Demand Estimation and Ordering under Censoring: Stock-out Timing Is (Almost) All You Need

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Retailers facing uncertain demand can use observed sales to update demand estimates. However, such learning is limited by the amount of inventory carried; when demand exceeds inventory (i.e., when a stock-out event occurs), a retailer in general cannot observe actual demand. We propose using observations on the timing of sales occurrences in a Bayesian fashion to learn about demand, and analyze this learning method for a multiperiod newsvendor setting. We find that, as previously shown with the use of only stock-out event observations, the optimal order quantity with timing observations is greater than the optimal order quantity with full demand observations. We prove this result using a novel methodology from the statistics literature on comparison of experiments. While the optimal over-ordering with timing observations tends to be less than that with only stock-out event observations in most cases, we do observe cases where the opposite is true. Such cases correspond to high demand uncertainty and low margins, where marginal learning from timing observations is significantly higher than using only stock-out event. In an extensive numerical study we find that, on average and with respect to uncensored demand observations, the use of timing observations eliminates 76.1% of the loss in expected profit from using only stock-out event observations. We show that, for Poisson and Normal demand with unknown mean, the proposed learning method is tractable as well as intuitively appealing: the information contained in the timing of sales occurrences is fully captured by a single number—the timing of stock-out. We also investigate checkpoint models in which the newsvendor can make observations only at predetermined times in a period, and illustrate its convergence to the models with timing and stock-out event observations.

Key words: Bayesian inventory; lost sales; censored observations

1. Introduction and Literature Review

With increased product variety, shorter product lifetimes, and longer lead times due to increased levels of global sourcing, managing stock-outs has become a major concern for manufacturers and retailers. Not only do stock-outs signify a loss of immediate sales and revenue, they also obscure observations of true demand. Such censoring of demand observations undermines a firm’s ability to improve its demand estimates. Yet, even when a stock-out occurs, additional valuable information is readily available that can be utilized to facilitate better demand estimation. The following anecdote, experienced by one of the co-authors, provides an example of such information.

The co-author, accompanied by a senior supply chain manager of Yijiaxian (a convenience store chain specializing in fresh food), visited one of the stores in Chengdu, China. During the visit, the manager casually asked a salesperson to name the store’s best-selling product. The salesperson pointed toward