A STUDY ON THE COORDINATION OF THE TWO-ECHELON SUPPLY CHAIN USING CREDIT AND QUANTITY DISCOUNT OPTIONS

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ABSTRACT

In this paper we study the coordination of the two-echelon supply chain using credit and quantity discount options. We determine the retail price, order quantity for the buyer, and the setup frequency, credit period for the supplier in four different scenarios (with or without coordination and with or without credit option). And we suggest a policy that incorporates both quantity discount and credit option, which will benefit both parties and maximize the total supply chain profit.

INTRODUCTION

In the last twenty years, supply chain coordination has been receiving enormous attention as it can achieve a global optimality for the supply chain and benefit all related parties. Some mechanisms such as quantity discounts, credit option, buy back, etc have been used for coordination purpose. In this paper, we compare the two coordination mechanism-quantity discount and credit option by setting and analyzing four scenarios (with or without coordination and with or without credit option). We build the models with price-sensitive demand, production rate that is greater than demand rate, for a single production multiple delivery system. We determine the retail price, order size, production size and credit period through mechanism to achieve an optimal solution for both parties individually or for the integrated system simultaneously. Then we explain where the additional profit originates from, and give advice on making decisions of when to use credit as coordination mechanism. We also suggest how to set up an appropriate policy to fully utilize the coordination, and how to divide the extra profit, which are incurred by both quantity discount and credit option.

NOTATIONS AND ASSUMPTIONS

Supplier:

\( \nu \): Unit price charged by supplier to the buyer
\( m \): Manufacturing cost of the supplier
\( n \): Number of batches per production run
\( R \): Annual Production rate
\( \rho \): Capacity utilization where \( 0 < \rho \leq 1 \)
\( A \): Setup cost per setup
\( K \): Capital cost of the supplier
\( h \): Other inventory cost of the supplier
\( h' \): Holding cost of the supplier where \( h' = h_1' + h_2' \)
\( \Pi \): Annual profit of the supplier

Buyer:
\( \rho \): Retail price charged by the buyer
\( D \): Annual demand rate, function of the retail price
\( Q \): Order quantity of the buyer
\( A \): Ordering cost per order
\( h_1 \): Capital cost of the buyer
\( h_2 \): Other inventory cost of the buyer
\( h_3 \): Holding cost of the buyer where \( h_2 = h_1 + h_3 \)
\( \Pi \): Annual profit of the buyer

**Chain:**
\( t \): Credit time
\( \Pi \): Profit of the chain
\( d \): Quantity discount factor
\( l \): Interest charged for the credit period
\( \hat{p} \): Price charged per item for the credit period, where \( \hat{p} = l \cdot \rho \)

**Assumptions:**
1. Only one supplier and one buyer are considered in this study. They share complete information. And both parties strictly follow the contracts.
2. Production rate is greater than demand rate.
3. Shortages are not allowed.
4. The other inventory costs excluding capital costs are the same for both parties.
5. The capital holding cost \( h_1 = r_1 \cdot \rho \) (\( t = 1, 2 \) where \( t = 1 \)(supplier) and \( t = 2 \)(buyer)), in which \( r_1 \) is the capital cost per dollar per unit time. \( h_1 \) is different for different items although \( r_1 \) is the same for all items.
6. Annual demand is price sensitive, \( D(\rho) = k \rho^{-\beta} \) where \( \beta \) is the elasticity coefficient. \( k \) is a constant coefficient of the demand function.
7. The manufacturer produces a \( n \) integer multiple of the quantity the buyer ordered.
8. Lead time is zero for replenishments.

**NON-COORDINATION WITHOUT CREDIT**

In this section we consider the situation where no coordination, neither credit nor quantity discount is present. The buyer optimizes its profit by deciding order size and retail price. And the vendor decides the batch multiplier \( n \) that maximizes its profit. The buyer decides the retail price and order quantity \((\rho, Q)\) to maximize its profit. The annual profit function is composed of sales revenue, production cost, setup cost and holding costs, including storage and capital costs. We can find the optimal price that maximizes the buyer’s profit. The vendor here only considers the number of batches produced each setup and maximizes the profit. We can get the optimal number of batches \( n \) that maximizes the vendor’s profit.

**NON-COORDINATION WITH CREDIT**
This is the scenario where the buyer optimizes its profit by determining order size \( Q \) and retail price \( p \) and the vendor optimizes its profit by choosing both credit time \( t \) and the number of batches \( n \), assuming he knows how the buyer will decide price and order quantity based on credit provided to achieve optimality.

**COORDINATION WITH AND WITHOUT CREDIT**

Under the assumption that the supplier and buyer share complete information and both strictly follow the credit contract, we compute here the total supply chain profit by determining the retail price and lot size for the buyer, the multiple of order quantity per setup for the supplier. Since the procedure and algorithms for the scenario of coordination without credit will be the same with the scenario with credit, we here only explore one model. The results for the scenario without credit will be similar to the results below only without the credit value factor \( (h_s^* - h_c^*) \cdot Dt \).

**COORDINATION MECHANISM SELECTION AND PROFIT SHARING**

In this section we discuss how to share the additional value gained through coordination so that both parties have a reasonable increase in profit, compared to the non-coordination scenario without credit. When the capital cost for the supplier is greater than that of the buyer \( h_s^* < h_c^* \). It is more economical for the chain to adopt a quantity discount option than to use the credit option [20]. If the vendor wants to stimulate the end demand when the buyer has not enough cash in hand, the vendor may want to use a credit option. The supplier can allow the buyer to have some permissible time until payment at an interest rate that is between their capital holding costs \( h_s^* < h_c^* = \lambda = \mu < h_s^* \). In this case, the chain can benefit not only from the quantity discount coordination but also from the difference in capital holding costs.

In coordination without credit, we use quantity discount to divide the profit. In coordination with credit option when \( h_s^* < h_c^* \), the longer the credit period, the more profits the supply chain gains. Thus the vendor will encourage the buyer to use the credit option. In sum, the supplier uses first the quantity discount option and then the credit option. To keep the credit option without the supplier losing money, he should charge the buyer interest on the amount owned at a rate that is between their capital holding costs.

**NUMERICAL EXAMPLE AND SENSITIVITY ANALYSIS**

It can be seen that when credit is adopted, the supply chain profit increases a little, because it stimulates the buyer to order more each time. When two parties act in a coordinated fashion, total supply chain profit increases significantly. Order quantity increases and retail price decreases significantly (from about 30 to about 15.6). Also the supplier can produce more times the order size of the buyer (6 to 7) in scenario of \( \rho = 0.7 \). And total chain profit increased by about 12%. When we use credit option as coordination mechanism, this increase grows even larger.

**CONCLUSION**
In this paper, we compare two different coordination models under various scenarios to explore the origin and incentive for extra profit. Based on that, we can develop appropriate polices and contracts to achieve as much profits for the chain as possible. Reasonable and easy carrying profit sharing methods are suggested where both quantity discount and credit option are used. In this case, the optimal chain profit is gained under suitable and comfortable credit length for both parties. Profits can also be easily shared under negotiation with flexibility. The suggested policy can fully utilize the drive for additional profit from the difference in capital cost in credit, and it is also very easy to apply. One other advantage of this method is that the credit length can be very flexible compared to that in the scenario of using credit option alone. The price, quantity size and number of batches produced do not need to be recomputed for new optimization when credit period is changed. The profit is shared nicely in the form of interest rate charged by the supplier, which makes the policy easy to be carried out in flexible manner in practice.

REFERENCES


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