Int. J. Production Economics ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Int. J. Production Economics

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

Coordinating contracts for fresh product outsourcing logistics channels with power structures

Qing Wu, Yinping Mu, Yi Feng *

School of Management and Economics, University of Electronic Science and Technology of China, Chengdu 611731, China

ARTICLE INFO

Article history:
Received 14 February 2013
Accepted 30 September 2014

Keywords:
Outsourcing logistics
Perishable product
Optimization
Contract design
Power structure

ABSTRACT

We consider an outsourcing logistics channel where a distributor procures a quantity of a fresh product and outsources his logistics operations to a third party logistics service provider (TPLSP), whose logistics service quality and price affect the product sellable quantity and quality on the market, and the distributor's order decision, respectively. The distributor sets his order quantity and product selling price. The determinations of logistics service quality and price depend on the channel power structures. We investigate each firm's decisions under a traditional unit pricing contract in the three power balance scenarios where the distributor or the TPLSP has the channel power, or they have equal power. The equilibrium results show that the power structures have an important influence on contract design, each firm's decision behaviors and channel performances. We further develop two novel incentive mechanisms to coordinate the decentralized channel considering the risk preference of the TPLSP. Computational studies show that the power structures' influences increase while the effects of logistics service quality on product quantity and quality increase, and illustrate these incentive mechanisms can achieve full channel coordination and win–win outcomes.

1. Introduction

Fresh products, such as fresh fruits and vegetables, cut flowers, and live seafood, are easily subject to deterioration and obsolescence during logistics process, often involving long distance transportation and long time storage, due to their highly perishable nature. To keep freshness, the products must be kept in a consistently chilled environment. Logistics service quality therefore plays a key role in avoiding product losses. According to a recent Accenture report, for instance, low logistics services quality (largely caused by only 15 percent of all perishable products in China transported by refrigerated vehicle) results in a loss of $8.9 billion annually in fruit and vegetable distribution, which represents about 30 percent of China's annual output. In developed countries, however, high logistics services quality (dependent on nearly 90 percent of perishable products transported by sophisticated transportation facilities) decreases product loss rate to about 5 percent, even to less than 2 percent in the United States (Bolton and Liu, 2006). It indicates that there is a significant opportunity for improvement of logistics service quality to reduce product losses in China.

Besides logistics service quality, logistics service price is another important influence factor on fresh product losses. High logistics service prices can lead fresh product distributors to decrease their order quantities, even to stop ordering, which causes unmarketable fresh product events to often occur in daily life, such as unmarketable pepper event in Hainan province (Meng, 2007), and unmarketable lettuce event in Pengzhou City, Sichuan province (Xu and Chen, 2010) in China. So, large amounts of fresh products cannot be sold out and decay in fields, which results in massive losses and resource waste.

In practice, a distributor procures a quantity of a fresh product and usually outsources his logistics operations to a *third party logistics service provider* (TPLSP). The logistics service quality has an important influence on the product losses, including "quantity loss" and "quality loss", which further affect the product surviving quantity and freshness, respectively, when the product reaches a target market. Moreover, the market demand for the product depends on its freshness level and selling price (Cai et al., 2010). Thus, the following problems arise:

(1) The TPLSP can exert efforts to improve his logistics service quality to reduce product losses, but it imposes considerable costs on him. So, can the most popular contract, a *traditional unit pricing contract* (TUP), motivate the TPLSP to improve his logistics service quality and decrease his logistics service price to reduce the product losses?

* Corresponding author. Tel.: +86 15928720216; fax: +86 28 61830926.
E-mail addresses: wuq@uestc.edu.cn (Q. Wu), ypmu@uestc.edu.cn (Y. Mu), fengyi@uestc.edu.cn (Y. Feng).

http://dx.doi.org/10.1016/j.ijpe.2014.10.007
0925-5273/

(2) There are three possible power balance scenarios in an outsourcing logistics channel as follows: (a) *TPLSP-Stackelberg* (TS) where the TPLSP and the distributor act as a Stackelberg leader and a follower, respectively, such as the large logistics company Maersk and his relatively small client; (b) *Distributor-Stackelberg* (DS) where the distributor dominates over the TPLSP, such as the large supermarket Wal-Mart and a medium-sized logistics company, Fudi Logistics; (c) *Vertical Nash* (VN) where each firm has an equal channel power, such as small or medium-sized vegetable distributors and transportation companies. How do the power structures affect contract design, each firm's decisions and channel performance?
(3) Can we design an effective contract to coordinate each firm's decisions and achieve a win–win outcome if their decisions under the TUP lead to suboptimal channel performance? Especially, when unmarketable fresh product events occur, can we devise an incentive scheme to induce the TPLSP and the distributor to cooperate in achieving a win–win outcome?

Therefore, this paper aims to resolve the above problems. Firstly, we establish the *integrated channel* (IC) model as a benchmark; secondly, we develop three game models in the above power balance scenarios under the TUP; thirdly, we design two novel incentive mechanisms to solve the efficiency problem of the TUP; finally, we conduct relevant computational studies.

The rest of the paper is organized as follows. The next section presents a survey of the relevant literature. Section 3 outlines the notations and modeling assumptions. In Section 4, we derive the optimal decisions of the IC. Section 5 studies each firm's decision behaviors in different power structure scenarios. In Section 6, two new coordination contracts are presented and some of their properties are discussed. We conduct some computational studies in Section 7. A discussion and conclusion follow. For clarity of presentation, main proofs appear in Appendix A.

2. Literature review

With rapid development of third party logistics industry, logistics outsourcing problems have been paid considerable attention in previous research. Razzaque and Sheng (1998), Maloni and Carter (2006), and Marasco (2008) provide comprehensive reviews of the logistics outsourcing literature, highlighting key research findings from journals and other publications. However, efforts to study logistics outsourcing contract design issues have so far been rather limited (Marasco, 2008). The literature in this line mainly studies how to design contracts to optimize a third party logistics buyer's utility from the buyer's perspective (Lim, 2000; Chen et al., 2001; Alp et al., 2003). For instance, Chen et al. (2001) explore properties and algorithms for the multi-period warehousing contract problems under random space demand from a user's perspective. Alp et al. (2003) consider a transportation contract design problem between a manufacturer and a transporter, aiming to minimize expected total costs for the manufacturer. Neither of the above papers considers a contract design issue from a system's viewpoint. This paper focuses on a fresh product outsourcing logistics channel coordination problem from a system's viewpoint.

Perishable products are often subject to both obsolescence and deterioration. However, research considering both types of losses is rather limited (Cai et al., 2010). Rajan et al. (1992) study the relationship between pricing and ordering decisions for a monopolistic retailer facing a known demand function where the product may exhibit physical decay and value drop over the inventory cycle. They assume waste rate and value drop rate are functions of time. Ferguson and Koenigsberg (2007) develop a two period model that captures the effect of the competition between new product and leftover product on the firm's production and pricing decisions. They assume that the quality of the leftover product is exogenous and find conditions under which the firm is better off carrying all, some, or none of its leftover inventory to the next period. Cai et al. (2013) study a fresh product supply chain coordination problem with logistics outsourcing under the CIF (Cost, Insurance and Freight) term. They assume product surviving rate and freshness level are also functions of time. In the above papers, the quantity loss or/and quality drop is not a function of a decision variable.

Recently, Cai et al. (2010) study a fresh product supply chain coordination problem under the FOB term. They consider product surviving rate and freshness level are functions of a distributor's freshness-keeping effort level. Similarly, we consider product surviving rate and freshness level are functions of logistics service level. However, there are significant differences between Cai et al. (2010) and our work. Cai et al. (2010) consider that a distributor determines his optimal product order quantity, level of freshness-keeping effort, and product selling price to maximize his expected profit under a wholesale contract. The distributor can directly obtain the benefits of improving effort level, decrease of quantity loss and increase of the market demand for the product. Thus, there exists no incentive problem for motivating the distributor to improve his effort level, which is supported by one of their results: as compared with the centralized system, the distributor in the decentralized system devotes a higher effort. In our work, however, under a TUP, the distributor can benefit from the decrease of quantity loss and increasing market demand for the product when the TPLSP improves his logistics service level. Although the market demand for the product increases, the product order quantity may decrease since the quantity loss decreases. Meanwhile, the TPLSP endures all logistics service cost alone. Thus, the TPLSP may lack of sufficient incentive to improve his logistics service level. Therefore, how to coordinate the decisions of the TPLSP is a critical problem in our work. Besides, we consider the impact of different power structures on contract design, each firm's decisions and channel performance. They only consider one case where a producer and a distributor act as a Stackelberg leader and a follower, respectively.

The topic on different power structures in supply chain management has been paid little attention in previous literature. These limited papers have discussed price competition problems with two competing manufacturers and a common retailer (Choi, 1991), drop-shipping coordination (Netessine and Rudi, 2001), commitment decisions with forecast updating (Ferguson, 2003) and partial information updating (Ferguson et al., 2005). Power can be modeled as move sequence (A power move firstly in a Stackelberg game, and equal decision powers move simultaneously in a Nash game) (Choi, 1991; Netessine and Rudi, 2001) or a decision right (A power owns the decision right) (Ferguson, 2003; Ferguson et al., 2005). Different from them using one of the above techniques to model power, we use both. Specifically, we simultaneously consider move sequences and who has the right to choose logistics service level in the three power balance scenarios. Importantly, we study a new problem different from the above papers.

In this paper, we consider logistics service level has an important influence on the product freshness level, which further affects the market demand for a fresh product. This effect is similar, to a certain extent, to that of retailer promotional effort on the market demand for the retailer's product. Supply chain coordination problems with retailer promotional effort have been paid much attention by many researchers (see, e.g., Cachon, 2003; Cachon and Lariviere 2005; Krishnan et al., 2004; Taylor, 2002). They focus on how to design contracts to allocate promotional effort cost and inventory risk for demand uncertainty. However, we consider the effects of logistics service level on supply as well

Please cite this article as: Wu, Q., et al., Coordinating contracts for fresh product outsourcing logistics channels with power structures. International Journal of Production Economics (2014), http://dx.doi.org/10.1016/j.ijpe.2014.10.007