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Forecasting for inventory control with exponential smoothing

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Abstract

Exponential smoothing, often used in sales forecasting for inventory control, has always been rationalized in terms of statistical models that possess errors with constant variances. It is shown in this paper that exponential smoothing remains appropriate under more general conditions, where the variance is allowed to grow or contract with corresponding movements in the underlying level. The implications for estimation and prediction are explored. In particular, the problem of finding the predictive distribution of aggregate lead-time demand, for use in inventory control calculations, is considered using a bootstrap approach. A method for establishing order-up-to levels directly from the simulated predictive distribution is also explored.

Keywords: Exponential smoothing; Fill-rate; Inventory control; Lead-time demand; Service level; Single source of error

1. Introduction

The conceptualisation of exponential smoothing (Holt, 1957; Brown, 1959; Winters, 1960) was an important development for demand forecasting in inventory control. Yet implementations of this method have often been surrounded by practices, summarized in Gardner (1985), that possess questionable theoretical roots and that, at best, have enjoyed mixed success. In this paper, we show that the relatively new state space models for exponential smoothing with a single source of error (SSOE) (Snyder, 1985a,b; Ord, Koehler, & Snyder, 1997), can play an important role in inventory control. These state space models can be put in a form that shows immediately the direct relationship with the usual formulas for the exponential smoothing methods.

1.1. The empirical case for non-constant errors

One of the interesting features of the SSOE models is that the variance of the disturbance term need not be constant but instead can vary with the mean of the time series. Thus, for each exponential smoothing method, there is an SSOE model with constant variance for the forecast error and a second SSOE model with non-constant variance. The possibility of basing

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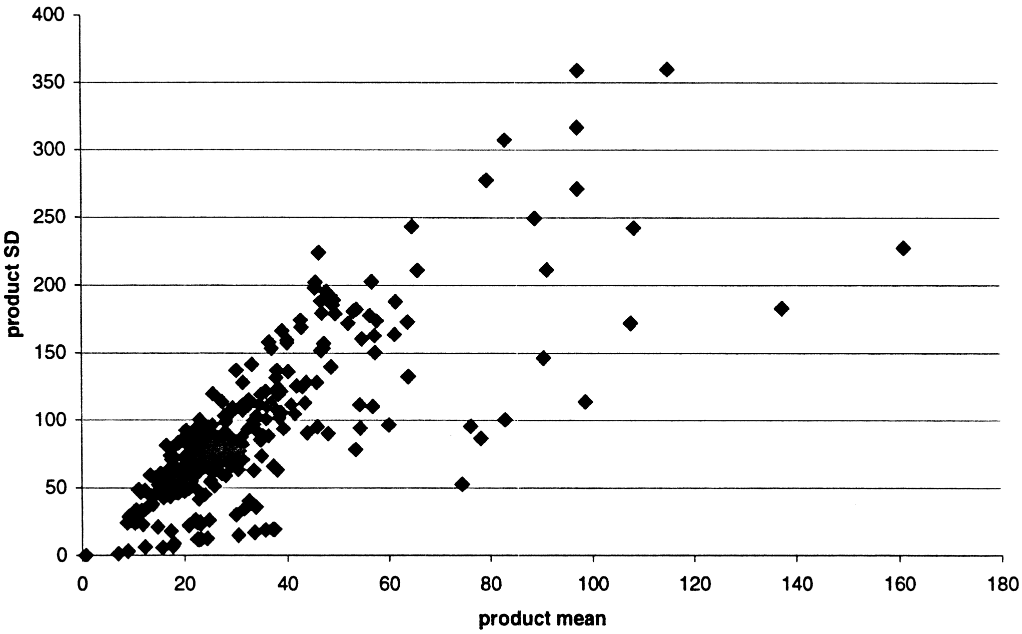

Fig. 1. Plot of standard deviation against mean for Monet data, by product, computed over weeks 5–46.

a theory of forecasting and inventory control on such non-constant errors has a certain attraction. Over 40 years ago Brown (1959, p. 94) said, 'you will be very likely to find that the standard deviation of demand is nearly proportional to the total annual usage, or to the average monthly usage'. When describing models of the demand process, other authors on inventory control have also allowed the variation in the forecast error to depend on the size of the forecast and have pointed to Brown's statement (Miller, 1986; Lovejoy, 1990; Heath & Jackson, 1994).

We now present some empirical results that suggest that the standard deviation may, indeed, be proportional to the mean rather than constant. Our data[1] are the weekly sales figures for weeks 5–51 of 1998 for 345 jewelry lines sold by The Monet Group. Since the period from Thanksgiving to Christmas is known for its high sales volume, we partitioned the data into weeks 5–46 and 47–51. We then computed the mean and standard deviation for each product within each period; the results are plotted in Figs. 1 and 2. The plots clearly suggest that the standard deviation is proportional to the mean, rather than constant.

1.2. Models for exponential smoothing

Models, as opposed to methods, for forecasting the demand process, are important in the development of policies for inventory control. In particular, a model enables us to specify the predictive distribution for future demand so that inventory policies may be derived in accordance with some criterion such as expected cost minimization. Further, the advantages of the SSOE models over other suggested models for inventory control include:

1. the use of logarithms can be avoided when the variance is nonstationary;
2. the most common types of trend and seasonality can be modelled;

[1]We are grateful to Dr. Bill Sichel of The Monet Group for providing these data.