Bayesian Inventory Control Using Leading Economic Indicators

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Research Problem Description

We were approached by a construction equipment producer who wanted to improve its spare parts inventory management. This producer faces extreme volatile demand in its service parts business, which makes the inventory holding and penalty costs so high that its profit is greatly reduced. One way to reduce these cost is to better forecast demand so that the mismatch between supply and demand is reduced. The producer finds that its spare part demand of a month is strongly correlated with a few month earlier's construction spending index, a leading economic indicators in the Conference Board Leading Economic Indicator Index. The produces wonders if it can use the leading economic indicators to better manage the spare part inventory system.

It turns out that the leading indicator also exists among group of products. Wu et. al. (2006) find that in high tech company, e.g., Agere system (a division of former Lucent Technology), a leading product demand has as much as 90% correlation with the six month later demand of other products in the same group. They discussed how to use the leading indicator to improve the demand forecast of other products in the same group. However, they did not study how to use the indicator to improve the inventory system. Hence, the research problem for us is to study the value of the leading indictor for a inventory management. In order to solve this problem, we have to answer the following subproblems:

1. What is a proper demand forecasting model to include the leading economic indicator?

2. What is a proper inventory control model that takes into account of the leading economic indicator information?

3. What is the value of the leading economic indicator information and what is the impact of the leading indictor's characteristics (e.g., leading periods) on this value?

Methodology and Assumptions

In order to address these problems, in this paper we first follow Azoury and Miyaoka (2009) to use linear regression model for demand forecasting where the explanatory variable is the correlated leading indicator. Then we model the inventory system a periodic review system for finite horizon where the demand are updated every period using the linear regression model. The demand update takes into account of both the historic demand and the leading indicator.

The resulted model is a Markov Decision Process with multidimensional state space. The state consists of the sufficient statistics that summarizes all the historic demand information and the leading indicator, in addition to the inventory on-hand. The complexity of the state space makes it a very challenge problem to find the optimal inventory control policies.

Major Results and Implication

Despite the challenge of the problem, we find the optimal policy in our model is a state-dependent base-stock level policy. We have also studied the properties of that optimal policy as a function of the state variables, and found several counter-intuitive results on monotonicity properties. For example, the optimal base-stock level can be smaller for a larger realizations of past demand.

Our model allows us to quantify the value of the leading indicator and the impact of the leading periods. We find that this value can be significant and it incases with the leading periods. However, the marginal value of the increasing leading periods decreases. This implies that with limited look-ahead, we can capture a large portion of the leading indicator value.

We finally try our model on the real case of the producer who motivated this research and find that using the construction spending index information can greatly reduce its inventory costs. We also compare it numerically to other models developed in the literature, such as Graves (1999) or Aviv (2003) and find our model performs better than their models for this producer.

References

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