Dynamic Pricing for Nonperishable Products with Demand Learning

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A retailer is endowed with a finite inventory of a nonperishable product. Demand for this product is driven by a price-sensitive Poisson process that depends on an unknown parameter that is a proxy for the market size. The retailer has a prior belief on the value of this parameter that he updates as time and available information (prices and sales) evolve. The retailer’s objective is to maximize the discounted long-term average profits of his operation using dynamic pricing policies. We consider two cases. In the first case, the retailer is constrained to sell the entire initial stock of the nonperishable product before a different assortment is considered. In the second case, the retailer is able to stop selling the nonperishable product at any time and switch to a different menu of products. For both cases, we formulate the retailer’s problem as a (Poisson) intensity control problem and derive structural properties of an optimal solution, and suggest a simple and efficient approximated solution. We use numerical computations, together with asymptotic analysis, to evaluate the performance of our proposed policy.

Subject classifications: dynamic pricing; Bayesian demand learning; approximations; intensity control; nonhomogeneous Poisson process; optimal stopping.

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1. Introduction

This paper is concerned with dynamic pricing policies for nonperishable products in the context of a retail operation with uncertain demand. In particular, we investigate the interplay between demand learning and pricing decisions and their impact on the long-term performance of the business.

Effective retail management is about managing a limited available capacity to procure and sell the right assortment of products while considering present and future market developments. This point of view is captured by one of the most popular measures in the retail industry, namely, average sales per square foot per unit time. Indeed, this measure highlights two fundamental aspects of a retail operation. First, it emphasizes the fact that capacity, measured by store or shelf space, is one of the retailer’s key assets, and thus must be managed as such; the challenge resides in choosing the best possible menu of products; failure to do so results in opportunity costs that would cut directly into the profit margins. Second, it highlights the time value of money when assessing the business performance. For example, a retailer might prefer to sell a product with a 5% margin over another one with a 10% margin if the former sells much faster than the latter (see Gaur et al. 2005 for a comprehensive empirical analysis of this “earns versus turns” trade-off). Thus, in optimizing this measure, retailers must balance the short-term benefits obtained by selling a given menu of products and the long-term opportunity costs incurred by allocating their resources (shelf space, time, capital, etc.) to these products instead of a different assortment.

In addition to such critical trade-offs, retailers cannot overlook the market conditions in which they compete. Customers’ preferences, competitors’ actions, new product introduction, regulations, and so on, are often unknown to the retailer and need to be factored into the business strategy. As a result, learning about these market factors—induced, for example, through the sales process—should be constantly performed. Such learning would shed more light on future demand and hint at the current strategy to adopt. The same product that sells well today might get stocked on the shelves tomorrow, wasting valuable space that could be used to sell a more profitable alternative. To prevent such a highly undesirable situation, a retailer must continuously monitor the products sales to infer customers’ preferences, identify early-on the selling pattern of each product, and adopt the appropriate strategy. Low-selling items must be removed either by shipping them to a secondary market (e.g., an outlet) or by liquidating their inventory through active price markdowns. It is precisely this relationships between demand learning, pricing policies, and inventory...