Applied Soft Computing 11 (2011) 1669–1678

Contents lists available at ScienceDirect

Applied Soft Computing

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

The return policy model with fuzzy demands and asymmetric information

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ARTICLE INFO

Article history:
Received 12 July 2009
Accepted 1 May 2010
Available online 7 May 2010

Keywords:
Fuzzy demand
Asymmetric information
Signed distance method
Coordination
Return policy
Fuzzy system models

ABSTRACT

Return policy, by offering the retailer some reimbursements for the leftover products, is one of the most efficient mechanisms for channel coordination. This paper considers a supplier–retailer channel to design the optimal return policy for the supplier. It is assumed that the supply chain operates under uncertain demands, which is represented by fuzzy sets. We first study the return policy in a supply chain with symmetric channel information, i.e. the channel information is completely shared between the supplier and the retailer. Further we assume the retailer keeps retail price information private, i.e. the channel information is asymmetric. Thus, the supplier makes the return policy on the basis of estimated retail price which is described as a fuzzy number. We formulate an inventory model with fuzzy demand and fuzzy retail price for the supplier to make a suitable return policy so that the retailer could be motivated to make the optimal order decision to improve the overall supply chain performance. Finally, some characteristics of the return policy are discussed, and numerical examples are presented to demonstrate the model applicability.

1. Introduction

A supply chain is a network consisting of many organizations acting together. Coordination mechanism, by providing a set of methods for effectively managing the interactions between multiple organizations, could be used to maximize the total expected profit of the supply chain. A return policy is one of such mechanisms in the supply chain, whereby the supplier allows the retailer to return unsold products for a partial or complete refund at the end of the selling season. This problem often occurs in seasonal sales and sometimes is referred as a newsboy problem. The return policy aims to encourage the retailer to increase order quantity by shifting part of the burden of demand uncertainty from the retailer to the supplier. Numerous papers on channel coordination have extensively discussed the return policy. Pasternack [3] shows in his study that the return policy could be used as an instrument for channel coordination, and the demand distribution has little effect on the return policies. Kandel [9] further discusses relationship between the return policy and the wholesale price. Emmons and Gilbert [10] examine the return policy under price-sensitive demand.

Most of the existing literature on return policy assumes there is complete information sharing between the supplier and the retailer, i.e. the channel information is symmetric or shared among channel members. However, in practice, the individual channel member often has his own private information and is unwilling to release the sensitive information to other members, thus information asymmetry occurs. For example, the retailer does not release the exact retail price to the supplier. Asymmetric-information models, by assuming one member has more or better information than the other, are used to deal with the study of decisions in the asymmetric-information framework. Some scholars have studied the asymmetric-information framework and the relevant coordination mechanisms. Lau and Lau [2] study the optimal strategies of both the retailer and the manufacturer under a stochastic-asymmetric-information framework, and analyze the impacts of different forms of demands on the optimal solutions. Lau et al. [1] present an extension of the framework, and propose a procedure for the manufacturer to design a profit-maximizing volume-discount scheme using stochastic and asymmetric demand information. Zhou [17] considers a two-echelon channel where the demand is assumed to be stochastic and price-sensitive, and studies the optimal quantity discount pricing policies in order to improve the profits of the two parities. Then the effects of the uncertain demand parameter on the optimal solutions, and a comparison of four discount pricing policies are explored. Suo and Jin [11] study the return policy in the framework with stochastic demand and asymmetric price information. In their model, the supplier is assumed to have the knowledge of the individual rationality constraint of the retailer, and the retail price is treated as a random number estimated by the supplier.

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doi:10.1016/j.asoc.2010.05.004

All studies mentioned above assume the demand is uncertain, and its uncertainty is described by the concept of randomness and probability theory. However, for new products, there is little historical data available for estimating the probability distribution function of the potential demands. In that situation, the supply chain members have to assess the demand from their previous experiences or expert knowledge. Often their assessments are fuzzified and could be expressed by the fuzzy linguistic terms. Due to their practical advantages, increasing attentions are given to the studies of applying the fuzzy set concepts into the supply chain management. Li et al. [14] obtain the optimal order quantity for the fuzzy newsboy models through fuzzy ordering of fuzzy numbers with respect to their total integral values. Kao and Hsu [5] propose a newsboy model for cases of fuzzy demand. They obtain the optimal policy to minimize the total cost by adopting a method for ranking fuzzy numbers. Yao et al. [13] apply the fuzzy stochastic single-period model based on the fuzzy integral method to solve the cash management problem.

The objective of this paper is to investigate the optimal return policy for coordination in a two-echelon model facing fuzzy demand. First we derive the optimal order quantity for channels with symmetric information, meaning the supplier and the retailer share the price information with each other. Then the model is extended to the asymmetric-information case by assuming the supplier has incomplete information of the retail price. The return policy is designed to coordinate the supply chain where fuzzy price information is present in the channel with the objective to maximize the channel profit. Some questions may arise naturally, such as, how could a supplier make a return policy in a two-echelon channel when facing fuzzy demand, and further in an asymmetric-information channel? What are the impacts of the return policy on the expected channel profit? These questions will be addressed systematically in the paper.

The rest of the paper is organized as follows: Section 2 introduces the model assumption and defines the symbols for the fuzzy models. Section 3 analyzes the return policy in the channel with fuzzy demand and symmetric information. Section 4 extends the model to the asymmetric-information case. In Section 5, numerical examples are provided for sensitivity analysis. Section 6 concludes the paper with some remarks on future research directions.

2. Model notations and assumptions

This paper focuses on the model development of two-echelon channels facing fuzzy demand. The shortage cost is not considered in current research. Assuming the channel information is symmetric, two different configurations are investigated in Section 3.

DC: Decentralized Channel. In this channel, the retailer and the supplier work independently.

IC: Integrated Channel. In this channel, it is assumed that a single firm owns the supplier as well as the retailer; hence, decisions are made to optimize the total channel profit.

For both DC and IC situations, the supplier offers to buy back any remaining products from the retailer at the end of selling season; hence the return policy for channel coordination is considered. The IC is used as a benchmark case for the supplier in the DC to make an appropriate return policy so that the DC could achieve the profit equal to that of the IC.

In Section 4, the models will be extended to the asymmetric-information channels where the supplier is unable to obtain the actual retail price, and the knowledge about the price is based on estimations or past experience. In other words, the retail price is treated as a fuzzy number estimated by the supplier. Since the retailer does not share the price information with the supplier, the supplier will design the return policy to maximize the expected profit of the channel based on the estimated price. Similar to Section 3, two channel configurations will be considered.

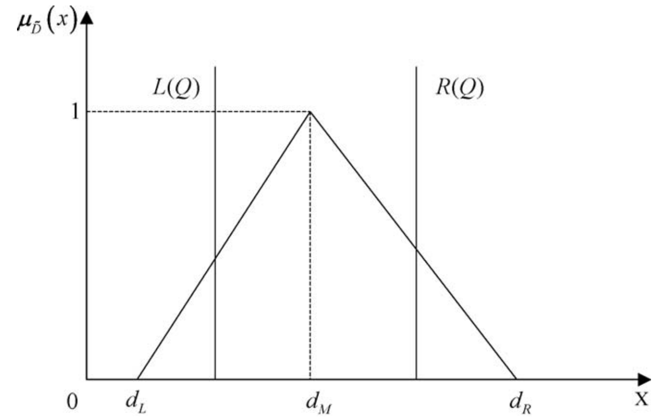

Fig. 1. The membership function of $\tilde{D}$.

DCE: Decentralized Channel Estimated by the supplier. It is a case where the retail price is estimated by the supplier. It is similar to the DC except that the retail price is assumed to be fuzzy.

ICE: Integrated Channel Estimated by the supplier. It is assumed by the supplier that a single firm owns the supplier as well as the retailer. This is a case where the retail price is estimated by the supplier. It is similar to the IC except that the retail price is treated as a fuzzy number.

In the channel with asymmetric information, the ICE is used as a benchmark for the supplier of the DCE to make an appropriate return policy so that the optimal expected channel profit is achieved. The following notation is used throughout the paper.

2.1. Notation and abbreviations

$\tilde{D}$	the fuzzy product demand during the selling season
p	unit retail price that the retailer charges the consumers
m	unit wholesale price that the supplier charges the retailer
$\tilde{p}$	unit retail price estimated in the ICE, DCE
c	unit cost incurred by the supplier
s	unit buy back price
Q	quantity that the retailer orders from supplier
Q^*_{IC}	optimal order quantity in the IC
Q^*_{DC}	optimal order quantity in the DC
Q^*_{ICE}	optimal order quantity in the ICE
Q^*_{DCE}	optimal order quantity in the DCE
$\tilde{\prod}_{IC}$	fuzzy profit of the channel in the IC
$\tilde{\prod}^{m}_{DC}$	fuzzy profit of the supplier in the DC
$\tilde{\prod}^{r}_{DC}$	fuzzy profit of the retailer in the DC
$\tilde{\prod}_{ICE}$	fuzzy profit of the channel in the ICE
$\tilde{\prod}^{m}_{DCE}$	fuzzy profit of the supplier in the DCE
$\tilde{\prod}^{r}_{DCE}$	fuzzy profit of the retailer in the DCE
$E(\bullet)$	expectation to "•"

2.2. Assumptions

The fuzzy demand $\tilde{D}$, faced by the supplier and the retailer, is assumed to be a triangular fuzzy number $\tilde{D} = (d_L, d_M, d_R)$ as shown in Fig. 1, and described by a general membership function $\mu_{\tilde{D}}(x)$:

$$\mu_{\tilde{D}}(x) = \begin{cases} L(x), & d_L \le x \le d_M \\ R(x), & d_M \le x \le d_R \\ 0, & x \notin [d_L, d_R] \end{cases} . \tag{2.1}$$