Robust Dynamic Pricing with Two Substitutable Products

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Abstract

In this paper, we consider a dynamic pricing problem with two substitutable products involving a number of business rules and issues commonly seen in practice. A given amount of inventory of each of the two products needs to be sold in a short selling season without inventory replenishment. Prices of the products can be re-set periodically subject to some business rules. Demand substitution exists between the two products and across different time periods. However, there is limited demand information such that it is not possible to precisely characterize the underlying probability distributions of the demand functions. We propose a robust optimization model for this problem. We use an interval (instead of a point estimate or a probability distribution function) to represent, respectively, the demand of each individual product, the aggregate demand of the two products in each period, and the aggregate demand of the two products across multiple time periods. We formulate the problem as a max-min problem in which we maximize the worst-case total sales revenue across all possible demand realizations in the demand uncertainty spaces subject to a number of constraints induced by the given business rules and the nature of substitution between the two products. We develop a dynamic programming algorithm to solve the max-min problem. To speed up the DP algorithm, we further develop a fully polynomial-time approximation scheme which guarantees a proven near optimal solution in a manageable computational time for practically sized problems. For a special case of the problem where only price markdowns are allowed, we show that the search spaces in the DP algorithm can be reduced greatly so that the algorithm is capable of generating optimal solutions in a reasonable amount of computational time. Our extensive computational experiments demonstrate the effectiveness and robustness of the proposed approaches. We also generate a set of interesting managerial insights on how the price elasticity, demand uncertainty level, and some other problem parameters impact on the optimal price paths of the products. These insights can help store managers make better pricing decisions when facing high demand uncertainty due to lack of information.