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A Simultaneous Model for Innovative Product Category Sales Diffusion and Competitive Dynamics

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Abstract

Diffusion of innovation has been the focus of an entire stream of research in marketing, and firm entry and exit decisions have been investigated by marketers, strategists, and economists. However, little attention has been paid to the relationship between changing demand and the entry and exit behaviors of competitors in the marketplace. Understanding this relationship is essential in making resource commitments, as profitability of options depends not only on the size and growth of the market, but also on the number of competitors likely to be encountered. This is particularly important in innovative markets, where changes occur rapidly and one cannot assume that either customer needs or competitors faced tomorrow will be the same as today. We simultaneously model demand and number of competitors, including the interactive relationship between these dynamics in the marketplace, and empirically investigate three technology-intensive markets—video cassette recorders, personal computers, and workstations. Our results suggest that competition and demand impact entry and exit, but that the nature of this impact may depend on whether or not a 'shakeout' has occurred in the marketplace. Further, an increasing number of competitors may lead to improved marketplace offerings, resulting in demand expansion.

Keywords: Innovative; Entry; Exit; Demand; Diffusion

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1. Introduction

Assessing market attractiveness is particularly difficult for firms considering entry into an innovative marketplace, because of rapid product development and unpredictability of eventual customer acceptance. However, projections of both demand and competition are essential inputs to strategic planning (Day, 1990; Kerin et al., 1990; Schnaars, 1991), particularly when a firm makes a decision to enter or exit a dynamic marketplace. Previous research in marketing has addressed demand dynamics through diffusion of innovation (see Mahajan et al., 1990a for a review), as well as entry and exit behaviors defining the number of competitors in a marketplace (e.g., Bridges et al., 1992). However, to our knowledge, no research investigates the interaction between these two key factors influencing competitive success. Our primary purpose in the present paper is to develop understanding of the dynamic, simultaneous relationship between demand and entry/exit timing of competitors in an innovative marketplace.

Patterns of market demand depend on such influences as stage in the product life cycle, current and potential market size, and growth rates (Day, 1977, 1986). Forces impacting the level of competition in the marketplace include rivalry among existing firms and availability of potential entrants (Porter, 1980; Day, 1986). Firm decisions to enter or exit a market may be based partially on observed product category sales and competitive entry and exit behavior, but they are also driven by managerial expectations regarding directions and rates of change in these key indicators. Further, degree of and changes in competition (reflected in firm entries and exits) may impact marketplace demand. Consequently, we posit a dynamic, interactive relationship between sales and number of competitors in the marketplace.

How can demand and competition influence market entry and exit decisions? Even if market potential and growth projections are favorable, a firm may choose not to enter a market due to predictions of intense competition, because such rivalry can dampen margins and profits by reducing revenue potential (e.g., through price competition) or increasing costs (e.g., for advertising or customer service) (Porter, 1980; Kerin et al., 1990). In addition, a firm may choose not to enter a market with a large number of current or potential competitors because market share can be expected to be low for new entrants, especially when there are substantial customer switching costs, as is often the case in innovative markets (Srivastava, 1987). As noted by Porter (1980), intense rivalry among competitors—which increases with the number of market participants—can deter new entries. Therefore, it is essential to assess current competition and predict imminent entries and exits.

Just as predicted demand and competition may influence market entry and exit decisions, an increasing number of competing firms can also be expected to spur growth in demand and market potential due to more aggressive product development, promotion, and pricing (Horsky and Simon, 1983; Parker and Gatignon, 1994). Several key questions motivate the present research:

- How do demand growth and the nature of the product life cycle affect the entry and exit patterns of competitors?
- Under what conditions does an increase in the number of competitors tend to attract or deter entry?
- How do changes in the number of competitors influence product category sales?

The key objectives of this paper, then, are to examine how, for a product category based on technological innovation, demand growth and competition influence market entry and exit, and how, at the same time, competition impacts sales diffusion. Recent research addresses the impact of development timing on market share for a technology-based product: Datar et al. (1997) find that a product (data network interfaces) which leads the competition in concept and volume production tends to have a higher market share. Bayus et al. (1997) also observe an impact of introduction timing on demand for a technology-based product (personal digital assistants). Others note the need to examine the relationship between the number of competitors and the rate of technology diffusion (Dolan et al., 1986; Mahajan and Wind, 1986; Lambkin and Day, 1989; Mahajan et al., 1990a; Bridges et al., 1991), but this interactive relationship has not, to our knowledge, been modeled. We address this need by developing and testing a system of simultaneous equations, where the dynamics of demand influence the rate of competitive entry and exit, and vice versa. Posited relationships are examined based on empirical applications in the video cassette recorder (VCR, personal computer (PC), and workstation markets.

The remainder of this paper is organized as follows. We first review selected diffusion of innovation research to develop two propositions describing the impact of competition on demand. Next, we explore the economics, strategy, and marketing literatures to develop an understanding of the nature of relationships between demand growth and firm decisions to enter or exit a marketplace. This leads to two propositions each regarding market entry and exit behavior. Our propositions are implemented in a system of simultaneous equations to capture posited relationships. Following estimation, we present our findings, and discuss their theoretical and managerial implications. We conclude with limitations and suggested extensions of our research.

2. Demand modeling and diffusion of innovation

A very successful means of predicting aggregate demand for new durable products was proposed by Bass (1969). The Bass diffusion model is useful in projecting industry sales to first-time purchasers in a new marketplace: potential buyers may purchase due to innovative and or imitative motivation. This model expresses change in cumulative sales over time as:

$$\frac{\mathrm{d}N(t)}{\mathrm{d}t} = \left[p + q\frac{N(t)}{M}\right]\left[M - N(t)\right] \qquad (1)$$

where $N(t)$ is the number of previous adopters of the durable good as of time t and M is the total market potential. The parameter p is often referred to as the coefficient of innovation (or external influence) because it reflects the impact of activities such as advertising and promotion on adoption. Similarly, q is often referred to as the coefficient of imitation (or internal influence) because it captures communication internal to the social system, i.e., interaction between the $N(t)$ adopters and the $[M - N(t)]$ potential adopters who have not yet purchased.

A number of researchers have tested extensions to the Bass model that incorporate competitive marketing mix variables such as price (Robinson and Lakhani, 1975; Kalish, 1983), advertising (Horsky and Simon, 1983; Teng and Thompson, 1983), product characteristics (Srivastava et al., 1985), and combinations of variables (Kalish, 1985; Parker and Gatignon, 1994). Dolan et al. (1986) provide an outstanding, detailed discussion of how competitive impact may be incorporated into diffusion models via marketing mix, product differentiation, and other decision variables.

In a special issue of the *Journal of Marketing Research* on the topic of competition in marketing, Eliashberg and Chatterjee (1985) suggest that primary demand may be stimulated by competitive marketing efforts, and that research is needed regarding the dynamics that follow multiple market entries. In a recent study incorporating competitive effects into diffusion models, Parker and Gatignon (1994) use brand-level data from a consumer product category to test various specifications of first-purchase diffusion models. As predictors, they include cumulative adoption by brand, as well as brand-level marketing mix variables. While the best model specification differs by brand (possibly due to order of entry or awareness/image of the brand name), this work opens a door to further consideration of effects of competition on diffusion.

We have seen that diffusion models can be modified to incorporate the effects of multiple marketing mix variables, but these effects may themselves be correlated. That is, increased competitive activity may simultaneously lead to price rivalry, enhanced advertising and promotional activity, a larger number of products and brands on the market, and improvements in product performance. One way to address the influence of various marketing mix activities is to use a single variable for current marketing effort, as suggested by Bass et al. (1994). Consistent with this and with the viewpoint of Mahajan and Wind (1986, p. 20), we suggest that the number of competitors in a marketplace is an indicator of current category marketing effort.

In light of the evidence presented, we anticipate that as the number of competitors in a marketplace increases, rivalry among them may have two effects on sales diffusion. First, to the extent an increase in competition leads to rivalry resulting in price reductions, we might expect the available market potential to increase. Second, increasing competition may lead to increases in distribution and/or promotional activity that tend to enhance innovation, or external influence on adoption decisions. We accordingly suggest the following propositions:

P1: *Available market potential increases with number of competitors.*
P2: *External influence on potential adopters increases with number of competitors.*

3. Perspectives on market entry and exit

As mentioned earlier, perspectives on market entry and exit are drawn from the economics, strategy, and marketing literatures. Researchers in economics address firm decisions to enter an innovative marketplace and the timing of such entry: in this stream of research, a decision to enter is typically made when the present value of expected profit gains compares favorably to the cost of a firm's investment in a new technology (e.g., Barzel, 1968; Gort and Wall, 1986). Kamien and Schwartz (1972) propose a model that considers the presence of competing firms in evaluating expected profits: under their model, rewards to a firm are greater if it introduces the new technology before any competitors have entered the market. Thus, a firm may wish to enter an innovative marketplace earlier if competitive entry is anticipated—this suggests that entries and competition increase in a new marketplace as long as expected profits are attractive.

Economic models do not have as much to offer when one wishes to assess the impact of product demand on market entry decisions. Economists often assume that demand is known (or uncertain with a known distribution); consequently, the interdependence of demand and competitive entry is neglected. For example, Gort and Klepper (1982) make the restrictive assumption that demand is constant over the life of a technology. Klepper and Graddy (1990) offer a more comprehensive model, in which drivers of firm entry and exit decisions include the number of potential competitors and the rate of change in firm sales. However, they assume that changes in demand depend only on changes in price, and not on any other effects of competition in the marketplace. Under these assumptions, entries tend to increase as the market develops and sales increase, and to drop when sales begin to slow.

Recent works by economists further address firm entry and exit over time. According to Klepper and Miller (1995) and Klepper (1996), there are innovative marketplace regularities that relate the numbers of entries, exits, and competing firms. These regularities suggest that the rate of entry may initially rise or fall, but that it eventually begins to decline. Exits may also increase, but eventually stabilize. Timing of these changes is related to the peak in the number of competing firms. If there is a 'shakeout' (substantial decline in number of competitors after a peak), entries tend to fall off sharply while exits remain relatively stable and may rise. Thus, a change in entry is the key difference between a market which has undergone a shakeout and one which has not. For product categories that have experienced a shakeout, Klepper and Miller find that entry peaks before the peak in total number of competitors in the marketplace, then declines precipitously. Exits do not tend to decline in tandem with entry, but more slowly over a longer period of time. For product categories which have not yet shaken out, entries tend to rise steadily to a peak, and exits increase with entries.

Similar points of view regarding entry and exit decisions are offered in the strategy literature (Porter, 1980; Harrigan, 1985). From the industry structure perspective, potential entrants are motivated by profit potential and deterred by entry barriers (e.g., cost advantages of early entrants, buyer switching costs, and product differentiation). Entry opportunities may be afforded by changes in entry barriers or by mechanisms to overcome the barriers, such as new technological developments. Profit potential is moderated by demand and by structural forces shaping competition: profits are likely to be depressed in industries characterized by a large number of competitors, low growth, low differentiation, and high exit barriers, because these conditions lead to intense price competition and low capacity utilization (Kerin et al., 1990; Schnaars, 1991). Thus, this literature suggests that entry increases following a new technological development, that it increases in tandem with demand, and that it decreases when a large number of competitors leads to a shakeout.

The industry structure viewpoint suggests that exits increase with competition, but they may be constrained by exit barriers such as specialized assets, emotional costs, and adverse effects on shared resources (Porter, 1980; Harrigan, 1985; Narayanan and Fahey, 1989; Kerin et al., 1990; Boulding et al., 1997). Decreases in profit potential, which may occur through decreased demand, may also lead to increases in exit. Although the industry structure perspective posits a clear influence of structural characteristics on entry and exit, it is less clear than the economic literature in predicting the timing of these events.

Several streams of research in marketing relate to entry and exit from the marketplace; these include the product life cycle, pioneering advantage, and competitive entry and exit literatures. The product life cycle perspective, which appears in economics and strategy as well as marketing, suggests that entries are most likely to occur during the category demand growth phase when early entrants (perhaps just a handful) have taken the risk to gain product acceptance, and their success encourages potential entrants. Motivation to enter the market decreases as competition intensifies, and the rate of growth in sales is more than offset by the increasing competition (Day, 1986, p. 90; Mahajan et al., 1990b). As the rate of demand growth decreases and the product category nears maturity, excess capacity typically results, and intense rivalry leads to a shakeout that forces less efficient firms out of the market (Day and Montgomery, 1983). Thus, the exit rate can be expected to increase as the number of competitors increases, and as the rate of sales growth declines (Narayanan and Fahey, 1989).

There is an extensive literature in marketing focusing on the advantages and disadvantages faced by pioneers, early followers and late entrants. Motivations for early entry in growth markets include the relative ease of gaining market share, lower price pressure, experience curve effects, buyer switching costs, and deterrence of later entrants (Day, 1986; Lieberman and Montgomery, 1988; Robinson, 1988). The advantages of early followers over late entrants are less clear, especially in the first few years of operation (Lambkin, 1988). Nonetheless, these findings would suggest a motivation for entries early in the product life cycle—this is substantiated by the recent popularity of process re-engineering and other strategies designed to reduce time-to-market. As a caveat, we note that many of the cited observations supporting early entry are based on analyses of the PIMS (Profit Impact of Market Strategy. database, which does not include firms making early exits from the marketplace.

It is also useful to examine arguments for the advantages of later entry; such arguments may be particularly appropriate in an innovative marketplace because of the rapid rate of change. Wensley (1982) notes that the advantages of early entry are not automatic because of technological uncertainties inherent in new markets. For example, the development of the RISC computer chip negated the experience curve advantages of earlier entrants using CISC chips in the workstation market. Further, there are advantages that accrue to early followers, such as the opportunity to improve upon earlier entries, leading to better products and manufacturing processes, and consequently a reduced likelihood of market rejection. Additionally, firms differ in their approaches to market opportunities—some firms wait for others to establish the market, and then move in with a lower price or a better product—as in the case of GE in the CAT scan market and IBM in the personal computer market. This suggests that the motivation to enter should increase just as the demand growth stage begins. Entries beyond an industry shakeout may be justified as they provide opportunities to buy capacity and market share at 'bargain basement' prices.

Models predicting the number of competitors in the marketplace at the time an entry or exit occurs increase our understanding of firm entry and exit decisions. In the marketing and strategy literatures, the population ecology perspective provides a supply- side model where the number of competitors grows over time according to an S-shaped logistic curve (Hannan and Freeman, 1977; Lambkin and Day, 1989). Several researchers have empirically tested logistic models using either deterministic or stochastic assumptions, and incorporating both exogenous (external) and endogenous (internal) influences on entry. Deterministic models typically use a logistic curve to model firm entry and exit (Bridges et al., 1993) or net entry (Modis and Debecker, 1988). Endogenous influences on a firm's decision to enter a market are those which are related to the activities of other competitors in the marketplace; for example, entry of a large number of firms may suggest a very attractive business opportunity. Exogenous influences are those not related to similar entries by competitors: a breakthrough in development of an innovative technology in-house could certainly impact a firm's decision to enter a dynamic market.

Stochastic models describe probabilities for firm entry or exit decisions, or for net entry. Gort and Konakayama (1982) examine the impact of perception of profit opportunities as well as relative advantage of the potential entrant in predicting net entry. The 'demonstration effect', or positive impact of successful competing firms on perception of profit opportunity, suggests the importance of endogenous forces driving firm entry. Consistent with this, Gottinger (1987) finds that number of competitors in the marketplace is the predictor having the greatest impact on net entry. Thus, indicators of profit opportunities as well as number of competitors should be incorporated into models for predicting entry into an innovative marketplace. We note that, although number of competitors is modeled separately as a function of time, it is implicitly related to the demand-side sales diffusion process; to date, the impact of supply on sales diffusion has seldom been estimated (Jain et al., 1991).

We found only one study in marketing relating demand to entry and exit behavior of firms. Narayanan and Fahey (1989), in a study of the television industry from 1955 to 1981, found that both entries and exits, the latter contrary to expectations, were more likely to occur in early stages of the product life cycle. This unexpected finding regarding exits could have been due in part to inappropriate market definition (see Day et al., 1979; Srivastava et al., 1984). Data regarding sales and competitive entries and exits were combined across the black-and-white and color television markets; thus, apparent early exits could have been due to substitution of the newer technology.

Combining insights from the economics, strategy, and marketing literatures, we develop two propositions regarding firm entry, and two regarding firm exit. Entry is motivated by expected profits; thus, firms enter growth markets that appear to offer increasing demand. As demand does increase, entries tend to increase as well. Early presence of competition may signal an attractive market, but as the number of competitors ramps up, entry begins to decline. In fact, entry may peak before the total number of competitors does. In markets where a shakeout has not occurred, entries may eventually begin to decrease even though demand has not yet peaked. One example where entries occurred early and led sales growth is the PC market: the 'open-systems' licensing approach by IBM inspired rapid growth in the number of 'IBM-compatible' PC manufacturers. In markets that do experience a shakeout, both number of entries and number of competitors tend to increase prior to shakeout. During a shakeout, entry declines precipitously. Sales may be a good predictor of entry both before and after shakeout, because entries increase with demand early in the product life cycle, and fall off sharply as sales decline. An example would be the VHS VCR market, where Matsushita slowly and selectively licensed the technology, leading to an increase in market entry following sales growth. Entry also dropped sharply as sales declined during industry shakeout. We accordingly propose:

P3: *Entries tend to change with sales.*
P4: *Entries may increase with the number of competitors early in the product life cycle, but as the number of competitors continues to increase, entries begin to decline.*

Exit is motivated by increasing competition and by decreasing demand. Early in the product life cycle, exits may increase with entries. This occurs because growth in the number of competitors may lead to adverse industry conditions (over-capacity and enhanced competitive rivalry), and therefore a larger number of exits. Following such an increase, exits tend to stabilize; they tend to remain stable even when a shakeout occurs, and to decline more slowly than entries following a shakeout. Further, exits may be linked to a decrease in industry sales, or a slowdown in demand growth. Accordingly, we propose:

P5: *Exits increase as current sales decrease.*
P6: *Exits change with the number of competitors.*

Interaction among factors driving competition may lead to contradiction of the above propositions (Cable and Schwalbach, 1991). For example, although we typically expect exits when the rate of sales growth begins to slow (**P5**), exits are also related to the number of competitors in the marketplace. Thus, when the rates of entry into and exit from the PC market begin to slow prior to the sales peak, this may be due to declining growth in the number of competitors. In Section 4, we develop a system of simultaneous equations modeling our six propositions, so they can be tested in the three innovative markets.

4. Model development and estimation issues

We anticipate that, as the number of competing firms increases, so do the market potential (**P1**) and the external influence on potential adopters (**P2**). Accordingly, we model sales diffusion as follows:

$$\frac{\mathrm{d}N(t)}{\mathrm{d}t} = \left[\alpha_1 C(t) + \frac{\alpha_2 N(t)}{M(1-\mathrm{e}^{-kC(t)})}\right] \times \left[M(1-\mathrm{e}^{-kC(t)}) - N(t)\right] \qquad (2)$$

where $N(t)$ is the cumulative number of sales as of period t, and thus, $\mathrm{d}N(t)/\mathrm{d}t$ gives the number of sales in period t. Further, $C(t)$ is the number of competitors in period t, and M is the long-run market potential, a constant. Parameters to be estimated include k, a coefficient capturing the effect of competition on available potential market, α_1, a coefficient measuring the influence of competition on sales, and α_2, the coefficient of imitation. Note that $\alpha_1 C(t)$ is similar to the coefficient of innovation in the Bass model, but varies with the number of competitors present in the marketplace during period t. The term $M(1 - \mathrm{e}^{-kC(t)})$ is the dynamic market potential, which increases to an asymptotic value of M as the number of competitors increases. Thus, it captures the increase in potential demand that can be expected as a result of a larger number of competitors. Further, its form is consistent with approaches suggested by previous researchers (Mahajan and Peterson, 1978; Ziemer, 1992). Propositions **P1** and **P2** are tested by examining the significance of k and α_1, which are expected to be positive. The coefficient of imitation, α_2, is also expected to be positive.

We defined $C(t)$ to be the number of competitors in the marketplace at time t; further, we use $C_1(t)$ to represent the cumulative number of entries, and $C_2(t)$ to indicate the cumulative number of exits at time t. Thus, $C(t)=C_1(t)-C_2(t)$ is an identity. Note that $\mathrm{d}C_1(t)/\mathrm{d}t$ and $\mathrm{d}C_2(t)/\mathrm{d}t$ are the numbers of firms entering and exiting the market during period t, respectively. Entries during period t are expected to depend on both demand (**P3**) and the number of competing firms (**P4**). Accordingly, we model the number of entries during period t as:

$$\frac{\mathrm{d}C_1(t)}{\mathrm{d}t} = \beta_1 \frac{\mathrm{d}N(t)}{\mathrm{d}t} + \beta_2 C(t) \qquad (3)$$

where β_1 and β_2 are coefficients reflecting the inclination of potential competitors to enter the market as a function of demand (**P3**) and the number of competitors (**P4**), respectively. Propositions **P3** and **P4** are tested by examining the significance of β_1 and β_2, respectively. β_1 is expected to be positive; as sales increase, entries should increase, and vice versa. β_2 is expected to be positive early in the product life cycle, but to be negative as competition begins to drive down entries.

Exits during period t are expected to increase as current period sales decline (**P5**) and/or as the number of current competitors increases (**P6**). Accordingly, we model number of exits during period t as:

$$\frac{\mathrm{d}C_2(t)}{\mathrm{d}t} = \gamma_1 \frac{\mathrm{d}^2 N(t)}{\mathrm{d}t^2} + \gamma_2 C(t) \qquad (4)$$

where $\mathrm{d}^2N(t)/\mathrm{d}t^2=\mathrm{d}S(t)/\mathrm{d}t$ is the rate of change in current period sales. We expect γ_1 to be negative, as the number of exits is expected to be higher when the change in sales trend is negative (**P5**). γ_2 is expected to be positive, because exits are expected to change with the number of competitors (**P6**). Thus, the dynamic relationship between demand and competition is captured by our system of continuous simultaneous Eqs. (2)–(4).

Because Eqs. (2)–(4) are in continuous form, we approximate them for estimation purposes by taking their discrete analogues as follows:

$$\begin{aligned}
&N(t) - N(t-1) \\
&\quad = \left[\alpha_1 C(t-1) + \alpha_2 \frac{N(t-1)}{M(1-\mathrm{e}^{-kC(t-1)})} \right] \\
&\qquad \times \left[M(1-\mathrm{e}^{-kC(t-1)}) - N(t-1) \right] + \varepsilon_{t1}, \quad (5) \\
&C_1(t) - C_1(t-1) = \beta_1 [N(t-1) - N(t-2)] \\
&\qquad\qquad + \beta_2 C(t-1) + \varepsilon_{t2}, \quad (6) \\
&C_2(t) - C_2(t-1) = \gamma_1 [S(t-1) - S(t-2)] \\
&\qquad\qquad + \gamma_2 C(t-1) + \varepsilon_{t3} \quad (7)
\end{aligned}$$

where $[S(t-1)-S(t-2)]$ approximates the first derivative of $S(t-1)$, and thus the second derivative of $N(t-1)$. In Section 5, we empirically test our six propositions in three dynamic, technology-based markets, including VHS VCRs, personal computers, and workstations.

5. Empirical applications

To estimate our proposed model in the VCR, PC, and workstation markets, we require entry, exit, and sales data for each market over a period of time. This time period must include the early years of the diffusion process for each innovative product. Sales data for the VCR market were obtained from the *Electronics Industry Association*, while entry and exit data were assembled from *Underwriters Laboratories*, *Inc.*, *Consumer Electronics*, and *US Government publications*. Personal computer sales data were obtained from *Predicasts*; entries and exits were based on data compiled by *InfoCorp*. Workstation sales, entry and exit data were assembled from issues of *Electronics* and *Electronics News*. A summary of our data is provided in Table 1.

Table 1
Sales, entry, and exit data for the three innovative marketplaces

Year	VCR			PC			Workstation		
	Sales	Entries	Exits	Sales	Entries	Exits	Sales	Entries	Exits
1976				0.01	6				
1977				0.03	9				
1978	0.402	1		0.07	14	1			
1979	0.475	1		0.18	17	1			
1980	0.802	1		0.39	15	1			
1981	1.471	2		0.91	20	1	0.1	1	
1982	2.02	0		3.01	20	5	0.3	2	
1983	4.127	7		5.41	24	15	2.9	4	
1984	7.881	0		6.58	19	19	10.1	3	
1985	11.786	6		5.61	13	25	24.5	5	2
1986	13.533	35		6.34	11	8	45.4	4	2
1987	13.231	5	10				117.0	2	3
1988	12.733	4	13				186.0	7	0
1989							282.0	3	2

Sales are measured in millions of units for VCRs and PCs, thousands of units for workstations. Entries and exits are measured in number of firms.

For each of the three markets, we estimate Eqs. (5)–(7) by applying nonlinear seemingly unrelated regression, or NSUR (Judge et al., 1988). For the NSUR estimation, we use the SYSNLIN procedure with Gauss–Newton optimization, in the SAS/ETS package. Because this estimation requires use of lagged variables, model-based predictions and tests of fit with data are restricted to time periods beyond the initial two years in the time series. Table 2 reports estimated parameter values and pseudo-R^2s for the proposed model, while Table 3 provides summary model performance measures, including root mean-squared error (RMSE) and mean absolute deviation (MAD), for one-year-ahead forecasts.

Table 2
Parameter estimates

Parameter	VCR	PC	Workstation
k	0.0807[a] (2.97)	0.0190[b] (2.22)	0.0221[a] (9.44)
α_1	−0.0033 (−1.21)	0.0007[c] (3.36)	0.0005 (0.41)
α_2	1.1732[a] (4.99)	0.5694[c] (3.65)	1.4962[a] (9.20)
β_1	3.7377[a] (5.43)	−3.7911[a] (−4.06)	−0.0168 (−0.77)
β_2	−0.8860[a] (−4.08)	0.3749[a] (8.32)	0.3694[c] (2.55)
γ_1	−1.0720[a] (−8.07)	3.7656[b] (1.92)	−0.0284[b] (−2.10)
γ_2	0.2373[a] (21.05)	0.1032[c] (3.26)	0.1845[a] (4.51)
Pseudo-R^2			
Sales	0.9979	0.9957	0.9995
Entries	0.9460	0.9925	0.9239
Exits	0.9906	0.9726	0.9632

Numbers in parentheses are t-values.
[a] $p < 0.01$.
[b] $p < 0.1$.
[c] $p < 0.05$.

Table 3
One-year-ahead forecasting results

	VCR	PC	Workstation
RMSE			
Sales	1.0088	0.6292	4.9370
Entries	5.1430	4.4590	2.1903
Exits	0.7268	4.6325	0.6440
MAD			
Sales	0.7149	0.4955	3.8703
Entries	3.6804	3.2290	1.8826
Exits	0.6294	3.6442	0.5140

Sales are measured in millions of units for VCRs and PCs, thousands of units for workstations. Entries and exits are measured in number of firms.

Our proposed model incorporates a dynamic market potential, $M(1\text{-}e^{-k\,C(t)})$, that increases with the number of competitors. Because parameters k and M are each part of a multiplicative term in our specification of market potential, and because we have a limited number of data points, it is difficult to separate their effects. Further, the use of a dynamic market potential renders the model less sensitive to external specification of long-run potential M. For these reasons, and to obtain increased stability in estimation (Heeler and Hustad, 1980; Lawrence and Lawton, 1981), we assume constant values for the long-run market potentials (M) externally estimated as 70, 45 and 2 million for the VCRs, PCs and workstations, respectively. We arrived at these constant values through triangulation of several sources, including (1) interviews with product managers in the relevant industries, (2) estimation of the Bass (1969) diffusion model incorporating market potential as a parameter, which obtains estimates of market potential based on sales to date, (3) total number of members of key target markets, and (4) market potential estimates from such industry publications as *Byte* magazine (January, 1983, p. 166).

The following observations are warranted based on parameter estimates for Eq. (5), which appear in Table 2:

- *Impact of number of competitors on the available market potential* (**P1**): In all three markets, k is positive and significant, which means that market potential increases with the number of competitors, strongly supporting **P1**. We note that the larger k value in the VCR market (relative to the PC and workstation markets. suggests the available market potential grew more rapidly to the long-run potential in this market.

- *Impact of number of competitors on external adoption influence* (**P2**): The coefficient representing the impact of competition on external adoption influence, given by α_1, is positive and significant in the PC market, supporting **P2**. In the workstation and VCR markets, the coefficient α_1 is not significant. Hence, we find support in the PC market for our proposition that the rate of sales diffusion is enhanced by an increase in the number of competitors.

Parameter estimates for Eq. (6), which describes the pattern of market entries, are also provided in Table 2. We make the following observations.

- *Impact of current sales on market entry* (**P3**): Entries are observed to vary with sales in the VCR market, as coefficient β_1 is positive and significant. β_1 is not significant in the work station market, and is negative in the PC market, implying that market entry rates drop as sales peak. Although this result is not consistent with **P3**, it is consistent with a market that has not yet undergone a shakeout, and may have occurred in part because low entry barriers and IBM's 'open systems' strategy brought in a rush of competitors early in the PC product life cycle. Thus, **P3** is supported only in the VCR market.
- *Impact of number of competitors on market entry* (**P4**): Existing competitors are expected to discourage entry in a market that has undergone a shakeout, and β_2 is negative in the VCR market. β_2 is positive in the PC and workstation markets, which have not yet undergone shakeout—this is consistent with the idea that the success of early entrants encourages entry. These results support **P4**.

Parameter estimates for Eq. (7), which describes the pattern of exits, are reported in the bottom panel in Table 2. The following observations are warranted:

- *Impact of change in current sales on market exit* (**P5**): Declining sales are expected to boost the number of exits. Coefficient γ_1 is negative and significant in the VCR and workstation markets, as anticipated. However, it is positive in the PC market, which implies that a slowdown in sales growth actually reduced exits. It is possible that exits from the PC market were mitigated after an early sales peak, because newer technology reduced the effects of market saturation. Alternatively, an increase in exits may have begun earlier than anticipated in the PC market, as this market also experienced an early pattern of entry (see **P3** above). Thus, **P5** is supported in the VCR and workstation markets.
- *Impact of number of competitors on market exit* (**P6**): Exits are expected to increase with growth in the number of competitors, leading to a positive coefficient γ_2. This coefficient is positive and significant in all three markets, strongly supporting **P6**.

During our model development, we assumed that marketing mix activity in an innovative marketplace increases with the number of competitors active in the market. While this assumption has precedence in the literature (Mahajan and Wind, 1986; Bass et al., 1994), we can test to see whether it holds for one marketing mix variable, price, in the three markets studied here. If an increase in the number of competitors causes price competition to intensify, prices in an innovative marketplace may actually be more closely related to the number of competitors than to cumulative volume. This would suggest that experience curve effects might not be the primary drivers of price reductions in technology-driven markets, as previously thought (Day and Montgomery, 1983). In our three markets, we find that price is much more highly correlated with number of competitors than with cumulative sales.[3] Thus, the number of competitors in the market can explain competitive price rivalry beyond what is explained by experience curve effects alone.

[3] In the VCR, PC, and workstation markets, price is correlated with number of competitors 0.630, 0.910, and 0.797, and price is correlated with cumulative sales 0.565, 0.195, and 0.343, respectively.

Fig. 3. Predicted and actual exits in each of the three high-tech markets.

We graphically compare the predictions of our proposed model to actual data for sales diffusion, entries, exits, and number of competitors in Figs. 1–4, respectively. In these figures, we note the following:

- *Ability to capture demand peaks*. In the VCR and PC markets, the proposed model captures the year in which demand peaked, although it slightly overestimates sales in early years and slightly underestimates later. Further, the model shows very good fit in the workstation market, which had not yet peaked.
- *Ability to capture entry patterns*. The proposed model captures the patterns of entry quite well in the VCR and PC markets. In the PC market, the actual entry peak was a year later than the estimated entry peak; the estimated entry peak for the VCR market was right on target.
- *Ability to capture exit patterns*. The proposed model captures patterns of exit in all three markets. Exits in the PC market, although high immediately after the sales peak, declined abruptly thereafter, possibly due to opportunities opened up by improved technology. Early exits in the workstation market may have been due to the rapid rate of technological innovation in that industry.
- *Ability to estimate number of competitors*. By combining predicted patterns of entry and exit, our proposed model performs well in estimating the numbers of competitors in all three markets.

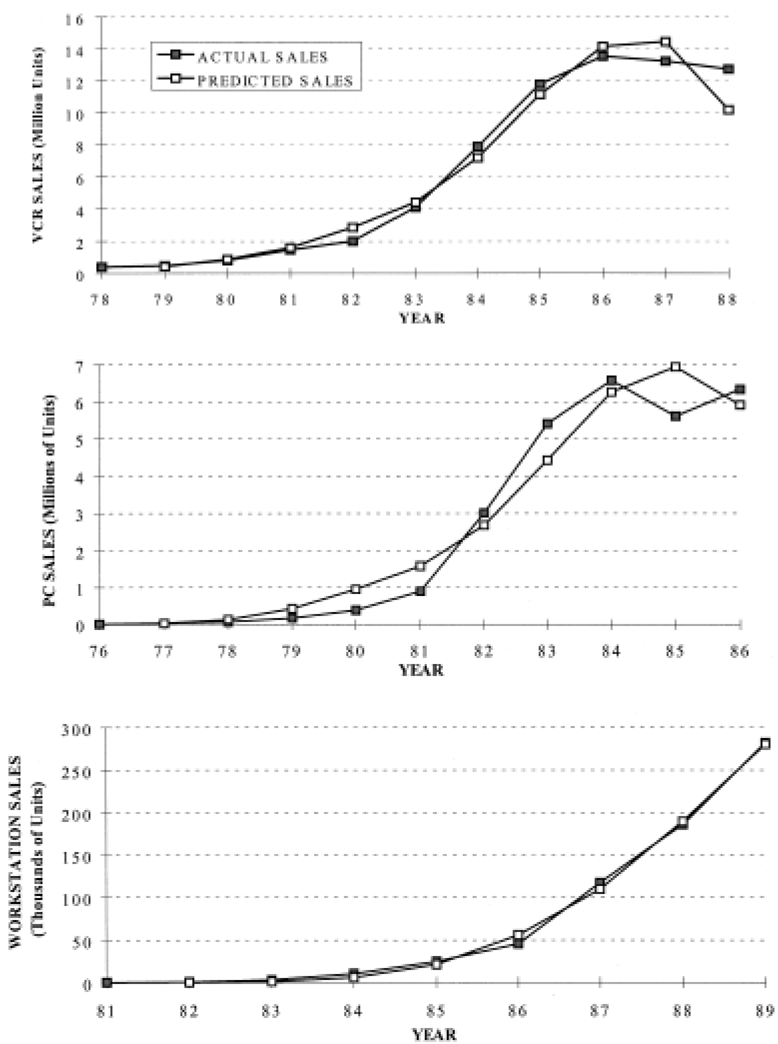

Fig. 1. Predicted and actual sales diffusion in each of the three high-tech markets.

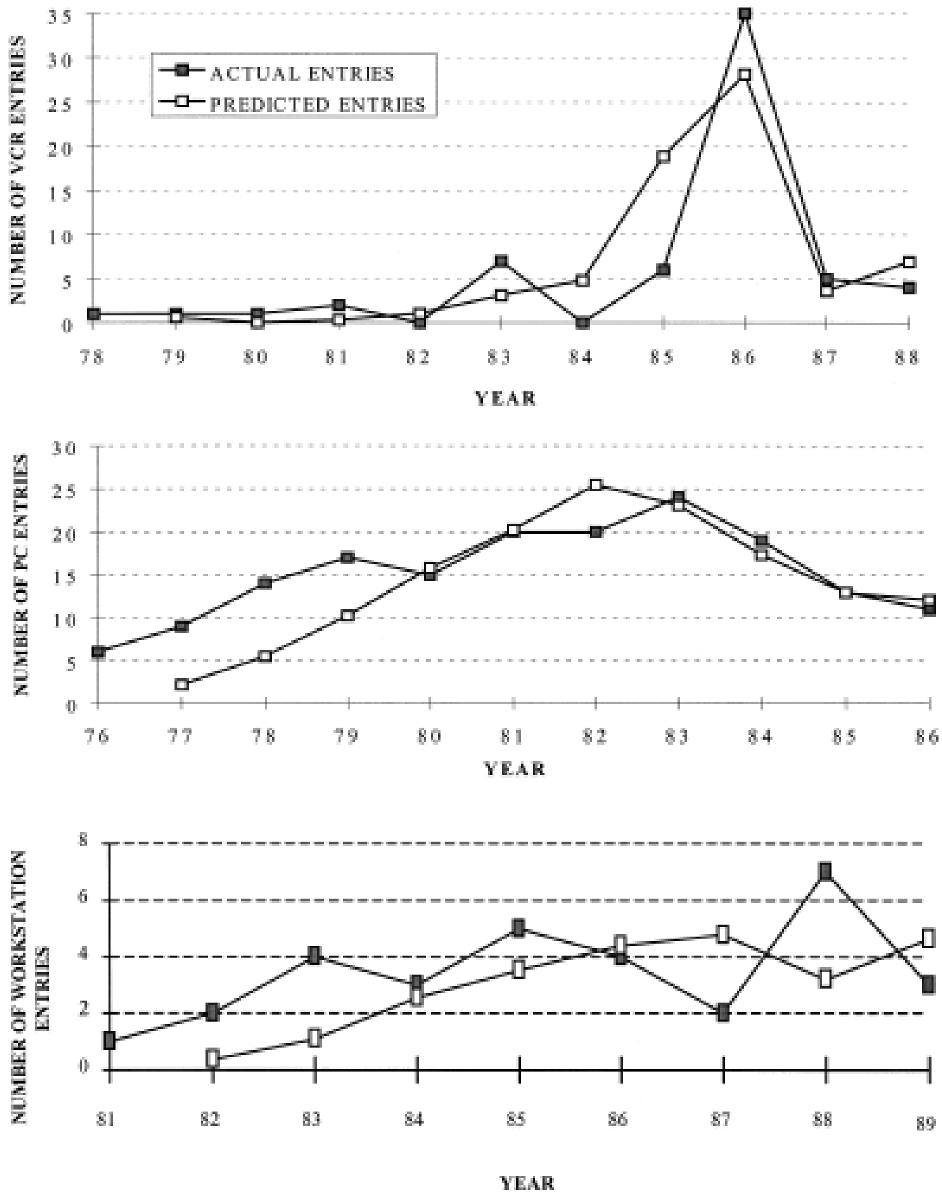

Fig. 2. Predicted and actual entries in each of the three high-tech markets.

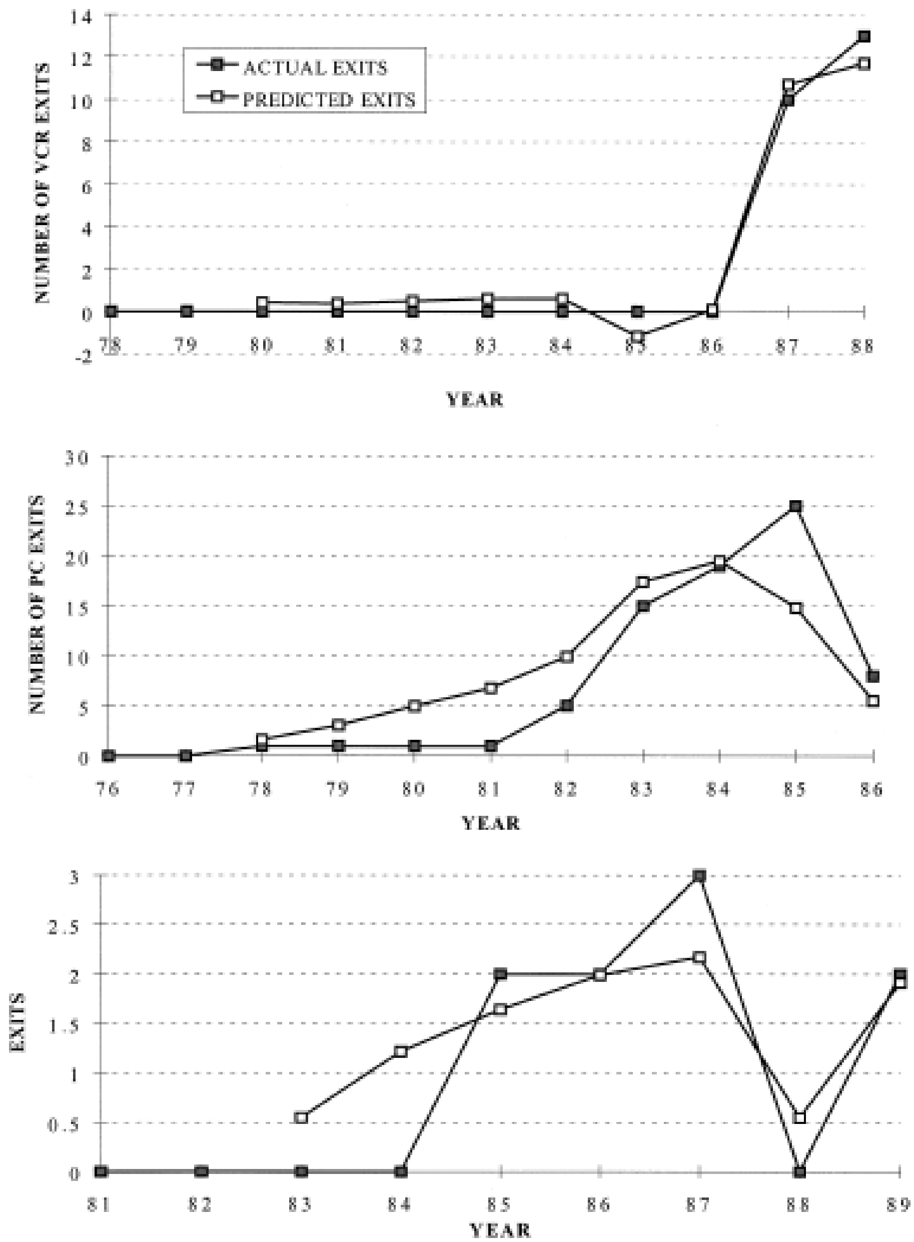

Fig. 3. Predicted and actual exits in each of the three high-tech markets.

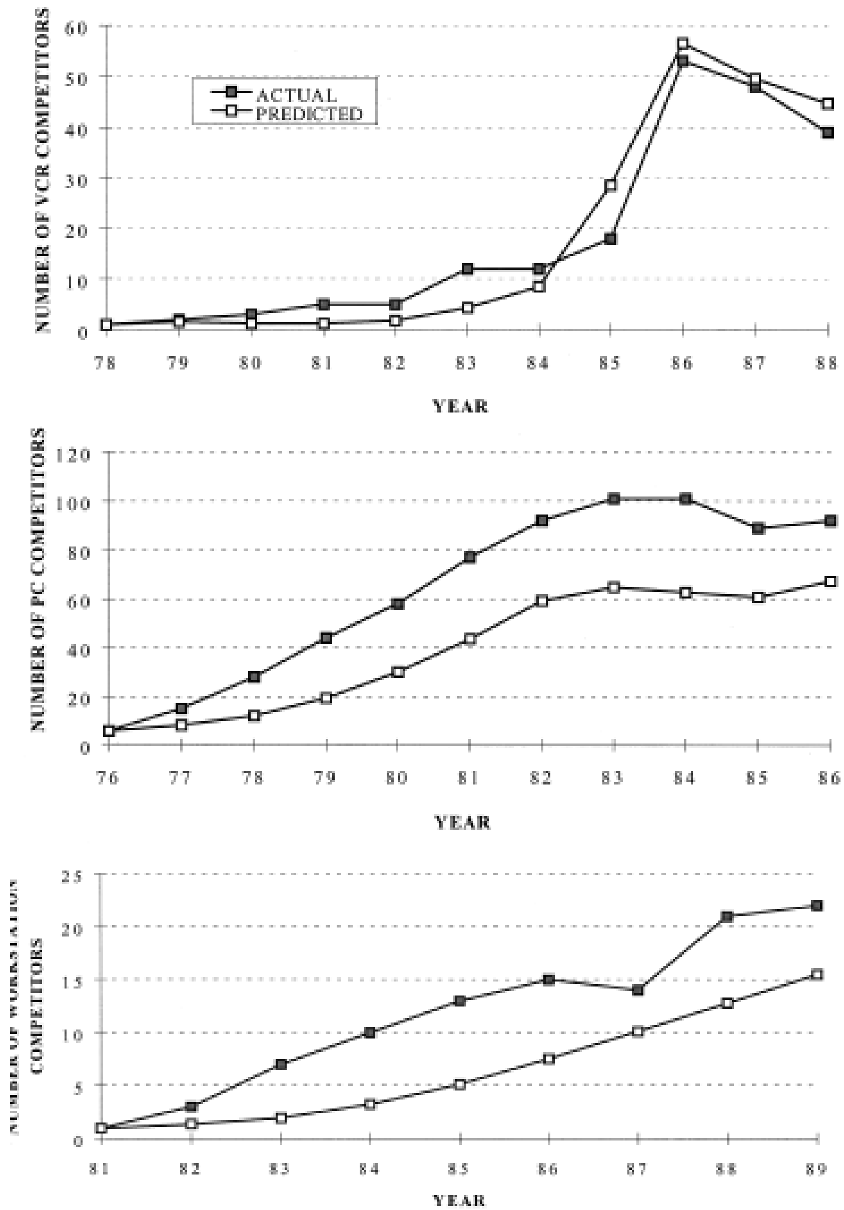

Fig. 4. Predicted and actual number of competitors in each of the three high-tech markets.

6. Managerial implications

Analysis using our proposed model, which simultaneously captures the sales diffusion of a technology- based innovation and marketplace entries and exits, leads to several important implications. First, we estimate dynamic market potentials for three innovative markets as a function of the number of firms competing in the marketplace, finding significant and positive relationships in all three. Thus, we find support for our proposition that an increase in the number of competing firms contributes to expanding the ‘pool’ of potential buyers, possibly by enhancing exposure to the product category through promotional activities. Further, as the number of competitors increases, rivalry among them may drive down prices, thus increasing the market potential. Thus, our results are consistent with the idea that the number of competitors in a dynamic, innovative marketplace is a good surrogate measure for marketing mix activity.

Second, we posit that an increase in the number of firms competing in the marketplace will enhance the rate of diffusion in early stages of the product life cycle through the coefficient of innovation; we find this effect to be significant in the PC market. Managerially, this implies that manufacturers such as IBM (in the PC market. and Sun Microsystems (in the workstation market. would benefit from the ‘competitive support’ provided by other (possibly licensed. entrants whose participation may increase the rate of diffusion for their technology. Further, this may enhance the likelihood of the technology becoming the industry standard.

We are able to do a good job of predicting entry, and find support for our two related propositions. Entry tends to be positively related to sales in markets that have experienced a shakeout, but negatively related when a shakeout is imminent. Further, entry tends to be encouraged by the presence of competition prior to a shakeout (possibly due to perceived risk reduction) while after a shakeout the opposite is true. Our proposed model also does a good job of predicting exits: we find strong support for our proposition that exits increase with competition, and. some support for the idea that exits increase with a slowdown in sales. Note that these results are consistent with our propositions, which suggest that entry is related to current period sales while exit is related to change in current sales.

Finally, our proposed model is able to capture and fit turning points in patterns of sales diffusion, entries and exits; thus, we observe anticipated relationships. Entries and exits are systematically related both to the number of current competitors and to sales diffusion patterns. As expected, the vast majority of entries occur during the demand growth phase. Exits tend to occur when the number of competitors has grown to a point that not all of them can supported in the marketplace. Exits also tend to increase as sales decline, although this is not supported in the PC market. This may be because an industry shakeout does not occur during the time period of the available data, or because of improvements in technology that persuaded firms to remain in the market.

In summary, understanding the relationships between competitive entry and exit decisions and patterns of diffusion has important managerial implications, including the following:

- *By modeling demand in connection with competitive entries and exits, it is possible to make better strategic decisions regarding entry, exit, and resource allocation*. For example, if a new product can be introduced prior to the majority of anticipated entries and prior to rapid growth in demand, it may be worthwhile to allocate additional resources to complete the product development effort quickly.
- *Advance warnings of marketplace dynamics can be used to make more informed assessments of such issues as the need for capacity and the likelihood of price rivalry*. For example, if a shakeout is imminent, a late entrant may avoid some development costs and instead take advantage of substantially lower costs of acquiring market share and production capacity when another firm exits the market.

7. Discussion and conclusions

Our primary objective is to improve understanding of the relationships between market entry and exit patterns, demand growth and competition, and market potential. To this end, we develop a model, grounded in theory and research from economics, strategy, and marketing perspectives. For example, the economics and strategy literatures suggest that market entries are based on supply-side factors, and we model the market entry rate as a function of both demand and competition. As such, our research provides an important link between the sales diffusion and strategic planning literatures—one that is both desirable and necessary to understanding of product-market evolution.

Overall, our findings clearly demonstrate the dynamic relationship between innovative product diffusion and competitive entry and exit behavior. Our results strongly support proposition **P1**, which states that market potential increases with the number of competitors, and provide some support for **P2**, which states that the coefficient of external influence is enhanced by an increase in number of competitors. Proposition **P3**, entries change with sales, is supported in the VCR market, and **P4**, entries increase with competition except after a shakeout, is supported in all three markets. We note that standardization and low entry barriers characterize the PC and workstation markets, which have not yet undergone a shakeout in the time frame of our data; these characteristics would also be consistent with early entry. Regarding exit, our results support **P5**, which states that exits increase when current sales decline, in the VCR and workstation markets, and **P6**, which states that exits increase with an increasing number of competitors, in all three markets. It is possible that **P5** is not supported in the PC market because exits either increased early due to competition or declined abruptly due to opportunities created by technological improvements.

As noted earlier, our findings have important managerial implications. We observe that market potential increases with the number of competitors in all three dynamic, innovative markets studied. Hence, competition in early stages of the product life cycle may actually expand the available market. Similarly, an increase in the number of competitors apparently enhances the influence of the marketing mix on demand. Our findings indicate that market exits are closely associated with an increase in the number of competitors, but suggest that entry is not necessarily deterred by a large number of existing competitors. In fact, lower perceived risk of market rejection as well as reduced concentration of power in fractured markets may encourage entry. In summary, the proposed model has managerial value because projections of demand growth, dynamic market potential, and market entry and exit are important inputs for strategic resource allocation as well as entry and exit timing decisions.

The proposed model is not without limitations. Model parameters were estimated using a discrete analogue of the continuous model. Although this is a popular practice in estimation of sales diffusion models, it is an approximation and may be problematic due to our limited number of data points in each market. Further, because market entry and exit data take on small values in comparison to sales data, they are subject to wider (percentage) fluctuations. In the workstation market, these numbers are so small that minor changes may lead to major shifts in predicted patterns. Future research in this field should attempt to capture replacement and additional purchases, making it more relevant for modeling relationships in later stages of the product life cycle. Other desirable directions for future research include examining the effects of market structure, entry and exit barriers, and availability of substitute products on patterns of product diffusion, entry and exit.

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