Cooperative advertising and ordering policies in a two-echelon supply chain with risk-averse agents

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This paper considers a cooperative advertising and ordering issue in a two-echelon supply chain in which a risk-averse manufacturer sells a product through a risk-averse retailer. We assume that demand for the product is a random variable influenced by the manufacturer’s global advertising and the retailer’s local advertising. To stimulate demand for the product, the risk-averse manufacturer induces the risk-averse retailer to increase local advertising expenditure through cooperative advertising contracts. With the objective of maximizing conditional value-at-risk, models for determining the retailer’s optimal order quantity and both agents’ advertising investments are developed for both centralized and decentralized settings. We reveal the effect of demand uncertainty and two agents’ risk aversion on both agents’ optimal advertising/ordering policies. Through both theoretical and numerical analyses, we find that: 1) the centralized scenario may perform worse than the decentralized one in many cases if the decision-maker of the centralized supply chain is more risk averse than its two participants; 2) whether the risk-averse manufacturer is willing to share the retailer’s local advertising expenditure depends significantly on the degree of two agents’ risk aversion; and 3) in the decentralized setting, it will be more beneficial for both agents that the leader is more risk averse than the follower. These new findings are further supplements to the results in the existing related literature.

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1. Introduction

Vertical cooperative advertising arises from a cooperative contract between a manufacturer and a retailer in which the retailer’s expenditure on local advertising is partly paid by the manufacturer. Through such a contract, the manufacturer can induce the retailer to increase spending on promotions to boost sales and improve profitability. Since the Warner Brothers Corset Company signed the first cooperative advertising agreement with its agents in 1903 [55], the adoption of cooperative advertising contracts spread swiftly into industries including electronics, automobile, and furniture [42,22], and in recent decades, cooperative advertising contracts have been widely used. US companies’ expenditure on cooperative advertising in the year 2000 was estimated to be $15 billion [36], rising to approximately $25 billion in 2007 [16]. More recently, Lieb [34] reported that US retailers’ cooperative advertising funds were $50–520 billion in 2012. The growing importance of cooperative advertising has motivated many researchers to explore the role of cooperative advertising contracts and transaction efficiency between manufacturers and retailers.

However, most recent research on vertical cooperative advertising has focused on deterministic market demand [6,29], in which the advertising effect is considered to be certain. The main topic of interest has been the design of cooperative advertising contracts in static or dynamic settings (see, for example, [8,25,28,51]). Little attention has been given to stochastic environments, although integrating of stochastic influences into models may improve the accuracy of the results attained [6,29]. Due to the reason of considering deterministic market demand, the existing literature on cooperative advertising assumes that the supply chain agents all maximize their own profits. Therefore, the previous studies do not involve risk. However, the effect of advertising on demand is often uncertain in reality. This means that there exists the risk when the supply chain agents invest in advertisement. Thus, the supply chain agents may have different attitudes towards risk [47], among which a common one is risk-averse [40]. With these in mind, we examine in this paper how the uncertainty of advertising effect influences risk-averse agents’ cooperative advertising schemes, by introducing conditional value-at-risk (CVaR) to assess risk-averse agents’ performances. Several questions are interesting to us:

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Q1: How should advertising, ordering and cooperative advertising contracts be set for risk-averse agents in a manufacturer-retailer supply chain?

Q2: Does a cooperative advertising contract reduce the retailers’ risk and encourage them to invest more in advertising and order more as well?

Q3: What are the effects of uncertainty in demand and the degree of risk aversion on the supply chain agents’ decisions?

Q4: Does a centralized supply chain still have better performance than a decentralized one when agents in the supply chain are all risk averse?

To answer these questions, we consider a two-echelon supply chain in which a risk-averse manufacturer sells a product through a risk-averse retailer. To stimulate demand of the product, the manufacturer offers the retailer a cooperative advertising contract, where the manufacturer invests in global advertising and shares the retailer’s local advertising expenditure as well. We assume that demand of the product is a random variable, which is dependent on both agents’ advertising investments. Following the manufacturer-Stackelberg game, we develop a cooperative advertising and ordering model for the two agents, in which with the objective of maximizing CVaR, the risk-averse manufacturer first decides on his global advertising expenditure and participation rate for the retailer’s local advertising expenditure, and then the risk-averse retailer determines the local advertising expenditure and an order quantity. In addition, we also discuss the corresponding advertising/ordering issue in the centralized setting.

Worthy of mention is that there are many measures of risk aversion in the literature; see Szgö [43] for example. The CVaR used in this paper is a mean-risk criterion that represents a trade-off between the expected profit and a certain risk measure. It avoids the drawbacks of other risk metrics and is easier to quantify, because the only subjective parameter for CVaR is the confidence level [13]. The remainder of this paper is organized as follows. Section 2 reviews related literature. Section 3 introduces background to the problem and some preliminaries. Section 4 develops a cooperative advertising model for a two-echelon supply chain with risk-averse agents based on CVaR, and presents two agents’ optimal advertising/ordering policies and corresponding properties in a decentralized setting. Section 5 investigates the corresponding advertising/ordering issue in the centralized setting, and then compares the centralized scenario with the decentralized one. Section 6 concludes the paper.

2. Literature review

Our research is mainly related to two streams of literature: vertical cooperative advertising and supply chain decisions with risk aversion. To highlight our contributions, we review the representative literature in these two streams.

2.1. Cooperative advertising

Existing cooperative advertising models can be classified into static and dynamic according to whether the model parameters and variables are time-dependent (dynamic) or not (static). In the following discussion, we limit our review only to static models that are closely related to our paper. For dynamic models, readers can refer to Jørgensen et al. [28], He et al. [23], Zhang et al. [56] and references therein.

Earlier research on static cooperative advertising models can be traced back to Berger [8], who was the first to analyze cooperative advertising issues between a manufacturer and a retailer quantitatively. He showed that mathematical modeling could significantly increase profits compared to the simplistic fifty-fifty cost sharing that was often used in practice. Many researchers further investigated cooperative advertising issues in various business environments. However, most of the earlier studies on cooperative advertising considered only the effect of local advertising on the volume of sales. As cooperative advertising programs are widespread in practice, many practitioners and researchers have come to realize that in addition to retailers’ local advertising, manufacturers’ global advertising can also stimulate consumer demand. This has led to many cooperative advertising models that consider the effects of both global and local advertising on demand.

Most of these models are one of two types. The first type limits analysis to the determination of agents’ optimal advertising strategies under different game structures (see, e.g., [26,27,33,50,48,2,3,31]). The second type extends the cooperative advertising models to include decisions on wholesale and consumer prices (see, e.g., [55,30,51,44,41,5,54,7]). For a detailed review of cooperative advertising studies, readers can refer to Jørgensen and Zaccour [29] and Aust and Buscher [6]. As said by Aust and Buscher [6] (see, p. 3): “…most studies of cooperative advertising assume a deterministic environment, although the integration of stochastic influences could improve the accuracy of the results attained”. In this paper, we discuss the cooperative advertising issues of a risk-averse manufacturer and a risk-averse retailer in a stochastic environment.

Xiao et al. [49] and Chen [12] studied cooperative advertising issues in a supply chain with stochastic demand. Xiao et al. [49] developed a game theoretic model for a one-manufacturer and one-retailer supply chain with second order. They investigated how to coordinate the order quantity and local advertising investment via a markdown money-cooperative advertising contract. However, they considered the retailer’s local advertising only and left the manufacturer’s global advertising out of consideration. Our paper is distinct from Xiao et al. [49] in three respects. First, we consider the effects of both global and local advertising on demand. Second, supply chain agents are risk averse in our model but risk neutral in their model. Third, Xiao et al. [49] focused on the effects of allowing second ordering on the equilibrium outcome and coordination mechanism, whereas we focus on the effect of the degree of risk aversion.

Chen [12] discussed a cooperative advertising issue in a two-level supply chain consisting of a manufacturer and a retailer under the newsvendor framework. He assumed that the potential market size is a random variable with an exponential distribution, and that both global and local advertising influence exponentially the proportion of the potential market. He investigated optimal ordering and advertising policies under both decentralized and centralized settings with a manufacturer’s pre-specified participation rate. Through numerical examples, he showed the superiority of the centralized decision over the decentralized one in the profit improvement of the supply chain and the possibility of achieving channel coordination by a profit-sharing mechanism. Unlike Chen [12], we (1) view demand as a random variable with a general distribution, (2) consider risk-averse decision-makers, but (3) do not specify a manufacturer’s participation rate.

Our paper also relates to studies of cooperative promotion such as Tsao and Sheen [46], Tsao [45] and Dai and Chao [17]. Tsao and Sheen [46] considered retailers’ promotion issues in a supply chain where a supplier sells through two competitive retailers. They assumed that the basic demand $x$ for each retailer is a random variable, and that the promotional effort $p$ for each retailer does not affect $x$, but affects the effort-induced demand $px (p > 0)$. Incorporating the sales learning curve into the promotion cost, they used promotion cost sharing as a mechanism to achieve coordination.

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