Retailer's Order Decisions under Delays: System Dynamics and Experimental Results

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ABSTRACT:

When final customer demand exceeds available supply, retailers often hedge against shortages by inflating orders to their suppliers. As several retailers compete for scarce supply, the amplification in orders lead to excess supplier capacity, high inventory variability, low capacity utilization, and financial and reputation losses for suppliers and retailers. While the amplification in orders caused by the competition for scarce resources has been described in the literature almost a century ago (Mitchell 1924), there is little research quantifying the impact of such order amplification by retailers.

This paper quantifies retailer order amplification decisions during a surge in demand. First, we motivate the problem and present a simple formal mathematical model describing its dynamics. We then develop an experimental environment to test subject's ordering decisions, when compared to a performance benchmark. Finally, results from different treatments (different ordering and supplier capacity acquisition delays) allow us to characterize subjects' performance in this system and formulate a heuristic that closely replicates subjects' ordering behavior in all treatments.

KEYWORDS:

Bullwhip effect, laboratory experiments, behavioral operations, supply chain management, demand bubbles.

1. INTRODUCTION

In a supply chain different approaches are used to integrate suppliers, retailers and customers. The merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system-wide costs while satisfying service level requirements (Zhang, 2006). Supply chains have had much attention in industrial and academic fields, and thus, a number of techniques are developed to model, analyze, and solve complex decision problems. One of the most frequent and costly problem in supply chains is known as the bullwhip effect (*or forrester effect*) (Gonçalves and Arango 2010; Lee et al. 1997a; Sterman 2000). This phenomenon shows how production and inventories chronically overshoot and undershoot around their appropriate levels forming fluctuations that propagate from the downstream to the upstream elements of a supply chain. These fluctuations lead producers and distributors to react imperfectly to the demand information; which could lead to both excess inventories and inventory stockouts throughout the supply chain (Sterman, 2000; Anderson et al., 1999, Gonçalves 2003; Lee et al. 1997a;). The *bullwhip effect* has been captured in the literature as early as 1924, when Mitchell described the case of retailers inflating their orders to manufacturers when competing with other retailers for scarce supply. He argued "if [retailers] want 90 units of an article, they order 100, so as to be sure, each, of getting the 90 in the pro rata share delivered." (Mitchell 1924, p. 645)

This builds upon a formal model developed by Gonçalves (2003) and Gonçalves and Arango (2010), capturing the impact of retailers amplification in orders when competing for scarce supply. It explains how the retailer and the supplier inflate their orders and capacity investment in order to satisfy their demands. This phenomenon is repeatedly shown in industry operations and macroeconomic data and it is also our initial hypothesis and motivation for creating an experimental environment that tries to reflect and explain this behavior. Our research suggests that subjects' performance deteriorates when they face larger ordering delays (lag associated with placing orders) and when the supplier faces longer capacity acquisition delays. Both conditions are consistent with the studies made by Sterman (1989a, 1989b) and Gonçalves (2003) and Gonçalves and Arango (2010). Subjects systematically deviate from an optimal benchmark. Moreover, subjects' ordering behavior can be explained econometrically by a simple decision rule. We discuss the systematic biases that result from their decisions

This paper starts out from the formal model developed by Gonçalves (2003, 2010), which captures the impact of the rationing game in a tree supply chain. The model considers a single supplier who sells to multiple retailers that compete for a scarce product. In section 2, we first describe and analyze the model behavior and then we compare the results with a benchmark. Section 3 illustrates the experimental design. Section 4 shows the results, where we find that subjects performance deteriorate when they face larger delays in retailer's orders and when the supplier faces longer capacity acquisition delays, which is consistent with the studies made by Sterman (1989a, 1989b) and Gonçalves (2003, 2010). Subjects systematically deviate from the benchmark, which are explained econometrically analyzing subjects' decision rules in section 5. We discuss the systematic biases that result from their decisions. Section 6 concludes.

2. MODEL DESCRIPTION

We build upon a model proposed by Gonçalves (2003) capturing a supply chain with a single supplier offering a unique, non substitutable, product to multiple retailers. The emphasis of our analysis is on a retailer's ordering problem trying to match supplier shipments and final customer demand. Figure 1 displays the structure of this supply chain.

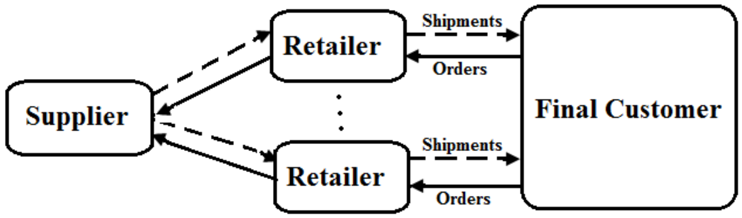

Figure 1 Supply Chain structure

RETAILER'S ORDERING DECISION:

Gonçalves (2003) models retailers' orders, R_D, using an anchor and adjustment heuristic, where retailers anchor their orders on a demand forecast, and then adjust it up or down to maintain orders at a desired level. The anchor term captures retailers' intention to place sufficient orders to meet their customers' orders. The adjustment term closes the gap between retailers' desired and actual backlog of orders. In addition, retailers close the gap between desired and actual backlog of orders within a specific adjustment time. Gonçalves (2003) also assumes that each retailer adopts the same heuristic with the model capturing total values for customer demand forecast (*d*), actual backlog of orders (*B*), desired backlog of orders (B^*), and adjustment time (τ_B). Finally, total retailers' orders are non-negative. Equation (1) shows this heuristics

$$R_D = Max\left(0, d + \frac{B^* - B}{\tau_B}\right) \quad \textbf{(1)}$$

Retailers' desired backlog of orders (B^*) is given by the product of the demand forecast, *d* and the expected delivery delay to receive orders from the supplier (*ED*).

$$B^* = d \cdot ED \quad \textbf{(2)}$$

Gonçalves (2003) assumes that the expected delivery delay is given by a linear function (*f*), with slope α, of the actual delivery delay (*AD*).The function (*f*) captures retailers' delivery delay adjustment, that is, when faced with long delivery delays, retailers set their expected delivery delay (*ED*) above the actual delivery delay (*AD*) quoted by the supplier. Longer expected delivery delays (*ED*) than actual (*AD*) leads to higher desired backlog of orders (B^*) and higher retailers' orders.

$$ED = \alpha\ AD = = \alpha\ (B/S),\ \text{where}\ \alpha \geq 1 \quad \textbf{(3)}$$

where, actual delivery delay (*AD*) is given by the ratio of the order backlog (*B*) to shipments (*S*).

SUPPLIER'S CAPACITY AND SHIPMENTS:

The supplier's backlog of orders (*B*) increases with retailers' orders (*Rd*) and decreases with supplier shipments (*S*).

$$\dot{B} = R_D - S \quad \textbf{(4)}$$