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Fresh-product supply chain management with logistics outsourcing

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ABSTRACT

We consider a supply chain in which a producer supplies a fresh product, through a third-party logistics (3PL) provider, to a distant market where a distributor purchases and sells it to end customers. The product is perishable, both the quantity and quality of which may deteriorate during the process of transportation. The market demand is random, sensitive to the selling price as well as the freshness of the product. We derive the optimal decisions for the three supply chain members, including the 3PL provider's transportation fee, the producer's shipping quantity and wholesale price, and the distributor's purchasing quantity and retail price. We find that the presence of the 3PL provider in the supply chain has a significant impact on its performance. We propose an incentive scheme to coordinate the supply chain. The scheme consists of two contracts, including a wholesale-market clearance (WMC) contract between the producer and the distributor, and a wholesale-price-discount sharing (WDS) contract between the producer and the 3PL provider. We show that the proposed contracts can eliminate the two sources of "double marginalization" that exist in the three-tier supply chain, and induce the three parties to act in a coordinated way.

1. Introduction

We consider a supply chain in which a fresh-product producer supplies the product to a distant market, via a specialized third-party logistics (3PL) provider, where a distributor purchases and sells it to end customers. Because of the vast distance between the production base and the target market, the transport time is long and usually quite unstable. As a result, the fresh product is prone to decay/deterioration during the process of transportation. Moreover, end customers are sensitive to both the retail price and level of freshness of the product, and thus the market demand is random, highly depending on these two factors. With uncertainties in transport time, level of freshness, and market demand, the decisions of the three parties involved in such a supply chain are complicated, which may cause great losses if not made appropriately. The main purpose of this paper is to develop a model to address these issues, to characterize the optimal decisions that each party should adopt, and to examine the appropriate incentive schemes to motivate the chain members to coordinate so that everyone benefits from the improved performance of the system.

Different structures exist in fresh product supply chains, depending on how parties such as producers, collectors, brokers, wholesales, and retailers, etc., are involved. Cadilhon et al. [9, p. 137] summarize five typical structures. The model we consider in this paper corresponds to one of the two modern distribution systems (Structure 5 of Cadilhon et al. [9]), which represents a direct distribution channel from the producer to the retailer. One example that supports our model is the Floratrading business developed in Ecuador's cut flower industry [7], which has been set up to capture the market opportunities in rural regions of America. The development gives rise to a fully integrated supply chain for roses, involving a grower-owned brokerage firm, Floratrading, located in the production base (which we call the "Producer" in our model), UPS for the logistics and transportation (the "3PL Provider" in our model), and a rural florist (which we call the "Distributor") to sell the product to end customers in the American market. Fig. 1 of [7] shows the new distribution channel consisting of Floratrading, UPS, and rural florist, in comparison with other more traditional channels. Another example that has motivated our work is Kunming Hongri Flower Plant Co., Ltd. (*kunming-hongri.en.ywsp.com*), a specialized export company of fresh cut flowers that locates in Kunming, one of the biggest flower plant bases in the world. The firm exports carnations, roses, lilies, etc., to other countries (including Japan and South Korea), through specialized 3PL providers. The market demand of

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the fresh-cut flower depends heavily on its freshness upon arriving at the destination markets. Therefore, how to maintain the quality of the flower is a key concern in their operations. Although motivated by the practices of fresh-flower supply chains, the model we study is also applicable to other problems that involve production, transportation, and distribution of fresh produces, including fruit, vegetables, live seafood, etc.

Long distance transportation is inevitable in most fresh-product supply chains due to the geographic separation of the production base and the target market. Because of the requirements on long-haul delivery and freshness keeping, transportation logistics is often outsourced to specialized logistics providers with the needed capacity and facility. In this paper, we are interested to understand how the involvement of the 3PL provider would impact the supply chain, in particular the corresponding decisions to be taken by parties concerned. On the one hand, the capability of long-distance shipping with the necessary cooling facility enables the 3PL provider to gain an advantage over other means of transportation. On the other hand, however, the 3PL provider still needs to consider the reactions of the producer while negotiating on the transportation fee and other clauses with the producer. As it is well known, carriers charge three types of rates: published, counter, and negotiated [16]. However, as stressed by Sanfilippo [37], no business firms should accept published shipping rates, and it is common that 3PL providers such as UPS, FedEx, and DHL offer shipment-specific pricing contracts to industrial shippers.

Variation of transport time can be very large for long-distance transportation. For instance, according to Vega [47], "*a shipment of fresh flowers, from the time of harvest on a farm located near Quito until the moment it arrives to a U.S. retailer*, *can take from 44 $\frac{1}{2}$ hours to almost 13 days.*" A large time delay can cause significant loss in value of fresh products (it is reported that most bouquets last up to 7–10 days if kept cool; see, e.g., www.gardenguides.com). Considering the uncertainties in transport time, how should the 3PL provider determine the transportation fee? How will the pricing of the 3PL provider affect the decisions of the producer and other players in the supply chain? Both [36,47] have pointed out, by statistic analysis, that transport costs are a significant component of the final prices for fresh products. Thus, how should the producer take into account the transport cost and time, to make the most appropriately decisions ? How would these affect the decisions of the downstream distributor? Could the three parties be motivated to take the coordinated decisions, so that the performance of the entire supply chain is optimized and consequently everyone benefits? Answers to these and other related questions are important for understanding the supply chain and the corresponding strategies and decisions its members should take, which we will investigate in this paper.

The remainder of the paper is organized as follows. In Section 2 we provide a brief review of the related literature. The problem formulation, assumptions, and notation are presented in Section 3. In Section 4, we characterize the optimal decisions of the three parties in the decentralized system. Optimal decisions in the fully centralized system and partially centralized systems are investigated in Section 5. Section 6 develops an incentive scheme to coordinate the decentralized system. Section 7 summarizes our work, where topics for future study are also discussed.

2. Related literature

One stream of the literature related to our research is on logistics outsourcing. This is a business strategy that has been widely adopted in practice and studied in the literature over the past two decades. For example, [40] develops a theoretical framework, including both transaction cost theory and network theory, to explain the role and motivation of third-party outsourcing arrangements. Tyan et al. [45] examine a special class of freight consolidation policies of a 3PL provider that seeks to maximize the utilization of expensive transportation such as aircraft. Vaidyanathan [46] explores the major considerations in searching for a 3PL provider and develops an evaluation framework. Fong [19] presents three new models for logistics network design with special focus on the perspective of 3PL companies. More discussion on outsourcing of logistical activities can be found in review papers by Lieb [27], McKinnon [28], Razzaque and Sheng [35], and Sheffi [39]. As can be seen, most of the literature considers issues on certain aspects of logistics outsourcing, whereas interactions between decisions of 3PL providers and their clients are not addressed [4]. Song et al. [41] is one of the few papers that study the decision problems faced by 3PL providers in a supply chain system. They focus on the scheduling problem of a 3PL provider, who needs to coordinate shipments between suppliers and customers through a consolidation center in a distribution network. Our model studies the 3PL provider's pricing decision and its impact on the decisions of other firms in the supply chain with a time-sensitive fresh product.

Research on supply chain management of perishable products is another stream of literature related to our research. Whitin [53] studied a perishable inventory problem in which fashion goods deteriorated at the end of certain storage periods. Since then, considerable attention has been paid to this line of research. Nahmias [29] provides a comprehensive survey of the literature published before the 1980s, in which perishable products with fixed lifetime and random lifetime were categorized. More recent studies on deteriorating inventory models can be found in Raafat [33], Goyal and Giri [20], Ferguson and Koenigsberg [18], Ketzenberg and Ferguson [22], and Blackburn and Scudder [6]. Kopanos et al. [23] consider the problem of simultaneous production and logistics planning in food industries. An integrated mixed integer programming model is developed, which incorporates various practical factors and constraints. Post-production perishability of food products is, however, not specifically considered in their model. Wang and Li [51] investigate different pricing policies based on dynamically identified food quality, in order to reduce food spoilage waste and maximize food retailer's profit.

Generally, two types of perishable loss, quantity loss and quality loss, may take place for a perishable product. The majority of the literature has dealt mainly with only one type of loss. One exception is Rajan et al. [34], who consider both value drop and quantity decrease. However, they focus on a model with deterministic demand, in which the decision maker aims to optimize the selling price and the order cycle length of inventory replenishment to maximize the average profit per unit time. Our model considers a fresh product subject to both types of loss during transportation: the quantity decrease affects the effective supply when the product reaches the market, and the quality deterioration affects the market demand. Both impacts are captured in our model using general functions of the actual transportation time. The fact that the market demand depends on the level of freshness of the product and that the freshness depends on the transport time makes the decision making of the producer a two-stage problem, because the wholesale pricing decision relies on the actual level of freshness after transportation. This is in sharp contrast with the literature on decentralized supply chain management, in which the upstream supplier only makes a one-stage decision (see, e.g., [2,5]).

Coordination of the three parties involved in a fresh-product supply chain – the producer, the 3PL provider, and the distributor – is a main subject addressed in this paper. Coordination of two parties, usually a supplier and a distributor (or a retailer), has been a subject of extensive study in the supply chain management field