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Determining adoption pattern with pricing using two-dimensional innovation diffusion model

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ABSTRACT

Studying the dynamics of the technology diffusions under the key determinants that influence the adoption of a technology across time and/or space into the market is crucial to assess the business case for new technologies. The topic diffusion has been widely studied by researchers from different disciplines, including Sociology, Economics, Psychology and Marketing. However a substantial amount of research has been focused on one dimension: either to examine the individual's adoption of an innovation or to explain the time path of adoption of technologies typically follows an S-shaped curve. The other dimensions of the diffusion of an innovation, has gained less attention. In this paper, we derive a two-dimensional technology diffusion innovation model which combines the adoption time of technological diffusion and price of the technology product. In the proposed model technological adoptions and the role of other dimensions are explicitly taken into consideration by using the classical Cobb–Douglas production function. The model is based on two main assumptions: the rate of adoption growth decreases in price and that there is diminishing returns to time because initial market size is fixed. The proposed model is also validated on a number of datasets and compared with established models. The empirical analysis shows that the model performs better than other one-dimensional diffusion model in terms of parameter estimation and model validity.

1. Introduction

Understanding and analyzing the rate of adoption of a new technology in the market place is of prime importance for a firm to assess the suitability of technology investment that can enhance the profitability. A product can be new in several ways: it can be entirely new for the market or the product is new for the firm but not for the market or it can be new to the segments. Successful new product introductions contribute substantially to long-term financial success and are an effective strategy to increase primary demand. It strengthens the competitive position of the company in the market. But the risk is formidable as for most business organizations especially in high technology product market development is associated with high cost and risks. Mathematical models have been proved to be useful tool for understanding the structure and functioning of a system, predicting future events and prescribing the best course of actions under known constraints. The bulk of the literature on new product sales model is based on innovation diffusion theory. The diffusion of innovation refers to the tendency of new products, practices, or ideas to spread among people. Usually, when new products or ideas come about, they are only adopted by a small group of people initially; later, many innovations spread to other people. Gabriel Trade (1903) first claimed that sociology was based on small psychological interactions among individuals, especially imitation and innovation. Rogers (1962) in his classic book "The diffusion of Innovation" has studied the diffusion process extensively from a variety of view points and concludes that consumers go through a number of stages before accepting and adopting a new product. Diffusion models, like any other mathematical models are simplification of reality. However they constitute a wide range of useful tools, in both academic and business context.

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Many marketing managers are regularly faced with decisions about what product features to offer and what price to charge. These decisions need to consider not only what the customer wants, but also how competitors will act. Innovation diffusion model can be useful for such decision making process. If the diffusion process is successfully modeled, and the components influencing the diffusion is reveled then the forecasting of the innovation's future diffusion is enabled. The topic diffusion has been widely studied by researchers from different disciplines, including Sociology, Economics, Psychology and Marketing. Since the introduction of diffusion modeling in the marketing literature in the early part of 1960, it has become the subject of considerable research interest. The highlight of these researches had been to study the apparent reason of high failure rates of new products and better decision making with the launch of such products (Fourt & Woodlock, 1960; Mansfield, 1961; Bass, 1969). Thus, the diffusion of an innovation modeling has been a very rewarding process. However most of the researches have been focused on one dimension of diffusion: either to examine the individual's adoption of an innovation or to explain the time path of adoption of technologies that typically follows an S-shaped curve. The majority of innovation diffusion research concentrates on modeling this sigmoid diffusion process of an innovation (Rogers, 1983). The other dimensions of the diffusion of an innovation, have gained less attention. The concern of this paper is the development of a theory of timing of initial purchase of new consumer products in two-dimensional frameworks. In this paper, we derive a two-dimensional technology diffusion innovation model that combines goodwill of technological diffusion and price of the technology product by using the classical Cobb and Douglas' (1928) production function. The proposed model of diffusion of new product is modeled as an event based process in which likelihood of the next adopter being in the two-dimensional region is based on two main assumptions:

- The rate of adoption growth, decreasing in price; and
- There is diminishing return to time because initial market size is fixed.

This paper is structured as follows. Section 2 reviews the relevant literature in the domain of innovation diffusion model. Section 3 introduces the model by outlining its assumptions. Section 4 gives the utility of the model by comparing it to existing models. The managerial implications of the current study are discussed in Section 5. Finally, the article concludes with a discussion on the possible extensions and limitations of the model.

2. Literature review

Many models have been proposed in the literature to study the sales growth of a new product (Fourt and Woodlock (1960), Mansfield (1961), Floyd (1962), Rogers (1962), Chow (1967) and Bass (1969)). Since the pioneering work of Fourt and Woodlock (1960) many marketing scientists have proposed sales growth models to measure the effectiveness/success of a new idea or new product among target populations. This high level of interest in measuring the diffusion of innovation has resulted in a large body of publications (Mahajan, Muller, & Bass, 1990). Among these earlier researches Bass' (1969) model is among the most quoted publications in this area. In this section we very briefly discuss the Bass model that has provided impetus for later developments in new products diffusion research.

2.1. Bass (1969) model

The Bass model is based on the assumption that there exists a finite population of prospective buyers who with time increasingly adopt the product. The buyers can be categorized as innovators and imitators depending upon the mode through which they receive the information about the product. Mathematically the model can be expressed as:

$$\lambda(t) = \frac{f(t)}{1-F(t)} = p + q\frac{N(t)}{m} \tag{1}$$

The physical interpretation of the above model is the probability that an adopter will purchase a product at time 't' given that no purchase has occurred till time 't' is a liner function of the number of earlier purchasers.

Where,

$\lambda(t)$	is the hazard rate that gives the conditional probability of a purchase in a small time interval $(t, t+\Delta t)$, if the purchase has not occurred till time 't'.
$N(t)$	is the cumulative number of adopters till time 't'.
m	is the initial market size.
p and q	are the innovation and imitation coefficients respectively.
$f(t)$	is the likelihood of purchase at time 't'.

$F(t) = \int_0^t f(t)\mathrm{d}t$ is the cumulative likelihood of purchasing the product at time 't'.

Eq. (1) can be rewritten as:

$$f(t) = (1 - F(t))(p + qF(t)); \quad \text{where} \quad F(t) = \frac{N(t)}{m} \tag{2}$$