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## Journal of High Technology Management Research



# Multi-stage diffusion dynamics in multiple generation high technology products



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## ARTICLE INFO

Available online 10 May 2015

### Keywords:

Awareness  
Stage wise diffusion  
Technological innovations  
Price  
Unfavorable information

## ABSTRACT

In marketing literature, traditional innovation diffusion models have been used for measuring new product sales growth with mixed results. This is primarily because such models fail to identify the difference between the diffusion of awareness about a new product and the actual adoption by consumers. This aspect is extremely important for manufacturers of high technology products because there is a definite lag between the time of reception of information about a new product and the time when the final purchase decision is made by a consumer. In this paper a new diffusion model has been proposed for products with multiple technological generations. The proposed model treats sales as a consequence of the spread in awareness about new products, and models awareness diffusion by explicitly incorporating the effects of unfavorable information along with the more traditional positive feedback effects. Our framework also incorporates the effect of prices, thereby addressing one of the major limitations of the existing diffusion models. The proposed model has been validated using data on world-wide DRAM shipments.

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## 1. Introduction

High technology markets are characterized as a complex system that exists under rapidly changing technological conditions which lead to shorter product life cycles. The importance of speed in such markets is driven by increasing competition and continually evolving expectations of customers. Apple is the one of the pioneers in technological investments, and has a very loyal set of customers. Due to strong customer loyalty Apple not only attracts new customers, but also retains them by continuously offering new technology innovations. To remain a leader in the industry, Apple has often introduced substitutable products that can satisfy a range of customer need. But the biggest threat to IT companies such as Apple comes from its highly established competitors.

High technology industries periodically introduce new products with better value and added features. But such technological advancements and feature additions do not essentially imply that previous generation products are immediately withdrawn from the market (Bayus, 1994; Jaakkola, Gabbouj, & Neuvo, 1998; Chanda & Bardhan, 2008). For personal computers Bayus (1998) observed that the rate of introduction of a new product is much higher than the rate of withdrawal of existing products from the market. As a result, very often more than one generation of products compete in the same market at a given time.

Rogers (1983) proposed that diffusion should be considered as the transmission of messages related to new ideas that lead to subsequent innovations (products, processes, technology, etc.). As a result diffusion generates expectations of change in receptor behavior which is evident from the adoption or the rejection of the innovation (Bonus, 1973; Lin & Burt, 1975; Weenig & Midden, 1991; Zaltman & Stiff, 1973).

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Thus, it is important to study a multi-stage empirical model that can distinguish the two separate aspects of diffusion—*awareness diffusion* and *adoption* by identifying different factors that influences consumer decision making process. Zaltman and Stiff (1973) reviewed several multi-staged models and observed that there is not a single model that considered the intergenerational diffusion aspect, even though it is crucial from the point of view of high technology industries.

In addition, high technology industries are dependent on the customer feedback effects; word-of-mouth behaviors have strong financial (positive and negative) impact on customer loyalties that ultimately affect growth of a company. Word-of-mouth effect is related to that aspect of consumer behavior where they feel encouraged to talk about a product or company to friends and neighbors. This sets off a chain of communication that could spread throughout the market and in the process creating strong, positive brand images and beliefs. Positive feedback effects can encourage existing customers to spend more on average and encourage potential customers to generate new business, whereas negative word of mouth may decrease the purchasing value (perhaps even defection), as well as increase the potential loss of new business. Thus, it is important to understand the sales growth pattern of innovations introduced in the market, as well as the different aspects that are affected by it.

Unfortunately diffusion modeling of products with technology generations has received little attention (Bayus, 1992a). The objective of this study is to propose an adoption–diffusion model for a multiple-generations product without violating the existing theories of individual behavior. The framework we suggest here is similar to that of Kalish (1985), where the awareness information of a product spreads in an epidemic-like manner, and the actual adoption depends on an individual's expenditure capacity. The model proposed here is a multi-stage mixed influence model for technological generations that relies on explicit assumptions regarding the adoption process.

## 2. Literature review

Several models have been proposed to study the pattern of sales growth of a new product. The Bass (1969) model is one of the most cited publications in this area. The model proposes the division of potential buyers into two groups—innovators and imitators—and models the adoption of a new product to be dependent upon the behavior of these two groups. Despite its good fit to historical data, the Bass model has been criticized for its oversimplifying conclusions regarding the adopter's decision making process without fully accounting for market heterogeneity, as well as, completely ignoring the role of marketing-mix (Bayus, 1992b).

Several attempts have been made to overcome these limitations through analytical modifications (Kalish & Lilien, 1983; Parker, 1991), multi-stage structures (Kalish, 1985), multi-innovations model (Fisher & Pry, 1971; Norton & Bass, 1987, 1992; Mahajan & Muller, 1996; Islam & Meade, 1997; Danaher, Hardie, & William, 2001; Chanda & Bardhan, 2008), individual level parameters (Roberts & Urban, 1988; Chatterjee & Eliashberg, 1990; Lattin & Roberts, 2000; Adner & Levinthal, 2001) or dynamic potential markets (Kalish, 1985; Mahajan & Peterson, 1978; Mahajan & Peterson, 1982; Milling, 1996; Weil & Utterback, 2005).

Furthermore, neither the basic diffusion model nor its extensions explicitly consider the impact of an innovation's characteristics or its perception among potential adopters—they all tend to consider that every innovation is equal. By ignoring the effect of an innovation's perceived attributes on its adoption rate, these models fail to reconcile that there is sufficient evidence to confirm that an adopter's perceptions of an innovation's attributes conditions the rate of adoption (Rogers, 1983).

The market success of a given innovation can also be aided by another product (multi-product interactions) or by product generations (successive generations). Shocker, Bayus, and Kim (2004) point out the relative lack of attention that multi-product growth models have received, compared to other research topics involving diffusion. Norton and Bass (1987, 1992) provided one of the earliest diffusion models that tried to describe the growth in sales for multiple generations competing in the same market. Later on several extensions of Bass model had been proposed for multiple-generation diffusion (Speece & MacLachlan, 1995; Mahajan & Muller, 1996; Islam & Meade, 1997; Jun & Park, 1999; Danaher et al., 2001; Chanda & Bardhan, 2008). But, they all failed to account for market heterogeneity and varied individual sensitivity associated with a new innovation.

Zaltman and Stiff (1973) hypothesized that adoption and diffusion of innovations is the outcome of a decision process. Most of the earlier research distinguishes two separate stages in the decision to adopt—awareness stage and evaluation stage (Bonus, 1973; Hauser & Urban, 1977; Kalish, 1985; Lin & Burt, 1975; Weenig & Midden, 1991). Lieberman (2000) has argued that what separates adoption from awareness is whether the object of adoption has appeal to the potential adopter.

Thus it becomes strategically important to explicitly distinguish between awareness and adoption to identify the different variables that influence the decision process. Van Den Bulte and Lilien (2001) has identified two such factors—marketing efforts and word of mouth—and suggested that the initial awareness of a new innovation occurs mainly through commercial sources such as salespeople and direct mailings, whereas personal contacts with colleagues gain importance in later stages (Coleman, Katz, & Menzel, 1966; Peay & Peay, 1984). Van Den Bulte and Lilien (2001) argued that without distinguishing the awareness stage and evaluation stage it is not possible to compare the effect of mass media and commercial efforts with the effect of word of mouth and other social transmission processes.

## 3. Modeling framework

Success of a new product largely depends on the product's goodwill (consumer perceived utility) and price over time. Therefore, while modeling the diffusion process it becomes imperative to get a clear distinction between the spread of product information and the consumer purchase dynamics (Kalish, 1985). The effective dissemination of initial product-information is very important to increase the awareness and that can be done primarily through advertising. Interpersonal communication and word-of-mouth also play important roles. On the other hand understanding of product attributes (e.g., consistency, robustness, performance) can be

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