Computers & Industrial Engineering 90 (2015) 132–145

Contents lists available at ScienceDirect

Computers & Industrial Engineering

journal homepage: www.elsevier.com/locate/caie

A single-period inventory and payment model with partial trade credit

Yong-Wu Zhou [a], Zong-Liang Wen [a,b], Xiaoli Wu [a,*]

[a] School of Business Administration, South China University of Technology, Guangzhou, Guangdong 510641, China
[b] College of Pharmacy, Guangxi University of Chinese Medicine, Nanning, Guangxi 530001, China

ARTICLE INFO

Article history:
Received 21 August 2014
Received in revised form 13 May 2015
Accepted 10 August 2015
Available online 28 August 2015

Keywords:
Inventory
Partial trade credit
Financing
Newsvendor framework

ABSTRACT

In this paper, we consider the ordering and payment issues for a retailer facing stochastic demand. We assume that the retailer can enjoy the partial trade credit from his supplier and borrow money from bank as well if needed, and he can also earn return by investing his superfluous on-hand cash (if any). The retailer's objective is to maximize the expected cash level at the end of the selling period. We formulate the model of this problem by taking initial inventory and capital levels as the two-dimensional state. First, given the exogenous fraction of immediate payment, we show that unlike the critical fractile solution the retailer's optimal ordering strategy is a two-threshold policy, which is independent of the retailer's initial inventory level and capital level. Second, we consider an extensive model where the fraction of immediate payment is decided by the retailer. We employ the sequential optimization procedure to solve the extensive problem, and present the structure of the retailer's optimal policies under different partial-trade-credit penalty rates. Numerical experiments show that if the fraction of immediate payment is exogenous, both partial trade credit and loan opportunity are detrimental to the capital-constrained retailer in many cases, although they can stimulate the retailer to order more.

1. Introduction

It's well known that cash flow plays a pivotal role in determining firms' operation decisions. As an important source of external financing, trade credit is the most important form of short-term financing for firms in the United States (Petersen & Rajan, 1997), and is also used widely in both Europe (Giannetti, Burkart, & Ellingsen, 2011; Wilson & Summers, 2002) and economy with less developed financial markets or weak bank-firm relationships (Booth, Aivazian, Demirguc-Kunt, & Maksimovic, 2001; Bruno & Gollier, 1997). According to the *Financial Times*, in 2007, 90% of world merchandise trade was financed by trade credit, with a value of about $ 25 trillion.[1]

However, the strategy of granting credit terms adds an additional dimension of default risk to the supplier. Some authors, like Kiyotaki and Moore (1997), argue that the use of trade credit causes shocks to propagate in the economy. For instance, if a company's main client has no money, then this company might not get paid to the end of the year, which means that it will have no profit for the year. The *Financial Times* reports that, in September 2004, the "exposure of Electronic Data Systems (EDS) to US Airways was such that it could slice almost a third from its third-quarter earnings as it [EDS] joined the list of creditors and suppliers to suffer following the airline's bankruptcy filing".[2] By collecting the answers from 131 US small businesses that filed for bankruptcy to a questionnaire about the causes for their failures in 2002, Bradley and Rubach (2002) indeed find that non-payments of trade credit is the most important cause for their bankruptcy (31% of the answers), before poor sales (28%). In practice, in order to reduce the default risk, the supplier usually requires that the retailer pay for the partial amount of the purchased items immediately when ordering and the account for the rest of the purchased items can be settled at the end of trade credit period. This is so-called partial trade credit. For example, Sany Heavy Industry Co., Ltd offers partial delay payment to his dealership on the permissible credit period and the rest of the total amount is payable at the time the dealership places a replenishment order. Another representative example is about financial service to capital-constrained paper manufacturers offered by China National Materials Storage and Transportation Corporation (CMST), one of the largest logistics enterprises in China. The paper manufacturers only pay a fraction of the procurement cost to the supplier and CMST covers the remaining procurement cost while providing the logistics services for their transactions. When

* Corresponding author. Tel.: +86 02022236983; fax: +86 02022236282.
E-mail addresses: zyw_666@hotmail.com (Y.-W. Zhou), mathwzl@163.com (Z.-L. Wen), wxiaoli@scut.edu.cn (X. Wu).

[1] "World Bank urged to lift trade credit finance," *Financial Times*, November 11, 2008.

[2] "EDS joins US Airways casualties," *Financial Times*, September 17, 2004.

http://dx.doi.org/10.1016/j.cie.2015.08.003
0360-8352/

demand is realized the manufacturers repay CMST the remaining fraction of the procurement cost. The financial service offered by CMST is essentially partial trade credit financing. Currently, partial trade credit is one of the most popular financing modes for small-and-medium companies in China.

Despite of wide and common usage, partial trade credit alone may be not sufficient to finance inventory. Hence, retailers must resort to other external sources (e.g. a bank) to finance inventory fully. Thus, the following natural questions arise. First, what is the optimal inventory and financing policy for a firm if partial trade credit is granted? For the traditional newsvendor problem, it is well known that the famous critical fractile solution is optimal. Then, whether is the critical fractile solution still optimal or not when a retailer can finance inventory by partial trade credit as well as short-term loans? Second, whether does the capital-constrained retailer, who has been offered partial trade credit, still need the loan opportunity from bank if granted?

To answer these questions, we consider a situation where a retailer purchases items from the supplier to satisfy random demand. The retailer is offered partial trade credit when he places an order. That is, only a fraction of the purchase cost can be paid after the selling period at a penalty interest rate. The remaining part of the purchase cost has to be paid at the purchased moment as usual. If needed, the retailer can borrow a short-term loan from the bank at a fixed loan interest rate. If there is still some surplus working capital after purchasing, the retailer can also use his surplus working capital to earn return. Once the random demand is realized at the end of the sales period, the retailer collects the revenue from sales as well as the investments, pays the trade credit ordering cost plus the interest, and then imburses his loan obligation (if any). Any unsatisfied demand is lost. The retailer is risk-neutral, and his objective is to maximize the expected terminal cash at the end of the sales period.

We first formulate the problem as a constrained optimization problem by viewing initial inventory and capital levels as the two-dimensional initial state. Then we characterize the retailer's optimal ordering strategy as a function of the given fraction of immediate payment. We show that the ordering strategy is a two-threshold policy that is independent of the retailer's initial state, which is unlike the critical fractile solution in the traditional newsvendor problem. We further extend the model to the case where the retailer can decide the fraction of immediate payment by himself. This extensive optimization problem can be solved by employing sequential optimization procedure. Under different penalty interest rate levels (low, moderate and high), we study the structure of the retailer's optimal policy. To highlight the insights of our model, we present a set of numerical experiments and show the differences of the optimal order policy and expected terminal cash with and without partial trade credit. We obtain the following interesting observations. If the fraction of immediate payment is exogenous, the initial capital status will affect whether partial trade credit and loan opportunity are beneficial to the capital-constrained retailer. When the retailer has relatively small initial capital, both partial trade credit and loan opportunity are beneficial to him. However, both partial trade credit and loan opportunity may be detrimental to the retailer who has relatively large initial capital, although they can still induce the retailer to order more.

In this paper, we have three major contributions. First, in a newsvendor setting, we study an ordering and financing issue for a retailer who can enjoy partial trade credit, earn interest by investing superfluous on-hand cash (if any), and borrow money from bank if needed. Provided the fraction of immediate payment is exogenous, we present the structure of the retailer's optimal policy. Second, we extend the model to the situation where the fraction of immediate payment is determined by the retailer, and present the retailer's optimal replenishment and financing policy under different penalty interest levels. Third, our numerical results indicate that in many cases offering partial trade credit and loan opportunity may hurt the retailer.

The remainder of this paper is organized as follows. We briefly review the related literature in Section 2. Section 3 focuses on the description and formulation of the model. Section 4.1 studies the case in which the fraction of immediate payment is exogenous. Section 4.2 extends the model to the case in which the fraction of immediate payment is endogenously decided by the retailer. In Section 5 we conduct a set of numerical experiments to illustrate the model. Finally, the paper concludes in Section 6 with some remarks and suggestions for future research.

2. Literature review

Our work belongs to the interface of operations and finance, which has recently been paid fast-growing attention (such as Babich & Sobel, 2004; Ding, Dong, & Kouvelis, 2007). We are mainly interested in the impact of partial trade credit on retailer's inventory and finance decision.

Most of the earlier inventory management literature considered partial trade credit was based on the classical EOQ/EPQ framework. One of the representative researches is Goyal (1985), where he obtained the EOQ formula when the buyer may delay payment by a prespecified number of days. From later on, many scholars did a lot of extensive researches from different angles. For instance, Ouyang, Teng, Goyal, and Yang (2009) generalized Goyal's (1985) model to the case with deteriorating items. Huang (2007) assumed that the supplier offers the retailer a partial delay in payments when the order quantity is smaller than a predetermined quantity. Taleizadeh, David, Mohammad, and Aryanezhad (2013) studied an EOQ problem with partially delayed payment and partial backordering. Trade credit involved in the models above is referred to as one level of trade credit. Some recent papers studied optimal order policies under the setting of two levels of trade credit. For example, Huang and Hsu (2008) developed an EOQ model where the retailer gets full trade credit from his supplier and then offers partial trade credit to his customer. Teng (2009) further considered such a situation, where a retailer receives full trade credit and then offers either partial/full trade credit to his bad/good credit customers. Thangam (2012) built a two-echelon supply chain model, in which two levels of trade credit and the advance payment scheme are both considered. Mahata (2012) investigated the retailer's optimal replenishment decisions for deteriorating items under the setting of two levels of trade credit. Mahata and Mahata (2011) further studied Mahata's (2012) problem under fuzzy setting. Recently, Zhang, Tsao, and Chen (2014) investigated the buyer's inventory policy under advance payment schemes, including all payment in advance and partial-advanced–partial-delayed, and demonstrated the effect of these schemes on inventory policy.

The work by Zhou, Zhong, and Wahab (2013) deserves our special attention. In their paper, the retailer is offered a two-part trade credit. If the retailer pays within the short permissible delay period, he will receive a price discount; otherwise, he must pay at the normal price. The retailer may choose to pay any fraction of the purchase cost within the short credit term and the rest must be paid within the long credit term. Under the EOQ setting, they studied the issue of how the retailer determines the optimal replenishment policy and payment plan.

All the above literature on partial trade credit mostly considered deterministic demand. Our work aims to study the effect of partial trade credit on the retailer's optimal inventory and financing policy under stochastic demand. A few recent exceptions