Omega 40 (2012) 891–905

Contents lists available at SciVerse ScienceDirect

Omega

journal homepage: www.elsevier.com/locate/omega

Price promotions, operations cost, and profit in a two-stage supply chain

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ARTICLE INFO

Article history:
Received 26 July 2011
Accepted 24 January 2012
Processed by B. Lev
Available online 17 February 2012

Keywords:
Inventory control
Operations management

ABSTRACT

The phenomenon in which demand variability increases as one moves upstream in the supply chain has been often observed in practice. This so-called "bullwhip effect" often increases upstream operations costs, including inventory holding and transportation costs. Price variations are considered to be one of the primary causes of the bullwhip effect, and thus everyday low price (EDLP) strategies are commonly recommended to counter the negative impacts of the bullwhip effect. However, trade promotions continue to play an important role in the U.S. supermarket industry as well as other industries. This paper investigates this apparent inconsistency between the literature and practice by employing a deterministic, two-stage supply chain model composed of a single supplier and a single retailer. We demonstrate that even though the use of trade promotions can indeed increase a retailer's and supplier's operations costs, these costs may be more than offset by increased revenues, even in the absence of explicit coordination. That is, if the supplier judiciously applies a trade promotion strategy and the retailer passes some of this discount to its customers, then under certain conditions, the resulting supply chain profit can exceed that under an EDLP strategy. We provide a broad set of computational results that validate this conclusion and discuss the resulting managerial insights.

1. Introduction

The so-called bullwhip effect, referring to the phenomenon of increasing demand variance as one moves upstream in a supply chain, has drawn a surge of research interest in the last 15 years. In the operations literature, this phenomenon is generally viewed in extremely negative terms because of its negative impacts on information distortion, excess inventory, higher raw material costs, overtime expenses, and added shipping costs. Previous research has mainly focused on identifying causes of the bullwhip effect, quantifying the cost impacts of the bullwhip effect, and developing strategies to reduce the bullwhip effect. Arguably the most influential work in recent years was provided by Lee et al. [27,28]. Their studies characterized price variations as one of the major causes of the bullwhip effect.

In this paper, we consider two distinct types of price fluctuation in supply chains: retail sales promotions and trade promotions. Retail sales promotions target consumers, while trade promotions are offered by an upstream supply chain player to a downstream player. We stress the difference between these two kinds of sales promotions because they affect the supply chain players and consumers in different ways. Companies typically exist to gain profits, and they thus take a profit maximizing view. In contrast, monetary savings is only one of many potential benefits that sales promotions can provide consumers. For example, sales promotions can also enhance a consumer's self-perception as a savvy shopper [13].

Since sales promotions can lead to the bullwhip effect, supply chain management researchers have suggested that suppliers and distributors adopt corresponding management practices (an EDLP strategy, for example) to stabilize prices. Despite these suggestions, trade promotions still play an extremely important role in the U.S. supermarket industry (as well as in many other industries). Supplier trade promotions for consumer packaged goods hit a record of $80 billion in 2004 [21]. More recently, a survey conducted by MEI Computer Technology Group Inc. showed that 42% of the respondents, comprised of consumer packaged goods (CPGs) manufacturers, said they would spend more on trade promotions in 2010 than ever before [26].

Suppliers offer retailers temporary price discounts for several reasons, such as a fall in material prices or a need to clear out inventory. Suppliers may also reduce prices for strategic reasons, so that a temporary price reduction can be transmitted to end consumers in order to stimulate demand. This strategic practice is particularly useful to introduce excitement to mature and mundane products. Miller [29] discusses A.C. Nielsen survey data showing that about 41% of consumers actively look for deals at retail stores. As a result, many suppliers justifiably believe that offering constant prices is not a universally profit-maximizing strategy.

This inconsistency between existing bullwhip effect theory and practice leads us to consider the conditions under which the revenue gain from price discounts can compensate for the extra

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doi:10.1016/j.omega.2012.01.010

costs induced by the bullwhip effect, and how suppliers and retailers should set pricing and inventory replenishment policies, respectively, in order to maximize total system profit.

The remainder of this paper is organized as follows. The following section summarizes related literature. In Section 3 we describe our supply chain model. Section 3.1 states our assumptions about consumer demand, followed by Sections 3.2 and 3.3, which derive mathematical models to optimize retailer and supplier profits, respectively. In Section 3.4, we elaborate on how we compute the variance of retailer orders and the variance of consumer demand, which together permit characterizing the bullwhip effect. Section 4 illustrates how promotions affect profits in our model via a set of numerical tests; we compare the retailer's profit, the supplier's profit, and the total system profit in both the promotion scenario and the constant-price scenario. We conclude in Section 5 with a discussion of the insights provided by our results.

2. Literature review

Despite the recent flurry of interest in the bullwhip effect, research on this subject has existed for half a century. Forrester [18] first identified the phenomenon of increasing demand variability as one moves up a supply chain via a series of case studies. He suggested that this effect was caused by time varying behaviors within industrial organizations. Sterman [33] used the well-known "Beer Distribution Game" to show that the amplitude and variance of orders increase steadily from customer to retailer to factory, attributing this phenomenon to players' "misperceptions of feedback." Lee et al. [27,28] further showed that even under the assumption that the supply chain members are rational, optimizing agents, the so-called "bullwhip effect" may still exist, and they identify four main causes of this effect: the use of certain demand forecasting methods, supply shortage games, order batching, and price fluctuations. In addition, they also proposed mechanisms to counter the negative impacts of the bullwhip effect on operations costs, one of which was the use of an EDLP strategy to counter the component of the bullwhip effect that results from price fluctuations. Chen et al. [14,15] quantified the impact of demand forecasting on the bullwhip effect for a two-echelon supply chain consisting of a single supplier and a single retailer. In their study, the demand distribution parameters are not known with certainty, and the retailer therefore uses moving average or exponential smoothing forecasts to estimate the demand mean and variance. These estimates are then used to implement an order-up-to inventory replenishment policy.

In measuring the bullwhip effect, Fransoo and Wouters [19] discussed potential measurement problems as a result of data aggregation, incompleteness of data, and the isolation of demand data. They used the ratio of the coefficient of variation of orders placed to the coefficient of variation of orders received as a measure of the bullwhip effect. Cachon [12] also used this approach to measure the bullwhip effect. He investigated a supply chain with one supplier and N retailers facing stochastic demand, who implement scheduled ordering policies, and found that the supplier's demand variability declines as the retailer's order intervals increase or the batch size increases. Potter and Disney [31] focused on the impact of batch size on the bullwhip effect, and they used the ratio of the variance of orders placed to the variance of orders received to measure the bullwhip effect. Hosoda and Disney [25] considered the bullwhip effect in a three-level supply chain with an autocorrelated end-customer demand, and quantified the degree of demand variance amplification at a stage as a function of the accumulated lead time to the customer.

However, little model-based research has addressed the extent to which the bullwhip effect might be a necessary evil in a profit-maximizing supply chain. That is, if an activity simultaneously increases revenue and cost (as a result of the bullwhip effect), how does a decision maker choose the level of this activity that optimizes system performance? In our study, this activity corresponds to a price promotion. Although price promotions are considered as one of the major causes of the bullwhip effect, research in marketing science provides evidence that well-designed price variations can benefit the entire supply chain system.

Blattberg et al. [9] summarized this view by contending that: (1) temporary retailer price reductions substantially increase sales; (2) the frequency of deals may alter a consumer's reference price; and (3) the greater the frequency of deals, the lower the height of the deal spike. Blattberg et al. [10] showed that food retailers predominantly prefer offering temporary price discounts to adopting an EDLP strategy, attributing this to a desire to increase market share, and to attract newcomers to their products by offering a lower risk level. Hoch et al. [24] thoroughly investigated the use of an EDLP strategy, and found that this strategy tends to improve a supplier's profit very little, while potentially leading to big losses for a retailer. Ailawadi et al. [1] used a numerical example to demonstrate that a well-designed trade promotion can increase the total supply chain system profits and that the upstream player gains a larger share of the total profit than the case in which the supplier fixes a single price and does not use promotions. In their single-supplier, single-retailer study, the supplier's unit costs are fixed, while the retailer's unit cost equals a fixed value plus the supplier's wholesale price. Moreover, their model does not account for fixed order costs or inventory holding costs, and therefore the bullwhip effect is not a factor. Chandon et al. [13] built a framework addressing the multiple consumer benefits of sales promotions, and they classified these benefits into six categories: monetary savings, quality increases, convenience, value expression, exploration, and entertainment. They also recommended against a retailer's blind use of EDLP, arguing that customers respond to sales promotions for reasons that extend beyond monetary benefits.

The presence of apparent inconsistencies between the marketing and operations views of promotions leads us to wonder how price fluctuations affect total system profit in a supply chain. Since the conclusions from the marketing science literature typically do not explicitly consider supply chain operations costs, a mathematical model that accounts for these operations costs in addition to the demand-side effects of price promotions may serve to partially reconcile these conflicting views.

Some past research has partially addressed this question, taking a retailer's view. A retailer's optimal order policy in response to a one-time price discount under price-insensitive customer demand has been well studied by Naddor [30] and Taylor and Bradley [34]. Ardalan [5,6] developed a model that determines both the retailer's optimal price and order policies in response to a temporary price discount using a general price–demand relationship. Arcelus and Srinivasan [3] generalized this work by accounting for potential forward buying at the retailer. Arcelus et al. [2] compared the benefits of short-term price discounts to those of trade credit terms and demonstrated a one-to-one correspondence between the two mechanisms. For a more comprehensive discussion of inventory management under short-term price incentives, please see Ramasesh [32].

Beyond the retailer's inventory and pricing policies, we are also interested in how system-wide (supplier and retailer) policies interact to drive performance. To this end, Goyal [22] proposed an integrated inventory model for a two-echelon system; his work compared independent and joint approaches