The Bullwhip Effect in Supply Chains

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INTRODUCTION

The bullwhip effect is an amplification of demand variability that affects supply chains. A company is subject to a bullwhip effect when customer demand leads to a change in inventory and purchases do not correspond to sales, thus leading to greater variability. The phenomenon may occur in cases of constant customer demand in a supply chain. It has been observed that supply chain demand variability increases upstream from end user to producer.

The bullwhip effect is a well-studied phenomenon both in theory and practice. In critical study, research has been conducted on simulation, empirical investigations, business games and qualitative as well as quantitative approaches. On the one hand, there are studies that examine the occurrence of the bullwhip effect and others that examine its mitigation. Although extensive research has already been done on the bullwhip effect (Lee, Padmanabhan, & Whang, 1997a; Lee, Padmanabhan, & Whang, 1997b; see Disney, Farasyn, Lambrecht, Towill & Van de Velde 2006 for an excellent review of research done to date), it is still a challenging field of study: the bullwhip effect can only occur in supply chains and research is subsequently tied to supply chain management and its approaches. Supply chain management is subject to ongoing changes and developments as a result of globalization and technological innovation, which influence collaboration of supply chain partners. The resulting need for further research on supply chain management leads to research opportunities on the bullwhip effect.

BACKGROUND

The first academic description of the bullwhip effect is usually ascribed to Forrester (Forrester 1972) who asserts that lead times are an immanent part of dynamic systems. Lead times take place between different parts of a system due to the handling of material and information. Forrester analyzes stock, production and lead-time in a supply chain. According to him - and validated by empirical data - it is common practice for the variance of orders to far exceed the variance of consumer demand. The effect is amplified at each stage of the supply chain.

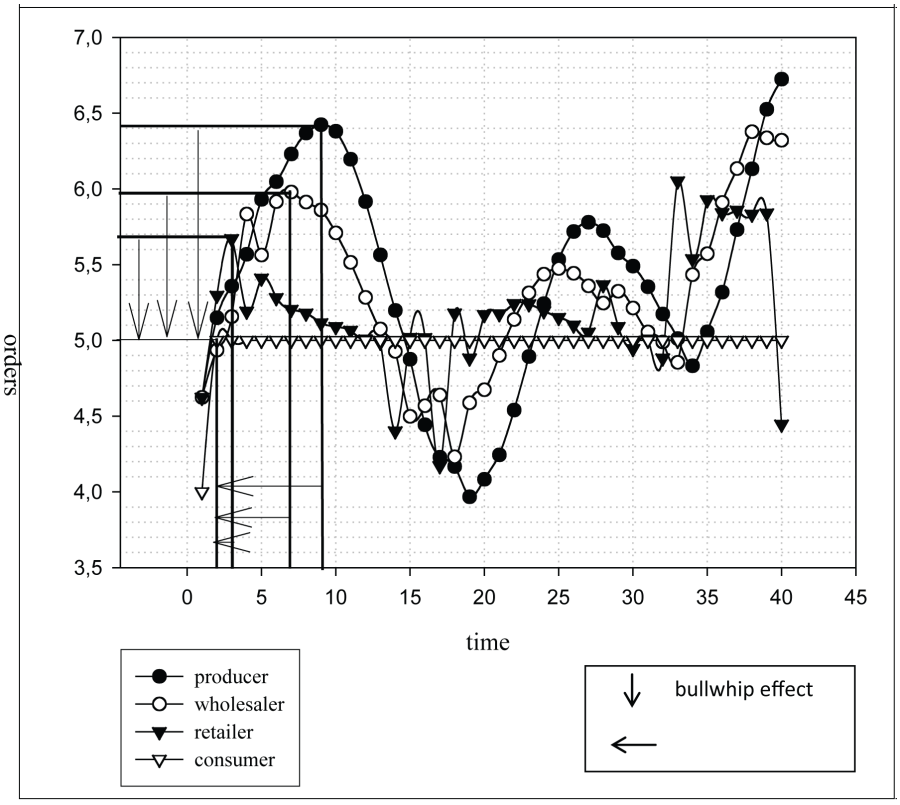
The most popular demonstration of the existence of the bullwhip effect is the "Beer Game" (Sterman, 1989), a simulation of rather simple supply chain, consisting of a producer, a distributor, a wholesaler and a retailer who are set up in the beer game. The bullwhip effect occurs, despite the fact that consumer demand changes only slightly at the beginning of the game and remains constant.

In general, the bullwhip effect can be characterized by three factors, which are shown in figure 1.

- **Oscillation:** Order and inventory quantities are subject to large fluctuations in amplitude even though consumer demand remains constant.
- **Amplification:** The amplitude and variance of order quantities increase steadily from consumer to producer. Despite the fact that consumer demand remains constant, retailer demands increase, while order quantities of the producer show a great variance (see vertical arrows in Figure 1).

DOI: 10.4018/978-1-4666-5202-6.ch222

Figure 1. Characterization of the bullwhip effect (Keller 2004)



- **Phase lag:** The order rate later peaks as one moves from the retailer to the producer (see horizontal arrows in Figure 1).

The bullwhip effect can be defined as an increase of variability (measured by variances) of orders related to the variability of consumer demand. Material and information do not flow steadily through the supply chain. The orders seem to be hit by a whiplash. Consequently, the objective of supply chain management (the rapid, cost-minimized and flexible satisfaction of consumer needs with high-quality goods) can no longer be guaranteed. It is noncontroversial that a reduction of the bullwhip effect leads to a profit increase in supply chains (e.g., Metters, 1997).

The bullwhip effect is subject to quantitative research approaches. A well-known approach taken by Lee, Padmanabhan, and Whang (1997a, 1997b) is based on a practical example of the bullwhip effect taken from an occurrence at Procter & Gamble, where the bullwhip effect was first observed. They show that the quantity of stock in a bullwhipping supply chain is too high. Another quantitative analysis by Chen, Ryan and Simchi-Levi (2000) attempts to show the impacts of different forecasting methods and different distributed demands on the forecast of demand.

Other approaches do not focus on the occurrence of the bullwhip effect but its reduction. One example is the use of vendor-managed inventory in supply chains to reduce the variance of orders (Disney & Towill, 2003a; Hohmann & Zelewski, 2011).

MAIN FOCUS

As shown above, the bullwhip effect is a well-documented phenomenon that has been the subject of recent research. One might assume that the bullwhip effect has only theoretical significance