Int. J. Production Economics 148 (2014) 133–144

Contents lists available at ScienceDirect

Int. J. Production Economics

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

Retailer shelf-space management with trade allowance: A Stackelberg game between retailer and manufacturers

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ARTICLE INFO

Article history:
Received 5 September 2012
Accepted 29 September 2013
Available online 11 October 2013

Keywords:
Optimization
Promotion
Statistical modeling.

ABSTRACT

Motivated by the significant influence of trade allowance on store operation and the efficiency of shelf-space allocation, this article develops a model for optimizing category-level shelf-space management. A category shelf-space allocation framework with trade allowance is presented and a multi-player Retailer Stackelberg game is introduced to model the interaction between retailer and manufacturers. With this framework, a retailer maximizes profit by taking the manufacturers' trade allowance response into account, which provides a realistic approach of simultaneously determining the shelf-space and trade promotion decisions under the consideration of interactions among products. A piecewise linearization method is employed to reformulate the Mixed Integer Nonlinear Programming (MINLP) problem into a linear MIP problem for optimal solutions. Numerical examples demonstrate significant advantage of the proposed framework and quantitative analysis leads to a variety of managerial insights.

1. Introduction

Data from the U.S. Census Bureau (2005) shows that the retail sales in the US have been increasing for 13 years. The highly competitive grocery retail industry had realized sales of roughly half a trillion dollars in the US in 2003 (Reyes and Frazier, 2007). Although retail stores are at the end of supply chains, they play the primary role in influencing customers to buy products. Shelf space is one of the most important resources in a retail store. Efficient shelf-space allocation is one of the key determinants in gaining an edge in the highly competitive retail industry (Lim et al., 2004). Increasing sales by attracting the consumer's attention and encouraging consumers by having additional purchase opportunities can be implemented by proper management of shelf space (Hwang et al., 2009). Thus, the decisions of which products to stock among the large number of competing products and how much shelf space to allocate to those products are questions central to retailing.

Due to the limited shelf space in retail stores and growing competition, manufacturers have pursued growth in mature markets by using trade promotions to increase their market share (MacClaren, 1992). An annual survey indicates that grocery manufacturers have increased their allocations to trade promotions from 39% in 1976 to 47% in 1993 (Messinger and Narasimhan, 1995). Trade allowances are growing increasingly popular between manufacturers and retailers in today's business, and can take many different forms, such as off-invoice allowances, bill-back allowances, flat allowances, free goods, display allowances, and inventory financing. Moreover, Hilarides (1999) indicated that manufacturers believe that only 51% of their trade promotion dollars are being passed through to consumers, with more than 20% of the trade promotion dollars going directly to the retailer's bottom line. Therefore, trade allowances are an important factor, significantly affecting both retailer profits and retail promotion activities, and in turn affecting operation costs and shelf-space management.

Most of the analytical research (see Section 2.2) on trade allowances is built on simple models where the demand function is linear or implicitly defined, and retail operation costs are not included. In this research, we introduce trade allowance and trade promotion into the category shelf management framework, where nonlinear demand is represented as a signomial function, providing a more realistic representation of the product demand in the retail store compared to that using a linear demand function. In the proposed framework, the decisions of category shelf-space allocation and retail category promotion activities are affected by the trade allowances paid by manufacturers. Our purpose is to develop a framework that optimally assigns the shelf space and promotion budgets among products in a category under the manufacturers' trade allowances. Since trade allowances are usually negotiated between the retailer and the manufacturers, we introduce a one-period profit maximizing Stackelberg game to model the negotiation, where a retailer is the leader and the

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http://dx.doi.org/10.1016/j.ijpe.2013.09.018

manufacturers are the followers. Large retailers such as Walmart and Target are examples for the case. Models similar to our Stackelberg game in shelf-space management research can be found in Amrouche and Zaccour (2007) and Chen et al. (2011). Our study extends the research stream by considering cross-space-elastic and cross-promotion-elastic to demand and trade allowances, which is not only theoretically advanced, but also more practical in retail management.

The contributions of this paper to the literature are as follows. First, this study considers shelf-space allocation and trade allowance simultaneously for category-level shelf-space management. This has not been studied in the literature, including in Irion et al. (2012). We discuss the interactions between trade allowance, shelf space, and retailer's promotion. Second, this paper also considers space-, cross-, and promotion-elastic demand. Since the demand is a nonlinear function of many parameters, the corresponding optimization problem is formulated as a Mixed Integer Nonlinear Programming (MINLP) model. This class of optimization model is hard to solve; thus, in the article, a piecewise linearization technique is employed to reformulate the model for MIP solutions. Third, this paper utilizes a statistical modeling approach to determine manufacturers' response functions and uses the Stackelberg game to model the negotiation between manufacturers and retailer. Fourth, we perform numerical analysis to study the effects of changing parameter values on the optimal solutions and to point out some management implications. The results of this study are a useful reference for managerial decision-making and administration.

2. Literature review

2.1. Shelf-space management

A number of optimization models on shelf-space management have been developed by the researchers. Recently, Hariga et al. (2007) developed a model to consider product assortment, self-space allocation, and inventory replenishment problems with a demand model of shelf-space size and display-location. Amrouche and Zaccour (2007) proposed a Manufacturer Stackelberg game in a one manufacturer and one retailer supply chain, in which the retailer sells the national manufacturer brand and her private label. The manufacturer determines the wholesale price and the retailer determines the retail prices and shelf-space allocations. Reyes and Frazier (2007) proposed a shelf-space allocation model that considers the tradeoff between profitability and customer service level under nonlinear price and shelf-space dependent demand. However, the latter two papers appearing in 2007 did not consider related costs such as inventory and restocking.

Abbott and Palekar (2008) developed retail replenishment models considering a linear function of sale rate to effective shelf space. They presented exact and approximate solutions for the single- and multi-product cases. Hwang et al. (2009) proposed a genetic algorithm to solve the shelf-space design and item allocation problem with the objective of maximizing the retailer's profit. Hansen et al. (2010) presented a retail shelf-space decision model that incorporates a nonlinear profit function, vertical and horizontal effects, and product cross-elasticity. Gajjar and Adil (2010) developed a model of the shelf-space allocation problem with space elasticity using a piecewise linearization technique. However, they did not consider the cross elasticity within different items in their demand function.

Murray and Talukdar (2010), Chen et al. (2011) and Szmerekovsky et al. (2011) made the price and shelf-space decisions in shelf-space studies. Murray and Talukdar (2010) developed a model that jointly optimizes a retailer's decisions for product prices, display facing areas, display orientations, and shelf-space locations in a product category. Chen et al. (2011) considered channel coordination through revenue-sharing contracts with price and shelf-space dependent demand. Szmerekovsky et al. (2011) considered the adoption of item level RFID in a two-echelon supply chain with shelf-space and price-dependent demand.

Lotfi and Torabi (2011) provided a fuzzy mixed integer non-linear goal programming model for the mid-term assortment planning under a given set of constraints in which three conflicting objectives, namely profitability, customer service and space utilization are incorporated. Irion et al. (2011) provided a hierarchical decomposition approach to manage the store level shelf space. Their model simultaneously considered how to divide store shelf space into categories and how to allocate shelf space to products within a product category. Irion et al. (2012) provided a piecewise linearization technique to solve the category-level shelf-space allocation problem. However, they did not consider the trade allowance/promotion issues and the interactions between trade allowance, shelf space, and retailer's promotion. Hubner and Kuhn (2012) made a complete review of the shelf-space management literature and of current practices. The issue of shelf-space management is popular in this field of research. Note that the trade allowance/promotion issues below have never been considered in the shelf-space management literature above.

2.2. Trade promotion

There is some research concerning the empirical analysis of retail response to trade promotions. Frequently cited work in this area are Chevalier and Curhan (1976), Curhan and Kopp (1988), and Armstrong (1991). Collectively, they either estimated the ratio of trade allowances pocketed by retailers or examined the factors that determine the strength of retail support for trade deals. Another research stream analytically investigates various strategic issues relating to trade promotions. Tyagi (1999) investigated the factors affecting the extent of retail pass through. Specifically, the paper analyzed relations between retail pass-through decisions and the curvature (linear, concave or convex) of consumer demand functions. Kumar et al. (2001) analyzed the factors that affect the retail pass-through as well as the strategy of alleviating the problem. They showed that by complementing trade promotions with advertising that informs customers about ongoing promotions, the manufacturer can enhance retail pass-through. This article complements the literature by employing a piecewise linearization technique to solve a complicated MINLP problem faced when trade allowance and promotion effects are considered in the shelf-space management models.

2.3. Stackelberg game in supply chain management

The Stackelberg game has been used in many studies to solve multi-echelon supply chain decision-making problems. Recently, Wu (2013) considered the buyback contract in vertical integration and the Stackelberg game in competing supply chains. Chern et al. (2013) developed the Stackelberg solution in a two-echelon supply chain model under delay in payments. Yu et al. (2013) introduced a Stackelberg game model to solve the retailer selection problem in a vendor managed inventory system. For the Stackelberg game in shelf-space management research, Amrouche and Zaccour (2007) used the Manufacturer Stackelberg game to determine the amount of shelf space to be allocated to national and private brands as well as their prices. Chen et al. (2011) used the Retailer Stackelberg game to determine the shelf-space and retail price decisions under consignment and revenue sharing contracts.