Chapter 9
Effects of Vendor-Managed Inventory on the Bullwhip Effect

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ABSTRACT
The bullwhip effect means that demand variability increases as one moves up the supply chain. In the following article the bullwhip effect is quantified for each part of the supply chain which is presupposed to consist of a producer, a wholesaler, a retailer, and a consumer. After considering the causes of the bullwhip effect, it will be shown with the help of a nonlinear optimization model to what extent the bullwhip effect can be reduced using vendor-managed inventory (VMI) as one concept of Collaborative Planning, Forecasting and Replenishment (CPFR). In contrast to other studies in this field the reduction of the bullwhip effect will be accurately quantified for each part of the supply chain.

MOTIVATION
The bullwhip effect in supply chains represents a long recognised phenomenon in the area of logistics. The material flows of the supply chain’s participants do not correspond to the consumer demand, which, known as “demand pull”, is the decisive factor in the supply chain. The chance of a smooth running of the supply chain in view of the material and information flow is missed on a regular basis as soon as the bullwhip effect occurs. The occurrence of the bullwhip effect leads to raised costs in the supply chain (McCullen & Towill, 2002; Reddy, 2001). The reduction of the bullwhip effect and therefore the reduction of raised costs in the supply chain lead to an increased profitability of business. Estimations suggest the increase of profitability of business may be up to 8.4 – 20.1% (McCullen & Towill, 2002) or up to 10 – 30% (Metters, 1997).

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The use of vendor-managed inventory (VMI) is based on a close cooperation between the producer and the participant that has point of sales data at their disposal. With this coalescence of supply chain parts the appearance of some causes that lead to the bullwhip effect can be prevented (Richardson, 2004; Waller, Johnson, & Davis, 1999). This article provides a multi-dimensional analysis of the different causes of the bullwhip effect, its impact on the different supply chain parts and its counteractions. It will, therefore, be exactly shown what impact the bullwhip effect has on the supply chain and to what extent the bullwhip effect can be reduced in each part of the supply chain by using vendor-managed inventory. This detailed approach adds a holistic, quantitative analysis to the existing literature and enables the prediction and reduction of the bullwhip effect. Vendor-managed inventory is chosen as the concept of CPFR which implies the closest collaboration between producer and retailer.

The appearance of the bullwhip effect can be attributed to five reasons in total: Demand distortion, misperceptions of feedback, batch ordering, price fluctuations, and strategic behavior (Keller, 2004). In this paper, we concentrate on two of these causes, demand distortion and misperceptions of feedback, because they are especially related to the examined topic of VMI. The analysis of these two causes provides the best approach to VMI’s efficiency evaluation. First, however, the conceptual principles will be explained.

**CONCEPTUAL PRINCIPLES**

**The Bullwhip Effect**

The phenomenon bullwhip effect means that goods and information do not pass through the supply chain in the required quantity and to the required point in time. Thus, the supply chain management does not result in a cost-optimised and just-in-time coordinated supply. The first academic description of the bullwhip effect is usually ascribed to Forrester (Forrester, 1972). Forrester assumes lead times to be an imminent part of dynamic systems. Lead times occur between different parts of a system due to handling of material and information. Forrester analyses different variables like stock, production and lead times and demonstrates the effects of changes in the system. He states that it is common in practice, and validated by empirical data, for variance of orders to far exceed the variance of consumer demand. This effect is amplified at each stage in the supply chain (Forrester, 1972). These variations had up to this point been regarded as inevitable, as they were said to be caused by external influences (Forrester, 1972). Forrester contradicts this by showing that the variations are caused by lead times. In practice the bullwhip effect is simulated by the well-known “beer game”. The result of this game is that the simulated costs are ten times higher than the benchmark costs (Sterman, 1989).

The distribution of orders in the “beer game” is characterized by three factors which are graphically shown in Figure 1.

- **Oscillation:** Order and inventory quantities are dominated by large amplitude fluctuations.
- **Amplification:** The amplitude and variance of order quantities increase steadily from customer to producer.
- **Phase Lag:** The order rate peaks later as one moves from the retailer to the producer.

The shortest arrows represent the bullwhip effect and the phase lag of the retailer respectively. The longest arrows represent the bullwhip effect and the phase lag of the producer respectively.

This increasing amplitude of order quantities is also well-known in practice. The most popular case is that of Procter & Gamble, who faced this amplitude with their brand Pampers despite the constant demand of diapers (Lee, Padmanabhan, & Whang, 1997a, 1997b). The orders do not