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A comparison of bullwhip effect in a single-stage supply chain for autocorrelated demands when using Correct, MA, and EWMA methods

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ABSTRACT

In this paper, the three Correct, MA, and EWMA Methods for series demand function model (ARiMA(1,0,0), ARiMA(0,0,1), ARiMA(1,0,1)) have been described, formulated, and presented to examine the influence of forecast-updating methods between order quantity and actual demand in the amplifications of bullwhip effect. By using these forecast-updating methods comparison, the optimal solution of the bullwhip effect control Policies with a time-series technique under a basic one supply chain stage perspective can be obtained. Through the comparison of the more flexible bullwhip effect control Policies, a more efficient demand function model strategy of the parameter setting, using and the integrated application method in the supply chain management procedure was decided to use. In addition, a simulated procedure and systems analysis regarding these series demand uncertainty modeling parameters will be conducted to investigate the fluctuation effects on the amplifications of bullwhip effect. The proposed method permits controlling the retailer orders' variability above the other factors in the bullwhip effect.

1. Introduction

For the past decades, the rule of competition has changed from one-by-one to chain-by-chain. A common phenomenon in the supply chain that has been observed and justified is known as "bullwhip effect"(Ouyang & Daganzo, 2006). In a supply chain model which consists of the retailers, agents, distributors and manufacturers, the retailer makes an order by using the customer demand plus future need to the agent; the agent uses this order plus its future demand to decide its orders for the distributors, etc. In this process, the correct information and actual demand have been distorted, resulting in a huge error of the demand variability from the downstream to the upstream in the supply chain. The disharmony of information transported is the main reason for this effect (Ouyang, 2007).

The impacts of bullwhip effect could be the inefficient production, exceeding supplies, unfavorable customer service, and higher inventory costs. For instance, in this opaque situation, the agent does not know the actual demand and then it will use the customer's demand, the retailer's future need, and its future demand to decide its production strategy and inventory level. After this decision is made, it would lead to tremendous variance of demand and supply; the production schedule destroyed in holding supply chain members, a serious inventory problem or unfilled customer demand, and a huge storage cost or lose of the corporate revenue and customers' confidence. Lee, Padmanabhan, and Whang 1997a, 1997b has identified four major causes of the bullwhip effect: demand forecast updating, order batching, price fluctuation, and rationing and shortage gaming. In accordance with these four causes, the policymaker would be likely to make wrong decisions in the station of opaque information (Daganzo, 2004).

Recently, many scholars have tried to quantify and eliminate this effect. In general, the actual demand model is difficult to evaluate, and the policymaker would not spend more time or waste money getting the right demand model. Most people try to use the convenient forecasting technique such as ES (exponential smoothing) forecast and MA (moving average) forecast to update its future demand (Brown, 1962). If the supply chain members are in an unequal position and do not have an efficient coordination, whatever they do, the bullwhip effect still happens. In this paper, we will use the exact forecasting technique to estimate the customers' future demand and quantify the bullwhip effect in three kinds of demand uncertainty modeling functions in a single-stage supply chain.

The result of the paper is organized as follows: the next section proves a literature review of a brief survey. Section 3 demonstrates three kinds of demand models of bullwhip effect in different

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forecast methods. In Section 4, we discuss the influence of bullwhip effect and provide conclusion at the end of this paper.

2. Literature review

The phenomenon of bullwhip effect has been discussed in industrial system dynamics analysis, economic, and management science for many decades. Forrester (1961), the first person to illustrate the effect in industrial system dynamics analysis, indicated that the variance of manufacturer's demand will be in excess of the variance of actual customer's demand and that this effect is coming from industrial system dynamics analysis or time-varying behaviors in the organizations.

A famous experiment of inventory management to prove the phenomenon of bullwhip effect is the "Beer Distribution Game" conducted by Sterman (1989). In beer distribution game, customers, retailers, wholesalers and suppliers are four players who make independent inventory decision without communicating to each other in this supply chain. Under this framework of the supply chain, a little swing of customer demand will cause tremendous undulation to the upstream members' production and inventories. Sterman (1989) indicated the causes of this phenomenon and players' irrationality of behavior are "misperceptions of feedback."

Lee et al. (1997a) identified four major causes of the bullwhip effect: demand forecast updating, order batching, price fluctuation, and rationing and shortage gaming and counteracted the bullwhip effect of the four causes. Lee et al. (1997b) developed simple mathematical models of supply chain to quantify this effect and discussed the managerial implications for channel coordination activities. Lee's proposition differs from that of Sterman's in what Lee demonstrates the bullwhip effect is an outcome of the strategic interactions among rational supply chain members. Sterman ascribe the bullwhip effect to personnel irrational behavior.

In the framework of a supply chain, orders are a signal of the customers' demand from downstream moving up to upstream.(Metters, 1997) Based on this immediate sign from customers, the company usually uses it to do prediction of material requirements planning (MRP), production planning, and controlling inventory level. (Hax & Candea, 1984) The company will spend more time in the process of transmitting order messages and distributing products to the supply chain members. This period of time is called "lead time." Each member in this supply chain must forecast the future demand and prepare enough stocks during the lead time. Any forecast methods to do prediction, the bullwhip effect will occur, and the variance of demand forecast updating will amplify the fluctuation in multi-stage supply chain. In fact, companies would not place an order to its supplier immediately. Most of companies make the economic scale in raw materials and transportations to reduce the company's ordering cost and time. If the company makes the batch order weekly or monthly, the supplier will face the more uncertain demand from company and the supplier's variability will be higher than that of company.

In addition, the other two causes of bullwhip effect – price fluctuation and shortage gaming – are company's poor decision. The price fluctuation will cause customer's "forward buying," especially the cutting price. For example, the supplier do a promotion by cutting price in a special period, like the celebration days, the customers will buy more products than they are needed. After the promotion is over, the price of products is back to the original level, and customers would not place an order until the quantity of the products are not enough during the lead time. It is a rational decision for the customers, but it will result in the distortion of information and inefficiency in the supply chain. The shortage gaming is still another cause of the bullwhip effect. If the demand is suddenly raised or the supply is in an uncertain situation, the company will increase its order quantity to get more quota in this rationing and shortage gaming, and the manufacturer will expand the production on large scale. While fashion is out of date or the demand suddenly cools, the company will cancel the previous order to decline its loss. The supplier is the loser in the shortage gaming.

Chen, Drezner, Ryan, and Simchi-Levi (2000) Chen, Ryan, and Simchi-Levi (2000) kept analyzing in demand single processing by using moving average method and exponential smoothing method to predict future demand in simple supply chain. The consequence of the bullwhip effect is similar to Lee's. Chen indicated that bullwhip effect will be influenced by the forecasting method used by retailers and the lead time influence bullwhip effect significantly. In correlated demand model by using the moving average forecasts, the parameter of "p", the number of observations used in the moving average is negative in variability of bullwhip effect and when "p" is large, the increase in variability is negligible; in a positive demand, the larger the correlation parameter is, the smaller the increase in variability; the parameter of lead time is the positive relation to this effect by using any kinds of forecast techniques. It also demonstrated that the centralized demand information could certainly reduce the bullwhip effect. Chen, Ryan, et al. (2000) assumed that the retailer applies an exponential smoothing forecasting technique and faces two demand processes, one is the correlated demands and the other is demands with a linear trend. Chen demonstrate that the variance of the orders placed by a retailer using a moving average forecast will be less than the variance of the orders placed by the same retailer using an exponential smoothing forecast in the demands with a linear trend. Chen, Ryan, et al. (2000) in his paper examined the phenomenon of bullwhip effect by using exponential smoothing forecast, but the formula of this effect had not been completely calculated. The value of the bullwhip effect is a low boundary. The exact value is at least greater than the Chen's result while α is not equal to zero.

Wang, Chu, and Lan (2003) continued Chen, Drezner, et al.'s (2000) and Chen, Ryan, et al.'s (2000) work to quantify the bullwhip effect in the multi-supply chain which consists of one retailer, one distributor, and one supplier. They examined the bullwhip effect in different kinds of demand models and analyzed the relations of these demand models in two of Chen's forecasting methods. In this study, they assumed that all members in the supply chain use the consistent forecasting and got some significant conclusions:

1. While companies predict its future demand by any kinds of forecast methods, the phenomenon of bullwhip effect still happened.
2. Different demand model's parameters (such as L Lead time, α and P) will be affected the range of fluctuation in the bullwhip effect. Hence, the manager must analyze the demand model's parameters to reduce the influence of bullwhip effect.

In the earlier mentioned studies in demand single forecast, Lee et al. (1997a) had already indicated that "if you are also using exponential smoothing to update your forecasts and safety stocks, the orders that you place with your supplier will have even bigger swings." Naturally the scholars of Chen et al. and Wang et al. (2003) still had the bigger swings of bullwhip effect phenomenon in any situations.

In this paper, we concentrate our attention on the demand single forecast in Correct method and compare the result of bullwhip effect on two different forecast methods – moving average (MA) and exponentially weight moving average (EWMA) (Gaur, Giloni, & Seshadri, 2005). We will examine other autocorrelated demands in these three forecast method and make some efficient suggestions at the end of our systems analysis.