Dan Horsky
University of Rochester

Comments on "The Relationship between Diffusion Rates, Experience Curves, and Demand Elasticities for Consumer Durable Technological Innovations"

Traditionally, marketing scholars have focused their attention on demand analysis; that is, they have attempted to explain consumers' response to various marketing activities. By and large, the supply side, or the producer's problems, have been ignored. The Bass paper (this issue) is one of the first marketing studies to analyze both the consumer's and producer's problems. The analysis is within the context of the diffusion of new products. In this note I will synthesize the Bass work and comment on some of the assumptions which underlie it.

The Bass (1969) model of the sales of new consumer durables can be equivalently represented as

$$q(T) = P(T)[m - E(T)], \tag{1}$$

where $q(T)$ are the sales at time T, $P(T)$ is the conditional probability that a purchase will be made at time T by an individual who has not purchased up to that time, and $[m - E(T)]$ is the number of individuals out of the potential, m, which have not purchased yet. That is, $E(T)$ is the cumulative number of product adopters at time T. If it is assumed that the probability of a nonadopter to purchase is dependent on both innovativeness and imitation and that the tendency to imitate is increasing proportionally to the number of previous adopters, then

$$P(T) = \alpha + \frac{\beta}{m} E(T). \tag{2}$$

Equations (1) and (2) lead to the new product sales model,

$$q(T) = \left[\alpha + \frac{\beta}{m} E(T)\right][m - E(T)]. \tag{3}$$

If equation (3) is divided through by m, the density function of time to purchase proposed by Bass (1969) is obtained:

$$f(T) = [\alpha + \beta F(T)][1 - F(T)], \qquad F(T) = \int_0^T f(t)dt. \tag{4}$$

(*Journal of Business*, 1980, vol. 53, no. 3, pt. 2)

0021-9398/80/5332-0011$01.50

In the current paper, Bass incorporates price, $p(T)$ in the demand equation, by modifying (3) from its definitional equivalent $q(T) = f(T)m$ to

$$q(T) = f(T)\, C[p(T)]^{-\eta}. \tag{5}$$

On the supply side, he adopts Arrow's (1962) formulation that marginal production costs decrease as cumulative production increases: $MC(T) = C_1[E(T)]^{-\lambda}$. He proceeds by assuming that managers maximize current period profits, and he obtains, based on the marginal cost function and the assumption of constant elasticity (embedded in [5]), an optimal pricing policy. The policy is one of price reductions as marginal costs decrease. Through substitution of the optimal pricing policy into demand equation (5), utilization of the fact that cumulative sales, $E(T)$, have to converge eventually to the potential, m; and maintaining assumption (4), Bass derives a revised (as compared with [3]) sales equation. He thus obtains two functions which are only dependent on the various parameters and time (or, alternatively, cumulative sales). One describes the time behavior of the product's price and the other describes the product's sales. The models are tested against time-series data of prices and sales relating to several durables and are not rejected in most categories.

The Bass work as a whole is a very elegant treatment of an interesting problem. This virtue has required, however, several strong assumptions; some for the demand side and some for the supply side. First, on the demand side is the form of the demand equation. The assumed density function (4) makes sense when it is based on sales equation (3) with its rationale of word-of-mouth effects. However, in the new work, leaving equation (4) as is but abandoning sales equation (3) in favor of (5) leaves a question about the behavioral rationale for (4). An alternative formulation of the demand equation may be one in which the potential, m, is dependent on price. That is, a reduction in price would be assumed to place the product within the budgetary limitations of a greater number of potential buyers, thus expanding the eventual number of adopters, m.

On the supply side, the assumption that firms maximize their profits for only a single period is probably unreasonable in the case of innovations. The firm has invested money in inventing the product and then introduced it with additional promotional costs in spite of the knowledge that many new products fail and that any expected profits will not be immediate. This suggests that the firm views the venture as an investment, one in which the firm could lose now for the sake of greater future returns. Moreover, in the specific demand and cost models used, the future is dependent on current and past activities. Both the number of future adopters and the future costs depend on how many people adopted so far. Thus it seems that this is a classic case for which multiperiod profit maximization should be used. In fact, given the objective of maximization of discounted profits subject to a demand equation which can be represented as a differential equation, optimal control theory could be used as an optimization tool. It is not clear what type of optimal multiperiod pricing policy would be obtained using the Bass (this issue) model and whether it would still be the often observed policy of price skimming—charging more at first and then less. It is worth noting that Robinson and Lakhani (1975), in an earlier attempt to incorporate prices and costs into the diffusion process, did maximize discounted profits through dynamic programming but obtained a sort of penetration policy—low initial price, then price gradually increasing and, finally, gradually decreasing.

The earlier Bass model (1969) can also be extended to other aspects of the diffusion phenomenon. Economists in the early sixties have proposed similar models related to information spread. Stigler (1961) assumed that information would spread through advertising rather than word of mouth and, thus, that $\beta = 0$ while $\alpha(T) = \gamma a(T)$, where $a(T)$ is advertising at time T. Ozga (1960) assumed that information is spread by word of mouth and that the likelihood that a knowledgeable individual will transmit information increases if he is reminded by advertising, that is, $\beta(T) = \gamma a(T)$. Recently, Horsky and Simon (1979) have postulated that equation (3) can be specified as

$$q(T) = \left[\gamma \ln a(T) + \frac{\beta}{m} E(T)\right][m - E(T)]. \tag{6}$$

That is, they assumed that the probability, $P(T)$, is related to the way the nonadopting population $[m - E(T)]$ receives its information. The innovator receives it and is likely to react to advertising, and the imitator receives the information through word of mouth. In an empirical validation of the model, both advertising and word of mouth were found to be effective. A subsequent multiperiod optimization demonstrated that the optimal advertising strategy is to advertise heavily in the beginning, to get the innovators to adopt and act as word-of-mouth carriers. Then, as word-of-mouth effects pick up, the advertising budget should gradually be reduced.

The introduction of price and advertising into the Bass (1969) diffusion model makes the model of greater managerial relevance. These extensions not only help explain existing managerial behavior but can also aid producers in determining the optimal marketing strategies to accompany the introduction of their new products.

References

Arrow, Kenneth J. 1962. The economic implications of learning by doing. *Review of Economic Studies* 29:155–73.

Bass, Frank M. 1969. A new product growth model for consumer durables. *Management Science* 15, no. 5 (January): 215–27.

Horsky, Dan, and Simon, Leonard. 1979. Advertising and the diffusion of new products. Working Paper, Graduate School of Management, University of Rochester.

Ozga, S. 1960. Imperfect markets through lack of knowledge. *Quarterly Journal of Economics* 74 (February): 29–52.

Robinson, Bruce, and Lakhani, Chet. 1975. Dynamic price models for new product planning. *Management Science* 21, no. 10 (June): 1113–22.

Stigler, George. 1961. The economics of information. *Journal of Political Economy* 69, no. 3 (June): 213–25.