

DISSERTATION PROPOSAL

Alp Akcay

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“Statistical Estimation Problems in Inventory Control”

A challenge faced by many businesses is linking inventory management and the estimation of demand from historical data. While it is common practice to use the standard deviation of the forecast error in safety-stock calculations, the implicit assumption about the demand is that it is normally distributed. In my analysis of industrial demand data, however, I identify a large number of demand histograms with significant levels of asymmetry and tail weight. This naturally sheds doubt on the optimality of the inventory-target estimates obtained from historical data under the assumption of a normal demand distribution. The first chapter of my dissertation addresses this issue in a newsvendor setting by modeling demand with a flexible system of distributions, which captures a wide variety of distributional shapes with asymmetry, peakedness, and tail weight. However, even if the demand is adequately represented by some distribution, the “optimal” critical-fractile solution does not necessarily minimize the newsvendor’s expected cost when the parameters of this demand model are estimated from a limited amount of historical data. Therefore, I quantify the expected cost that is attributable to incorrectly estimating the unknown demand parameters (i.e., demand parameter uncertainty), and identify improved inventory-target estimates with reduced expected cost by integrating parameter estimation and cost minimization into a single task.

In the second chapter of my dissertation, I consider a problem in which inventory review periods may be shorter than the times between successive demands. Therefore, the demand process is “intermittent,” and the historical data set contains many zero demand values. Due to the dual source of uncertainty (i.e., the demand size and the number of zero-demand periods preceding the demand), the intermittent demand process is difficult to forecast. In the presence of limited

intermittent demand data, I characterize an inventory-target estimation rule which reduces the expected cost of incorrectly estimating the unknown demand parameters compared to the policy which naively treats the estimates of the unknown parameters as the true values. Motivated by an industrial data analysis, I also overcome three common assumptions – the triple-threat – in intermittent-demand modeling: (1) The normally distributed demand size; (2) the independence of the demand size from the number of zero-demand periods preceding the demand; and (3) the constant demand-occurrence probability. I further combine inventory management and parameter estimation into a single task, and minimize the expected regret associated with the incorrect estimation of the unknown intermittent demand parameters. Insights are presented as to when and why the method provides significant improvement over the traditional approach based on the level of intermittency, the holding and backlogging costs, and the length of the intermittent demand history.

The last chapter of my dissertation focuses on a demand process with temporal dependence. The first-order autoregressive process with normally distributed random shocks is a widely used time-series model in inventory management. It is well known that the linearity of this process implies that the marginal demand distribution is normal. The distinguishing feature of my study is the use of a semi-parametric time series model that allows the inventory manager to avoid any parametric assumptions about the marginal demand distribution. I estimate performance guarantees – that hold uniformly for all demand distributions – associated with the resulting inventory-target estimators in the presence of both stochastic demand uncertainty and the uncertainties around the estimates of the marginal demand distribution and autocorrelation. This enables me to provide insights on when it is critical to account for the autocorrelation in the demand process despite the limited history of autocorrelated demand.