DOCTORAL PROGRAMME

ESSAYS ON MATCHING SUPPLY WITH DEMAND FOR SHORT-LIFE PRODUCTS

By

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To all my teachers

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Abstract

Short-life products include dairy products, fruits, vegetables, frozen foods, pharmaceutical drugs and blood. These are ubiquitous as well as indispensable to our society. This makes their efficient inventory management extremely important. Although important, such products are tremendously challenging to manage especially when the demand side is stochastic. An important trade-off is that keeping high stock may lead to outdates and keeping low stocks may lead to a loss in sales. Despite this simple-looking newsvendor trade-off, the problem becomes complicated in the presence of a finite lifetime as one needs to keep track of the vector of inventories of different ages. Making things worse, the optimal replenishment is a state-dependent policy and thus one needs to keep track of the full inventory vector and hence the problem suffers from the infamous *curse of dimensionality*. Another important challenge in managing these products is the customers' perception of them. Depending on usage as well as other factors, customers generally prefer products with sufficient remaining lifetime and may not purchase old units. Selling old units may even have serious implications on the brand image of the retailer.

In this dissertation, we examine the management of such perishable products where demand depends on the product's perceived freshness. The focus is on understanding the structure of the optimal policy and developing computationally fast heuristics. In particular, we consider periodic review, finite horizon models. The first essay considers a supermarket context whereas the second and third essays consider an online retailer (e-tailer). The first essay examines the joint replenishment and clearance policy for a perishable product in a supermarket context considering customer-driven LIFO (last-in-last-out) issuing policy. The key objective of the model is to understand the effect of the age dependence of demand on the optimal replenishment and clearance policy. We show that the optimal policy when demand depends on age may diverge substantially from the optimal policy when demand is independent of age. We also develop an efficient heuristic to compute the order and clearance quantities. The second essay considers joint issuing and replenishment decisions when the vendor controls the fulfillment of demand. While

studies have shown the optimality of issuing a perishable product in FIFO (first-in-first-out) sequence when demand is independent of age, it may not be so when demand is age-sensitive. We fully characterize the structure of the optimal policy when the product lifetime is two periods and partially characterize the optimal policy when the product has lifetime of more than two periods. Further, the optimal policy is compared with the cases when issuing is fixed to simple policies such as LIFO and FIFO. The third essay considers replenishment decisions when the vendor fixes the issuing sequence to FIFO. We show that existing structural results on optimal replenishment policy break down in the presence of age-sensitive demand. We develop an approximation algorithm for which we show the worst-case performance guarantee of two for any arbitrarily correlated demand process.