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Coordination of two-echelon supply chains using wholesale price discount and credit option

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ABSTRACT

This paper, studies the coordination of two-echelon supply chains using a credit (delayed) payment option and/or a wholesale price discount offer. We develop models for optimizing individual members', as well as supply chain's objectives. These models lead to the determination of the retail price and the order quantity for the buyer, as well as the production batch size, wholesale discount and/or the credit period offer for the supplier, under five different scenarios. Our analysis indicates the superiority of a coordinating policy that incorporates both a quantity discount, as well as a credit payment option. With equitable profit sharing, such a policy can be beneficial for both the parties towards increasing total supply chain profitability.

1. Introduction

During the past two decades, supply chain coordination has received a great deal of research attention, focusing on globally optimal supply chain decisions that can benefit all the parties involved, as opposed to each party making its own decisions individually. A number of mechanisms, such as price discounts, credit payment options, buy-back contracts, etc., have been used for coordination purposes. The notion of joint operation and coordination was first developed by Goyal (1976). Subsequently, Banerjee (1986) extends this work by suggesting a joint economic lot size (JELS) for the system and compensating the buyer through a quantity discount offer. Lee and Rosenblatt (1986) study the lot sizing issue and a quantity discount policy for increasing the supplier's profit. Chen and Chen (2005) later consider a situation where a manufacturer produces several products within the same facility and propose a joint replenishment policy using Pareto improvements, such that no party is worse off, while increasing the total supply chain profit. Along similar lines, Munson and Rosenblatt (2001) examine supply chain coordination via the quantity discount approach in three-echelon systems.

Another important means for achieving supply chain coordination is the credit option, where the supplier specifies to the buyer a finite time interval (credit period) within which the payment for a purchase is to be made, in lieu of immediate payment. The supplier's incentive for offering such an option is to stimulate demand by allowing credit to a downstream buyer who may not have sufficient capital to make a sizeable immediate payment, but may be induced to buy larger quantities, if some flexibility in terms of delaying purchase payments is available. Thus, from the supplier's perspective, the resulting potential increase in sales may compensate for the loss from issuing credit (Mehta, 1968).

Moreover, previous research has shown that the total supply chain profit can be improved if the cost of capital for the buyer is greater than that for the supplier (Sarmah et al. (2007)). Other benefits of the credit option are mentioned in Shinn and Hwang (2003) and Sarmah et al. (2007). For instance, a credit policy can serve as a useful tool for enhancing the supplier's competitive position and can facilitate the development of a stable, long term buyer–supplier relationship, which can yield benefits for both the parties. Goyal (1985) introduced this mechanism in an EOQ model with a determined credit time from the standpoint of the buyer; a concept that has been extended and improved by Chung (1998). Kim et al. (1995) develop a model for determining the optimal credit period length from the perspective of the supplier. Also, Khouja and Mehrez (1994) compare policies with and without the credit time linked to the order quantity and show that suitable policies can lead to substantially different buyer order quantities.

Most of the above mentioned studies attempt to develop appropriate policies from the standpoint of a single entity in the supply chain, but not from the overall supply chain's perspective. Abad and Jaggi (2003) first considered the problem of delay in payments under non-cooperative and cooperative relationships with price sensitive demand. They develop their analysis by utilizing the concepts of both Pareto efficiency solution, as well as Nash bargaining cooperation. Later, Jaber and Osman (2006)

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develop an integrated model, considering opportunity gain and loss that have a compounding rate of return. Subsequently, Yang and Wee (2006) extend their work for deteriorating items with finite replenishment rates.

More recently, Ouyang et al. (2008) have proposed an inventory model where both trade credit terms and freight rate are determined by the order quantity. Chang et al. (2009) present a similar model where trade credit is offered with a threshold time, without considering freight costs. Both of these papers specify fixed credit periods and consider only the coordinated situation without comparison with the un-coordinated scenario; thus, leaving no room for profit sharing. Therefore, the profit for each party, which is determined by the relevant model parameters, is fixed. In contrast, Chen and Kang (2007) consider both the scenarios, i.e. with and without coordination, with a fixed threshold credit time, under the assumption of deterministic demand. Sarmah et al. (2007) also studied both situations and suggest a procedure that divides the supply chain surplus equitably, after both parties achieve their own profit targets. Finally, Sheen and Tsao (2007) have developed a model with price sensitive demand and quantity discounts for freight cost with a fixed cost for quantities within a range. Their model assumes that the opportunity costs of capital are the same for both parties in determining the order quantity, price and credit time to achieve maximum channel profit, leading to the specification of the credit period range that should be offered.

In this paper, we consider the two coordination mechanisms of wholesale price discount and credit payment option by analyzing five situations (with or without coordination and with or without the credit option and/or a discount). Our problem scenario, involving a single product manufactured by a single supplier for a single buyer, incorporates price-sensitive demand and the notion of the production batch size being an integer multiple of the order (delivery) quantity, with a production rate that exceeds the retail demand rate. We determine the retail price, the buyer's order quantity, the supplier's manufacturing batch size and the credit period allowance when each party attempts to derive its own individually optimal policy. Then we develop the corresponding system optimal decisions from the perspective of the entire integrated supply chain. Furthermore, we explain where the additional profit originates from, and provide managerial guidelines for the use of a wholesale price discount and a credit payment option as coordination mechanisms. We also derive an appropriate policy to fully achieve supply chain coordination, and suggest ways for the two parties to equitably share the additional profit, resulting from the deployment of a price discount and/or a credit payment period.

Our analysis indicates that there are some disadvantages of using the credit option alone. First, we determine the maximum allowable credit time by setting the profit of the supplier with the credit option equal to its profit without such an option. In such an instance, there is no additional profit on the part of the supplier to be shared with the buyer. Secondly, the suitable credit time to share the excess profit can be relatively long, making it impractical under real world conditions. Also, in practice, it is not always easy to strictly enforce and follow the credit terms in buyer–supplier contracts. Finally, as our analysis indicates, more profit can be generated for the supply chain if we increase the credit time (even beyond the maximum allowable credit period), as long as the cost of capital for the supplier is lower than that for the buyer. Consequently, this work focuses on the supplier's price discount offer in conjunction with a credit payment option, which makes equitable profit sharing a tractable proposition. Generally speaking, the credit period is often negotiable and flexible, rendering the enhancement of a coordinated supply chain's profit possible.

Previous research involving the integration and coordination of supply chains has largely used either the delayed credit payment option, or a wholesale price discount, as separate mechanisms for achieving coordination. Our work differs from such endeavors in that we consider the possibility of the supplier offering to the buyer a delayed payment option, as well as a discount in the wholesale price of the product, simultaneously, in order to coordinate the supply chain and enhance its gross profit. Furthermore, in our models, we treat the credit period length as a decision variable, which allows the supply chain some flexibility, while enabling it to divide the surplus resulting from coordination, between the buyer and the vendor, in a fair and equitable manner.

2. Assumptions and notation

2.1. Assumptions

1. The operating environment is deterministic.
2. The supply chain structure considered in this study involves a single supplier (manufacturer) and a single buyer dealing with a single product.
3. For a coordinated supply chain, both parties share complete information and strictly follow the terms of the purchase/delivery contract.
4. The supplier's production rate is greater than the buyer's market demand rate.
5. Shortages are not allowed.
6. The item's unit physical inventory holding costs per year are the same for both parties.
7. The item's demand is price sensitive; i.e. the demand, D, as a function of the unit price, p, is given by: $D(p)=kp^{-\beta}$ where β is the demand elasticity coefficient ($\beta>1$) and k is a constant parameter.
8. The manufacturer's production batch size (nQ) is an integer multiple of the buyer's order quantity (Q), where n is a positive integer.
9. The product's regular (undiscounted) wholesale price is greater than its production cost and is exogenously determined, based on current industry practice.

2.2. Notation

For the supplier

v	unit wholesale price charged by the supplier to the buyer ($/unit)
m	unit manufacturing cost of the product ($/unit)
n	number of delivery batches per production run (batch size multiplier)
R	supplier's production rate (units/year)
A_1	fixed setup cost of a production batch ($/setup)
h_1^c	opportunity cost of capital for the supplier ($/unit/year)
h_1^s	supplier's physical inventory holding cost ($/unit/year)
h_1	total holding cost for the supplier in $/unit/year, where $h_1=h_1^c+h_1^s$
Π_1	supplier's annual gross profit ($/year)

For the buyer

p	retail price charged by the buyer ($/unit)
$D(p)$	product's market demand rate as a function of the retail price (units/year)
Q	buyer's order lot size (units)
A_2	buyer's fixed ordering cost ($/order)