Pricing and cold-chain service level decisions in a fresh agri-products supply chain with logistics outsourcing

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ABSTRACT

This paper develops two Stackelberg game models to investigate the pricing and service level decisions of a fresh agri-products supply chain consisting of one supplier, one retailer, and one third-party logistics provider and examines the impacts of channel leadership on the price and service level decisions and profits. We consider two game scenarios: the logistics provider-first scenario and the supplier-first scenario. When the cold-chain service price is exogenous, we find that when the service sensitivity is sufficiently low, each player can obtain a higher profit under the logistics provider-first scenario than under the supplier-first scenario. Counter-intuitively, for the supplier, channel leadership does not guarantee it a higher profit. When the cold-chain service price is endogenous, we find that although the relative magnitude of the supplier's and retailer's profits is changed under the supplier-first scenario, the other main results are unchanged qualitatively.

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1. Introduction

When customers select and purchase fresh vegetables or fruits in supermarkets or community stores, they may not be aware that some of these fresh vegetables and fruits come from a production base with thousands of kilometers away from the market. During the long distance transportation between a production base and a target market, for example, the distance up to 2700 km between Hainan, a base providing fresh vegetables in winter, and Beijing, a target market, fresh agri-products inevitably suffer from quality loss and quantity loss (Cai, Chen, Xiao, Xu, & Yu, 2013; Wu, Mu, & Feng, 2015) due to the characteristics of deterioration and decay of fresh agri-products. Quality loss refers to the drop of freshness level in the long distance transportation, on which the market demand for agri-products heavily depends. When fresh agri-products are transported from a production base to a target market, some of them will decay and deteriorate gradually. Thus, the deteriorating and decaying agri-products which become unsaleable need to be selected carefully and dealt with in an applicable manner, which is related to quantity loss. In the process from production fields to dining tables, fresh agri-products not only are prone to be contaminated again and again, but also suffer from loss and waste. According to a survey in China, the quantity loss rate of

fresh fruits and vegetables reaches up to between 20% and 25%, while developed countries can keep the quantity loss rate less than 5% in the long distance process.[1] Given the high quantity loss rate, a firm can use cold-chain logistics service in all operational processes and construct a standardized cold-chain logistics system related to transportation, trading, storage, packaging, etc. As a result, these measures contribute to the improvement of freshness of agri-products, as well as reduce the quantity loss rate effectively in the long distance transportation. For instance, Yonghui Superstores applies a cold-chain logistics system to effectively keep the quantity loss rate of fresh agri-products at about 5%, which is much less than the average level in the agri-products industry.[2]

With the rapid development of the third-party cold-chain logistics, a traditional fresh agri-products supply chain frequently outsources its logistics service to a *third-party logistics* (*3pl*) provider. As a 3pl provider, Shuanghui Logistics provides cold-chain logistics service in transportation, distribution and delivery to firms producing fresh fruits and vegetables.[3] By utilizing advanced technology, comprehensive standard and intelligent information system, the cold-chain logistics service offered by a 3pl provider substantially reduces the quantity loss rate in the operational processes referring

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[1] The loss rate of fruits and vegetables in the long distance transportation up to 20–25%. <http://www.vegnet.com.cn/News/830521.html>, 2013.
[2] How to control the loss rate of vegetables at about 5% from fields to YONGHUI Superstores. <http://www.wtoutiao.com/p/E44IW3.html>, 2015.
[3] http://www.shwl.com.cn/info.asp?id=51&dbs=info.

to transportation, storage, distribution and retailing, and significantly improves the quality of fresh agri-products, i.e., freshness. Obviously, a 3pl provider participating in a traditional supply chain will complicate the players' decisions. We pay main attention to such a supply chain with cold-chain logistics outsourcing.

In an agri-products supply chain, following the time sequence of decisions for the 3pl provider and the supplier, we consider two channel leadership (game) scenarios: the logistics provider-first scenario (3S) and the supplier-first scenario (SS). To be specific, under 3S, the 3pl provider first acts to decide the cold-chain service level, and then the supplier decides the wholesale price. Under SS, the supplier first acts and then the 3pl provider acts. It is evident that different players act as leaders relative to other players, suggesting that there are different channel leadership scenarios. Different channel leadership scenarios may have significant impacts on supply chain decisions and profits (Chen & Wang, 2015; Choi, Li, & Xu, 2013). We consider an agri-products supply chain comprising of one supplier, one retailer and one 3pl provider under the 3S and SS scenarios. Our main objective is to explore the price and service level decisions of the agri-products supply chain and how channel leadership influences the price and service level decisions and profits. In particular, we aim at resolving the following problems:

(1) How channel leadership impacts the selling price, cold-chain service level and unit wholesale price?
(2) How channel leadership influences the players' profits and supply chain profit? Is there a channel leadership scenario beneficial to all players? If there exists a scenario, then which one?
(3) How channel leadership affects social welfare and consumer surplus?

To address the above issues, we derive the equilibrium price and service level decisions under 3S and SS, and examine the effects of channel leadership on the supply chain by comparing the equilibrium decisions and profits under 3S and SS. In terms of the cold-chain service price, we develop models with an exogenous and endogenous cold-chain service prices, respectively. There are some interesting results generated when the cold-chain service price is exogenous. First, for the supplier, channel leadership does not necessarily lead to a higher profit, which is in contrast to our conventional wisdom. Second, the 3S scenario is more beneficial to all players under a certain condition that the service sensitivity is sufficiently low. However, when the service sensitivity is sufficiently high, the 3S scenario is more beneficial to the 3pl provider, while the supplier and the retailer can benefit more from the SS scenario. When the cold-chain service price is endogenous, most results in the case where the cold-chain service price is exogenous are kept qualitatively.

2. Literature review

This paper is related to supply chain management on deteriorating items, logistics outsourcing, and channel leadership.

The supply chain management literature on deteriorating items is particularly rich, and most of previous research papers on this issue focus on supply chain coordination and inventory control. For instance, Zhang, Liu, Zhang, and Bai (2015) investigate cooperative investment in preservation technology to reduce deterioration. Xiao and Xu (2013) design a generalized revenue-sharing mechanism to coordinate the price and the service level under VMI. Huang, Su, and Lin (2011) design a lead-time discount coordination strategy to maximize the profit of the entire supply chain. Giri and Bardhan (2012) design a revenue-sharing contract to coor-

dinate a two-echelon supply chain for a deteriorating item with stock and price-dependent demand. Blackburn and Scudder (2009) investigate supply chain strategy for fresh products through the marginal cost of time for a product. In terms of inventory control of deteriorating items, some works are made in pricing and ordering (Cohen, 1977; Maihami & Kamalabadi, 2012), production (Chen, Teng, & Skouri, 2014), production-inventory (Chang, 2014), credit period (Wang, Teng, & Lou, 2014), marketing (Shah, Soni, & Patel, 2013). For example, Wang, Lin, and Jonas (2011) design an optimal integrated inventory policy for time-sensitive deteriorating products. Das, Das, and Mondal (2013) study an integrated production inventory system of constant deteriorating items, where the supplier provides a delay in payment to the retailer. Ghiami, Williams, and Wu (2013) analyze deteriorating inventory where the capacity of the retailer's warehouse is limited. Chen and Sapra (2013) investigate a periodic review model over a finite horizon for a perishable product. Dye and Yang (2016) propose a generalized model for a joint dynamic pricing and preservation technology investment. Above research papers characterize deteriorating items by capturing quantity loss, while the characteristics of quality loss of some special products like fresh fruits, vegetables and flowers are ignored. Quality loss is related to the reduction in the degree of freshness, which is incorporated into our model.

In practice, there are many deteriorating products, e.g., vegetables, fruits, cut flowers, and milk, characterized by both quantity loss and quality loss. So far, several papers focus on supply chain management with quantity loss and quality loss. For instance, Cai, Chen, Xiao, and Xu (2010) characterize the optimal decisions of a fresh product supply chain where the distributor's freshness-keeping effort impacts the quality and quantity of the product delivered to the market. By extending Cai et al. (2010), Cai et al. (2013) introduce a 3pl provider into a fresh-product supply chain. Recently, based on Cai et al. (2010, 2013), Wu et al. (2015) investigate equilibrium decision and coordination issues in an outsourcing logistics channel where logistics service quality and price affect the quantity and quality of the sellable product. From the above, we find that the effort offered by a distributor in Cai et al. (2010) and the service provided by a 3pl provider in Wu et al. (2015) can effectively affect the quality and quantity of the product delivered to the market. In Cai et al. (2013), the factor that affects quantity loss and quality loss is the exogenous transportation time, whereas in our study the cold-chain service level is endogenous. In addition, Cai et al. (2010, 2013) both involve one channel leadership scenario where the producer has leadership and the 3pl provider has leadership, respectively, while we consider two channel leadership scenarios and examine the impact of channel leadership.

There have been a large number of research papers about logistics outsourcing in the context of a supply chain. Rajesh, Pugazhendhi, Ganesh, Muralidharan, and Sathiamoorthy (2011) point out that, with the rapid development of logistics industry, a 3pl provider offers not only direct transportation (e.g., Balakrishnan & Natarajan, 2014; De Matta, Hsu, & Li, 2015; Giri & Sarker, 2017; Gürler, Alp, & Büyükkaramikli, 2014; Jiang, Wang, & Yan, 2014; Santibanez-Gonzalez & Diabat, 2015; Ülkü & Bookbinder, 2012), but also the whole cycle of logistics activities such as inventory management, financial service, cold-chain service and other value-added services. For example, Yao, Yue, Mukhopadhyay, and Wang (2009) study three different inventory strategies and one of them is that the e-tail operation is outsourced to a 3pl provider. Zhang, Nault, and Tu (2015) explore the pricing decision of a 3pl provider that provides ware-housing and transportation services. Chen and Cai (2011) consider a supply chain with a 3PL firm providing financial service. Li, Li, Cai, and Shan (2016) assume that a third party, such as a 3pl provider, provides demand-enhancing service, and then examine which service