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A study on the life of an innovative product using a Bayesian approach

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ABSTRACT

In this paper, the life cycle of an innovative product is divided into three stages, where a nonhomogeneous Poisson process (NHPP) with a power law intensity function is employed to illustrate the entry process of rival firms in a competitive market. The effects of the competitors' entry on the profits of the incumbent firm are taken into consideration, with an objective of deriving the optimal product life to maximize the incumbent's profit. Furthermore, a case study of a new type of LCD (liquid–crystal display) TV is empirically investigated to examine the effectiveness of the proposed approach. The results of the posterior analysis suggest that the influence of the competitors' entry on the optimal product life is overestimated in the prior analysis. The results of sensitivity analyses indicate that the effect of competition of the introduction and growth stages on the optimal product life is greater than that of the maturation stage on the optimal product life, which is subsequently greater than that of the decline stage on the optimal product life.

1. Introduction

In most situations, before introducing an innovative product to the market, it is considered essential for an incumbent firm (hereafter abbreviated as the incumbent) to consider different challenges incurred during the selling process. Among them, competition is the primary issue to deal with in order to successfully launch the innovative product, particularly from the firms who are able to offer similar products in a competitive market.

As far as the incumbent is concerned, these potential competitors not only can affect the product profitability, but also may significantly alter the product life cycle (PLC) of the innovative product. Accordingly, the managers of the incumbent have to constantly observe the competitors' behavior, so as to translate such information into useful knowledge in making decisions effectively. For instance, Krishnan, Bass, and Kumar (2000) discovered the strength of the effect of competitors' entry on the incumbent's own brands by analyzing the sales data, while Debruyne et al. (2002), using a field study of 509 new industrial products introduced in the US, UK, and Netherlands, revealed that competitors would usually react to two-thirds of new product launches in the market. However, little attention has been paid to developing an analytical model which can account for the entry and exit behaviors of competitors in the market.

The Poisson process has been employed to describe the entry behavior in various research fields. For instance, Hur and Nam (2006) assumed that the commands of storage and retrieval enter a system according to a Poisson process with different entry rates; Maille and Tuffin (2003) assumed that players would randomly enter or exit a competitive environment according to a Poisson process; Zeephongsekul and Bedford (2006) classified the customers who enter a dual queuing system into two groups by two Poisson processes. Furthermore, the nonhomogeneous Poisson process (NHPP) is a commonly used stochastic model for describing the repeated occurrences of certain time-dependent events or conditions, and also, the power law intensity function is a popular stochastic formulation of the empirical phenomena of such the time-dependent behavior observed in experiments (Bandyopadhyay & Sen, 2005). For example, the failure process of a repairable system can be illustrated by an NHPP with a power law intensity function (Huang, 2001; Rigdon, Ma, & Bodden, 1998). Accordingly, an NHPP with a power law intensity function would be suitable in explaining the entry process of competitors in the market.

It is well known that a product may experience a PLC consisting of introduction, growth, maturation, and decline stages, which has been utilized as either an analytical approach or an applicable assumption in a number of studies. For instance, Morrison (1995) suggested that the time with respect to the inflection point of the PLC curve can be identified as one-half of the product life; Chi and Liu (2001), and Allanson and Montagna (2005) developed models utilized to maximize the expected product profit, and to estimate the reduction in the number of firms during the PLC, respectively; Chang and Chang (2003) presented a PLC stage model

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by aggregating the interactive behaviors of the separate stages; Shankar, Carpenter, and Krishnamurthi (1999) proposed a dynamic sales model by considering the competitors in each stage of the PLC of pharmaceuticals; Moon and Lee (2000) employed the PLC as a random variable that follows either a normal or an exponential distribution. Consequently, in this paper, in addition to the NHPP with a power law intensity function, the conceptual framework of the PLC is also employed to illustrate the competitors' entry process.

While a firm may take risks of having a deficit in selling an innovative product, a sound information collection scheme in advance might be beneficial to reduce such risks, or even to improve the product profits. For example, the relevant information about the competitors' entry into the market would assist managers in evaluating future product profits more reasonably. However, in considering a tradeoff between the cost of collecting information and the accuracy of prediction, it would be essential to probe into whether it is worth collecting such information in order to avoid allocating too many resources such as personnel and materials. Additionally, the Bayesian approach is frequently utilized to discuss and analyze the risk of launching an innovative product (Lee, Boatwright, & Kamakura, 2003; Pammer, Fong, & Arnold, 2000; Talukdar, Sudhir, & Ainslie, 2002).

Based on the aforementioned discussions, in this paper, the entry process of competitors is illustrated by a particular NHPP with a power law intensity function. Furthermore, considering the product's selling process as well as the properties of the collected data, the effects of the competitors' entry on the incumbent at the three hypothetical stages of the PLC are investigated, with an objective of estimating the optimal life to maximize the expected profit in launching an innovative product under competition through the proposed Bayesian analysis. This paper is organized as follows: The competitors' entry behavior from the incumbent's viewpoint is discussed in Section 2. In Section 3, a Bayesian analysis is proposed to estimate the optimal life for an innovative product. In Section 4, an application of the proposed approach to an industrial case is provided, and sensitivity analyses are also performed. Finally, conclusions are drawn in Section 5.

2. Effect of competitors' entry

In general, in a highly competitive market, there may be a large number of rivals can offer heterogeneous products that are similar but not identical to the incumbent's products. These rival firms tend to behave competitively yet act independently with a freedom of entering or exiting the market. In such a case, the competitors' entry behavior can be presumably modeled by an NHPP (Ho & Huang, 2009). Moreover, a number of intensity functions (e.g. lognormal, Gamma, exponential, Weibull, etc.) have been employed in many studies for the application of NHPP models (Bandyopadhyay & Sen, 2005; Lee, Kim, & Park, 2004; Pham & Zhang, 2003; Shyur, 2003; Tamura & Yamada, 2006). In particular, the power law intensity function is found to be more flexible in evaluating the number of failures within the product life (Huang, 2001), which is essentially equivalent to the number of the entered competitors during the PLC from the incumbent's viewpoint. Therefore, the power law intensity function is utilized with the NHPP model to express the competitors' entry process, which is denoted as $f(\zeta) = \lambda\beta\zeta^{\beta-1}$, $\lambda, \beta > 0$, where λ, β, and ζ are scale factor, expanding rate, and elapsed time, respectively.

To construct an analytical model, Ho and Huang (2009) stated that the optimal life of an innovative product, T, can be divided into three stages by two cutoff points rT and sT ($0 < r < s < 1$), where the values of r and s can be specified by expert opinions and past experience in selling similar products. These three stages are sequentially consistent with the introduction and growth, maturation, and decline stages of the PLC, which suggests that the competitors' entry rate tends to increase in Stage 1 due to the growing market profits, and gradually diminishes to be constant in Stage 2, and finally, starts decreasing in Stage 3 since the product profits are not so attractive anymore. The scale factors of the competitors' entry processes of Stages 1, 2, and 3 are respectively signified by λ_1, λ_2, and λ_3 ($\lambda_1, \lambda_2, \lambda_3 > 0$), and the corresponding varying rates of Stages 1 and 3 are respectively signified by β_1 and β_3 ($\beta_1, \beta_3 > 0$). Accordingly, the competitors' entry processes of Stages 1 and 3 respectively follow the NHPP with increasing ($\beta_1 > 1$) and decreasing ($\beta_3 < 1$) power law expanding intensities, whereas that of Stage 2 follows a homogeneous Poisson process (HPP) with a constant entry rate (i.e. zero varying rate).

Since the competitors' entry processes of Stages 1 and 3 have been described as the NHPP with the power law intensity functions, the corresponding expected numbers of competitors can be calculated as

$$N_1 = \int_0^{rT} \lambda_1\beta_1\zeta^{\beta_1-1}d\zeta = \lambda_1(rT)^{\beta_1} \tag{2.1}$$

and

$$N_3 = \int_{sT}^{T} \lambda_3\beta_3\zeta^{\beta_3-1}d\zeta = \lambda_3[T^{\beta_3} - (sT)^{\beta_3}], \tag{2.2}$$

respectively. Furthermore, owing to the invariance of the competitors' entry rate of Stage 2, the corresponding entry process degenerates to an HPP, where the expected number of competitors turns out to be

$$N_2 = \lambda_2(s-r)T. \tag{2.3}$$

Since each appearance of a competitor would cause a decrease in the incumbent's profits, it is assumed that x_{ij}, the reduced profit owing to the jth arrived competitor of Stage i, is normally distributed with parameters μ_i and σ_i, which is given as

$$x_{ij} \sim N(\mu_i, \sigma_i^2), \quad i = 1,2,3, \quad j = 1,2,\ldots,N_i, \tag{2.4}$$

where μ_i and σ_i^2 denote the mean and variance of x_{ij}, respectively. Note that both μ_i and σ_i^2 differ in each stage due to their different effects on the incumbent's profits. Therefore, Y_i, the reduced profit owing to the entered competitors of Stage i, can be illustrated as a compound Poisson process given as follows:

$$Y_i = \sum_{j=1}^{N_i} x_{ij}, \quad i = 1,2,3. \tag{2.5}$$

On the other hand, Fotopoulos and Spence (1998) considered that competitors' entry and exit can be compared as two faces of the same coin, where both occurrences are closely related to each other. Consequently, apart from the competitors' entry into the market, the corresponding probable exit behavior should be taken into account in the factors influencing the incumbent's profit. Specifically, from the incumbent's viewpoint, since the competitors' entry can lead to a reduction of profits, whereas their exit may lead to a cessation of the profits being taken away from them, it is assumed that h_i represents the increased profit percentage resulting from a decrease in competitors of Stage i, and the reduced profit of Stage i, then, turns out to be $\sum_{j=1}^{N_i}(1-h_i)x_{ij}, \quad i = 1,2,3$. In addition, a logarithmically increasing function, denoted by Q, which had been used to extrapolate the profits (McElroy & Siegfried, 1985; Transier, Füßler, Widmer, Mauve, & Effelsberg, 2007), is suggested to illustrate the anticipated profit over the PLC without any competitors in the market. It is due to the situation that Q is, without loss of generality, increased gradually as T increases, where the increased amount of Q with a smaller T is somewhat greater than that with a larger T. It turns out that $Q = \omega_1 + \omega_2 \ln T$, where the coefficients ω_1 and ω_2 can be estimated according to expert opinions and previous experi-