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Strategic decision making for multiple-generation product lines using dynamic state variable models: The cannibalization case

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ABSTRACT

Multiple-generation product lines require carefully planned strategies. Under a multiple-generation product development strategy, companies introduce a line of products to the market instead of introducing a single product to better utilize technology assets and resources in an elongated time span. For such product development and launch scenarios, cannibalization can occur, however. That is, multiple product generations compete in the same market and partition the company's market shares. In the paper, we propose a new framework to predict the sales and introduction timing for every product generation in a multiple-generation product line while considering cannibalization. We demonstrate a case study implementing the proposed framework on Apple Inc.'s iPhone product line. The results show that the forecast performance of the model matches the realized data. Moreover, because the proposed framework is not computationally prohibitive, it can be used widely.

1. Introduction

From Gillette's razor products to BMW's 3-series sedans, we are surrounded by multiple-generation product lines. In fact, owing to today's rapidly changing and technology-intense market environments, adopting multiple-generation product strategies has been a favorable strategy for companies [1]. For example, Apple Inc. has been generally acknowledged to obtain huge success from its three well-known multiple-generation product lines: the Apple iPods, iPhones, and iPads. These three multiple-generation product lines have turned Apple into the most profitable and valuable company in the world.

Under a multiple-generation product strategy (MGPS), a company first launches an initial product generation to the market. After this initial launch, it sequentially introduces successive generations over time, each featuring unchanged core functionality but updated technologies, features, appearances and usability [2,3]. The use of such a strategy enables companies to elongate the product lifespan from one single product to a line of products, and relax the necessary development time span. Accordingly, companies could better utilize their resources and technologies to plan for better products, and could have higher chances to acquire long-term success.

Conceptually, multiple-generation product lines might resemble product families; however, there are vast differences. A product family refers to a set of products that shares common components yet exhibits adequate differentiation intended to target different market niches [20,21]. The ultimate goal of designing a product family is to provide a variety of products to the market with effectiveness close to that of mass production [19]. However, in multiple-generation product lines, the product generations are introduced to the market over time, in a sequence. For most of the cases, these different generations of products within the product line aim at the same market niche and perform in a similar way. For example, BMW 3 series has been in the market since 1975. Each generation of 3 series is different from the others. The common thing across generations for the BMW 3 series is that they are all designed for a certain market niche, target a certain customer group; functionally, they are all high performance sedans with great handling, which is the core function or value of this product line. In addition, multiple-generation product lines involve a higher degree of uncertainty since we do not know what would be the future technologies that will be implemented in the future product generations.

Several studies attest to the success of the MGPS. Morgan et al. [4] modeled an active competition scenario in a fast-moving market and found that it was better to apply a forward-looking, multiple-generation product strategy; respectively, 40% and 26% more profitable than only introducing a single product generation and sequentially introducing a single generation product. Edelheit [5] indicated that General Electric (GE) recognized that focusing

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R&D on successive generations of products ensured effective product sales strategies. Therefore, GE centers on building forward-looking multiple-generation product strategies across all of its product lines rather than developing a single product with limited availability in time and technologies. For instance, when GE introduced its then-revolutionary four-slice LightSpeed CAT scanner, the developers already had the design ideas for the future 8-slice and 16-slice models in mind. GE periodically looks back on those strategies and makes adjustments based on the market dynamics. These are among the academic and industrial testaments in support of adopting a multiple-generation product development strategy.

Since multiple-generation products generally possess longer lifecycles, even decades; and markets are highly uncertain in the long-run, it is conceivable to apply product line thinking and regard them as a whole, and evaluate the performance of the entire product line rather than looking into individual product generations separately. Moreover, for companies that develop forward-looking, multiple-generation product strategies, using single product line thinking enables them not only to create more comprehensive and flexible strategies, for both operations and marketing throughout the lifecycle of the product line, but also to reduce the analytic complexity involved so that companies are able to better interpret the overall behavior of the product line.

Even though applying multiple-generation product strategies can greatly benefit companies, there exists the possibility of cannibalization, a scenario where multiple product generations directly compete with each other in the same market. The cannibalization scenario may lead to unanticipated profit loss since less profitable older product generations divide the market share originally expected to be monopolized by the latest generation with the highest profit margin. To avoid the loss caused by cannibalization, companies need to carefully plan and create adequate differentiation (e.g., price) among product generations when setting multiple generation product strategies.

In this study, we propose a novel framework centering on a dynamic state variable model. This new framework is capable of effectively forecasting the sales performance and the introduction timing for every generation in a multiple-generation product line, and also takes into account the cannibalization condition among product generations. The proposed framework is suitable to be applied for two different problem types. First of all, with partial sales and market share information of an existing and on-going multiple-generation product line, it can generate the complete lifecycle prediction of future sales and introduction timings of successive product generations. Secondly, it can be applied to predict the full performance of a whole new multiple-generation product line with the input of adjusted historical data taken from a past similar product line within the same mature market. In this study, we demonstrate the proposed framework on a case study for the first problem type. In addition, the novel framework can also assist companies in developing dynamic market strategies for multiple-generation product lines.

In Section 2, we provide a summary of our literature review on both quantitative models for multiple-generation products and dynamic state variable models, and then unfold the details of the research methodology. Following the methodology is a case study implementing the proposed framework to the real sales data from Apple's iPhone product line. Section 5 concludes this study as well as identifying plans for future work.

2. Literature review

Below are the summaries of our literature review on quantitative models relevant to multiple-generation of products and dynamic state variable models.

2.1. Quantitative models for multiple-generation of products

Existing quantitative models of multiple-generation products (MGPs) could be roughly categorized into two types: (1) behavioral models, and (2) dynamic competition models. Behavioral models attempt to simulate or interpret the behaviors of MGPs whereas dynamic competition models consider that the market is a competitive environment and attempt to formulate competitive scenarios to derive market strategies for companies.

One of the earliest behavioral models involves the use of Bass diffusion model. Norton and Bass [6] applied the Bass diffusion model to study the sales behavior of high-tech MGPs. The authors proposed a model, which considers that the demands diffuse over time and that the non-revertible substitution effect arises to repetitively replace the demands from the current product generation with the successive one. This model can be applied to forecast the future demand change of the entire MGP. Mahajan and Muller [7] extended the research of Norton and Bass [6] by proposing a new demand behavior model, which takes into account both the adoption and substitution effects of durable technological products. Different from the Bass diffusion model when evaluating the substitution effect, the new model not only dealt with the substitution between two consecutive generations, but also considered the substitution occurring across generations, termed as the ‘‘leapfrog’’ effect. Furthermore, the authors derived optimal timing strategies from the proposed demand behavior model. More recently, Bardhan and Chanda [8] extended the work from Mahajan and Muller [7] where they divided the cumulative adopters into two different types—first time purchasers, and repeat purchasers—and modeled them respectively.

Morgan et al. [4] studied the quality and time-to-market trade-offs for MGPs. In their study, product quality improvement is assumed to accompany an increase in product development cost. The authors constructed an optimization model for a forward-looking multiple-generation product line (MGPL) that aims at maximizing profits while considering different types of costs, the focal firm's quality, its competitive quality and its market share with an active competitor. Their proposed forward-looking MGP launch model was compared to a pure single-generation and a sequential single-generation product launch model. The results indicated that applying a forward looking MGP launch strategy was significantly more profitable than adopting a pure single-generation or a sequential single-generation product strategy, but that it logically involves a longer product development time. Krankel et al. [3] applied a dynamic programming technique to construct a multiple-stage decision model to examine successive product generation introduction timing strategies. The model incorporated Bass diffusion elements to predict future market demands and was based on two assumptions: (1) the technology level is additive, and (2) the new generation completely replaces the previous product generation. By changing several parameters, the authors examined the relative effects of the technology level and cumulative sales to determine the introduction timing threshold for the successive generation of products. Huang and Tzeng [9] proposed an innovative, two-stage fuzzy piecewise regression analysis method to forecast product lifetime and yearly product shipments of MGPs. The entire forecast is based on historical data; in the first stage, product life time of each product generation is predicted by fuzzy piecewise regression technique. After that, the yearly product shipment of each generation is assessed.

Ofek and Sarvary [1] looked into the dynamic competition between market leaders and followers. They developed a multi-period Markov game model (seeking Markov Perfect Nash Equilibrium) and used it to examine the influences of both innovative and reputation advantages in R&D for market leaders as