Chapter 38
Bullwhip Effect Analysis in a Supply Chain

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ABSTRACT

In today's world, all enterprises in a supply chain are attempting to increase both their and the supply chain's efficiency and effectiveness. Therefore, identification and consideration of factors that prevent enterprises to attain their expected/desired levels of effectiveness are very important. Since bullwhip effect is one of these main factors, being aware of its reasons help enterprises decrease the severity of bullwhip effect by opting proper decisions. Now that forecasting method is one of the most important factors in increasing or decreasing the bullwhip effect, this chapter considers and compares the effects of various forecasting methods on the bullwhip effect. In fact, in this chapter, the effects of various forecasting methods, such as Moving Average, Exponential Smoothing, and Regression, in terms of their associated bullwhip effect, in a four echelon supply chain- including retailer, wholesaler, manufacturer, and supplier- are considered. Then, the bullwhip effect measure is utilized to compare the ineffectiveness of various forecasting methods. Owing to this, the authors generate two sets of demands in the two cases where the demand is constant (no trend) and has an increasing trend, respectively. Then, the chapter ranks the forecasting methods in these two cases and utilizes a statistical method to ascertain the significance of differences among the effects of various methods.

1. INTRODUCTION

Nowadays, all enterprises in a supply chain are attempting to increase their efficiencies and effectiveness. Since bullwhip effect in supply chain is one of the main obstacles in attaining expected levels of effectiveness, being aware of its determinant factors can help enterprises reduce the severity of the bullwhip effect. One of the factors which generate bullwhip effect in a supply chain is inaccurate utilization of demand forecasting methods (Lee et al., 1997a). Bullwhip effect has become a well-known phenomenon in supply chains and suggests that variation will significantly increase as

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one moves up in a supply chain. For this purpose, this chapter considers the role of various forecasting methods on demand amplification or bullwhip effect in a four-echelon supply chain, including retailer, wholesaler, manufacturer and supplier, in the two cases of constant and increasing demand trends. Considering the literature shows that many researches utilize Moving Average or Exponential Smoothing as a forecasting method. Moreover it is clear that Linear Regression can be utilized as a suitable method to forecast the future in the case of increasing demand. For this reason, the impacts of these three methods on the bullwhip effect in a supply chain are compared in this chapter. Furthermore the longest supply chain which has been considered in this area is a four-echelon supply chain with one component in any echelon. For this reason, we, also, investigate a supply chain with four echelons and one component in any echelon. In addition, to evaluate the bullwhip effect we apply the ratio of order variance in the most upper and lowest layer of the chain as by Warburton (2004). Also, we utilized statistical test to ascertain the significance of difference among various forecasting methods.

2. BACKGROUND

The root of bullwhip effect can be traced back to Forester (1961). Although Forester described the bullwhip effect in some cases and pointed out management policies and decisions can generate variation in supply chain, however, the bullwhip effect owes its renown to Sterman's studies in inventory management. Sterman (1989) reported his observations from bullwhip effect as "Beer Distribution Game" or simply "Beer Game". In general, the researches in this area can be divided into three groups. In the first group, the researches focus on analyzing the creators (causes) of the bullwhip effect (for instance: Lee et al. (1997b), Bourland (1996), Miragliotta (2006)) whereas more detailed and specialized subjects are surveyed in the two last groups. The second group includes researches which measure or consider the bullwhip effect generated from creators known in the previous researches and the third group includes the researches which compare the created bullwhip effect generated from various methods or causes. Since this chapter aims to consider the impact of various forecasting methods on the bullwhip effect, we focus on those papers of the second and the third groups which considered the impact of forecasting methods on the bullwhip effect. Generally, four methods of forecasting have been considered so far: Exponential Smoothing, Moving Average, Linear Regression and ARIMA. In addition, it is assumed in these papers that a supply chain consists of three-echelons with one product and the same forecasting method in each echelon. Then, the chain was modeled and the bullwhip effect indices were analyzed. Some of these papers are summarized in Table 1.

Lee et *al.* (1997b) presented an analytical model to consider the bullwhip effect of exponential smoothing method in a three-echelon supply chain. Moreover, in another paper Lee et *al.* (2000), he presented a mathematical model to determine optimized constant of exponential smoothing in a two-echelon supply chain. Chen et al. (2000) quantify bullwhip effect for simple, two-stage supply chains consisting of a single retailer and a single manufacturer. Their model includes two factors: demand forecasting and order lead times. Furthermore, Thonemann (2002) presented a mathematical model to improve supply chain performance by sharing demand information in a three-echelon supply chain. Xiaolong Zhang (2004) developed mathematical model to demonstrate bullwhip effect generated from moving average and exponential smoothing forecasting methods. In addition, Gang Li et *al.* (2005) considered information transformation in a three-echelon supply chain using an ARIMA forecasting method. Chandra (2006) developed a forecasting method to decrease bullwhip effect in a three-echelon supply chain. As aforementioned, in addition to papers which investigate the effect