Modeling and analyzing the effect of stochastic production on product rollovers

Niklas Owens
University of Regensburg, Regensburg, Germany, niklas.owens@ur.de

Justus Arne Schwarz
University of Regensburg, Regensburg, Germany, justus.schwarz@ur.de

Barış Tan
Özyeğin University, Istanbul, Turkey, baris.tan@ozyegin.edu.tr

Oktay Karabağ
Izmir University of Economics, Izmir, Turkey oktay.karabag@ieu.edu.tr

In many industries, frequently introducing new generations of already existing products is a common tool for manufacturers to maintain their market share. Before the market introduction of a new product generation, decisions on production and sales quantities as well as prices must be made. The resulting product rollover strategies can be divided into single and dual rollover strategies. Phasing the old product generation out of the market before the introduction of the new generation is called a single product rollover strategy while selling both generations simultaneously is known as a dual rollover strategy. Stochastic production capacity consumption regarding the new generation is common due to the lack of knowledge with its production process. We analyze the effect of stochastic capacity consumption required by the new product generation due to new production processes associated with the new product generation on optimal sales and production decisions and the resulting rollover strategies. This talk proposes a stylized multi-period model for determining optimal product rollover decisions under stochastic production processes. Preliminary numerical results about structural properties of optimal sales and production decisions during product rollovers are presented.

Key words: Product Introduction; Product Rollover; Stochastic Capacity Consumption

---

1. Introduction

A product rollover refers to the process of transitioning from one version of a product to the next generation with updated or new features. This typically involves either a direct retiring of the older version, i.e., a single rollover strategy (SRS), or temporary sales of both generations, i.e., a dual rollover strategy (DRS) (Billington et al. 1998). The goal of a product rollover is to maintain customer satisfaction and market shares by offering consumers the latest innovations and advancements. The observed frequency of rollovers depends on the industry, e.g., in the home appliance industry new washing machines are introduced every two to three years.

When executing a product rollover, firms need to decide on the amounts to be produced of both product generations, the product offering, i.e., the rollover strategy, and the prices to be charged for the products to maximize their profits. These decisions need to be made under consideration of stochastic customer behavior with cannibalization if both products are offered simultaneously as well as under consideration of stochastic production processes.

There is a large body of literature that analyzes product rollovers with unlimited production capacity under different customer demand models, e.g., Lim and Tang (2006), Liang et al. (2014), Çelik et al. (2024). Limited but deterministic production capacities are considered by Schwarz and Tan (2021). We propose a new model to analyze the impact of stochastic capacity consumption required by the new product generation due to new production processes associated with the new product generation.

2. Model

The model considers a monopolist with finite production capacity that offers its old product generation on the market and plans to introduce a new generation to the market. The dynamics of the transition are captured in three periods (see Figure 1). The manufacturer's objective is to maximize the expected profit from the revenue during the pre-introduction, the introduction period, and the post-introduction period subtracted by the production and holding costs by deciding on production quantities, offered products, and prices.

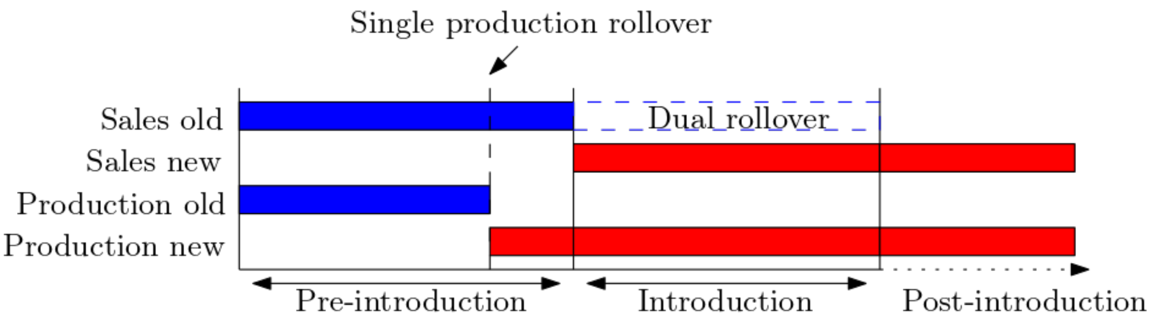

Figure 1. Product rollover timeline.

During the pre-introduction period, only the old product generation is offered to the customers. Old products produced during the pre-introduction period can be used to fulfill a stochastic and price-dependent demand during the pre-introduction period. It is assumed that the new generation is produced on the same production line but only one generation can be produced at a time. Consequently, if the manufacturer also wants to produce new products during the pre-introduction period, a single production rollover has to be executed. That means the manufacturer has to decide when to switch from producing the old generation to producing the new generation. The capacity consumption is known for the old product generation. However, the potentially increased capacity consumption of the new generation is stochastic due to new production technologies and processes. After making the production decisions and observing the realized capacity consumption the corresponding production output is received. The manufacturer decides on how many of the old product units to offer on the market during the pre-introduction period and the respective price. Old products that were not offered or not sold due to the stochastic customer behavior, as well as any new products can be carried over to the introduction period under the consideration of inventory holding cost. Any units not carried over are salvaged.

At the beginning of the introduction period, the manufacturer decides on how many units of the new product generation will be produced during the introduction period while considering the inventory levels of both product generations. After observing the realization of the still stochastic capacity consumption of the new generation, the manufacturer also decides on the rollover strategy and the prices. After the realization of the stochastic demand process, the manufacturer observes the remaining units in stock.

It is assumed that in the post-introduction period, there is still positive demand for the new generation but the old generation becomes obsolete. Hence, there is no demand for the old generation. During the post-introduction the manufacturer has the production processes under control so that there is no longer an additional stochastic capacity consumption. Because the production capacity is typically chosen to match the long-term demand, it is sufficient to satisfy the demand for the new product. Thus, leftover units of the new generation from the introduction period may be used for sales in the post-introduction period, saving the manufacturer production costs but incurring holding costs. Leftovers of the old generation can only be salvaged at the end of the introduction period.

3. Solution approach and numerical findings

Solutions for the proposed model are obtained numerically by backwards induction. Optimal production, sales, and carry over decisions on each stage of the dynamic program are determined via complete enumeration. Prices are discretized in a reasonable price range that is determined by the cost structure and the demand model.

The numerical study shows that the optimal production and pricing decisions feature structural properties in the available stock levels as well as the model parameters. Moreover, the numerical study compares optimal decisions under deterministic and stochastic capacity consumption. The results indicate that the manufacturer can choose from multiple mitigation actions at hand to cope with the stochastic production process. These actions range from minor changes in pricing to a change in the rollover strategy. In particular, using a DRS to leverage the predictable production of old products is observed.

4. Conclusions

We propose a multi-period model to obtain optimal production and sales decisions for product rollovers under stochastic production capacity consumption. First numerical studies show that optimal decisions under stochastic production processes differ from those made under deterministic conditions. Future research will focus on formally establishing numerically observed structural properties and the development of more efficient solution approaches.

References

Billington, C., H. L. Lee, C. S. Tang. 1998. Successful strategies for product rollovers. *MIT Sloan Management Review* **39** 23–30.

Liang, C., M. Çakanyildirim, S. P. Sethi. 2014. Analysis of product rollover strategies in the presence of strategic customers. *Management Science* **60** 1033–1056.

Lim, W. Shi, C. S. Tang. 2006. Optimal product rollover strategies. *European Journal of Operational Research* **174** 905–922.

Schwarz, J. A., B. Tan. 2021. Optimal sales and production rollover strategies under capacity constraints. *European Journal of Operational Research* **294** 507–524.

Çelik, B., J. A. Schwarz, B. Tan. 2024. New product introductions with selection of unique and common features in monopoly markets. *Omega* **125**.