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## Int. J. Production Economics

journal homepage: [www.elsevier.com/locate/ijpe](http://www.elsevier.com/locate/ijpe)

# Supply chain coordination with trade credit and quantity discount incorporating default risk



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## ARTICLE INFO

### Article history:

Received 25 October 2012

Accepted 10 March 2014

Available online 29 March 2014

### Keywords:

Newsvendor

Trade credit

Credit risk

Advance payment

Mean-variance model

## ABSTRACT

We explore the issue of supply chain coordination by considering trade credit and its risk. It shows that, in a retailer–manufacturer system, the manufacturer may deliver less than the retailer's order quantity when the payment is delayed, and the manufacturer's risk aversion makes this result hold in a wider range. These findings are different from the common sense believed in the retailer–manufacturer coordination literature, which suggests the manufacturer to entice the retailer to enlarge the lot size. The manufacturer's decision of decreasing the order quantity prevents the supply chain from operating in the optimal situation. In order to coordinate supply chain, we propose a modified quantity discount based on both order quantity and advance payment which means the manufacturer offers quantity discount if the retailer pays part of the payment in advance and enlarges her order quantity. The ranges of advance payment ratio and the quantity discount are derived. Numerical examples are used to demonstrate the conclusions.

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## 1. Introduction

In the past decade, the issues of supply chain coordination have been extensively studied. One of the key findings is that in the decentralized system, the retailer's optimal order quantity is less than the whole supply chain's optimal order quantity. Therefore, the proposed incentives, mostly in the form of contract, are aimed to encourage the retailer to enlarge her order quantity. However, most of these studies implicitly assumed that the retailer must pay for the items as soon as she receives them from the supplier, which ignores the influence of the commonly used trade credit and its associated risk. The goal of this paper is to examine whether this widely accepted belief still holds when trade credit and its risk are considered, and, if it does not hold, how to coordinate supply chain.

In practice, transactions between firms seldom occur instantaneously; meanwhile payment arrangements are mostly credit terms. If payment is made after delivery, the manufacturer extends credit to the retailer. The converse is true if payment is made before delivery. There are two basic forms of delayed payment. The simple form, net terms, specifies that full payment is due within a certain period after delivery. The more complex form of

trade credit, two-part terms, means the retailer can get some cash discount when she pays the manufacturer in the discount period, otherwise the retailer should pay all of the payment before the due date.

Trade credit is widely used and has important influences on firm's operations. According to Ng et al. (1999), during the 1990s manufacturer financing has accounted for an average 1.5 trillion of the book value of all assets of US corporations and has represented approximately 2.5 times the combined value of all new public debt and primary equity issues during a given year. In Germany, France and Italy, trade credit represents more than a quarter of total corporate assets, while in the United Kingdom 70% of total short-term debt (credit extended) and 55% of total credit received by firms is made up of trade credit (Guariglia and Mateut, 2006). In China, non-state owned firms get limited supports from the banks, and trade credit is used as a very important short term financing instrument.

Indeed, when payment is delayed, the risk that the retailer cannot pay all of the payment needs to be considered, especially when the final demand acts volatile and the credit condition of the downside firm ranks low. In such a situation, instead of encouraging the retailer to enlarge her order quantity, the optimal decision of the supplier may be delivering less quantity to avoid default risk. In this paper, we try to prove this conjecture. Further, we discuss how to coordinate supply chain with quantity discount and trade credit.

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The rest of this paper is organized as follows. In Section 2, we summarize the related literature. In Section 3, we derive the manufacturer's decisions of delivered quantity to the retailer for both risk neutral and risk averse cases. Section 4 is devoted to discuss the difference between a buy-back contract and a trade credit when considering default risk. In Section 5, we illustrate how to entice the manufacturer to satisfy the retailer's order quantity and how to achieve supply chain coordination by using advance payment and quantity discount. Section 6 offers numerical examples to demonstrate the results of the models. Conclusions and future research directions are discussed in the last section.

## 2. Related literature

There is an extensive literature on supply chain coordination based on the newsvendor models. Papers by Pasternack (1985), Padmanabhan and Png (1997), Taylor (2002), Dawn et al. (2002), Cachon and Lariviere (2001, 2005), Krishnan and Winter (2010), Cachon and Kok (2010) are the examples. For an excellent review, please refer to Cachon (2003). However, trade credit term between firms is not considered in these papers.

We now review some papers investigating the influences of trade credit on inventory policy. Goyal (1985) firstly considered the manufacturer's delayed payment in analyzing the retailer's EOQ. After that, Goyal's work was extended by considering more general model settings, such as, perishable products (Aggarwal and Jaggi, 1995; Jamal et al., 1997; Ouyang et al., 2009; Musa and Sani, 2012; Yu, 2013; Chung et al., 2014); price sensitive demand (Arcelus et al., 2001; Abad and Jaggi, 2003; Teng and Chang, 2005); linear non-decreasing demand (Teng et al., 2012; Teng and Chang, 2012); two-part terms of delayed payment (Goyal et al., 2007; Ho et al., 2008; Sana and Chaudhuri, 2008); two levels of trade credit (Huang, 2007; Teng and Chang, 2005; Tsao, 2009; Min et al., 2010; Chen et al., 2014); partial delayed payment (Taleizadeh et al., 2013); discounted cash flow (DCF) approach (Chung and Liao, 2006, 2009; Chang et al., 2010), etc. See Seifert et al. (2013) for a comprehensive review of the papers addressing trade credit.

Instead of setting the delayed payment as given, some papers set trade credit as a decision variable and discussed the effect of delayed payment in coordinating supply chain. Jaber and Osman (2006), Luo (2007), Sarmah et al. (2008), Chan et al. (2010), Luo and Zhang (2012) explicitly used trade credit as a mechanism to coordinate a buyer-vendor supply chain under different settings.

Besides delayed payment, advance payment is also a kind of trade credit and attracts many attentions; see Maiti et al. (2009), Gupta et al. (2009) and Thangam (2012) for example.

However, these papers ignored the risk associated with trade credit, while the supplier's inventory decision was not considered. In this paper, we take trade credit and its risk into consideration and investigate their influences on the manufacturer's decision, and at the same time examine whether the manufacturer's delivered quantity is less than the buyer's order quantity. In addition, we also address the supply chain coordination when the trade credit and its risk are considered.

## 3. The basic model for given trade credit

Consider a tightly coupled system with a single manufacturer and a single retailer. The retailer's inventory policy can be described by the newsvendor model. In specific, the retailer orders a single product with quantity  $q_r$  from the manufacturer well in advance of a selling season with stochastic demand. After receiving the retailer's order, the manufacturer chooses the optimal

quantity, defined as  $q_m$ , to produce and deliver to the retailer at the start of the selling season. The retailer has no additional replenishment opportunity. Other notation to be used is defined as follows.

$p$	product's retail price
$w$	product's wholesale price
$c$	product's production cost
$s$	product's salvage value
$D$	final demand for the product
$U(\cdot)$	manufacturer's utility function
$V(\cdot)$	the variance of the manufacturer's profit
$F(\cdot), f(\cdot)$	prior distribution and density function of $D$
$\pi_r(\cdot), \pi_m(\cdot), \pi_s(\cdot)$	retailer's, manufacturer's, supply chain's profit

### 3.1. The risk-neutral manufacturer's decision

We begin our analysis with a review of the situation from the retailer's point of view. We use "he/his" to denote the manufacturer, and "she/her" to denote the retailer. When there is no coordination between the retailer and the manufacturer, according to the classic newsvendor model, the retailer's profit is  $\pi_r(q) = p \text{Min}(q, D) + s \text{Max}(0, q - D) - wq$ , which has the expectation

$$E[\pi_r(q)] = (p - w)q + (s - p) \int_0^q F(x)dx. \quad (1)$$

Maximizing  $E[\pi_r(q)]$  leads to the retailer's optimal lot size

$$q_r = F^{-1}\left(\frac{p - w}{p - s}\right). \quad (2)$$

For the manufacturer, when no payment risk is considered, his profit function is

$$E[\pi_m(q)] = (w - c)q, \quad (3)$$

so that his individual optimal  $q$  is the largest allowable lot size. While the expected profit function of the whole supply chain is

$$E[\pi_s(q)] = (p - c)q + (s - p) \int_0^q F(x)dx. \quad (4)$$

The jointly optimal lot size of the system is

$$q_s = F^{-1}\left(\frac{p - c}{p - s}\right), \quad (5)$$

which is obviously larger than  $q_r$ . Therefore, when there is no coordination between the firms the supply chain is not operated in the optimal situation. This has also been addressed in previous literature, and different kinds of contracts, such as quantity discount, sale rebate, buy back, etc, have been suggested to solve this problem.

However, all of these studies did not consider the risk of payment. In the real world, credit transactions are widely used, and the manufacturer usually gets payment after quite a long time after the transaction. When payment is delayed, the risk associated with the credit policy cannot be neglected especially when demand for the product is very volatile and the retailer is not in good financial condition. If the realized demand is very small, the retailer's gains from selling and salvage of the left products are small too. When these gains are smaller than the retailer's procurement cost, the probability of default exists. In this context, in order to reduce such risk, the manufacturer may expect the retailer to order less so as to reduce the risk of overstock, that is, instead of increasing the retailer's order quantity, the manufacturer will encourage the retailer to decrease procurement volume.

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