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Coordinating orders in a two echelon supply chain with controllable lead time and ordering cost using the credit period ☆

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ABSTRACT

In this research, a coordination mechanism based on a credit period in a two echelon supply chain with one buyer and one supplier, is designed. The buyer is faced with uncertain demand by coping with normal distribution. Both lead time and ordering cost for receiving his order can be reduced at an added cost; in other words, they are controllable. The optimization models with and without integration are proposed. Then a way to coordinate orders in supply chain based on the credit period so that the total cost of supply chain would be minimized is designed. By using this mechanism we also discuss how the credit period is to be determined in order to achieve channel coordination and a win–win outcome. Finally, numerical examples are solved to illustrate the theoretical results and obtain the managerial insights.

1. Introduction

A supply chain (SC) is a complex network consisting of multiple interrelated members with different objectives that often conflict with one another (Hou, Zeng, & Zhao, 2009). Therefore, it is necessary to overlay a coordination system, which may include: an explicit definition of processes, responsibilities and structures aligned with overall objective of whole SC to bring together multiple functions and organizations (Arshinder, Kanda, & Deshmukh, 2008). Supply chain management (SCM) deals with the coordination of manufacturing and logistic activities between autonomous decision making units (Gaudreault, Frayret, & Pesant, 2009).

Various types of coordination mechanisms have been proposed in the literature on supply chain coordination such as quantity discount, credit options, and buy back/return policies. Sahin and Robinson (2002) proposed price, non-price, buy-back and return policies, quantity flexibility, allocation rules, information sharing and flow coordination as major categories of coordination mechanisms. In the literature on Production/Operations Management, quantity discount has attracted much attention as a coordination mechanism (e.g. Benton & Park, 1996; Goyal & Gupta, 1989; Lee & Rosenblatt, 1986; Li & Liu, 2006; Monahan, 1984; Munson & Rosenblatt, 1998; Viswanathan & Piplani, 2001; Viswanathan & Wang, 2003; Weng, 1995a, 1995b). Li and Liu (2006) considered a supplier–buyer system selling one type of product with multi-period and probabilistic customer demand. They designed a model for illustrating how to use quantity discount policy to achieve supply chain coordination. Jaber, Osman, and Guiffrida (2006) are the first to consider price discounts in a three level supply chain. They proposed a three-level (supplier–manufacturer–retailer) supply chain model with a profit sharing mechanism to maximize the supply chain profit. In their paper, demand at the retailer's end is assumed to be price dependent. Also, an all-unit price discounts scheme is used to coordinate the order quantities among the supply chain levels.

Li and Wang (2007) reviewed coordination mechanisms of supply chain systems in a framework that is based on supply chain decision structure and nature of demand. They provided a review of the literature on the coordination of centralized and decentralized supply chain systems. In a centralized SCM system, a single decision-maker controls all inventory and production operations to optimize system performance, whereas in a decentralized SCM system, supply chain members will act independently and opportunistically to optimize their individual benefits.

Jaber and Zolfaghari (2008) reviewed the literature on quantitative models for centralized supply chain coordination that emphasize inventory management for the period from 1990 to end of 2007. They also provided a map indicative of the limitations of the available studies and steered readers to future directions along this line of research.

In this paper, we consider a two echelon supply chain consisting of one buyer and one supplier. Our particular interest is supply chain coordination, especially how the supply chain can be coordinated with credit period policy. Also, in modern production

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management, controllable lead time and ordering cost reduction are keys to business success and have attracted considerable research attention (Chang, Ouyang, Wu, & Ho, 2006). Thus, with more adaptation with the real world, we assumed that the lead time between the buyer and the supplier is controllable; that means this important time could be reduced by adding cost. It also considers that ordering cost can be reduced and is controllable by more investment.

The objective of our model is to view the system as an integrated whole and determine the optimum buyer's and supplier's ordering quantities, lead time, buyer's ordering cost, buyer's safety factor and suitable credit period that minimizes the total cost of system.

We first analyze a decentralize model in which each part would decide so that his total cost would be minimized. Then a way is proposed in which based on the credit period, order in supply chain is coordinated and the total cost of supply chain is minimized.

The proposed model illustrates that there are upper and lower bounds to the credit period which either of the parties can offer to the other. Depending on the opportunity cost of the buyer and the supplier, one of the credit period bounds is used to optimize the global system performance. By using this mechanism we also prepare a method for dividing the extra saving between the buyer and the supplier so that each party's cost could be reduced. Only when each of the two parties could reduce his cost, we can implement the credit period as a coordination mechanism. Finally, the numerical examples are used to show the power of the proposed model.

The rest of this paper is organized as follows. Section 2 presents the related literature. Section 3 introduces the notations and assumptions and studies traditional mode without coordination in supply chain. In Section 4, the necessary conditions to implement a credit period policy are derived and then, in Section 5, we discuss how to establish and realize the coordination mechanism such that minimize the total cost of supply chain. Numerical examples are provided in Section 6. Finally, Section 7 ends with conclusion and discusses future researches.

2. Literature review

Every businessman strives to increase his profits, his goodwill, and his customer base. One of the most unrealistic assumptions in much of previous literature is that the retailer must pay for the items as soon as the items are received. In the real world, it is more and more common to see that in order to motivate retailers to order more quantity, very often suppliers offer a certain credit period without interest during the permissible delay time period (Liao & Huang, 2010).

In recent studies on inventory management, delay in payments is used to determine the optimal order quantity and reorder level. Davis and Gaither (1985) consider a one-time opportunity to extend payment. Maddah, Jaber, and Abboud (2004) investigated the effect of permissible delay in payments on ordering policies in a periodic review setting when the (s,S) (reorder level, order-up-to level) inventory policy is used with stochastic demand. They proposed a new mathematical model and presented an approximated method for practical purposes based only on the mean and the standard deviation of the demand.

Chen and Kang (2007) considered a permissible delay in payments in the integrated model from the viewpoint of the vendor–buyer cooperation in the supply chain management. Other treatments of repetitive payment periods are provided by Thompson (1975), Kingsman (1983), Arcelus and Srinivasan (1993), Kim, Hwang, and Shinn (1995), Shinn, Hwang, and Park (1996), Jamal, Sarker, and Wang (2000), Salameh, Abboud, Kassar, and Ghattas (2003) and Jaber (2007).

Jaber and Osman (2006) were the first to treat delay in payment as a decision variable when coordination between the two stages of a supply chain is considered. In their paper, a centralized model where coordinate their orders to minimize their local costs and that of the chain is proposed.

Sarmah et al. developed coordination model with credit option to determine the optimum production in two works, (I) single-manufacturer and single-buyer (Sarmah, Acharya, & Goyal, 2007) and (II) a single-manufacturer and multiple heterogeneous buyers' situation (Sarmah, Acharya, & Goyal, 2008). Ho, Ouyang, and Su (2008) investigated the production and ordering policy under a two-part trade credit in an integrated supplier–buyer inventory model. Jaggi, Goyal, and Goel (2008) have developed a simple EOQ model (Economic Order Quantity) in which the retailer's demand is linked to credit period alone. Liao (2008) developed an EOQ model with non-instantaneous receipt and exponentially deteriorating items under two-level trade credit financing. Huang and Hsu (2008) have developed an inventory model under two-level credit period policy by incorporating partial trade credit option for the customers dealing with the retailer. Chang, Ho, Ouyang, and Su (2009) presented a model to determine the optimal strategy for an integrated vendor–buyer inventory system under the condition of trade credit linked to the order quantity, where the demand rate is considered to be a decreasing function of the retail price. Chung and Liao (2009) developed the optimum order quantity of the EOQ model under trade credit depending on the ordering quantity from the discounted cash-flows approach.

Also, in modern production management, controllable lead time and ordering cost reduction are keys to business success and have attracted considerable research attention (Chang et al., 2006).

Most of the literature dealing with inventory problem, centers on inventory lead time as a prescribed constant or a stochastic variable, which therefore, is not subject to control (for example: Chaharsooghi & Heydari, 2010; Li & Liu, 2006; Silver & Peterson, 1985). But in many practical situations, this may not be realistic. As pointed out by Tersine (1982), lead time usually comprises several components, such as order preparation, order transit, supplier lead time, delivery time and setup time. In many practical situations, lead time can be reduced at an added crashing cost; in other words, it is controllable.

Liao and Shyu (1991) presented a probabilistic inventory model in which the lead time is a unique decision variable and order quantity is predetermined. Later, Ben-Daya and Raouf (1994) extended Liao and Shyu (1991) model by considering both lead time and ordering quantity as decision variables where shortages are neglected. Ouyang, Yeh, and Wu (1996) generalized (Ben-Daya & Raouf, 1994) model by allowing shortages. Moon and Choi (1998) and Hariga and Ben-Daya (1999) further improved and revised Ouyang et al. (1996) model by considering the reorder point as one of the decision variables. Ben-Daya and Hariga (2003) investigated the problem of reducing lead time for a stochastic inventory system with learning consideration. Pan and Hsiao (2005) presented integrated inventory model with controllable lead time and backorder discount considerations. In their study, lead time crashing cost is represented as a function of reduced lead time. Ouyang, Wu, and Ho (2007) formulated and solved an integrated inventory model with controllable lead time.

Leng and Parlar (2009) considered game-theoretic models of lead-time reduction in a two-level supply chain involving a manufacturer and a retailer. In their work, the lead-time consists of three components: setup time, production time and shipping time. The first two lead-time components are naturally determined by the manufacturer, whereas the shipping lead time may be chosen by