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A Bayesian approach to determine the value of information in the newsboy problem

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Abstract

The potential benefits of demand forecasting in a newsboy problem are to decrease the risk of overstocking or shortage, but forecasting is usually not free. In this paper, a model to help the decision-maker in a newsboy problem to assess the value of information is presented. First, two cases on available demand information are considered to develop an upper bound of the cost that the decision-maker would spend on forecasting. Then, a Bayesian approach to forecasting is proposed and EVAI, the expected value of additional information, is computed to help the decision-maker in deciding whether to use the extra information. Finally, the relationship between the EVAI and model parameters is discussed.

Keywords: Forecasting; Newsboy problems; Bayesian analysis; Value of information

1. Introduction

In business operations, forecasts are the basis for budgeting, planning capacity, sales, production and inventory, purchasing, personnel, distribution, financing, and more. Demand forecasting is particularly important for the newsboy problem since the shelf life of goods is limited. In general, forecasting methods can be divided into two types: qualitative and quantitative. When assessing forecasting methods, accuracy is not the only criterion to be considered; the cost of forecasting is also an important factor. In this paper, a model to help the decision-maker in a newsboy problem to assess the value of information is presented and a Bayesian approach to forecasting is proposed. Then, some useful managerial insights about the value of information are derived to guide the decision-maker when forecasting demand.

The rest of this paper is organized as follows. Section 2 presents an overview of the most relevant literature. Section 3 proposes our models and its analysis. Section 4 reports our numerical studies. Section 5 concludes the paper and points out possible future research directions.

2. Literature review

Bowerman et al. (2005) point out that, in choosing a forecasting method, the forecaster must consider the following factors: time frame, pattern of data, cost of forecasting, accuracy desired, availability of data, and ease of operation and understanding. Choosing the forecasting method for a particular situation involves finding a method

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that balances the above factors. When considering the cost of forecasting, several costs are relevant, including cost of data collection and analysis, developing and operation of the model, report writing, etc. In our paper, we propose a model to compute the potential cost-savings of forecasting. If the cost-savings are greater than the cost of the forecasting method, this means that the method may be used.

The newsboy problem is to find the optimal order quantity under the assumption that unsold inventory cannot be carried forward from one period to the next. Khouja (1999) classifies the newsboy problem literature into 11 categories and provides some suggestions for future research. One category relates to different states of information about demand. In this category, the papers in the newsboy problem using or studying distribution free approaches, Bayesian approaches, fuzzy models, the effects of increased variability of demand, etc., are reviewed. To avoid redundancy, we discuss these studies using distribution free approaches and Bayesian approaches which are much related to our paper.

Several authors have analyzed the distribution free newsboy problem, in which the distribution of demand is unknown but only the mean and variance are specified. Scarf (1958) first addresses this kind of newsboy problem and derives an optimal ordering rule in closed form. Gallego and Moon (1993) provide a simpler proof of Scarf's rule and extend the analysis to four cases: the single product case, the fixed ordering cost case, the random yield case, and the multi-product case. Alfares and Elmorra (2005) further extend the models in Gallego and Moon (1993) to incorporate shortage penalty cost beyond lost profit. Computational experiments have been used to evaluate the improvement in profit resulting from using the new models. Mostard et al. (2005) study the case of returned goods in a mail order retailer. Returned goods arriving before the end of the selling season can be resold if there is sufficient demand. They find the optimal distribution free ordering rule for the case performs well when the coefficient of variance is less than 0.5.

As one of the studies using Bayesian approaches, Murray and Silver (1966) develop a model for the style-goods inventory problem. They assume that the chance of a customer buying an item follows a density function from the beta family. New information comes to light at the end of each period by observing demand. Then, the distribution is changed adaptively through the use of Bayes' Rule. The problem is formulated as a dynamic programming problem, and computational shortcuts, which make larger-scale problems feasible, are discussed. Crowston et al. (1973) consider the problem of multistage production planning for a seasonal good. They assume that the total level of demand is a Gaussian variable with known prior mean and variance, and the seasonal pattern of demand is expressed by defining, for each period, an average fraction of total seasonal demand. As the season progresses, the actual demand observed in each period provides sample information about the true underlying level of total demand. A forecast revision is made by applying Bayes' theorem to determine a posterior distribution for total demand. Shih (1973) studies the newsboy problem in which demand has an exponential distribution with an unknown parameter distributed according to a prior inverted Gamma distribution. Data on past demands is used as the sole source of additional information. Analytical solutions are obtained for both prior and posterior analyses. Bitran et al. (1986) study the problem of determining a multi-item production plan for style goods with resource constraints and a finite planning horizon. The demand for each item is stochastic and is concentrated in the last period; the forecast for each item is revised at the beginning of each period using a Bayesian approach. They formulate a deterministic, mixed integer problem and solve it by an algorithm that provides an approximate solution. In a multi-period context, Bradford and Sugrue (1990) present a model of the two-period style-goods inventory problem for items having heterogeneous Poisson demand. Their model utilizes a Bayesian forecasting procedure whereby period-one demand is used to update the prior parameters and revise the period-two forecast. The forecast is then incorporated into the model to derive optimal inventory-stocking policies. Hill (1997) assumes that demands are from a known distribution with a fixed, but unknown parameter. Based on collateral data a prior distribution for the parameter is constructed. As new data come in the prior distribution is updated to generate a posterior distribution. This posterior distribution of the unknown variable can then be used to estimate the posterior distribution of demands. He compares the classical and Bayesian approach to estimate the unknown parameter and, then, shows the superiority of the Bayesian approach in numerical comparisons.