabhu (2003) use to define radical product innovations. Thus, we classify a new product introduction as a radical product innovation if it meets the criteria of being a new molecular entity (a distinct advancement in technology) and receiving priority review (a distinct advancement in customer benefits). This operationalization

FIGURE 1
A Conceptual Model of Competitive Response to Radical Product Innovation



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

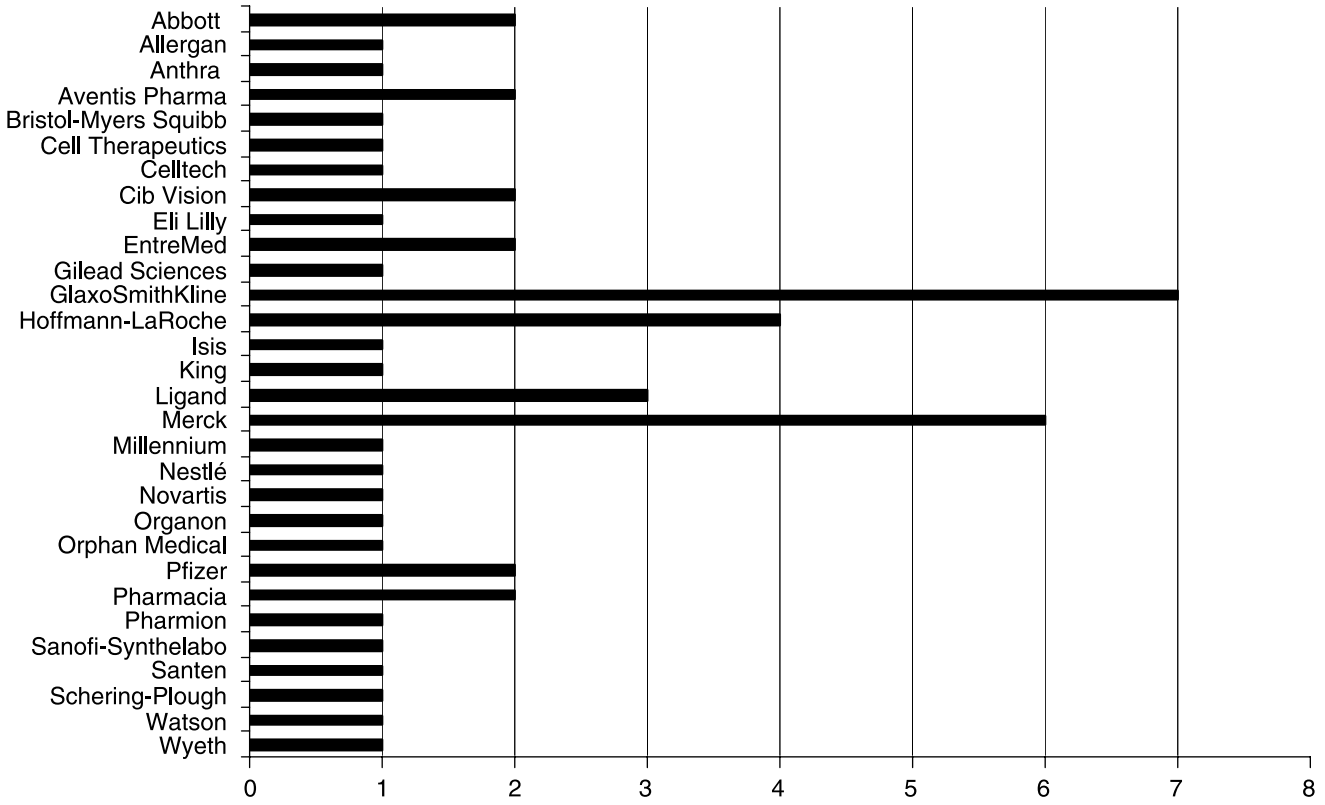
Our data contain 52 radical product innovations introduced by 32 different companies in 27 therapeutic categories over the 1997–2001 period. On average, each innovation faced 14 incumbent products within its category (high = 47, low = 2), for a total of 714 observations for potential response by incumbents. 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.

We measured response 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 one and a half years that competitors took to respond to breakthrough pharmaceutical products in the 1990s (Pharmaceutical Research and Manufacturers of America 2003). A three-year period allows us to examine responses without causing substantial censoring in the data.

Within the three-year observation window, we measured each competitor's response as the number of days after the introduction of the innovation before the competitor introduced a product of its own. We treated competitors that did not respond by the last date in the window as censored observations in the hazard model. Overall, approximately half the competitors introduced products within the three-year window. We also obtained data on competitive product introductions 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 United States go through a multi-

FIGURE 2
Number of Radical Product Innovations per Introducing Firm



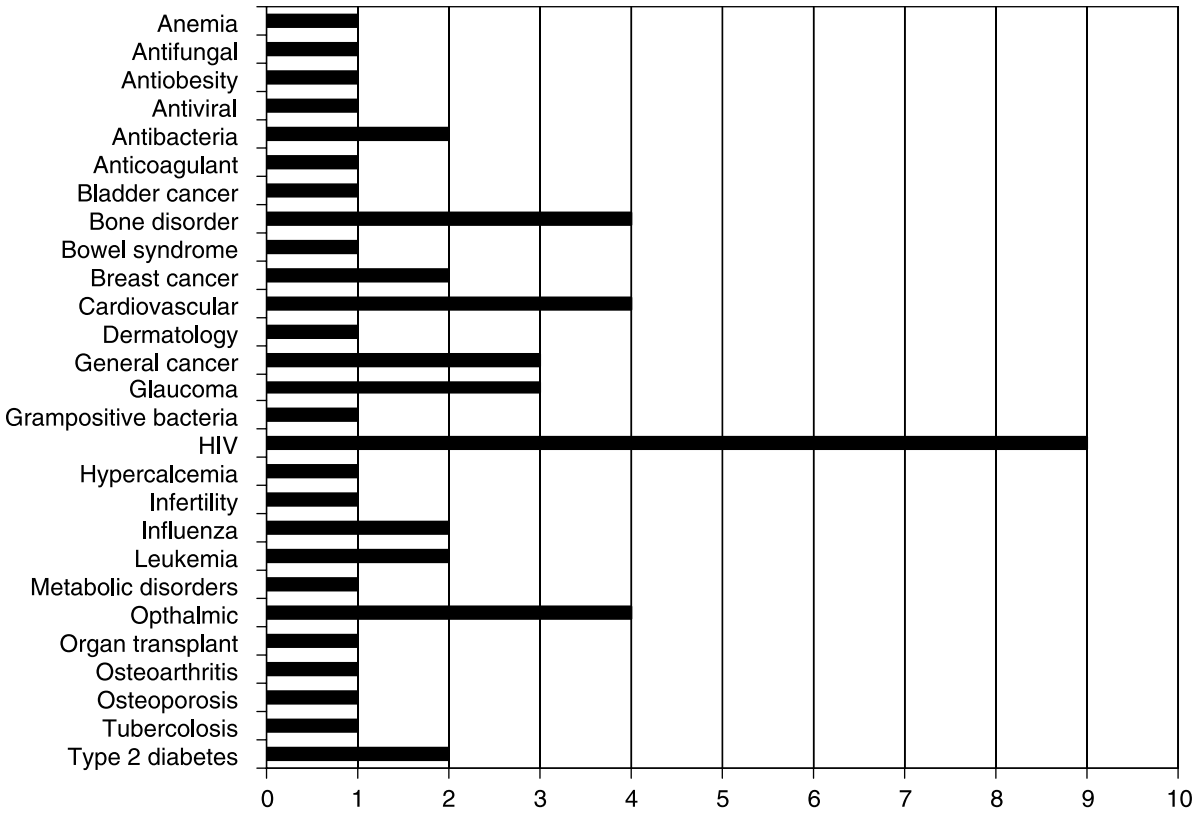
stage FDA approval process (see Figure 4; FDA 1999). The drug sponsor first applies for an investigational new drug application based on preclinical animal tests. If approved, the drug proceeds to three phases of clinical trials with humans. If the drug is approved through all three phases of clinical 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, a company may be working on an innovation, but this does not necessarily mean that a successful product will result. This may be particularly true in the pharmaceutical industry. Only 1 in 1000 new drug compounds makes it as far as the clinical studies phase, and according to the Tufts Center for the Study of Drug Development, only 1 in 5 drugs that make it to clinical testing is ultimately approved for introduction (www.fda.gov). Therefore, the various stages of preintroductory product development have uncertain implications, and competitors that respond to products in the early stages are often 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 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 these reported finding have implications for the timing of competitive response in the pharmaceutical industry (for a review, see Mathieu 2002). Competitors receive information about radical product innovations before the 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 FDA 2005; Keyhani, Diener-West, and Powe 2006; Mathieu 2002). Overall, some competitive products may appear within months of the introduction of a radical product innovation, but as we indicated previously, the average response period is approximately one and a half 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

FIGURE 3
Number of Radical Product Innovations per Category



Paquette 2004). In the latter case, the observations are right censored, and we account for this in our empirical model.[3]

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 one another (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.

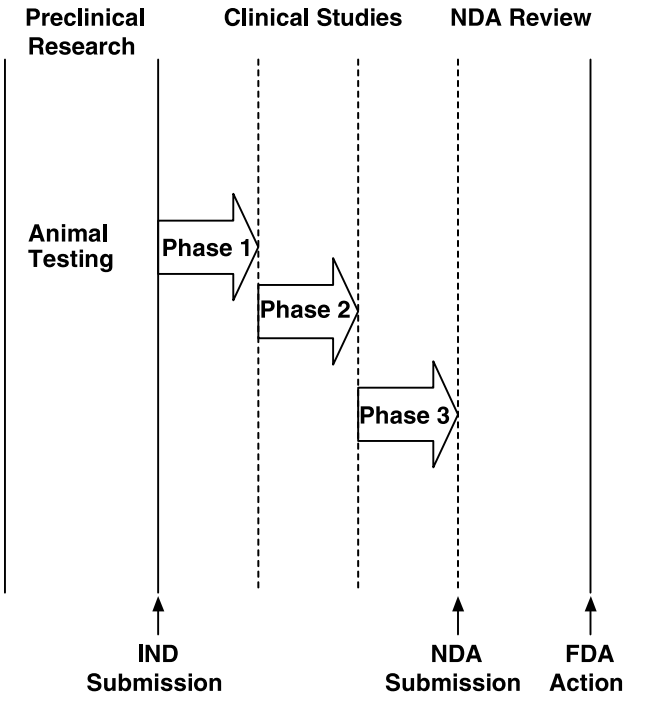
It might be argued that the effects of the introducer's firm size are relative rather than absolute; that is, the likelihood of competitive response depends not so much on the absolute size of the introducing firm but rather on the relative sizes of the introducer and its competitors. The use of a relative measure is consistent with the effects of introducer firm size as discussed in prior literature, in which 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.

We obtained firm size data 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) Hoover's, which also covers some smaller and private companies; and (4) company Web sites.

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

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

FIGURE 4
New Drug Development Process



Source: Adapted from FDA (n.d.).
Notes: NDA = new drug application; IND = investigational new drug.

Health Global Services, which is a source of detailed market research data about the pharmaceutical industry.

Market size. We operationalized market size, which is hypothesized to interact with introducer firm size and introducer market dependence, 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). We obtained market size data from IMS Health Global Services.

Operationalizations and Data Sources for Control Variables

Control variables we used in the analysis include competitor firm size, competitor market dependence, market growth, market size, market concentration, prior product introductions by the competitor, and order of response. We used these variables as controls because they could be related to competitive response for reasons discussed previously. We also used a control variable for whether the product is in the HIV therapeutic category. We used this variable 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. We already described the operationalization of market size; we operationalized the other control variables as follows:

- *Competitor firm size*. We measured firm size for each competitor in the same way and from the same data sources as introducer firm size.
- *Competitor market dependence*. We measured competitor market dependence in the same way and from the same data sources as introducer market dependence.
- *Market growth*. We operationalized market growth as the rate of change in market size in the year before introduction of the radical product innovation (relative to the previous year). We calculated growth rates from market size data obtained from IMS Health Global Services.
- *Market concentration*. We measured market concentration 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 alternative measure of market concentration—the sum of market shares of the top four firms in the market—provides similar results to those we report herein. We obtained market concentration data from IMS Health Global Services.
- *HIV category*. We included a dichotomous dummy variable that represents whether the radical product introduction belonged to the HIV category. We obtained relevant data from the NDA Pipeline.
- *Prior product introductions by the competitor*. We operationalized this variable as a dichotomous variable that represents whether a given competitor introduced a new product in the relevant product category during the three years before the introduction of a radical product innovation. We obtained data from the NDA Pipeline.
- *Order of response*. We measured order of response as the number of firms that already responded to the radical product innovation before response by a particular competitor. We obtained data from the NDA Pipeline.

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

Model Specification

We now turn to specification of the model used in our analysis. Our hypotheses address 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 must be accounted for in any model specification. 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 did not introduce 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 (e.g., a product introduction) occurring.[4] Such models account for right censoring and the temporal nature of the

[4]Our interest in this article is on a single outcome—namely, whether firms respond with a product introduction. If there are multiple outcomes of interest, a competing risks modeling framework should be used (Lunn and McNeil 1995).

TABLE 1
Variables, Measures, and Sources

Variable	Operationalization	Source
Competitive response	Number of days until a focal competitor introduces a new product, starting from the day the radical innovation was introduced.	NDA Pipeline
Introducer size$_t$	Total dollar sales of the firm introducing the radical product innovation, in year t.	Standard & Poor's COMPUSTAT Thomson Datastream Hoover's Company Web sites
Introducer market dependence$_t$	Ratio of sales in a therapeutic category divided by the total sales for the introducing firm, in year t.	IMS Health Global Services
Market size$_t$	Total dollar sales of the therapeutic category in which the radical product innovation was introduced, in year t.	IMS Health Global Services
Competitor firm size$_t$	Total dollar sales of the focal competitor, in year t.	Standard & Poor's COMPUSTAT Thomson Datastream Hoover's Company Web sites
Competitor market dependence$_t$	Ratio of focal competitor's sales in a therapeutic category to the firm's total sales, in year t.	IMS Health Global Services
Market growth$_t$	Percentage change in the size of the market in year t – 1 compared with sales in year t – 2.	IMS Health Global Services
Market concentration$_t$	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 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 before response by the focal firm.	NDA Pipeline

TABLE 2
Descriptive Statistics

Variable	M	Minimum	Maximum
Competitive response (days)	790.68	.00	1096.00
Introducer size (in millions of dollars)	1,949.85	<.01	43,651.58
Introducer market dependence (%)	.20	<.01	1.00
Market size (in millions of dollars)	4,989.07	28.89	16,000.00
Competitor firm size (in millions of dollars)	2,041.74	<.01	43,651.58
Competitor market dependence (%)	.16	<.01	1.00
Market growth (%)	28.57	3.34	86.13
Market concentration (%)	.61	.30	1.00
Order of response (count)	4.38	.00	22.00

data naturally and have been widely used in marketing (e.g., Helsen and Schmittlein 1993; Jain and Vilcassim 1991; for an introductory primer, see Li 1995).

Having decided on a hazard specification, we needed to address several issues 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 follows:

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

where $h(t|x_i)$ refers to the instantaneous hazard at time t, given a vector of covariates x_i; $h_0(t)$ 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. A parametric specification could be used, and then either a specific distribution (e.g., exponential, Erlang 2) would be assumed or a flexible specification, such as the quadratic Box–Cox (Jain and Vilcassim 1991), would be chosen. Unfortunately, misspecified parametric specifications can lead to inconsistent estimates (Meyer 1995). The alternative, which we adopt, is to use a nonparametric 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, parametric specifications can be compared with nonparametric specifications of the baseline hazard to determine which fits the data better; see, e.g., Seetharaman and Chintagunta 2003.) Because the intercept in the model in Equation 1 is unidentified from the baseline hazard in the Cox proportional hazard specification, we can rewrite the model as follows:

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

Although it is widely used and powerful, this specification does not account for unobserved heterogeneity (Gönül and Srinivasan 1993; Jain and Vilcassim 1991). 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 it could be argued that it might influence a firm's competitive response. It is well known that the exclusion of such factors could lead to a bias toward 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 biostastitics field; see, e.g., Vaupel, Manton, and Stallard 1979; and, more generally, Hougaard 2000), this is often referred to as a "frailty" model, and u is the frailty term. Formally, the specification now is as follows:

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

Now, it is important to note that any firm in our data could have multiple incidences of product introductions (thus, the data are an unbalanced panel). Suppose that each firm i has J_i observations. With some abuse of notation,[5] we can write the hazard rate for the jth observation of the ith firm as follows (Fan and Li 2002):

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

where each firm i can be thought to constitute a "group" with j "members." The vector **x** contains all the independent variables discussed previously (i.e., introducer firm size, introducer market dependence, market size, and other control variables).

We still need to specify the distribution of u. Following common practice in the literature (Clayton 1978; Hougaard 2000; Vaupel, Manton, and Stallard 1979), we specify a gamma distribution[6] for this random variable, with a mean of 1 and a variance of $1/\theta$; that is,

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

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, we obtain the following:

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

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 Equation 5 gives us the likelihood of the observed data, which is maximized to obtain the parameters θ (capturing frailty) and the vector β:

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

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

Results

A Wald test for the overall fit of the model yields a chi-square value of 363.13, which is significant at the $p < .01$ level. Table 3 reports the estimated coefficients. A comparison of the full model (with main effects and interactions)

[5]In general, this notation would be used in the case in which there were j individuals as part of a group i, sharing a common frailty u_i. In such a case, the frailty would be a random term multiplicatively affecting the hazard rate of all members of the group.

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

TABLE 3
Hazard Model Results

	Main Effects–Only Model		Main + Interaction Effects Model	
Hypothesized Variables	**Coefficient**	**SE**	**Coefficient**	**SE**
Introducer firm size	.55*	.08	.64*	.11
Introducer market dependence	.34*	.05	.52*	.07
Introducer firm size × market size	—	—	–.55*	.16
Introducer market dependence × market size	—	—	.03	.09
Control Variables	**Coefficient**	**SE**	**Coefficient**	**SE**
Competitor firm size	1.18*	.14	1.15*	.14
Competitor market dependence	.43*	.05	.44*	.05
Market size	.09	.06	.24*	.06
Market growth	.01*	2.69×10^{-3}	.01*	2.69×10^{-3}
Market concentration	.10	.06	.70	.49
HIV category	.08	.16	.06	.16
Prior product introductions	–.19*	.06	–.18*	.06
Order of response	–1.04*	.10	–1.13*	.10
Frailty parameter	.23*	.08	.19*	.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	

*$p < .01$.

Notes: 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 $L - .5 \times k \times \ln(n)$, where n is the number of observations. Models with lower values of BIC are preferred.

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.

Results of Hypothesis Tests

H_1 suggested that the larger the firm introducing a radical product innovation, the greater is the likelihood of competitive response. The effect is significant and in the expected direction ($\beta = .64$, $p < .01$), in support of H_1. Although 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 that it positively influences the probability of response, and a ratio less than 1 suggests a negative influence. The more the ratio departs from 1, the stronger is the effect. The hazard ratio for introducer firm size is 1.91, which implies that at any given time, a one-standard-deviation increase in the size of the introducing firm almost doubles the chance that any given competitor will respond in the next period if it has not responded already.

This finding reverses prior results obtained in the context of incremental innovations, in which 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.

H_2 argued that the more market dependent the firm introducing a radical product innovation, the greater is the likelihood of competitive response. The effect is significant and in the hypothesized direction ($\beta = .52$, $p < .01$), in support of H_2. The hazard ratio is 1.69, which suggests that increasing market dependence by one standard deviation increases the probability of responding 1.69 times.

H_{3a} predicted that market size would negatively moderate the influence of introducer size on the likelihood of competitive response, such that as the market becomes larger, the effect of introducer size becomes smaller (and as the market becomes smaller, the effect of introducer size becomes larger). The hypothesis is supported ($\beta = –.55$, $p < .01$). The hazard ratio is .57, which suggests that an increase in market size by one standard deviation cuts the effect of introducer size almost by half.

H_{3b} predicted that market size would negatively moderate the influence of introducer market dependence on the likelihood of competitive response, such that as the market becomes smaller, the effect of introducer market dependence becomes larger. The observed effect is not significant ($\beta = .03$, $p > .1$), with a hazard ratio of 1.03.

Overall, three of the four hypotheses are confirmed. In general, the results are consistent with our argument that competitive response to radical product innovations is higher when some aspect of the product introduction, such

as the introducer firm size, introducer market dependence, or the interaction of market size with introducer firm size, provides competitors with signals that the innovation is likely to increase the size of the market.

Other Results

Competitor firm size. Competitor firm size has a significant, positive impact on the likelihood of response (β = 1.15, $p < .01$). 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 threefold increase in the probability of reacting at any given time. This result contradicts prior findings in the context of incremental innovations that show either 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, it can also be argued that larger firms have greater resources and, thus, greater capabilities for response (Chandy, Prabhu, and Antia 2003; Chandy and Tellis 1998; Sorescu, Chandy, and Prabhu 2003), and in the context of radical product innovations, in which 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 could be qualitative differences in competitive dynamics for radical and incremental innovations.

Competitor market dependence. Competitor market dependence also has a significant, positive impact on response (β = .44, $p < .01$). The hazard ratio is 1.55. This finding is what would be expected; namely, 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 elicits a greater likelihood of response (β = .24, $p < .01$). The hazard ratio is 1.27. This finding supports the idea that competitors respond more aggressively in larger markets.

Market growth rate. A faster-growing category elicits a greater likelihood of response (β = .01, $p < .01$). 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 is 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 has no significant impact on the likelihood of response (β = .70, $p >$ .1). The hazard ratio is 1.08.

HIV category. A product introduction in the HIV category has no significant affect on the likelihood of response (β = .06, $p > .1$). The hazard ratio is 1.06.

Prior product introductions. Competitors that 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 (β = –.18, $p <$ .01). The hazard ratio is .32.

Order of response. The greater the number of competitors that have already responded to a radical product introduction, the less likely it is that a given firm will respond with a product introduction (β = –1.13, $p < .01$). The hazard ratio is .83.

Robustness Checks

We conducted several robustness checks. First, we examined whether our results were sensitive to the cutoff date in our sample (i.e., whether changing the extent of right censoring affects the results). To do this, we estimated a Cox hazard model with the cutoff date in our sample changed from three years to two years. Table 4, Panel A, reports the results of this change in the degree of right censoring. The results are qualitatively unchanged. In the same vein, we estimated 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 4, Panel B, reports the results of this analysis; the results are qualitatively unchanged.

Second, we checked 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 similar in both cases and are similar to the Cox proportional hazard model we reported.

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

Fourth, we checked the predictive validity of our specification (Srinivasan, Lilien, and Rangaswamy 2006). To do this, we randomly picked two-thirds of our sample as the estimation sample and the remaining one-third as the holdout sample. Using estimates from the estimation sample, we calculated the hazard ratio for each observation in the holdout sample. If the hazard ratio exceeded the baseline rate, we counted that observation as having experienced the hazard (i.e., responded to the product introduction). We then compared this with the actual response to determine whether the model predicted correctly, and we computed the hit rate over all observations. The hit rate on the holdout sample is 83.35%; this high figure provides reassurance about 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 .22 and a false-negative rate of .02. Using the approach that Morrison (1969) suggests for evaluating the predictive validity of a discriminant classifying function, we find that our .83 hit rate compares favorably with .49, the hit rate that would have been obtained by chance: $c_{pro} = \alpha p + (1 - \alpha)(1 - p)$, where p = true proportion of responders and α = proportion of responders predicted by the model.

Discussion

In this article, we 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 elicit a greater competitive response. The likelihood of competitive response is the greatest when large firms enter small markets. The subsequent paragraphs discuss the implication of this research for research and practice.

TABLE 4
Robustness Checks

A: Robustness to Degree of Right Censoring

Hypothesized Variables	Estimate	SE
Introducer firm size	.18**	.05
Introducer market dependence	.26**	.05
Introducer firm size × market size	–.21*	.09
Introducer market dependence × market size	.03	.06
Control Variables	**Estimate**	**SE**
Competitor firm size	.26**	.05
Competitor market dependence	.14**	.04
Market size	.11*	.04
Market growth	.01**	.002
Market concentration	.03	.04
HIV category	–.04	.13
Prior product introductions	–.25**	.08
Order of response	–.10**	.01
Frailty parameter	.04**	.02
Log-likelihood value	–3650.81	
Wald χ^2 statistic	210.90**	

B: Probit Model Estimates (Dependent Variable: Response)

Variable	Estimate	SE
Introducer firm size	.486**	.121
Introducer market dependence	.492**	.120
Introducer firm size × market size	–.744**	.229
Introducer market dependence × market size	.182	.143
Competitor firm size	1.635**	.187
Competitor market dependence	1.137**	.124
Market size	.210*	.104
Market growth	.017**	.004
Market concentration	.035	.086
Prior product introductions	–.418**	.093
Order of response	–.588**	.115
HIV category	.106	.266
Intercept	–.956**	.227

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

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. Whereas consumer response models are often calibrated with detailed empirical analyses of responses from current and future customers, competitor response models are often ad hoc and based on subjective judgments (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 they send about their own 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. 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 article suggest a need to rethink this conclusion.

TABLE 5
Bootstrap Analysis

Hypothesized Variables	Estimate	SE
Introducer firm size	.65**	.11
Introducer market dependence	.53**	.076
Introducer firm size × market size	–.56**	.21
Introducer market dependence × market size	.01	.12
Control Variables	**Estimate**	**SE**
Competitor firm size	1.15**	.13
Competitor market dependence	.43**	.08
Market size	.25**	.10
Market growth	.01**	.004
Market concentration	.08	.06
HIV category	.06	.14
Prior product introductions	–.37*	.16
Order of response	–.20**	.03
Frailty parameter	.04**	.02
Log-likelihood value	–3650.81	
Wald χ^2 statistic	338.98**	

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

Our results emphasize the need to examine markets dynamically, not just by considering them as they are today but as they could be tomorrow. Radical product innovations can cause previously 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 a signal 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 because of fears of retaliation (Robinson 1988; Shankar 1999). This logic would lead to the conclusion 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 just the opposite. Specifically, 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 in which the large firm enters a small market because 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 Further Research

This research has several limitations, and some of these can provide avenues for further research. Although testing our model within the context of a single industry and using the U.S. pharmaceutical industry in particular have advantages, we acknowledge the specific characteristics of this industry, including heavy regulation, preannouncement of innovation research, the particular speed of innovation cycles, and a mix of firm sizes ranging from extremely large multinational corporations to small companies. We believe that confidence can be placed in the direction of the effects we observed in this research because most of the effects are predicted by our hypotheses or replicate prior research (regarding the role of theory and replication in research generalization, see Blair and Zinkhan 2006). 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, nonprescription drug markets, various unregulated markets), innovation cycles (e.g., semiconductors, electronics, paint), or concentration (e.g., aircraft manufacture).

In addition, we consider only one dimension of response, 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 be on the product dimension as well (and especially so for radical product innovations), it would nevertheless be worthwhile to examine, for example, how large versus small firms behave on other marketing-mix dimensions when reacting to the introduction of a radical product innovation.

It would also be a worthwhile 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, as is common with most studies that use secondary data, we inferred firm decision making from observed outcomes. It would be useful to supplement our study with primary data obtained from managers to examine how decision making is influenced by the variables we suggested and to examine whether there are any important variables our study omitted.

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