Growth-Cycle Decomposition Diffusion Model

YOUNG J. JOO
Techno-Economics Dept., ETRI, 161 Kajng-dong Yusong-gu, Taejon, 305-350, Korea

DUK BIN JUN
Department of Industrial Management, Korea Advanced Institute of Science and Technology (KAIST), 373 1 Kusong-dong Yusong-gu, Taejon, 305-701, Korea

(Received 1-3-95 / Accepted 3-21-96)

Key words: diffusion model, growth-cycle decomposition

Abstract

The diffusion model has been widely used to explain the S-shaped cumulative growth of markets for retail service and consumer durable goods. In many situations, sales fluctuate because of both growth of innovation diffusion and transitory changes in an external factor, called cycle. The traditional diffusion model, however, cannot distinguish between the two. We develop the growth-cycle decomposition diffusion model to distinguish the growth from the cycle, where the cycle incorporates a few external variables determining the transitory sales environment. The proposed model is applied to estimating the diffusion process for the annual sales of room air conditioners in Korea.

The diffusion model describes the long-run growth curve dynamics of innovation diffusion among potential adopters for consumer durable goods, retail service, and so forth. In the well-known Bass (1969) model, two separate groups of innovators and imitators adopt a product according to predetermined innovation and imitation coefficients without accounting for any external contingencies related to marketing mix, the state of economy, or other input factors.

In many situations, however, changes in these external contingent variables may strongly affect the innovation diffusion pattern of a product. Some recent developments in the diffusion model involved incorporating a few external effects into the diffusion model. The innovation coefficient increases as the level of advertising grows in the study of Horsky and Simon (1983), while in Horsky (1990) the number of potential adopters follows a logistic growth pattern according to the reserved price for the product that is a function of the product benefits and price and the average wage of the consumer. Incorporating these external variables into the Bass model highlights the descriptive and normative use of diffusion model, while its traditional use is mainly for forecasting. For details of various studies on the diffusion models, refer to Mahajan and Muller (1979) and Mahajan, Muller, and Bass (1990).

In addition, changes in the external variables may affect not only the long-run growth of the innovation diffusion but also the short-run deviations from the growth (called cycle).
For example, in the diffusion the annual sales of room air conditioners (RAC), the growth of the innovation diffusion alone cannot explain its transitory sales increase from unusually high temperatures in any given year.

Changes in the innovation and imitation coefficients or in the number of potential adopters alter the fundamental shape of the diffusion process. These changes in growth may be caused by a permanent shift of product price, a change in the advertising effect, an increase of market size, and so on. On the other hand, any transitory changes in the external environment such as a transient change in the price discount rate and economic booms and recessions can increase or decrease sales in a specific period without altering the fundamental shape of the diffusion.

In the following sections, we propose a model that allows us to decompose the growth and the cycle of the sales to extend the Bass model to some situations where the diffusion processes are distorted by a few systematic outliers. The proposed growth-cycle decomposition diffusion model is applied to RAC sales in Korea. Land prices and the temperatures in summer season are incorporated into the model to explain the cycle.

1. Growth-cycle decomposition diffusion model

As is a common practice in previous studies of diffusion models, we will exclude replacement purchases and consider only the initial purchase of a product. Thus the general form of the purchase probability period $t$ given that no purchase has yet been made becomes $f_t / (1 - F_t)$, where $f_t$ denotes the probability that a representative purchases a product at $t$ and $F_t = \int_0^t f_r \, dr$, $F_0 = 0$. When we assumed that there exit $N$ homogeneous buyers and the purchase probability is independent of the number of buyers, the number of the initial purchases at $t$, $S_t$, can be obtained by $N \times f_t$. In the traditional diffusion model, $f_t$ is defined as $(p + qF_t)(1 - F_t)$ to make $F_t$ a S-shaped growth, where $p$ and $q$ are the innovation and imitation coefficients, respectively. This makes the whole volume of $S_t$ follow the growth.

When the sales are largely affected by transitory changes in sales environment, however, the estimation results of the traditional diffusion model might be misleading by ignoring the effects of both negative and positive outliers. For example, as shown in Joo (1995), a large negative shock in a late period of sample underestimates the market potential, overestimates the innovation and imitation coefficient, and has an effect of finishing the entire diffusion too early.

The basic idea of growth-cycle decomposition diffusion model is to split the sales at $t$, $S_t$, into the sales due to growth curve, $S^g_t$, and those form cyclical variations, $S^c_t$:

$$S_t = S^g_t + S^c_t,$$

where $S^g_t$ follows the traditional diffusion model and $S^c_t$ incorporates transitory sales increases and decreases due to variations in external factors. To make the volume of the cycle proportional to the volume of the growth, $S^g_t$ is considered multiplicative to $S^c_t$. Thus we have