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Profit maximization by virtue of price & warranty length optimization

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ABSTRACT

Warranties serve as persuasive marketing tools: (i) promotional and (ii) protectoral. As a promotional tool, warranties serve to promote the reliability and quality of a product with longer and better warranty terms implying a more reliable product. As a protectoral tool, warranties provide assurance to consumers against defective products that fail to perform satisfactorily over the warranty period. This assurance reduces the risks associated with purchase of the product but introduces some impedimentation in profit management for the manufacturer. Using a two dimensional innovation diffusion model to demonstrate product sales cycle, this study presents a methodical approach to obtain optimal price and warranty length for a product. The model examines significance of these decision variables and estimates the overall maximum profit for the manufacturer. Exponential distribution has been used to represent the life time distribution of a product and the model has been validated using real life data set.

1. Introduction

For most products (such as consumer durables, industrial and commercial products), a manufacturer will have several competitors who are producing similar products and attempting to sell them to a given set of consumers, so that the market (for the product) is competitive. For some specific products (mainly industrial and commercial products), the manufacturer has no competitor so that the market is monopolistic rather than competitive. The market outcome depends on the interaction between several variables. On the manufacturer side, the variables include price, promotion, warranty etc. whereas on the consumer side, product choice (between no purchase/purchase; which of the competing brands to purchase) depends on several variables such as product features, perceived risk, brand, reputation.

The goal of most manufacturing firms is to maximize profit through the market, which includes the stream of profits over time. This may be achieved through increased sales so as to increase earnings. Higher prices increase unit profit. However, for non-Giffen goods, quantity demanded falls as price increases, thereby decreasing sales and earnings. Therefore, producers must choose the appropriate price that can stimulate customers to purchase the quantity that will achieve the maximum profit (Priest (1981)). Customers, in general, regard price as a reflection of the quality of a product. Very often, customers also use warranty

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information to assess the quality of a product and to decide if the price is appropriate. Thus, price and warranty are the two major factors that decide the sales and ultimate profit of a product.

Price is the easiest and most direct signal that customers use to evaluate a product. Standard economic approaches (screening and signaling) to product quality imply an upward sloping relationship between price and product quality (George (1996)). Customers will inevitably apply price as a clue to form their attitude about a product if they lack complete information (Suri and Monroe (2003)). On the other hand, warranty, as a signal of quality, has a direct impact on producer's costs and the ultimate pricing of a product through warranty length. Priest's market signal theory (Priest (1981)) posits that warranty terms are used by consumers as a signal of product reliability. Short warranty length does not make customers confident enough about product quality, while long warranty length may bring about unnecessary cost to producers. Lutz (1989) found, through empirical evidence, that the relationship between warranties and product quality is consistent with the use of warranties as signals of product quality when consumer moral hazard is present.

A warranty represents the commitment for producers to restore the functionalities of faulty products within a certain period after it is sold. Several kinds of warranties are available on the market; most of them guarantee the repair of faulty products that are still within the warranty period (Wang and Pham (2006)). Other types of warranties guarantee free replacement of faulty products within the warranty period, and are generally found with products whose maintenance costs exceeding replacement costs. In approaching the problem of finding the optimal control paths of pricing and warranty length that may assist management in devising market strategies, the determination of warranty length and price of a product plays a very important role. Since the decision on one will affect that of the other, both variables must be considered at the same time to maximize profits.

Diffusion research is the branch of marketing that aims to answer these important questions of modeling the sales cycle of new products. Since its start in the 1960s, diffusion research has been, and still is, the only modeling framework in marketing that is targeted at modeling the entire life-cycle course of an innovation from the perspective of communications and consumer interactions. Earliest and most famous first purchase models of new product diffusion in marketing is by Fourt and Woodlock (1960), Mansfield (1961) and Bass (1969) that attempted to describe the penetration and saturation aspects of the diffusion process. However, the main impetus underlying diffusion research is the Bass model. It focuses on the development of a life cycle curve and serves the purpose of forecasting first purchase sales of innovation. But, Bass model like most of the other diffusion models studies the time path of adoption or examines the individual's adoption of an innovation and doesn't spotlight on any other dimensions of marketing. Therefore, in the proposed optimization problem we consider a two-dimensional technology diffusion innovation model proposed by Kapur, Singh, Chanda, and Basirzadeh (2010) which combines the adoption time of technological diffusion and price of the technology product. Sales rate is dependent not only on time but price is another important aspect that governs the pace of adoption. Therefore the marketing diffusion model must incorporate marketing variables like price and marketing decisions must be made jointly so that the ultimate goal should be the result of the improved effectiveness with an increase in the net profits to the firm.

Using the mathematical structure of Cobb and Douglas (1928),

$$x(t, r_s) = t^{\alpha}.{r_s}^{1-\alpha}$$

where, x is the value of the product; t is the continuation time of the product in the market; r_s is the revenue per unit; α is the output elasticity.

The two dimensional model considered in the paper is given by the following differential equation:

$$n(x) = \frac{dN(x)}{dx} = p(m - N(x)) + \frac{q}{m}.N(x)(m - N(x)) \tag{1}$$

where, $N(x)$ is the cumulative number of adopters due to the value of the product x; $n(x)$ is the number of adopters due to the value of the product x; m is the initial market size; p and q are the innovation and imitation coefficients respectively; r_s is the revenue generated per unit for the products.

With the initial condition $x(0, 0) = 0$ and $N(0, 0) = 0$, on solving Eq. (1) we have

$$N(t, r_s) = m.\left(\frac{1 - e^{-(p+q)t^{\alpha}.{r_s}^{1-\alpha}}}{1 + \frac{q}{p}.e^{-(p+q)t^{\alpha}.{r_s}^{1-\alpha}}}\right). \tag{2}$$

After discussing the two dimensional model we focus on profit maximization that uses price, warranty length and production function as simultaneous decision variables. The factors like fixed cost, production cost and inventory cost are also considered in the problem of profit maximization. The current paper takes into consideration the fact of counting the revenue loss; the situation when manufacturer looses profit by providing warranty and how this loss (due to warranty) is related to its addition in cost for the manufacturer. This paper studies these concepts together as a whole and determines the optimal warranty length and price of