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ANALYZING NATURAL EXPERIMENTS IN INDUSTRIAL MARKETS

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In most industrial markets, buyers and sellers have long-standing relationships, and sales, marketing and market share data are not collected with the same frequency and degree of precision found in consumer markets. For these reasons it is difficult to make quantitative inferences about the effectiveness of marketing instruments. This paper presents an approach for studying industrial markets where the effect of marketing spending can be measured and analyzed. We call these market situations natural experiments. The analysis best applies in those situations where marketing experimentation cannot be justified because of time or cost constraints or for competitive reasons.

First, we develop a procedure to identify markets where sufficient historical variability has occurred to enable statistical analysis. Then a model of industrial market response follows from a set of theoretical conditions. Finally, the model is applied to six case studies with encouraging results. The models fit well and the signs of all estimated coefficients are consistent with *a priori* expectations.

The approach allows quantitative analysis of market response and provides answers to market budget questions such as whether an increase in marketing spending will increase or decrease profitability.

1. Introduction

Industrial marketing is the marketing of goods and services to organizations for use in their business operations. Industrial markets themselves differ dramatically. Products may be high or low ticket items, frequently or infrequently purchased, with many or few customers. Such diversity suggests that a single approach to market analysis is unlikely to fit all situations.

Consider a range of product–market settings. At one extreme, products such as copiers have as potential customers almost all organizations. Potential volume is large, and much variation occurs in the marketing mix (use of broadcast media, frequent price discount programs, targeted direct mail campaigns, etc.). This situation, with a large customer base and high number of purchases per year, has many properties of consumer markets. We refer to this as a "general" purchase situation, to indicate that a large subset of all possible industrial customers comprise the potential market. Other examples include office supplies, business forms, word processing equipment, and telecommunication products and services.

At the other extreme are "products" like off-shore oil rigs whose potential customers are few and well-defined, where no two products are identical—each meets a specific set of demand dimensions—and where the purchase takes months and often years of negotiation. We refer to this as a "custom" purchase situation, where "custom" means that a specially designed marketing effort may be developed for each sale. The sale of products and services to governments and other institutions, and joint development projects between a supplier and a potential customer fall into this category.

Suppose we wish to determine quantitatively the sales response to marketing spending for these two extreme types of situations. For general situations, where there are a large number of purchase occasions, market experimentation, suitably modified for industrial settings, is a feasible and suitable approach for quantitative analysis of sales response. On the other hand, custom situations do not usually provide data bases sufficient for statistical inference, which requires grouping at one stage or another; instead customer-by-customer, situation-specific analyses are required there.

But what of the situations in between? These are characterized by a moderate number of customers and moderate sales rate. With relatively small markets, if the expenditure for marketing experiments is analyzed on the basis of the value of added information, the cost cannot justify the expense. (For a discussion of evaluating marketing spending in this way, see Blattberg [2] and Peters and Summers [37].) Furthermore, buyer–seller relationships are often long-term so that the historical variability needed to read response to marketing strategy variation is usually missing. Finally, it should be noted that analogies to Nielsen and SAMI data, i.e. regularly and frequently collected product–class sales data, do not exist in industrial markets. This lack of data makes sales response modeling difficult and/or extremely expensive.

Some of these products do hold promise for analysis, however. They have markets that have gone through a significant disruption—a major competitive entry, a product modification or some similar event. This disruption gives us knowledge both of causality and of the magnitude of the effect. Following Stouffer [50] and Campbell [6], we refer to the event as a *natural experiment* and the resulting overall change in the market-equilibrium situation as a *market in transition.* Table 1 summarizes our proposed classification.

The objective of this paper is to develop an approach for analyzing natural experiments in industrial markets. We proceed by discussing what characterizes a market-in-transition. A model of market response follows along with an estimation procedure for the model. The procedure is then applied to

Table 1
A classification of industrial marketing situations and analyses

Type of purchase situation	Typical products	Type of market	Preferred mode of analysis
Custom (few customers/purchases)	Oil rigs	Customized	Customer by customer examination
Intermediate	Machine tools	Mixed	Analysis of natural experiments
General (many customers/purchases)	Copiers/supplies	Mass/general	Experimentation

six cases and the results are evaluated. Few examples of time-series analysis of response to marketing spending for industrial products exist in the marketing literature; Weinberg [57] is a well-known exception. The procedure, and the six cases analyzed, represent a contribution in this area.

2. Industrial markets in transition

Most intermediate industrial products will not show enough historical variation in marketing spending levels and competitive activities to allow a statistically significant estimation of marketing effects. A standard approach to overcome this difficulty and to get a clear causal direction of the effects would be to perform a controlled field experiment. As previously mentioned, this is frequently impossible because of timing, costs and institutional constraints. Results are typically wanted yesterday; a field experiment, especially if the product is a durable, may take years to complete and evaluate. The results may be readily available to competitive scrutiny. Costs of performing the experiment may exceed the potential value of the added information. Furthermore, it may be impossible to vary, say, sales call frequency without disrupting long-term marketing programs. Thus, a *natural experiment* in a market-in-transition may be the only viable mechanism to permit response modeling.

Two examples of markets in transition are illustrated in fig. 1. Fig. 1(a) is drawn from the data in case A (see the Appendix). Here, as can be seen, the company introduced marketing spending in a market where nothing had been spent historically. The result was a dramatic increase in market share. Fig. 1(b) illustrates a very different effect (case C, appendix). Here, a number of competitors entered a company's market over a period of years, cutting into market share in a significant way.

Intuitively, a natural experiment can be said to have occurred when some

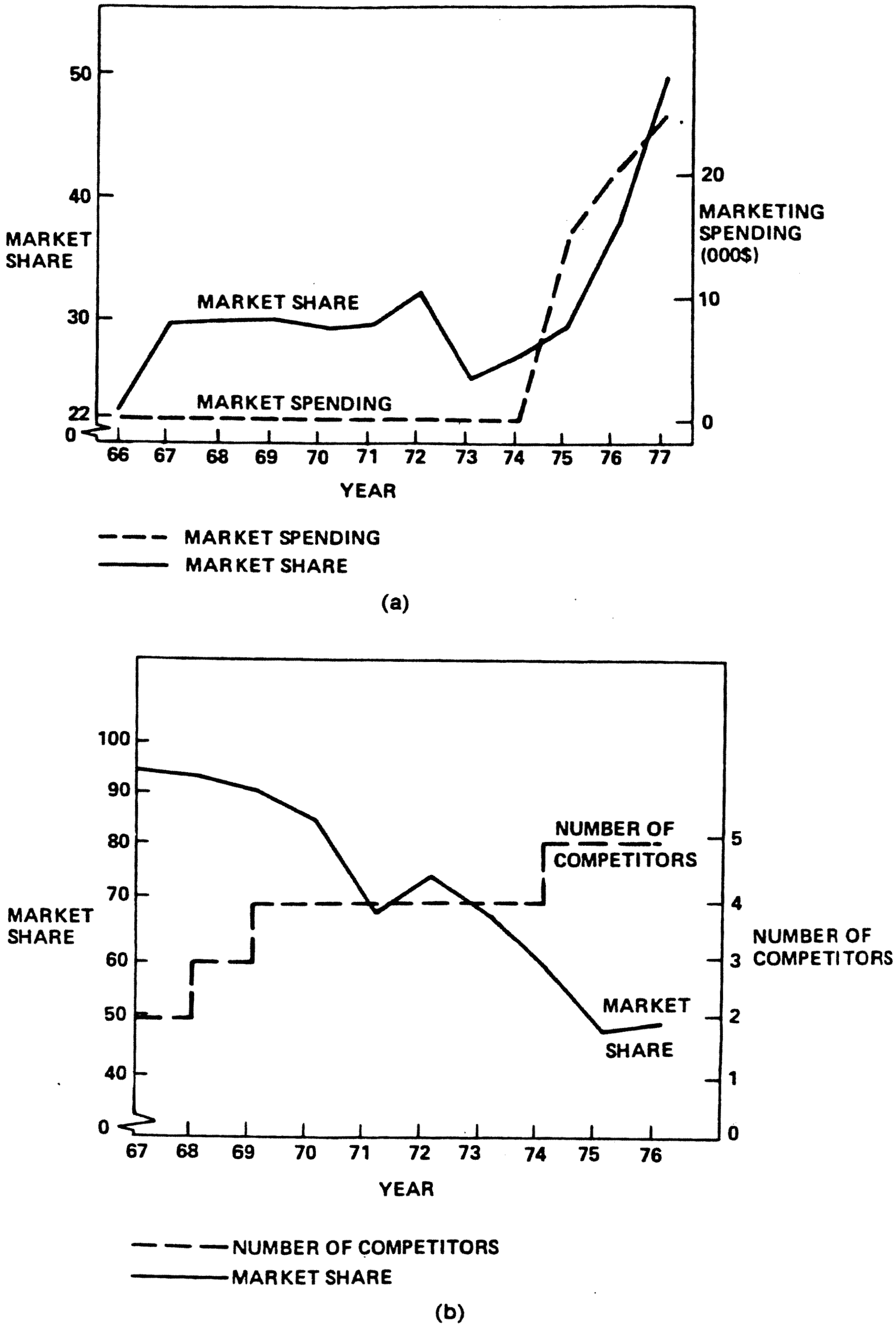


Fig. 1. Some illustrations of natural experiments. (a) Case A—company A's introduction of marketing dramatically increased its market share. (b) Case C—company C's share went down as its number of competitors grew.

dramatic change in the company's historical behavior or in the competitive environment has occurred that could be expected to affect the company's market position. The event or events should be identifiable and the cause-and-effect relationship clear, both intuitively and statistically, for a situation to be acceptable for analysis. This view is articulated by Cook and Campbell [10, p. 296]: "The event being evaluated has to be abrupt and precisely dated, and not a reaction to prior change in the level of the indicator."

Several procedures exist in statistics to operationalize this concept, typically by detecting changes in time series (e.g. see Box and Tiao [4]; Bagshaw and Johnson [1]; Quandt [38]; Chow [9]; Farley and Hinich [15]). All these procedures are founded on the notion of a departure from stationarity of a stochastic time series. Similarly, the theory of statistical quality control (Shewhart [47]) draws upon the same notion, i.e. to establish bounds beyond which an "assignable cause" of variation is expected to have occurred.

None of the above approaches can be used here because of our limited data bases. However, we can use the underlying concept of nonstationarity and design a test suitable for our limited data base. We shall say that a natural experiment has occurred in a market if either the time series of observations on the dependent variable (market share, in general) or any of the independent variables (marketing spending, competitive spending, etc.) is found to be generated by a nonstationary process. The departure from stationarity is observed at the time of a change in the market or the environment and it is identified by the company participating in the analysis. The associated market will be called a market-in-transition.

Following this convention we shall characterize a natural experiment by its deviation from an autoregressive model. In an autoregressive process of order r, the current observation of the variable (market share, m_t, for example), is generated as a weighted average of past observations going back r periods together with a random disturbance, e_t, in the current period. The process can be represented with the following equation:

$$m_t = d_0 + d_1 m_{t-1} + d_2 m_{t-2} + \dots + d_r m_{t-r} + e_t. \tag{1}$$

The necessary and sufficient condition for stationarity of this process is given by Box and Jenkins [3]:

$$|d_1|, |d_2|, \dots, |d_r| < 1.$$

Or, the process is nonstationary if

$$|d_1|, |d_2|, \dots, |d_r| \geqslant 1. \tag{2}$$

To identify conditions for a natural experiment we look for situations where expression (2) holds. Condition (2) is a very strong one from the standpoint of looking for stationarity, much stronger in fact than those proposed by Box and Tiao [4] or by Farley and Hinich [15]. However, the data series that we will be working with are quite short, requiring clear, strong conditions of non-stationarity to permit parameter estimation.

Just as large differences are required to see statistically significant differences between two populations when their sample sizes are small, so we must require strong conditions on nonstationarity here, with our short data series.

Ideally, one would like to make a statement about the statistical properties of the estimates in (2). In practice this leads to difficulties, due to (a) the short time series we have available (except for stationary time series which we are not interested in here, when Hibbs' [21] approximation could be used) and (b) the fact that any statistical statement of the characteristics of the auto-regressive coefficient in a nonstationary series depends on the process one assumes is generating the nonstationarity (see Box and Jenkins [3, ch. 6]).

For our purposes, we consider (2) a condition to be satisfied and apply it to the variables (dependent or independent or both) that we hypothesize have undergone a change. The reason for considering both independent and dependent variables, and requiring only one for a disruption, is that marketing activities may vary widely and not affect share (an interesting, and analyzable event); also, share may change without noticeable influence from marketing spending (perhaps from a new sales strategy), suggesting a need to analyze the situation and discover reasons for the change.

3. Analytic approach for industrial markets

Our objective is to assess market response in industrial markets-in-transition. In the previous section, we proposed a small sample procedure to identify such markets. Many candidate products were discarded from the data base of products collected for the ADVISOR project (Lilien [26]) because of insufficient data for complete analysis even if a natural experiment had occurred. This was because, in the industrial markets we were able to observe, data collected more frequently than on an annual basis were misleading and/or impossible to obtain. We found difficulty in separating purchase commitment from signed sales orders and orders from shipments; these quantities were frequently moved forward or backward in time to balance sales quotas. Finer reading of effects simply registered additional noise. Due to personnel turnover and other causes, time histories in many products were difficult to trace, so data streams were often very short. We were forced to discard products whose sales history did not generate quite a few more points than the number of model parameters we wish to estimate.

Fig. 2 presents a flow chart of our analysis. We started with 131 potential

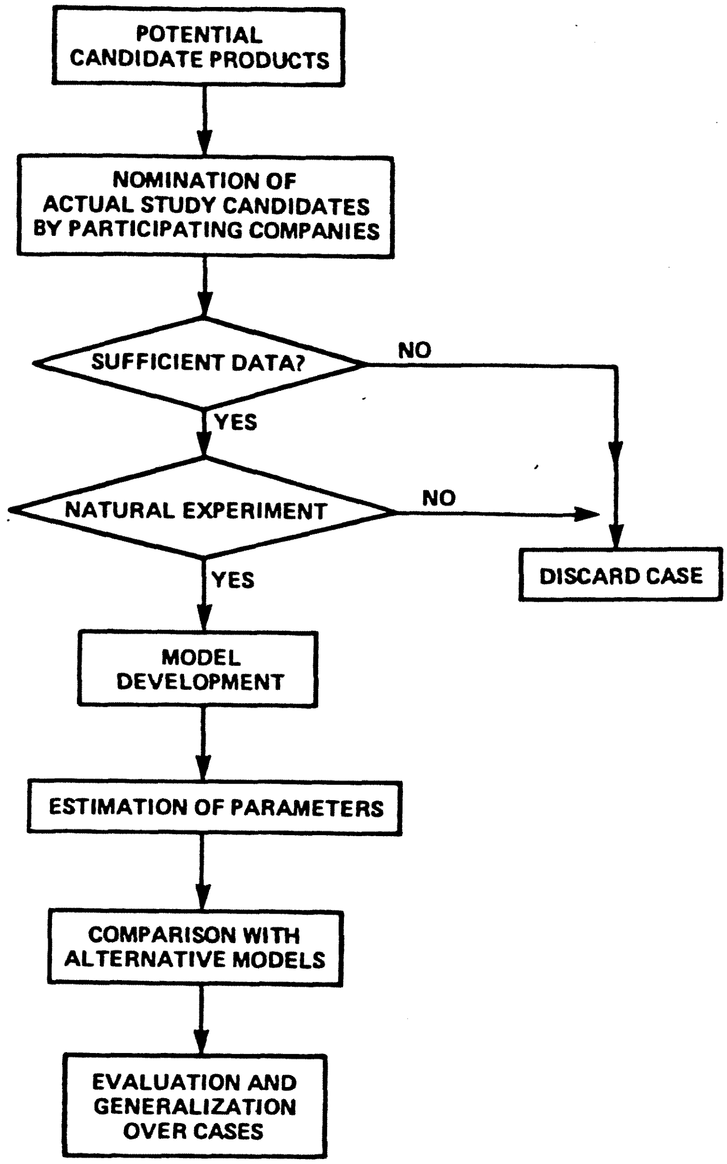


Fig. 2. Outline of analytic approach.

candidate products. Of these, 10 were nominated by participating companies as study candidates, following identification of a potential natural experiment. Of these 10, 3 data base were insufficiently large to enable even small sample estimation and 1 additional case was discarded as not passing the test for nonstationarity. For the products that passed both screens, coefficients of a model, presented in the next section, were estimated. This was done for each situation. Finally, the models of different situations were compared across the cases in search of generalization.

In the next three sections we develop a modeling and estimation approach and then apply it to a number of product-specific situations.

4. A model of industrial market effectiveness

We are interested in a model of industrial marketing effectiveness that is both conceptually sound and managerially useful. Little [31,32], Urban [53] and Lilien [26] discuss strategies related to building marketing models which we follow here. As we were particularly interested in model relevance and use, we interacted heavily with company representatives in the study design, data collection, case study development, modeling and interpretation of results. Recalling that we are dealing with intermediate products, if we draw from Corey [11], Webster [56] and Choffray and Lilien [8], we assert that an effective model of industrial market response should exhibit the following properties:

- The model should relate sales and/or profit to major company control variable(s).
- Market share should vary only between 0 and 1.
- Competitive activity should be explicitly included.
- Zero marketing effort should not necessarily imply zero sales.
- The effectiveness of a marketing program should be greater when the company spends more.
- Long-term relationships between the buyer and seller should be explicitly included in the structure. Reciprocity and long-term buyer–seller relationships are often the rule in industrial markets, so interruptions of marketing should not immediately stop sales.
- The model should have a symmetric structure. By this we mean that if a market has two identical producers with two identical product–market relationships and the same marketing effectiveness, then the model should show these situations as identical.
- The total market for the product is exogeneously given and is not affected in a major way by selling and advertising activities.

The conditions we wish to model incorporate a situation where a few competitors, using product and market "weapons" are "battling" for sales. Lanchester's [24] models of warfare, first introduced into the management science literature by Kimball [23] (and applied by Little [32] in a marketing context), address these issues. Those models also include the special kind of competitive framework one finds in industrial markets where there are few competitors who all know each other well, i.e. a market that could be described in a game-theoretic framework (Von Neumann and Morgenstern [55]). In these analyses companies divide a relatively fixed market and a reasonable model should incorporate the competitive nature of those markets.

For expository simplicity, first assume a market with two competitors, companies 1 and 2. These companies can compete only by changes in the effectiveness of their marketing programs. (Marketing effectiveness will be operationalized later; one can think of it as the dollar amount of marketing spending for now.)

Let

$s_i =$ sales of company i (function of time),
$\varepsilon_i =$ marketing effectiveness of company i, either constant or a function of time,
$M =$ market sales $= s_1 + s_2$ (function of time),
$m_i =$ market share of company i (function of time).

For two competitors, a model consistent with the above conditions is:

$$\frac{\mathrm{d}s_1}{\mathrm{d}t} = \varepsilon_1 s_2 - \varepsilon_2 s_1 \quad \text{and} \quad \frac{\mathrm{d}s_2}{\mathrm{d}t} = \varepsilon_2 s_1 - \varepsilon_1 s_2. \tag{3}$$

The complete solution for (3) follows from:

$$M = s_1 + s_2 \quad \text{or} \quad s_2 = M - s_1. \tag{4}$$

Thus,

$$\frac{\mathrm{d}s_1}{\mathrm{d}t} + (\varepsilon_1 + \varepsilon_2)s_1 = \varepsilon_1 M \tag{5}$$

or

$$s_1(t) = \frac{1}{\mu(t)}\left[M\int \mu(t)\varepsilon_1 \,\mathrm{d}t + c\right], \tag{6}$$

where

$$\mu(t) = \exp\left[\int (\varepsilon_1 + \varepsilon_2)\,\mathrm{d}t\right]. \tag{7}$$

In particular, if

$$s_1(0) = C_1, \qquad s_2(0) = C_2 \tag{8}$$

and ε_1 and ε_2 are constant, we get

$$s_1(t) = \left[\frac{\varepsilon_2 C_1 - \varepsilon_1 C_2}{\varepsilon_1 + \varepsilon_2}\right] \exp[-(\varepsilon_1 + \varepsilon_2)t] + \frac{M\varepsilon_1}{\varepsilon_1 + \varepsilon_2}. \tag{9}$$

The steady-state solution to this equation is the second item in (9):

$$s_1 = \frac{\varepsilon_1}{\varepsilon_1 + \varepsilon_2} M \quad \text{or} \quad \frac{s_1}{M} = \frac{\varepsilon_1}{\varepsilon_1 + \varepsilon_2}. \tag{10}$$

If a large number of observations are available at frequent intervals, parameters of the transient portion of the model can be estimated. However, the steady-state solution can be used in the analysis provided that changes in the market occur within a time period shorter than our period of observation. Little [32] gives evidence of the short duration of advertising influences primarily in consumer markets, which is supported by unpublished research findings from one of our participating companies in an industrial setting.

Eq. (10) generalizes in the case of n competitors to

$$\frac{s_1}{M} = \frac{\varepsilon_1}{\sum_{i=1}^{n} \varepsilon_i}. \tag{11}$$

Assuming that market shares reach equilibrium annually (our unit of measurement), we can use eq. (11) as our response model.

An important issue here is the specification of the functional form of the sales response to marketing. Empirical evidence is not clear on this relationship. In a variety of settings from retail outlet management (Hartung and Fisher [20]; Lilien and Rao [28]) to the measurement of sales call effectiveness (Hyman [22]) there is evidence for a region of increasing returns to marketing effort. The PIMS study (Schoeffler et al. [45]) supports this contention indirectly in a cross-sectional analysis, indicating that decreasing levels of marketing (as a percent of sales) are needed to maintain a given level of sales across a wide range of industry situations. Also, Rao [39] presents evidence in a variety of consumer goods categories for regions of increasing returns, and Wittink [58] finds larger coefficients of advertising spending variables at larger advertising rates, indicating increasing returns to scale.

However, there is also empirical evidence on decreasing returns: Simon [48] reviews a number of studies and concludes that there is diminishing returns to individual brand advertising, and Weinberg [57], in a study of sales response to industrial advertising, concludes that in the region observed there is decreasing returns to spending.

Much of the evidence is inconclusive (Ferguson [16]) but both increasing and diminishing return hypotheses can be accommodated with an S-shaped sales to marketing response hypothesis, the position we take here. This view is supported in the consumer marketing literature by Cardwell [7], Longman [34], Rao and Miller [40], Rao [39], and Little [32] on an aggregate basis and by McDonald [35] at the individual consumer level.

There are several aggregate S-shaped functions that can be used in model (11). Domencich and McFadden [13] indicate that these several closed form S-shaped functions are difficult to discriminate between, and suggest adopting a logistic form for computational reasons. In this case, eq. (11) can be rewritten in the form:

$$\frac{s_1}{M} = \frac{e^{a_0 + a_1 X_1}}{e^{a_0 + a_1 X_1} + e^{a_2 X_2}}, \tag{12}$$

where

X_i = marketing effort for product i
a_i = coefficient of marketing effectiveness, $i = 1, 2$,
a_0 = constant (Srinivasan [49]).

(Note that a little algebra will show that only one intercept term can be specified in eq. (12).) Here marketing spending is the only influence on brand share.

Let us now define marketing effectiveness as the impact of all the components of a brand's activities on its sales. The current marketing effort component of effectiveness can be divided into:

X_i^1 = advertising spending for product i,
X_i^2 = personal selling spending for product i,
X_i^3 = technical service spending for product i.

That is, $\varepsilon_i = f(X_i^1, X_i^2, X_i^3)$.

Variable effectiveness of communications programs (copy/media effectiveness for example) can be included as factors multiplying spending levels.

Dorfman and Steiner [14] suggest that the model should also include variables such as price and product quality. In general, we denote

X_{ki} = market factors, such as communications spending, introduction of new products, etc. for product i ($k = 1, \ldots, K$).

Then, the general model becomes, for two competitors:

$$\frac{s_1}{M} = \frac{\exp\left(a_0 + \sum_k b_k X_{k1}\right)}{\exp\left(a_0 + \sum_k b_k X_{k1}\right) + \exp\left(\sum_k c_k X_{k2}\right)}. \tag{13}$$

In the cases investigated, the nonmarketing factors included technological change (e.g. a clear quality change) and competitive market entries. In the 131 cases examined, no situation was observed where product managers indicated competitive pricing variation was important. This result is perhaps not surprising since oligopolists are considered to substitute nonprice for price competition (see Scherer [47, pp. 334–337]).

Two key simplifying assumptions should be pointed out here. First, we assume the model coefficients are stable during the period in question and that we can ignore higher order interactions in the exponents. Our data will not generally permit these kinds of complications. If sufficient data exist, the model can be extended to examine such complexities as when $\varepsilon = \varepsilon(t)$. A classical treatment of this issue can be found in Forsyth [17, p. 158] with numerical solution tables available in Richards [42, p. 351]. Also, interaction terms can be estimated (see Lerman and Manski [25]).

Secondly, although the generating equation for the model incorporates competitive effort, no mechanism for specifying competitive reaction to a specific company's spending level has been included within the model itself, and competitors have been lumped together as a single competitor for purposes of analysis here.

5. Estimation procedure

The parameters of eq. (13) can be estimated either using regression analysis or a maximum likelihood method (MLE). We decided against a weighted least squares approach (WLS) such as suggested by Cox [12]; Domencich and McFadden [13] have shown that in small samples WLS estimates have a larger systematic bias and mean square error than the MLE, the approach we follow here.

The logistic response function represented by eq. (13) can be written in the following form:

$$\frac{s_1}{M} = \frac{\exp\left(a_0 + \sum_k b_k X_{k1}\right)}{\exp\left(a_0 + \sum_k b_k X_{k1}\right) + \exp\left(\sum_k c_k X_{k2}\right)} + \eta_t, \tag{14}$$

where η_t = a stochastic term with zero mean and variance σ^2.

In constructing a likelihood function here, we assume (and test) whether the successive values of η_t are independent. The results of the test for autocorrelated disturbances is described in section 6.

Oliver [36] has derived solutions for the maximum likelihood estimators of the parameters in (14) and discussed their properties. He has shown, using Monte Carlo simulation, that except under very special data conditions, the maximum of the likelihood function obtained from eq. (14) is unique, even for small samples. His estimator is unbiased and consistent and is the one used here.

6. Application

We have applied the approach to products from the ADVISOR study (Lilien [27]). The results of the stationarity analysis for the relevant variable in the seven products retained for study (see fig. 2) are displayed in table 2. Although first, second and third order autoregressive schemes were estimated, for expository clarity only the first order scheme results are presented here. The stationarity test led to the elimination of one of the cases, case F. (Note that, as described earlier, the paucity of data limits our ability to make statistical inferences about the d's.)

Coefficients of the model defined by eq. (14) were estimated for the six cases studied. Sketches of the case situations are given below, with more detail available in the appendix. Graphs of the critical changes are displayed in fig. 3(a–d), as well as in fig. 1(a and b).

Briefly, the situations are as follows:

Case A: The company discovered marketing, having produced this material since 1966 but only having started a formal marketing effort in 1975.

Case B: This case deals with a significant quality improvement in a widely used material, halting a long-term market share decline.

Case C: In this case, during the period from 1968 to 1974, four new competitors entered the market for a specialty chemical, cutting company market share in half.

Case D: Here, competitors introduced a technological innovation as well as a new end-use form (in 1970 and 1972, respectively). The results affected the OEM and replacement markets differently, and they are studied separately here.

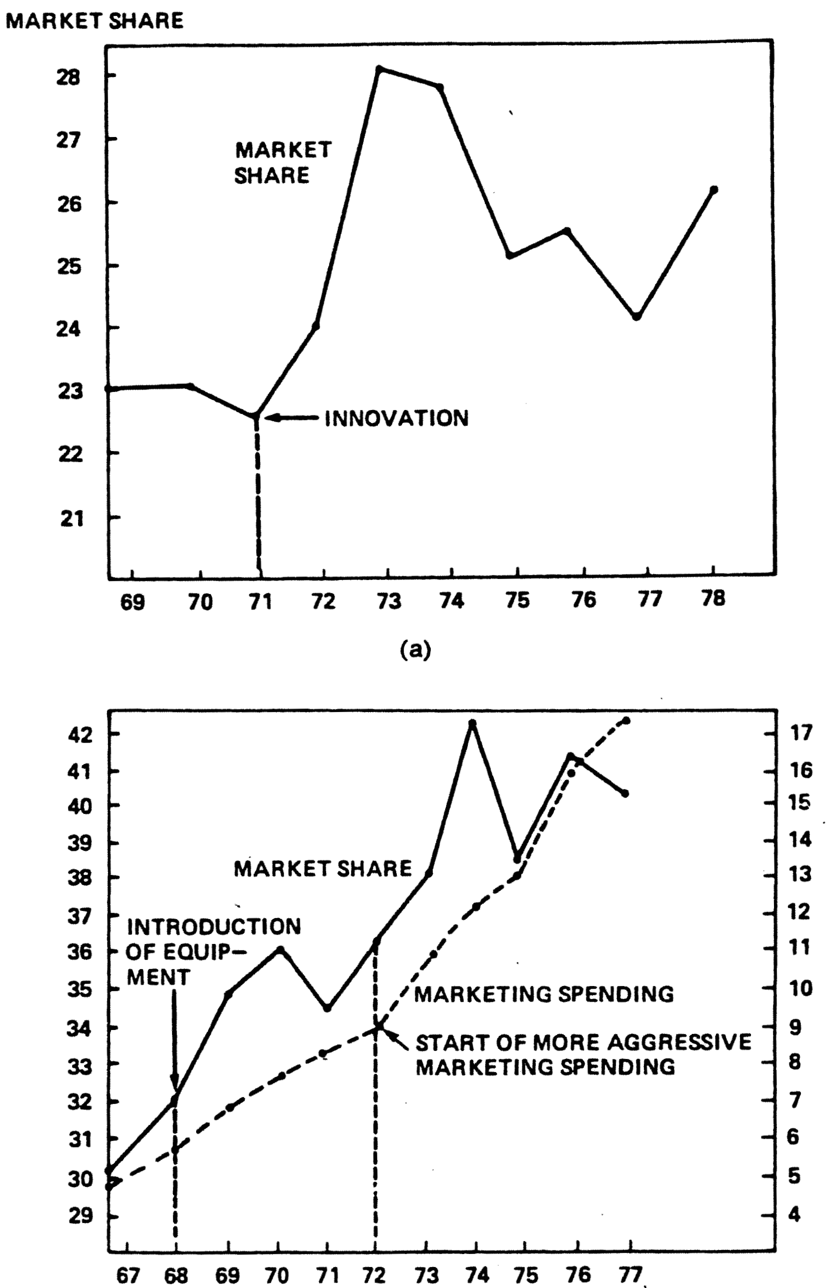
Case E: This case deals with vertical integration, the company adding equipment to what had been previously a supply business only. The

Table 2
Test for stationarity: Coefficients of the autoregressive model indicate that A through E are nonstationary, F is stationary

Case	$\|d_1\|$	Series tested
A	1.24	Marketing
B	1.23	Share
C	1.07	Share
D (new)	1.22	Marketing
D (replacement)	1.11	Marketing
E	1.21	Marketing
F	0.81	Marketing

resulting marketing activity around an integrated system led to a share increase.

It is important to emphasize that the companies were able to provide detailed data for all important variables except competitive marketing spending. These expenditures were generated using the ADVISOR norm model for marketing spending (Lilien [27]). These estimates of competitive spending were then reviewed by the marketing management and reconciled with their esti-



(a)

(b)

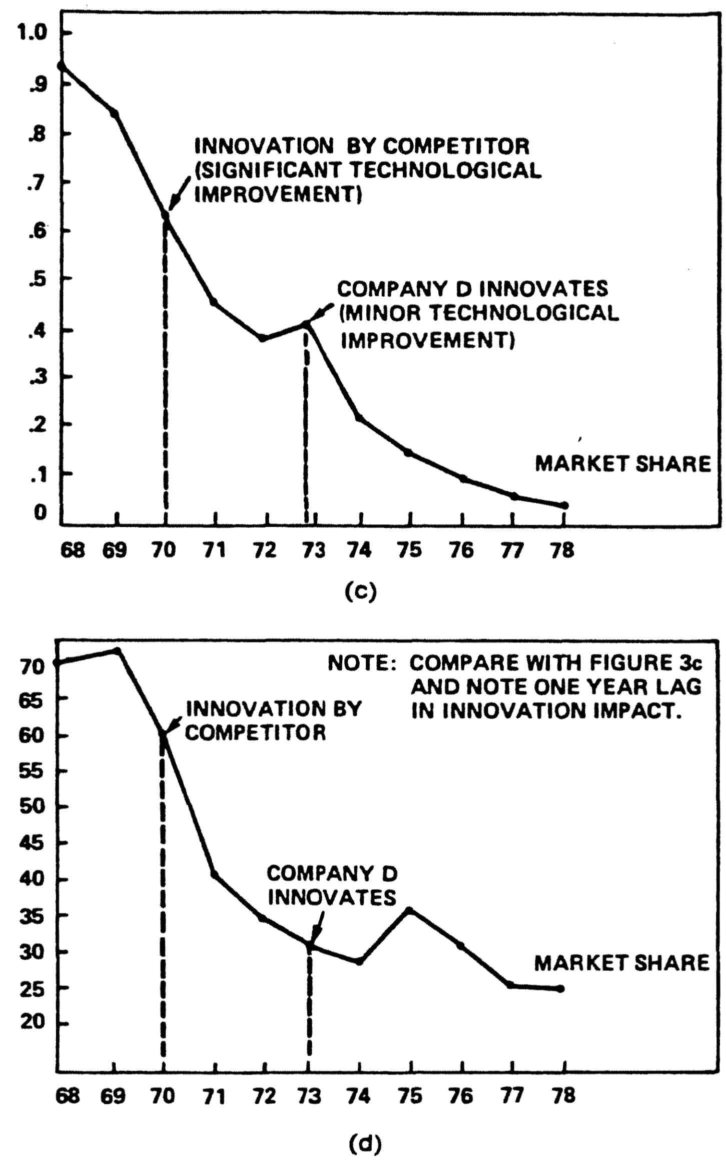


Fig. 3. (a) Case B—company B's introduction of a product improvement boosted its market share temporarily. (b) Case E—company E's introduction of equipment and more aggressive spending program in marketing yielded share growth. (c) Case D (OEM). Market share for product is eroded by market entry of competitive materials in 1970. (d) Case D (replacement). Market share for replacement sales of product is also eroded by market entry of competitive materials, but fall is more gentle, less severe than with OEMs.

mates of competitive spending; in most cases there was no difficulty in resolving differences.

Each of the models was of the general form specified in eq. (14); the key independent variables are defined as:

- Our marketing: Total $ level of marketing effort in year t associated with the product.

- Our sales inertia: Past year's sales in \$, an instrumental variable for sales inertia.
- Competitive marketing: Total \$ level of competitive marketing spending.
- Competitive sales inertia: Past year's sales of competition.
- Environmental factor: a 0–1 or multi-valued variable depending on the case (e.g. in case B it is a dummy variable equalling 1 when the new material was introduced and 0 before).

For none of the models did sufficient data exist to separate out the differential effects of the elements of the marketing mix—personal selling, technical service and advertising; they are aggregated here.

The results of the estimation together with some qualitative descriptors of each particular situation are presented in table 3. The results show that all coefficients have the *a priori* expected sign; for example, an increase in our marketing effort results in an increase in market share while an increase in competitive marketing effort has the opposite effect in all cases. The majority of adjusted t-statistics indicate that the coefficients are significant above the 90% level. As an index of goodness of fit (roughly analogous to R^2) we use one minus the ratio of the log of the likelihood functions (Theil [51], Richards and Ben-Akiva [41]):

$$\ell^2 = 1 - \frac{L^*(a)/(i-k)}{L^*(0)/(i-1)}, \tag{16}$$

where $L^*(a)$ is the value of the log likelihood function for the vector of estimated coefficients and $L^*(0)$ is the value of L^* for the coefficient vector $= 0$, i is the number of observations, and k is the number of variables. Note that ℓ^2 lies between 0 and 1.

A test for the presence of autocorrelated disturbances developed for use in a regression analysis framework was performed using (1) Theil's BLUS estimator and (2) the Durbin and Watson test (or a modified Durbin test for the inconclusive cases). In all six cases the hypothesis that the disturbances were not autocorrelated could not be rejected at the 5% level.

The very small sample sizes for the six models limits our confidence in the estimation results: small errors in measurements of the variables could result in large errors in the estimated coefficients, the corrected t-statistics, and ℓ^2. Thus, all results must be treated with caution; they are more suggestive of the general magnitude of the effect than its exact level.

Other ways of evaluating the sensitivity of parameters besides the corrected t-statistics—such as jack-knifing—(Tukey [52], Sharot [46]) might have been used. However, these methods assume all points to be equally important while our analysis is based on the premise that points around the natural experiment are the most important and thus cannot be excluded from the analysis. For this reason jack-knifing would simply demonstrate that the points around the time

Table 3
Estimation results/case summaries

Independent variable \ Product case	A	B	C	D (New)	D (Repl)	E
Our marketing	0.659(−5) [a]	0.195(−6)	0.318(−5)	0.473(−5)	0.640(−5)	0.402(−7)
	(2.56) [b]	(1.03)	(2.05)	2.70)	(2.76)	(2.01)
Our sales inertia	0.361(−6)	0.189(−8)	0.194(−7)	0.505(−7)	0.540(−6)	0.319(−8)
	(1.76)	(3.75)	(1.81)	(1.41)	(1.02)	(3.82)
Environmental factor	[c]	+0.212	−0.967(−1)	−1.01	−0.81	0.921(−2)
		(2.21)	(1.96)	(1.72)	(1.59)	(1.62)
Competitive marketing	0.217(−5)	0.547(−7)	0.871(−6)	0.195(−5)	0.133(−5)	0.781(−7)
	(1.73)	(1.82)	(2.01)	(1.26)	(1.43)	(1.51)
Inertia of competition	0.123(−6)	0.972(−9)	0.128(−7)	0.873(−7)	0.226(−7)	0.112(−8)
	(1.26)	(1.65)	(1.42)	(1.91)	(1.82)	(1.07)
Kind of change	add marketing	innovation	new competition	comp. innov.	comp. innov.	add equipment
Number of observations	12	11	11	12	12	11
Overall ℓ^2 fit	0.92	0.94	0.90	0.80	0.80	0.86

[a] (−5) means $\times 10^{-5}$.
[b] (2.56) is corrected t-statistic.
[c] not relevant in this case.

Table 4
Relative effects of marketing spending, sales inertia and other factors on market share show that the relative marketing effects differ considerably

Case	Marketing	Sales inertia	Other
A	0.29	0.71	-
B	0.67	0.10	0.23
C	0.49	0.08	0.43
D (new)	0.50	0.03	0.47
DR (replacement)	0.17	0.41	0.42
E	0.11	0.88	0.01

Note: These effects are computed as of the end of the last year of the respective analysis period.

of the natural experiment are very influential in parameter estimation.

Let us then consider what would be a minimal number of observations to obtain statistically valid estimates of coefficients given (a) that the variables of the model are drawn from normal distributions (over intervals before and after change), (b) that coefficients have a 10% confidence level, and (c) that effects have the same magnitude as our estimates. We performed a simulation study to investigate this issue and found the number of points to be about 15; 7 before the change in the market, 7 after, and 1 during the change. Since none of our models has this quantity of data, we must be careful not to overemphasize the accuracy of the parameter estimates.

Assuming for the moment that the parameter estimates are reasonable, what do the models say about the influence of marketing spending on market share? To answer this important managerial question, consider a simple way of relating the relative size of the effects—by multiplying each coefficient by the value of the associated variable and then normalizing. This allows us to compare the relative magnitude of effects across models. Table 4 performs these calculations, showing great variability. For example, note that the new and replacement markets in case D show similar responses to the change in market conditions; however, the new market is much more responsive to marketing effort than the replacement market. Case E shows that the new addition of equipment is not effective in influencing sales (effect = 0.01) while case B shows a much more effective innovation (effect = 0.23). In sum, then, the relative effects of marketing spending compared to other market factors varies widely over the cases studied here.

7. Evaluation and further research issues

The models and the procedure should now be evaluated in terms of statistical fit, conceptual soundness, managerial use and parsimony. As the previous section noted, the models fit adequately. With respect to conceptual soundness, the models were built to satisfy a set of predetermined criteria and used structural forms motivated by other work in marketing and allied fields. The models are intuitively appealing and their soundness is supported by the fact that all the estimated coefficients have the right logical sign.

Since the models are market share response models, they can be incorporated in a profit function to evaluate anticipated marketing program changes. In this sense the models meet the use criterion as well. At the same time, the models cannot be used in a precise, prescriptive manner because coefficient estimates, clearly based on a small number of data points, are sensitive to variations in the data. However, the models suggest policy inferences of the following sort: (a) spend much more, (b) spend more, (c) stay about the same, (d) spend less, or (e) spend much less, than what you are spending now. This type of inference can be made with reasonable assurance and, from a decision-maker's standpoint, is a valuable result. It is an important way of summarizing what is in the data that is available to the manager.

These results were reviewed with the participating companies (Galper [19]) with generally supportive results: the managers interviewed concurred with the recommendations of the model and some plan to modify future spending plans following the analysis.

Finally, the model was compared with time-series extrapolation models. If the model explains real market factors, it should perform better in terms of statistical fit whenever a change occurs. As reported elsewhere (Lilien and Ruzdic [30]) the model performs significantly better than three time-series extrapolation models: the model was compared with a linear trend, an exponential growth model and an autoregressive trend. Several measures of comparative fit were calculated; an indication of the quality of the results is that the *largest* percentage root mean square error (RMSE) for any of the cases was 15% for our model while the smallest RMSE was 44% for any of the extrapolation models.

This discussion suggests that the model and the associated estimation procedure seem to perform adequately in the situations tested. Hence, the procedure developed here appears reasonable for studying markets-in-transition.

An issue we are currently studying is whether the results about market response and the relationship between marketing spending and profitability can be generalized from markets-in-transition to a larger universe of industrial products. This is an important issue as the universe of natural experiments is small.

Investigations of the determinants of industrial product profitability have been correlated by economists and marketers for many years. Economists (e.g. Scherer [43], Vernen [54]) have, by and large, focused on variables that managers cannot control such as the number of competitors and concentration ratios. Marketers (Schoeffler, Buzzell and Heany [45] and Buzzell, Gale and Sultan [5]) have used cross-sectional data, generally without strong guiding theory, to study this problem.

All these results have been cross-sectional in nature. A limitation of cross-sectional analysis is that directions of causality—i.e. what causes high profitability—are often unclear. Firms with large market shares may make more profit, but the high share and the profit may result from high product quality or value. High market share does not "cause" high profit. The company with a poor product and consequent low market share can do nothing worse than try to "buy" market share (Fruhan [18]).

The importance of this research is that our analysis rests on knowledge of the direction of causality. As such, at least in the region close to the current spending level, it can be expected that changes in marketing spending will result in predictable sales and profit changes. As a first step in this direction, consider Π_m, where

$$\Pi_m = \frac{\partial \text{ profit}}{\partial \text{ marketing}} \tag{17}$$

and

$$\begin{aligned} \text{profit} &= \text{revenue} \times \text{contribution} \\ &= \text{industry sales} \times \text{contribution} \times \text{market share}. \end{aligned} \tag{18}$$

Our preliminary results analyzing Π_m using our earlier models as input have been encouraging. If we consider the markets-in-transition as representative samples from the universe of industrial products, then it would be desirable to see if we can relate variations in Π_m to observable product and market characteristics. The development of such a model is beyond the scope of our study here. The work needs development in terms of data generation, theory and estimation. The PIMS and ADVISOR results, however, encourage further work in this direction of cross-section analysis of industry operating relationships.

8. Conclusion

This paper develops a procedure for identifying and assessing market response in markets undergoing natural experiments. A response model and associated estimation procedure has been developed and applied to six case situations.

The situations studied varied greatly, as did model parameters. The results are consistent with *a priori* expectations and provided useful, managerial guidance. There are, however, several limitations. The models assume stable coefficients in changing markets. Competitive reaction is not specifically included: competitive firms are viewed similarly and aggregated into a single "competitor". From the standpoint of estimation, the results are based on small data sets, the situation found in such markets.

There are several directions research in this area can lead. First, we have isolated a set of situations in an industrial marketing setting where causally sound modeling leads to useful managerial results. The concepts and the procedure can, thus, be applied elsewhere. Further research in this area should be aimed at a more integrated procedure, allowing for more elaborate models in those cases where more data are available. That data may be available through longer time series or, more likely, through geographic breakdowns of shorter time series. Given better data a scientific and philosophical basis for analyzing markets-in-transition is required, extendable to different length series; in particular, a theory dealing with the tradeoff between variability and the length of the series should be developed.

Our most promising direction for research is the development of a causal relationship between profitability and marketing spending as applied to the wider universe of industrial products. This would use natural experiments to generate the data base on which to test hypotheses about the determinants of responsiveness and profitability in industrial markets.

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Appendix: Case details

Case A

The company selling the product here was founded in 1937 as an equally owned joint venture subsidiary of two companies. The company's initial product is still an important part of the company's line. The major part of the product line consists of construction products for a variety of applications. Constructed from a proprietary material, this material is produced in a rigid cellular form in blocks by a baking process. It is lightweight, waterproof, vaporproof, and noncombustible. These characteristics, coupled with its dimensional stability and high compression strength, make it well suited to construction applications.

The special situation involves a product application that is totally removed from the company's main business direction. The product is basically the application of the company's cellular material to a specialized need of restaurants and fast food outlets.

The company manufactures material that is sold to distributors who cut and wrap the material, and sell to restaurant supply wholesalers who in turn sell to restaurants. The customer for this market is the restaurant. The material normally is supplied to the restaurant by the restaurant supply wholesalers. There are over 400 restaurant-supply wholesalers in the United States and over 500,000 food service outlets.

These materials are a very small cost of the food service operation and produces low volume for the restaurant-supply wholesaler. Thus, restaurant management is not aware of the cost and usage of the supplies used; rather, their concern centers around attributes such as ease of use, residue remaining, and safety of the process. Restaurant supply wholesalers are in the position of being the buying influence, i.e. their influence is the key to what material is used or not used.

The company had been aware since 1966 that its material has been used for this purpose and began to monitor its sales in this market since then. A research report suggested giving this particular market-opportunity specific company attention and support. This involved a full marketing program, including product design and packaging, branding, authorized distributorships, and a comprehensive communications program directed at restaurant management and restaurant supply houses. As part of this study a restaurant survey was conducted which revealed that in 1973 approximately 50% of the food outlets responding used some form of specialized product; an equivalent survey in 1977 indicated that 60% used such iems. Over this period national market share for the product increased from 25 to 50%, according to the company. (It should be noted that none of the competitors offers exactly the same product.)

Formal marketing effort for the product by the company did not commence until 1975 and due to the length of the distribution channel (three stages) there is lag between the initiation of marketing communication expenditures and the occurrence of a change in sales. Through 1977 the marketing effort expended has been exclusively in the form of personal selling to the company's distributors (converters). In 1978 the company started a low level media campaign directed at restaurant managers, as a form of "pull" strategy to increase awareness, stocking, and promotion by restaurant supply houses. A coupon offer in the ad for a free sample is a key part of the promotional concept.

Fig. 1(a) graphically depicts the market effects.

Case B

The company is one of the world's leading manufacturers in its field, currently holding a 25% share of the world-wide market for this basic industrial product. In 1976 the company's major business accounted for over 50% of its approximately $600 million in sales.

The main product can be broadly divided into two areas. One portion is generally considered to be the more technically sophisticated of the two and is classified by size, shape and material used. The other is also varied by size, shape and material based on the application. Product B is part of this business.

The market for product B has grown since 1967, increasing from nearly $100M in sales to approximately $250M in 1977. Since the product line is a production supply, it is closely related to the level of economic activity. As a result, industry sales have shown some volatility within the overall growth trend. The market is highly diverse by industry segments as well as by annual use. The company estimates that there are in excess of 15,000 user locations that purchase these products. The company, as well as its two major competitors, service the market through networks of selected distributors. Each of these participants has a distribution organization of approximately 600 outlets. Approximately 95% of the company's sales volume is handled by these distributors.

Since World War II, the company had seen its market share in its major business steadily decline as new competitors emerged to offer specialized products and services in limited geographic market areas. This decline was particularly noticeable in the area under study. The company has identified more than 40 competitors in this product area; it considers two to be major competitors and one other to be an important minor one. The top three participants, which include the company, have controlled more than 85% of business over the past several years.

The decline in market share continued unchecked until 1972, when the company introduced a revolutionary new patented material which significantly outperformed existing materials in most applications. Its major advantages were longer life, fast production rates, less operator fatigue and improved operator efficiency (at user organizations).

Initial shipments of this new material in the line took place in the fourth quarter of 1972. The introduced was supported by a major increase in marketing effort which incorporated personal selling, advertising, and dealer promotions. An important objective of the introductory program was the specific effort to "go after" competitive business. This new product program not only stemmed the market share decline, but also reversed the trend, resulting in an increase in market position. This continued until 1975, when a number of internal and external factors combined to intervene and halt the gain. Most significant among these factors were the entry in 1974 and 1975 of the two major competitors with comparable products. This came about as a result of the company's decision to license these two competitors rather than battle them in a lengthy and expensive patent suit.

Fig. 3(b) details the market share history of the product.

Case C

Company C manufacturers a diverse line of specialty chemicals produced primarily from renewable natural fats and oils—the oils of soybeans, coconuts, pine trees, cotton seeds and animal fats. The company's products are used by a wide range of industries in highly diverse applications. In fiscal year 1977 a sales peak of $183.8 million was achieved.

Product C's line are viscous liquids produced by the polymerization of fatty acids. Two important characteristics that these products impart to other materials are thermal stability and flexibility. These products have been used in a variety of applications. Among the most important are surface coatings (paints), synthetic lubricants, inks, and adhesives. The company introduced these products in 1950 and was the sole merchant (noncaptive) supplier for almost 10 years.

The market for the product line expanded rapidly in the early seventies after being stable for several previous years. This growth reflects a shift away from petroleum-based chemicals in favor of those with a more consistent and renewable supply. Since 1973, when approximately 26 million pounds were shipped, the market dropped more than 25%, reflecting the 1974–75 recession. Current shipment levels reflect an improved market situation, though company executives indicated the industry has excess capacity. Prices have become less stable over the past five years as a result of volatile raw material costs and dramatically expanded competition. An important element in the market structure for this product is the limited number of prospective customers, which has been estimated by company executives to be approximately 300. Company C currently supplies products to about 65% of these.

One of the most significant aspects of this market is the rapid change that took place in the competitive environment during the period from 1968 to 1974. Until that time the company and one other firm shared the market with most of the competitors' capacity being used internally. By 1974 there were four additional firms supplying the product for the merchant market and two companies with substantial capacity dedicated to internal requirements. In 1976 the company was still the dominant supplier in this market, but it had an expanded number of competitors.

Since 1968, when the third participant entered the field, the company has seen a steady drop in its market position in the merchant market. From 93.5% in 1968 its share has dropped to just under 50% in 1976. This loss of market share very closely parallels the increase in competition witnessed over this same period. In addition, the decline in participation was undoubtedly accelerated by a reduction in marketing communications expenditures during these years as well. Most notable was a nearly 55% reduction in technical service support over the 10-year period.

Fig. 1(b) gives details of the rise in number of competitors along with the associated drop in market share.

Case D

Company D is the world's leading manufacturer of its class of products, which are manufactured in two basic forms: (1) one type used in construction products, and (2) the other used for weaving fabrics and for reinforcing plastic, rubber and paper products. In 1976 the company reached the billion dollar sales level; it has grown dramatically since 1973, nearly doubling its sales between then and 1976.

Product D is made from filament, which is produced through an extrusion process. The filament is then impregnated (coated) with rubber and combined through twisting with other impregnated filaments into a yarn. This is the form in which the product is sold to its customers. These customers then weave the yarn into a fabric that is cut into specific sizes and shapes required for their use.

The particular application of this material is a fairly recent development. Experimental work began in 1964 with significant commercialization first appearing in 1967. The development work on this product was supported by the company in cooperation with major customers. This close working relationship between company D and its customers led to a rapid acceptance of this material once the product's superior performance characteristics were demonstrated. Those advantages led to a doubling of the average operating life of the users' products when compared with existing materials.

After initial market introduction, market development and acceptance occurred very rapidly with the announcement of a major customer end product on national television in 1969. An extensive and aggressive promotion effort led to strong consumer acceptance of the end product over the next few years.

According to trade sources there were 219.6 million end products sold in 1976. The market is segmented further into products sold as original equipment (OE) and those sold for replacement. In defining the market served by company D, we have segmented the end use market, since the company's marketing and product development efforts have been directed at specific areas.

With the introduction of product D in 1967, the company became an important factor in this business. It enjoyed dominant market shares in both the OE and replacement markets through 1970, when the aggressive introduction of competitive materials reduced its market position. In 1972–73 a new end use product form was introduced as a premium long-life product. This form also received considerable recognition for the improvements in operating efficiency it provided. The oil embargo and the subsequent concern over energy conservation provided a timely boost to the interest in this product. This culminated in the OE market going heavily into this form in 1974. The company saw its market position in the OE segment deteriorate rapidly over the period. It was, however, making both a technical and a market research effort to determine if a medium priced niche could be developed for its material. These efforts proved successful, and the company introduced its design in 1975, which ultimately led to two OE manufacturers accepting the product for use in 1977.

The company's marketing effort accelerated sharply during the period from 1965 to 1970 and has remained relatively constant since that time in spite of significant loss of market position. Technical service and sales efforts were directed at the customers' customers as well as direct customers. Extensive advertising and sales promotion resources (trade shows, POP displays, and advertising support) as well as sales effort were directed at both independent distributors as well as large retailers. The company considered and rejected a direct consumer campaign as too costly.

Figs. 3(c and d) depict the dynamics of company share movements in this market.

Case E

Company E is a widely known diversified manufacturer. Its 1977 sales volume of over $2 billion reflects steady growth in sales since 1968, increasing by over 240%. Product E represents the supply portion of the product line being studied. The company presently markets a complete system of products and services, including equipment, supplies and support services under a single brand name. The major properties of the product E line are derived from the use of a tough moisture-resistant plastic as the base material. This material was applied to product E in the early 1960s and provided the company with important product advantages in quality and consistency that were well received by users. As a result, the company has been able to receive a 10–15% price premium for its supplies over most competitive brands.

The market for the product has grown nearly three-fold in unit volume since 1969. The market for these products consists of institutions and individual users, totalling approximately 14,000 customers. Most of these products are marketed through specialty distributors (estimated at 300 organizations nationally) who provide inventory services for both individual and institutional users.

The company markets its line of products through a 180-person dedicated sales force. This organization is responsible for servicing 250 distributors as well as approximately 8,000 users. This channel handles over 90% of the company's business in this product line.

The company has approximately eight significant domestic and foreign competitors in this product area. Until recently one competitor held the dominant market share, received a premium price for its product, and matched company E in technological advances in the field. Of late, the leadership position has been yielded to company E due to inattention, according to some company executives.

Since 1960, company E has gained an increasing share of this expanding market. A closer investigation reveals that the gains in unit-based market share have come about at three discrete intervals since 1960. The first of these occurred between 1963 and 1965, when the company's market share increased from 20.8 to 29.2%. The principal factor behind this movement was the introduction of a major technological improvement. The second significant jump in share took place between 1967 and 1969 (29.8 to 34.8%), and this has been ascribed to the company's entry into the equipment business, which permitted it to market an integrated system. This development enhanced the company's reputation as the technological leader in the field. The third sizeable gain took place between 1972 and 1974. Company managers attribute this improvement to their aggressive marketing posture, which is revealed in significant increases in their communication expenditures. In addition they recently implemented programs designed to assist the user in managing his business, training his staff, and enhancing the quality of service. There is also some feeling, as noted previously, that the major competitor's attention may have been diverted to other businesses at this time, which permitted the company to assert industry leadership.

Fig. 3(b) details the market share and market spending history for the product through 1977.

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