

A data-driven based approach for newsvendor problem subject to inventory inaccuracy

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Abstract : *A cornerstone of operations management study and practice is the newsvendor problem. This problem began as a simple one-period problem for a price-taking newspaper salesman. Since then, it has motivated several researchers and improved inventory control at numerous companies. The expansion of the choice variables to include price was an important extension of the newsvendor problem. This extension has been known for decades but recently gained a new story since researchers have expended considerable energy in analyzing and exploring this problem under data-driven decision-making. We investigate data-driven approaches for pricing decisions of a retailer where there is only one perishable product with price-dependent stochastic demand. As well-known in marketing, the attraction model is adopted to quantify customer behavior. We also use real retailing data to study the pricing decision of a retailer under the uncertainty of its inventory record inaccuracy.*

Key words : *inventory management, data-driven, newsvendor, inventory record inaccuracy*

1 Introduction

Over six decades have been spent on the issue of identifying the optimal stocking level for a perishable product (Whitin, 1955). Although several explanatory frameworks have been used, the conventional terminology for problems of this type, newsvendor problems, continues to provide a simple and valuable analysis for the decision maker (Petruzzi & Dada, 1999). The newsvendor model has expanded in a wide range of directions from this straightforward starting point. Whitin (1955) introduced the first extension, expanding the original single decision problem to add price as a decision variable. Despite the price being a decision variable in these early works, the price-setting newsvendor problem would not develop to its full potential for several decades as a study centered on the inventory policy applications of the quantity-setting newsvendor problem.

Besides, as a result of the underlying assumption that there are no abnormalities in the anticipated physical and information flows, the inventor manager operates correct inventory records. This is one of the fundamental premises behind the formulation of classical inventory problems. This assumption might not be validated in real practice due to operational process errors, leading to worse performance. Therefore, inaccurate inventory records, or the disparity between reported inventory and the actual goods physically present on the shelf, maybe a serious issue in retail settings. It is essential to have complete and accurate inventory-level information.

According to the above issues, this work mainly focuses on the following research questions in price-setting newsvendor problem under inventory record inaccuracy :

- How does a retailer make joint pricing and ordering decisions to meet customers' demands considering customers' purchasing behavior and inventory record inaccuracy while maximizing profit ?
- How does the change in return rate affect the optimal decisions and the total retailer profit ?

— What are the appropriate uncertainty sets for the inventory record inaccuracy to make tradeoffs between the model’s conservatism and the profit maximization ?

To answer these questions, a newsvendor-based pricing and ordering problem is examined. A robust nonlinear pricing and ordering optimization model is proposed, and a solution method is developed. The attraction-demand model is adopted to quantify the price-dependent demand and customers’ purchasing behavior. Besides, a data-driven robust optimization approach based on support vector clustering kernel learning is applied to handle the constraints for the uncertain inventory record inaccuracy in the selling channel. Finally, numerical experiments based on a case study are performed to show the credibility of the proposed model and the effectiveness of the solution method.

2 Optimization problem and approaches

We model the problem as a stochastic optimization problem. The objective is to determine the optimal replenishment level and price of items simultaneously by considering the related attractive demand and inventory record inaccuracy.

Let p be the retailing price, ξ be the potential market demand. The actual demand depends on the price and the potential market demand via the attraction model

$$D = \xi \frac{g(p)}{1 + g(p)} \quad (1)$$

To characterize the inventory record inaccuracy uncertainties, the additive case is employed, and the uncertain inventory under inventory record inaccuracy is given by

$$Q^u = Q + \epsilon, \quad (2)$$

where Q is the inventory information of the store, and ϵ is the uncertainty parameter of the inventory record inaccuracy.

In addition, c denotes the operating cost, s denotes the value of the item at the end of selling period. The price-setting newsvendor problem to maximizing the total retailer profit under the inventory record inaccuracy is formulated as

$$\begin{aligned} \max_{p, Q} \quad & p \min(D(p), Q^u) + s(Q^u - D(p))^+ - cQ^u \\ \text{s.t.} \quad & p \geq c \geq s, \\ & Q \geq 0. \end{aligned} \quad (\text{P})$$

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