Computers & Industrial Engineering 75 (2014) 96–101

Contents lists available at ScienceDirect

Computers & Industrial Engineering

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

Supply chain coordination using time-based temporary price discounts ☆

Jafar Heydari *

School of Industrial Engineering, College of Engineering, University of Tehran, Tehran, Iran

ARTICLE INFO

Article history:
Received 18 May 2013
Received in revised form 10 June 2014
Accepted 22 June 2014
Available online 28 June 2014

Keywords:
Supply chain coordination
Safety stock
Time-based price discount

ABSTRACT

In this paper, the issue of supply chain coordination (SCC) in a buyer–seller supply chain (SC) with an order size constraint is investigated. The buyer keeps safety stock to cope with lead time demand uncertainties from customers' side. Unsatisfied demand will be lost. Therefore the whole SC sales volume depends on the service level provided by the buyer. By proposing a time-based temporary price discount in each replenishment cycle, the seller intends to convince the buyer to optimize its safety stock globally. Maximum and minimum discounts, which are acceptable for both parties, are determined and an appropriate discount schedule is derived. A set of numerical experiments are conducted to show performance of the proposed model. The results show that the safety stock coordination is profitable; the proposed model is capable of coordinating supply chain. In addition, the model can share extra benefits between SC members fairly.

1. Introduction

Most of actions taken by one SC member affect other members as well. One SC member may make decisions associated with production planning, inventory control, replenishment strategy, advertising, purchase strategy and so on. Almost all of these decisions can influence other partners. There is a lack of system view in the field of supply chain management (Agrell & Hatami-Marbini, 2013). All of the coordination schemes in the field of SCC look for applicable mechanisms to convince all members to optimize their decisions from the whole SC viewpoint. Usually, SC members decide based on their own profit/cost functions; although the result is optimum for an individual member, it is not optimum from the whole SC viewpoint. In contrast, SC optimum decisions (without appropriate incentives) do not necessarily maximize profitability of all participants.

Most common decisions throughout SC are replenishment decisions. Similar to other decisions, replenishment decisions should be also coordinated. Two main groups of replenishment decisions usually made in a SC are: (1) how much to order (2) when to order. The answer to the first question is associated with determination of the order quantity. There is an extensive volume of literature about the order quantity coordination. Among various coordination models, quantity discount models are the most common ones. Quantity discount models are developed to coordinate order quantity through the SC. Based on the basic quantity discount model the seller offers a discount for purchasing more products. In addition to the quantity discount models, other coordination schemes have been proposed to coordinate the order quantity in SC (e.g. delay in payments, quantity flexibility, sales rebate, and buyback contracts). The second question (i.e., when to order?) is related to the reorder point and keeping safety stock for coping with lead time and demand uncertainties. Coordinating the safety stock in SCs is investigated less compare to the order quantity coordination. The safety stock is one of the critical parameters in uncertain environments, which determines service level. The service level has a direct impact on the SC success in competitive markets. A smaller safety stock leads to more stock-outs and more unsatisfied customers, while an excess of safety stock results in larger inventory costs. In traditional supply chains, the downstream determines the safety stock level, while this parameter affects upstream members as well. In most cases, customers cancel their orders when facing stock-outs in retailers' sites. Therefore, a smaller safety stock affects all SC members negatively by reducing their SC market share.

In this paper, a two-stage SC consisting of one buyer and one seller is investigated. Market demand is deterministic while lead time (LT) has normal distribution. The buyer keeps safety stock to overcome lead time demand uncertainty and provide a reasonable service level. Customers cancel their orders if not receiving the product immediately. The buyer uses a continuous inventory review system. Order quantity is fixed and predetermined due to shipment and truckload limitations. Fixed order size has been

☆ This manuscript was processed by Area Editor Mohamad Y. Jaber.

* Tel.: +98 21 82084489.
E-mail address: J.Heydari@ut.ac.ir

http://dx.doi.org/10.1016/j.cie.2014.06.015
0360-8352/

considered in previous studies (Chen, 1998, 2000; Chaharsooghi & Heydari, 2010; Heydari, 2014). This paper extends the previously published paper by Chaharsooghi and Heydari (2010). The mentioned study showed benefits of centralized decision making on reorder point and safety stock while the current research focuses on achieving such benefits by proposing an applicable incentive scheme.

In the proposed model, the seller, by offering a time-based temporary price discount in each replenishment cycle, tries to induce the buyer to turn toward the optimal solution. The seller, by proposing a temporary price discount in a specific time, pursues to shift timing of the buyer's orders. This mechanism differ from the quantity discount models; based on a quantity discount model, the seller offers discount (all-unit or incremental) for purchasing above a certain quantity. Quantity discounts are used to change the buyer's decision on order quantity. However, time-based discounts have the ability of shifting order time. Safety stock is determined based on reorder point. Reorder point in turn is associated with the time of placing orders; therefore, a time-based temporary price discount is able to coordinate safety stock throughout the SC. To formulate the model, two main parameters of discount model should be determined: (1) discount rate, and (2) discount schedule. Two main aspects of this paper are: (1) coordinating safety stock while major literature considers order quantity coordination, (2) proposing a tailored time-based discount which is completely adopted with the research problem.

2. Literature review

Discounts are extensively used to coordinate supply chains. Various discount models have been studied by considering different supply chain settings. Most of the researchers in this field have made efforts on solving the joint economic lot sizing problem (JELP) using price discount models. Qi, Bard, and Yu (2004) tailored a wholesale quantity discount policy to coordinate a two-stage supply chain when demand was disrupted. In the mentioned model, disruption caused deviation (from the original plan) costs throughout the system which in turn created complexity in solving the problem. Li and Liu (2006) considered a single-buyer single-supplier supply chain with one type of product facing stochastic customer demand. They showed quantity discount was capable of achieving coordination on order quantity. Tsai (2007) proposed a non-linear model which was capable of treating various quantity discount functions such as linear, step, single and multiple break point functions. Afterward, Qin, Tang, and Guo (2007) developed a discount model to increase sales volume when demand was price-sensitive. In the proposed model, the jointly agreed discount was formulated and it was shown that discount was not capable of maximizing SC profit. In the next step, a model based on volume discount along with a franchise fee which was capable of maximizing SC profit was developed.

A wholesale price-discount scheme was developed for coordinating a system consisting of one manufacturer and multiple retailers with early order commitment strategy (Xie, Zhou, Wei, & Zhao, 2010). The model allowed the supply chain partners to share net savings resulting from early order commitment strategy. A quantity discount model for coordinating a two-stage serially connected SC with a fixed lifetime product was developed (Duan, Luo, & Huo, 2010). It was demonstrated that, by coordinating two members, order size became larger if supplier's unit holding cost were greater than retailer's unit holding cost. Sinha and Sarmah (2010) have developed a single-vendor multi-buyer discount pricing model under stochastic demand information. It has been shown the benefit of coordination increases by increasing number of pricing schedules.

The condition of false failure return in a reverse supply chain was considered and a quantity discount model was developed to align retailers with suppliers for reducing such costly returns by Huang, Choi, Ching, Siu, and Huang (2011). All-unit quantity discount policy was used to coordinate the system of a single buyer and multiple vendors to minimize total SC cost by considering the number of defective items and number of late delivered items (Kamali, Fatemi Ghomi, & Jolai, 2011). In the mentioned study, a multi-objective supplier selection and order allocation model was solved. In another case, all-unit price discount was used to streamline product flow in a single-supplier multiple-buyer supply chain (Wang, Chay, & Wu, 2011). In the proposed model, supplier tried to synchronize buyers with its own replenishment cycle by offering a discount to eliminate warehousing costs. In addition, the proposed model was capable of inducing buyers to have more orders. Using wholesale-price-discount along with return policies for coordinating a supply chain under newsvendor setting was also examined by Chen (2011). Using return policy in this model encouraged the retailer to order more products and also promoted retailer's loyalty. A branch-and-cut approach for solving the capacitated total quantity discount problem was developed by Manerba and Mansini (2012). In the proposed model, the buyer purchased products from a set of suppliers who offered total quantity discounts. The problem was to make selection between suppliers to minimize purchasing costs when suppliers' capacity was limited. Based on Ke and Bookbinder's (2012) research, a discount can be offered for aggregate purchases of a group of products to maximize the seller's profit. In the investigated model, impact of price sensitivity of demand and joint decision making on the supplier's discount policy was also investigated. A coordination scheme which was hybrid of quantity discount and delay in payments was developed by Du, Banerjee, and Kim (2013). The proposed model maximized the whole SC profit by joint determination of retail price, the buyer's order quantity, wholesale price discount, and credit period.

By reviewing the previous researches, it is revealed that most of discount models have sought to coordinate order quantity. Some other studies in this field have considered discounts as a substantive setting of the SC structure. Instead, in this paper, a discount scheme is tailored to coordinate the buyer's safety stock and SC service level for maximizing SC profitability by creating a win–win situation for both SC members.

3. Mathematical modeling

In this paper, a system consisting of one buyer and one seller with one type of product investigated. The buyer faces stochastic lead time and deterministic demand. Lead times follow a normal distribution with known parameters. Customers must receive their orders immediately; otherwise, they would cancel their orders. Therefore, the customer orders would be lost in the case of stock-outs occurrence on the buyer's warehouse. The buyer uses a continuous inventory review system (s,Q). The order size Q is fixed and predetermined due to shipment and truckload restrictions. The seller uses order multiplier n to replenish its stock. Lead time between the seller and external supplier is negligible. Capacity of the external supplier is infinite. It was shown that the order multiplier n must be a positive integer to optimize the seller's replenishment system (Rosenblatt & Lee, 1985). In the decentralized decision making, the buyer optimizes the safety stock based on its own profitability. From the whole SC viewpoint, it can be viewed as a local optimization. In the proposed model, the seller as the leader of the SC attempts to change the buyer's decisions about reorder point and safety stock by providing appropriate incentives.