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Inventory models and trade credit: a review*

by

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Abstract: This article reviews the literature on quantitatively oriented approaches for determining the optimal lot-size when supplier offers credit period to the retailer to settle their account. An attempt is made to provide an up-to-date review of existing literature, concentrating on descriptions of the types of problems that have been solved and important structural results.

Keywords: lot-size model, trade credit, deterioration, probabilistic demand.

1. Introduction

Trade credit is an important economic phenomenon. It can be used as a multi-faceted marketing/relationship management tool and/or as a means of directing information to the market or to specific buyers about the firm, its products and its future prospects/commitments. Most of the extensions are customer focused; encouraging frequent purchasers by accommodating customer's demand for credit to help finance their production period. The requirements/bargaining power of large customers can influence a firm to extend more credit. Firms will manipulate the respective terms in anticipation of capturing new business, in order to attract specific customers and achieve specific marketing goals.

The Wilson's EOQ model was derived with the assumption that the retailer must pay for the items as soon as it is received by the system. However, the most prevailing practice is that the supplier may offer a credit period to the retailer to settle his account within the fixed stipulated settlement period. Thus, the

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delay in the payment offered by the supplier is a kind of price discount, since paying later indirectly reduces the purchase cost and encourages the retailers to increase their order quantity.

Ferris (1981) derived a transaction theory of trade credit to economize on the joint costs of exchange. Trade credit can be viewed as a tool that separates the exchange of money between two trading parties. Trade credit permits a reduction in precautionary money holdings and a more effective management of net money accumulation.

For supplier who offers trade credit, it is an effective means of price discrimination as well as efficient tool to stimulate the demand of his products. The length of credit period is considered as supplier's dominant strategy against the competitive suppliers. The factors like credit risk, the size of the account, customer type and market competition are the most prominent in determining the length of the credit period. For the sake of better production and inventory control, manufacturers prefer less frequent orders with larger order sizes to frequent orders with smaller order sizes, if the annual ordering quantities are equal.

In such situation, they offer a longer credit period for larger amount of purchase. Their policies are meant to motivate the retailer to make order size large enough to avail for a credit period.

Mehta (1968) applied the statistical technique of sequential decision process to the problems of trade credit management. He tried to examine two problems, i.e. credit extension policy on a specific request or account and construction of indices measuring the effectiveness of such a policy. The aim was to establish a decision system which has an analytical solution. He studied indices in terms of bad debt level, receivable level, etc. and measured the impact of credit extension procedures on the subsequent phases of credit policy. The logical relationship between the operating decision rules and the control indices were suggested to the management in framing the optimal credit policy.

2. Literature survey

Haley and Higgins (1973) studied the relationship between inventory policy and credit policy in the context of the classical lot size model. It is observed that in general, optimality of the total cost of an inventory system requires order quantity and payment time decisions simultaneously. They derived the conditions under which the standard solution reduces to optimal solution.

2.1. EOQ and trade credit

Chapman et al. (1984) derived an economic order quantity model which considers possible credit periods allowable by suppliers. This model is shown to be very sensitive to the length of the permissible credit period and to the relationship between the credit period and inventory level. It is also shown to be more sensitive to estimates of the demand for inventory items and less sensitive

to ordering cost than the classical economic order quantity model. They gave numerical example to show how inventory costs may be considerable reduced by taking the advantage of a credit period into account.

Goyal (1985) pioneered in developing the mathematical model when supplier announces credit period in settling the account, so that no interest charges are payable from the outstanding amount if the account is settled within the allowable delay period. The supplier will obviously charge higher interest if the account is not settled by the end of the permissible delay period. In fact, this brings some economic advantage to the system, as retailer would try to earn some interest from the revenue realized during the period of permissible delay. Shah et al. (1988) extended the above model by allowing shortages. Mandal and Phaujdar (1989a, b) have studied Goyal's model by including interest earned from the sales revenue on the stock remaining beyond the settlement period. Chung and Huang (2003) extended Goyal's model when replenishment rate is finite.

Davis and Gaither (1985) developed optimal order quantities for firms that are offered a one time opportunity to delay payment for an order of a commodity. Such delayed payments result in a reduction of the effective purchase cost, which is a function of the return available on alternative investments, the number of units of commodity ordered and the length of the extended period. Optimal order quantities are developed for extended payment privileges that occur at a reorder point of between reorder points. Six suppliers' extended payment scenarios are studied. The sensitivity of derived models to the changes in the various input parameter is carried out. The simulation with realistic parametric values revealed that the additional discounted order quantity is insensitive to large changes in the ordering cost and unit price; sensitive to changes in the inventory carrying cost and return rate of funds, but without significantly affecting the total cost; and extremely sensitive to the annual demand. They gave simple analytic decision rules to guide firms that are offered such extended payment privileges. Using principles of financial analysis, Dallenbach (1986, 1988), Ward and Chapman (1987), Chapman and Ward (1988) argued that if trade credit has the character of a renewable source of capital, the usual assumptions as to the incidence and the value of the inventory investment opportunity cost made by the traditional inventory theory are correct, contrary to research articles on this subject. They also established that if trade credit surplus is taken into account, the optimal ordering quantities decreases, rather than increase, as argued in some papers.

Chung (1998) established the convexity of the total annual variable cost function for optimal economic order quantity under conditions of permissible delay in payments. He showed analytically that the economic order quantity under conditions of permissible delay in payments is generally higher than the economic order quantity given by the classical economic order quantity model.

Abad and Jaggi (2003) considered the seller-buyer channel in which the end demand is price sensitive and the suppler offers trade credit to the buyer. The

unit price charged by the seller and the length of the credit period offered by the seller to the buyer both influence the final demand for the product. They considered both to be the policy variables for the seller. The case of no credit was used as a benchmark in analysis. The article provides algorithm for determining the seller's and the buyer's policies under non cooperative as wall as cooperative relationships. In the non cooperative, they determined the seller's optimal unit price and the length of the credit period. For the cooperative scenario, they provided a procedure for characterizing pare to efficient solutions.

Chung et al. (2005) determined the economic order quantity under conditions of permissible delay in payments where the delay in payments depends on the quantity ordered when the order quantity is less than the quantity at which the delay in payments is permitted, the payment for the item must be made immediately. Otherwise, the fixed credit period is allowed.

Shinn and Hwang (2003) dealt with the problem of determining the retailer's optimal price and order size simultaneously under the condition of order size dependent delay in payments. It is assumed that the length of the credit period is a function of the retailer's order size and also the demand rate is a function of the selling price.

Most of the researchers while developing EOQ models for a retailer when the supplier offers a permissible delay in payments assumed that the selling price is same as the purchase cost. Teng (2002) expanded Goyal's model by considering the difference between unit selling price and unit cost to derive closed-form solution to the offer of the trade credit. Teng et al. (2005) developed the model by considering the difference between the selling price and the purchase cost. They gave algorithm for a retailer to determine optimal selling price and lot size simultaneously when the supplier offers a permissible delay in payments. They concluded that the economic replenishment interval and order quantity increases marginally under the permissible credit period.

Carlson and Roussean (1989) examined EOQ under date terms supplier credit by partitioning carrying cost into financial cost and variable holding costs. When a distinction between these types of holding costs is made, Wilson's EOQ may not hold good. They gave search procedure to find optimal order quantity over a well defined range of order quantities which encompasses the classical EOQ. They contradicted the fact that the optimal order quantity under date terms is always given by an integral multiple of monthly demands. The unique feature of date terms credit is the possible existence of multiple EOQs is established.

Huang (2007) examined optimal retailer's replenishment decisions in the EPQ model under two levels of trade credit policy by assuming that the supplier would offer the retailer partially permissible delay in payments when the order quantity is smaller than a predetermined quantity. Teng et al. (2007) derived retailer's optimal ordering policies with trade credit financing.

Shah et al. (1997) derived (T_j, S_j)-policy with increasing demand when delay in payment is permissible. Shinn (1997) dealt with the problem of optimizing

the retailer's selling price and lot-size simultaneously under the condition of permissible delay in payments when the retailer's demand rate is represented by a constant price elasticity function which is a decreasing function of selling price. The effect of credit period on retailer's decision variables is examined. Ouyang et al. (2005b) derived integrated vendor-buyer optimal strategy by considering adjustable production rate and trade credit. Robb and Silver (2006a, 2006b) derived optimal policy under date-terms supplier credit with probabilistic demand and lead-time. Recently, Ouyang et al. (2007) established an EOQ model with limited storage capacity, in which the supplier provides cash discount and permissible delay in payments for the retailer.

The most of the inventory replenishment policies under trade credit are developed under the assumption of instantaneous receipt of the goods in an inventory system and the supplier also offer a cash discount to encourage retailer to pay for his purchases at the earliest. Ouyang et al. (2005) developed an inventory model with non instantaneous receipt under trade credit, in which the suppler provides not only a permissible delay in payments but also a cash discount to the retailer. Recently, Huang and Hsu (2007) investigated the retailer's optimal replenishment policy with non instantaneous receipt under trade credit, cash discount and the retailer's unit selling price is not lower than the unit purchasing price.

Arcelus and Srinivasan (1993) attempted to formulate decision procedure for a vendor who wants to dispose of the extra stock Q due to large levels of inventory. In such situation, vendor offers either a discount in the unit price or a credit period, M, within which no payment is required, in exchange for the purchase of an additional $x \leq Q$ units over and above the regular order. They evaluated a bargaining range within which negotiations may take place as to purchase lot-size and its corresponding credit period, a range of indifference as to whether the transaction should take place at all, the set of (x, M)-values within the bargaining range which gives the desired benefits to both parties and leads to the largest combined benefits.

2.2. Deterioration and trade credit

Deterioration or decay is defined as a physical phenomena which hinders an item from being used for its original purpose such as (i) spoilage, as in perishable food stuffs, fruits and vegetables; (ii) physical depletion, as in pilferage or evaporation of volatile liquids such as gasoline, perfumes, alcohol; (iii) decay as in radioactive substances, degradation, as in electronic components or loss of potency as in photographic films, pharmaceutical drugs, fertilizers etc. For perishable goods such as dairy products, bakery items, vegetables, fruits etc, it is observed that the age of inventory has a negative impact on consumer confidence for reasons such as (i) proximity to expiry dates, (ii) detrimental effects on the quality of the product, (iii) general conception that an item lying unsold for a long time may be of inferior quality. Not only manufacturing goods but also services may

deteriorate, for example, flight seats, hotel rooms, theatre seats and curtain etc. Refer to review articles by Raafat (1991), Shah and Shah (2000) and Goyal and Giri (2001), which extended Goyal's (1985), Shah (1993a), Aggarwal and Jaggi (1995) and Chung (2000) lot-size model when units in inventory are subject to constant rate of deterioration and the supplier offers credit period M for settling the accounts for the purchase quantity. The optimal order quantity is obtained by minimizing the total cost of the inventory system. Chu et al. (1998) established piece-wise inventory of the total variable cost per time unit given by Aggarawal and Jaggi (1995). Jamal et al. (1997) extended Shah's (1993a) model by allowing shortages and permissible delay in payments.

Sarker et al. (2001) and Ouyang et al. (2005a) obtained optimal payment time under permissible delay in payments when units in an inventory are subject to deterioration. Jamal et al. (2000) discussed the problem in which the retailer can pay the supplier either at the end of credit period or later incurring interest charges on the unpaid balance for the overdue period. They developed a retailer's model for optimal cycle and payment time for a retailer when units in inventory are subject to a constant rate of deterioration where a wholesaler allowed a specified credit period to the retailer for payment without penalty. The objective was taken to be a cost minimization to determine the optimal payment time under various system parameters. They concluded that the retailer has always an option to pay after the permissible credit period depending on interest rates, unit purchase and selling price and the deterioration rate of the units.

Chang and Dye (2000) derived mathematical model of an inventory system for deteriorating items with partial back-logging when supplier offers fixed credit period to settle the account.

Liao (2007) derived a production model for the lot-size inventory system with finite production rate, taking into consideration the effect of deterioration under permissible trade credit. He made restrictive assumption of a relaxed permissible delay at the end of the credit period. It is assumed that the retailer will make a partial payment on total purchasing cost to the supplier and pay off the remaining balance by loan from the bank. The existence of a unique optimal cycle time to minimize the total variable cost per unit time is established. The bounds for the optimal cycle time are obtained.

Chung and Liao (2004) extended Hwang and Shinn's (1997) and Khouja and Mehrez (1996) model for exponentially deteriorating items under the conditions of permissible delay in payments. They assumed that the delay in payments depends on the quantity ordered.

Chung and Huang (2007) developed a retailer's replenishment model to reflect the real-life situations by assuming that the retailer also adopts the trade credit policy to stimulate his/her customer demand. Based upon the above argument, they proposed a two-warehouse inventory model for deteriorating items under permissible delay in payments.

Lokhandwala et al. (2005) extended Davis and Gaither's (1985) model to determine optimal order quantities for firms where units in an inventory are subject to deterioration at a constant rate, which are offered a one time opportunity to delay payment for an order of a commodity. Such delayed payment reduces purchase cost which is a function of the return available on alternative investments, the number of units ordered and the length of the extended period. For the following four scenarios, the optimal order quantities are developed for extended payment privileges that occur at a reorder point, namely

(1) Extended payment privilege is allowed on all units, when $(Q + x)$-units are ordered, if $x > 0$ at a reorder point.
(2) Extended payment privilege is allowed on all units, when $(Q+x)$-units are ordered if $x > x_{min}$ where x_{min} is pre-stated quantity at a reorder point.
(3) Extended payment privilege is allowed on all additional x-units only, when $(Q + x)$-units are ordered, if $x > 0$ at a reorder point.
(4) Extended payment privilege is allowed on all additional x-units ordered if $x > x_{min}$ where x_{min} is pre-stated quantity at a reorder point. (Here reorder quantity Q is specified by the supplier to quality for the offer of extended payment privilege)

Chang et al. (2001) considered linear demand to derive inventory model for deteriorating items under permissible trade credit. Chang et al. (2003) derived an EOQ model for deteriorating items in which the supplier provides a permissible delay to the purchaser if the order quantity is greater than or equal to a pre-determined quantity. Chang (2004) studied effect of inflation rate in above model. Chang and Dye (2005) derived EOQ model when units in inventory are subject to deterioration and for time varying demand.

In the classical EOQ model, it is assumed that the quantity requisitioned is same as the quantity ordered. Silver (1976) developed an EOQ model when the quantity received is uncertain and is a random variable with specified mean and variance. Shah and Trivedi (2005) analyzed an EOQ model for deteriorating items when the supply is random and supplier allows a certain fixed credit period for settling the accounts. During the time when account is not settled, it is assumed that the cost of unit sold is deposited in an interest bearing accounts and the profit margin is used to meet the operational expenses of the system.

Hwang and Shinn (1997) developed mathematical model to determine the retailer's optimal price and lot-size simultaneously when the supplier permits delay in payments for an order of a product whose demand rate is a function of constant price elasticity when units in inventory are subject to constant rate of deterioration.

Sarker et al. (2000), Chung et al. (2001) and Shah (2006) discussed a model to determine an optimal ordering policy for deteriorating items under inflation, permissible trade credit and allowable shortage. The optimal order quantity and maximum allowable shortages are obtained by optimizing the present value of the total cost incurred. The effect of inflation rate and time discount is derived

on the optimal order quantity and maximum allowable shortages.

In general, the rate of deterioration increases with the age of the longer the items remain unused, the higher the rate at which it looses its usability. Gor and Shah (2003, 2005) developed a mathematical model by allowing/not allowing shortages in the inventory system in which units are subject to time dependent deterioration and supplier allows credit period to settle the account. Shah et al. (2004) extended Gor and Shah's (2003) model by taking demand to be stock dependent.

Yang and Wee (2006) developed a collaborative inventory system of a single vendor and single buyer to maximize the total profit of the whole system. However, the optimal solution for the whole system is not always acceptable to both parties. A negotiating factor was introduced to share profit between two players according to their contributions.

The permissible delay in payment is a win-win strategy for sharing profit in the collaborative system. A deteriorating inventory model with finite replenishment rate and price sensitive demand is assumed to occur in a high-tech, short life cycle and perishable electronic product. It is established that the percentage of extra total profit is significant when both the collaboration strategy and the deterioration rate are considered.

2.3. Discounted–cash–flows (DCF) and trade credit

The average cost approach has following two main drawbacks:

(1) The time value of money is not explicitly taken into account.
(2) There is no distinction between out-of-pocket holding costs and opportunity costs due to inventory investments.

To overcome these drawbacks of the average cost approach, number of researchers suggested present value (PV)) approach (discounted-cash-flow (DCF)). The DCF approach allows proper recognition of the financial implication of the opportunity cost and out-of-pocket costs in the inventory analysis. It also permits an explicit recognition of the exact timing of cash-flow associated with inventory system and considers the time value of money as well.

Chung (1989) presented the DCF approach for the analysis of the optimal inventory policy under the effect of trade credit. He studied effect of the delayed payment in determining the optimal order size. Rachamadugu (1989) established that the best order quantity is an increasing function of allowable delay period.

Carlson et al. (1996) obtained economic order quantity under both all – units and incremental – quantity discounts when purchase cost, ordering cost and inventory holding cost are all incurred on date-terms supplier credit. Payment dates for the three cost components need not be the same. Differences in the characteristics of day-terms and date-terms solutions to the quantity discount case are studied.

Chung and Liao (2006) extended Jaggi and Aggarwal's (1994) article under the assumption that the trade credit is linked to ordering quantity using DCF – approach.

2.4. Stochastic demand and trade credit

The demand of product may not be known and constant, though it can be formatted using past experience by distributions. Shah and Shah (1992), Shah (1993b, 1993c) developed a stochastic inventory model under permissible trade credit. The probabilistic order level system is considered in which the scheduling period T is fixed and the supplier offers a fixed credit period (say) M-time units. The optimal order level is obtained by minimizing the total average expected cost of the system. Later on Shah (1993b) extended above model when units in inventory are subject to constant rate of deterioration.

Shah (1993b, 1993c) derived a probabilistic time-scheduling model for an exponential decaying inventory when supplier offers a credit period to settle the account. The expressions are derived for the total average expected cost of the system, the optimum cycle time and the time for obtaining optimum order level. Shah and Shah (1998) derived above model by treating time to be discrete variable.

Salameh et al. (2003) examined the continuous review inventory model under permissible delays in payments, i.e. a retailer can pay for the goods immediately upon the receipt of the order or delay the payment till the next replenishment order, where supplier will charge interest over the delayed period. They assumed demand to be constant over the time and the lead – time to be random variable. The optimal ordering quantity and reorder level are obtained by maximizing the vendor's total expected profit per time unit when trade credit is offered.

2.5. Comparison between trade credit and discount policy

In this section, the two incentives, i.e. price discount and trade credit are compared. Arcelus and Srinivasan (1990) studied a buyer's decision whether to increase the size of the usual order in exchange for either a discount on the purchase price or a credit period within which no payment is required. For each payment reduction model, they computed maximum level of stock advantageous to the buyer as well as the level of extra stock which maximizes the difference between buying and refusing to order the additional stock. They established a trade-off between the level of discount and the length of the credit period which renders the buyer indifferent to the scheme of payment reduction offered. Arcelus and Srinivasan (1992) studied effect of payment by dividing the holding cost into the costs of physically holding the units in inventory and of the funds tied up in them. Arcelus et al. (2001) analyzed the advantages and disadvantages of two scenarios, that is, payment reduction scheme i.e. discount in unit purchase price and a delay in the payment of the merchandise. The analysis is

made under the assumption of a price dependent demand where price includes the ability of the retailer to pass on some of the savings to the customers. The integration of both purchasing and the sale implications of the vendor's offer on the retailer's profit forms an integral part of the model. Arcelus et al. (2003) extended the above model when units in inventory are subject to constant rate of deterioration.

2.6. Progressive trade credit policy

The concept of progressive credit period given by the supplier for settling the account is as follows: If the retailer settles outstanding amount by M-time units, then the supplier does not charge any interest. If the retailer pays after M but before N ($N > M$), then the supplier charges the retailer on an unpaid balance at the rate Ic_1. If the retailer settles the account after N, then he will have to pay an interest rate of Ic_2 ($Ic_2 > Ic_1$). Soni and Shah (2005) developed mathematical model when units in inventory are subject to constant rate of deterioration and supplier provides two progressive credit periods. Soni et al. (2005) derived a mathematical model when units received by the retailer are random and supplier offers two progressive credit periods to the retailer to settle the account. Huang (2006) extended Huang (2003) inventory model under two levels of trade credit by considering the retailer's limited storage space capacity. The optimal cycle time is established in terms of easy – to – use analytic theorems.

3. Conclusions

The aim of this article is to bring out a complete and up-to-date review of published articles on trade credit scenario. The available relevant models have been classified into a number of categories and their principal features have been discussed.

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