



# Optimization and coordination of supply chain with revenue sharing contracts and service requirement under supply and demand uncertainty



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## ABSTRACT

In a one-supplier-one-buyer supply chain, uncertainty occurs not only at the demand side, but also at the supply side, which is commonly observed in business. Optimization and coordination of such a supply chain is rarely investigated in literature, especially with service requirement. In this paper we model the supply chain with revenue sharing contract and service requirement under supply and demand uncertainty. Firstly, we derive the buyer's and the supplier's optimal policies, and find the conditions to coordinate the supply chain. Secondly, we prove that the buyer's and the supplier's optimal quantities are both non-decreasing of the service requirement. We also find there exists an optimal supply quantity for the supplier, if the buyer's ordering quantity based on her service requirement exceeds the supplier's optimal supply quantity, then the supplier's profit is a non-increasing function of the buyer's order quantity; otherwise, the supplier's profit is a non-decreasing function of the buyer's order quantity. Thirdly, by comparing with the benchmark supply chain model where only demand uncertainty is considered, we find that in the coordinated supply chain under supply and demand uncertainty, the revenue sharing ratio for the supplier will be higher if the wholesale price remains the same, or the wholesale price will be higher if the revenue sharing ratio for the supplier keeps the same.

## 1. Introduction

As the innovation of technology and the uncertainty of consumers' preferences, various products have the characteristics of perishability with short life cycle and random demand (Linh and Hong, 2009). This uncertainty of consumers' preferences increases the difficulty to forecast the demand quantity, and thus increase the buyer's sales risk. In order to hedge the risk, the buyer tends to reduce her inventory, which aggravates the mismatch of the supply and demand. Existing researches have proved that revenue sharing contracts are beneficial to weaken the buyer's risk aversion, match the supply with the demand better, and achieve the coordination for various types of supply chains (Cachon, 2003; Cachon and Lariviere, 2005). Under revenue sharing contracts, the supplier attracts the buyer to keep a higher inventory by offering a lower wholesale price in order to minimize lost sales. Revenue sharing contracts are widely used in various industries (Mortimer, 2008).

Not only the demand can be uncertain, sometimes the supply is also uncertain. Supply uncertainty is becoming a major concern in the supply chain management. The industrial survey conducted by Protiviti and APICS (American Production and Inventory Control Society) showed that 66% of respondents considered supply interruption as

one of the most significant concerns among all the supply chain related risks (Shou et al., 2009). Supply uncertainty, such as yield uncertainty, exists in many industries, including semiconductors, electronic fabrication and assembly, food processing, bio-pharmaceuticals, and resource based industries such as mining and agriculture (Xu and Lu, 2013). For example, in agriculture, fruit supply fluctuates because of weather conditions, diseases and so on (Kazaz and Webster, 2011). Clearly, the supply uncertainty will also affect the supplier's and the buyer's decisions and the whole supply chain coordination.

In addition, a high fulfillment rate or service level is a key aspect to keep customers satisfied. For example, in the apparel industry, Dayton Hudson committed to a planned 100% service level to its customers (Iyer and Bergen, 1997). Pharmed Group (PMG), the largest independent, full line distributor of medical, surgical, and rehabilitative supplies, guaranteed a minimum 98% delivery to customer orders (PMG, 2006). Costless Express, a business products catalogue retailer in Canada, committed 100% to order fill rate and next-business-day delivery to customers (Sethi et al., 2007). High customer satisfaction can help the firm retain existing customers and attract potential customers, which gives a business organization a competitive edge (Sethi et al., 2007). The service requirement, a constraint on the probability of meeting demand, is becoming a popular tool in industry

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(Iyer and Bergen, 1997), and also a challenge faced by industry (Lee, 1996; Shang and Song, 2004). Service requirements not only restrict the downstream enterprise's procurement decision, but also affect the upstream enterprise's supply decision through the transferring of order. Therefore, it is necessary to investigate the impact of service requirement on the supply chain under revenue sharing contract and supply and demand uncertainty.

The supply and demand uncertainty and the service requirement will increase the complexity of decision making and coordination of the supply chain, which is rarely studied in literature. The major contributions of this work can be summarized as follows:

- (1) We model the revenue sharing contract with service requirement under supply and demand uncertainty, and derive the buyer's optimal ordering policy and the supplier's optimal supply policy, which is rarely investigated in literature.
- (2) We find due to the supply uncertainty, service requirement has an inconsistent impact on the buyer's and the supplier's expected profit. The buyer's expected profit is non-increasing with her service requirement, while the impact of buyer's service requirement on the supplier's expected profit is subject to his optimal supply quantity: There exists an optimal supply quantity for the supplier, if the buyer's ordering quantity based on her service requirement exceeds the supplier's optimal supply quantity, then the supplier's profit is a non-increasing function of the buyer's order quantity; otherwise, the supplier's profit is a non-decreasing function of the buyer's order quantity.
- (3) By comparing with the supply chain without supply uncertainty, we find that in the coordinated supply chain under supply and demand uncertainty, the revenue sharing ratio for the supplier will be higher if the wholesale price remains the same, or the wholesale price will be higher if the revenue sharing ratio for the supplier keeps the same.

The remainder of this paper is organized as follows. Section 2 summarizes the related literature. Section 3 describes the model and various notations used throughout the paper. In Section 4, the benchmark model without supply uncertainty is described. Section 5 studies the model with supply and demand uncertainty. We discuss the effects of service requirement and supply uncertainty on the supply chain in Section 6, respectively. In Section 7, we provide a mechanism for the revenue sharing contract parameters design. Section 8 concludes the paper with future extension directions.

## 2. Literature review

This paper attempts to understand the optimization and coordination of supply chain with revenue sharing contracts and service requirement under double uncertainties of supply and demand. Thus, the literature review includes three main research streams: revenue sharing contract, supply chain considering supply and demand uncertainty and service requirement respectively.

We first review the literature on revenue sharing contracts. Revenue sharing contracts have been widely studied and implemented in real supply chain practice. Cachon (2003) provided a good survey on this topic. Wang et al. (2004) examined a consignment contract with revenue sharing under the iso-price-elastic demand model. They showed that, under such a contract, both the overall channel performance and the performance of individual firms depended critically on demand price elasticity and on the retailer's share of channel cost. Giannoccaro and Pontrandolfo (2004) studied both two-echelon and three-echelon supply chains under revenue sharing contracts, and emphasized the decision and coordination condition deviations caused by supply chain structure changes. Cachon and Lariviere (2005) intensively discussed a revenue sharing contract between a single manufacturer and a single retailer in a single period newsvendor

problem, and compared the proposed contract with other types of contracts. Yao et al. (2008) investigated a revenue sharing contract for coordinating a supply chain comprising one manufacturer and two competing retailers. They showed that the provision of revenue sharing in the contract can lead to a better supply chain performance than a price-only contract. Bellantuono et al. (2009) considered two types of contract schemes (a revenue sharing contract and an advance booking discount program) that are intended to coordinate a decentralized supply chain as well as to increase sales. They showed that each scheme would enable the supply chain to increase its expected profit. Pan et al. (2010) discussed different contracts: a wholesale price contract and a revenue sharing contract under both manufacturer-dominated and retailer-dominated scenarios in a supply chain with either two manufacturers and one retailer, or one manufacturer and two retailers. They found that at least one member benefits from using revenue sharing contracts without sacrificing performance of the other members. Govindan and Popiuc (2014) investigated reverse supply chain coordination by revenue sharing contract. They showed that performance and total supply chain profits are improved through coordination with revenue sharing contracts on both two- and three-echelon reverse supply chains. Recently, Zhang et al. (2015) studied a two-echelon supply chain for deteriorating items involving a manufacturer and a retailer with controllable deterioration rate and price-dependent demand. They showed that a revenue sharing and cooperative investment contract which combines revenue sharing and cost sharing can achieve supply chain coordination. Avinadav et al. (2015) investigated the effect of risk sensitivity on a supply chain of mobile applications under a consignment contract with revenue sharing and quality investment. They found that the revenue sharing contract could prevent double marginalization and a risk-seeking developer may obtain a higher expected profit compared with a risk-neutral one. Arani et al. (2016) considered a novel mixed revenue-sharing option contract that intends to coordinate a retailer-manufacturer supply chain. They modeled the contract through a game theoretic approach and provided the optimal conditions for achieving the coordination.

Next, we examine the existing work incorporating supply and demand uncertainty in the model. Mula et al. (2006) provided a good survey on this topic. This research stream can be classified into three categories: (i) inventory policies, (ii) pricing policies and (iii) supply chain management. As to inventory policies, Mohebbi (2004) considered a continuous-review inventory system with compound Poisson demand and uncertain supply process, and devised a level-crossing methodology for obtaining the stationary distribution of the inventory level in a lost-sales continuous-review(S,Q)-type inventory system. Bollapragada et al. (2004) considered a two-echelon serial inventory system with demand and supply uncertainty and a minimum customer service level requirement. They showed that the chance-constrained problem of determining optimal base-stock levels minimizing the total inventory investment subject to a service constraint is a convex programming problem. They also characterized the relation between the optimal base-stock levels of the component and the end-product, and illustrated how an optimal internal (component) service level can be computed. Recently, Yeo and Yuan (2011) investigated the optimal inventory policy with supply uncertainty and random demand cancellation. They showed that because of supply uncertainty, the optimal inventory policy has the structure of re-order point type. That is, it is optimal to make orders if the initial inventory falls below the re-order point, otherwise it is optimal to do nothing. As to pricing policies, Tang and Yin (2007) investigated the supply management of responsive pricing under supply uncertainty. They showed that the retailer would always obtain a higher expected profit under the responsive pricing policy. Xu and Lu (2013) considered a price-setting newsvendor model with supply uncertainty and investigated the effect of yield randomness on optimal decisions and expected profit. As to supply chain management, Kouvelis and Milner (2002) studied the interplay of demand and supply uncertainty in capacity and outsourcing decisions in multi-stage

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