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# Pricing and replenishment policies in a supply chain with competing retailers under different retail behaviors

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ABSTRACT

This paper develops game models for a two-echelon supply chain with one supplier and multiple competing retailers. We study the pricing decision and the replenishment policy for each member under both the decentralized channel and the centralized channel, and examine the impacts of retail behaviors on them. Compared with the centralized operation, the decentralized operation with linear wholesale price obviously inflates the holding cost for each retailer, which results in the inefficiency for the whole channel. For the decentralized system, both retail-competition and retail-cooperation models are considered. The comparative analysis illustrates how the retail pricing and replenishment decisions are affected by the retail behaviors. We find that the retail cooperation is not stable since each self-interested retailer has an incentive to lower his retail price unilaterally. Finally, in order to improve the performance of the channel and each member, a Groves wholesale price contract is designed to achieve the perfect coordination between the supplier and the retailers. Meanwhile, this coordination model can also be used in the case of a supply chain with independent retailers.



## 1. Introduction

In modern industry, many retailers have complex supply systems distributing 20,000–30,000 individual stock keeping units through some distribution centers, ultimately delivering these items to hundreds of mini-markets, supermarkets, and hypermarkets (Morgan & Dewhurst, 2008). Usually, the downstream firms are competing for the consumers. In this paper, we consider the two-echelon supply chain system in which the retailers are competing for the market demand. The retailers replenish their inventories from the supplier, and the supplier replenishes his inventory from an outside source. The earlier studies usually assume that there is only one manager in the system who makes all pricing and replenishment polices so as to maximize the channel profit (e.g., Boyaci & Gallego, 2002; Federgruen & Zheng, 1995). Usually, the replenishment policy refers to the method that the replenishment lot size in a period is determined by weighing between inventory holding costs versus transportation and set-up costs. Choosing an efficient replenishment policy that fitting realistic circumstances of the supply chain can effectively reduce the organizational cost (Silver, Pyke, & Peterson, 1998; Yang, Wee, Chung, & Huang, 2013).

In the actual operation, a supply chain is a complex network consisting of multiple interrelated members with different objectives that often conflict with each other, and the member on the supply side usually acts as a Stackelberg leader in the decentralized decision. That is, the supplier firstly chooses a unit wholesale price and decides his own replenishment policy. Secondly, the retailers respond simultaneously to the unit wholesale price by choosing their replenishment policies and making their pricing or order decisions. The Stackelberg model is a sequential game. The firm, the Stackelberg leader, is perhaps better known or has greater brand, and moves first, while the other firm, the Stackelberg follower, observes this and moves sequentially. Obviously, the performance of the decentralized channel is not as perfect as that of the centralized one due to the double marginalization effect. Our first objective is to investigate how retail behavior affects the channel efficiency, and how the general channel operations (i.e., centralized and decentralized operations) influence the retail pricing decisions and replenishment policies.

We study two kinds of retailers' game models, i.e., retail-competition model and retail-cooperation model. Game theory is extensively used to the analysis of multiple players' decisions, where the players have to seek their optimal solutions. These approaches may be different in their theoretical content and the methodology used in the analysis; however, they are really just two different ways of looking at the same problem. We investigate

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the differences of the retailers' pricing decision between these two games and study equilibria of these two games as well as their stability. The different game behaviors may result in the whole different pricing or order decisions for channel members. The cooperation among the players can increase the total performance of all the players. However, it again raises the question of whether this cooperation is real among the players. Therefore, our second objective is to study how the different retail behaviors including retail competition and cooperation affect the pricing decision and investigate the equilibrium stability of game behaviors.

The third objective of the paper is to investigate how to coordinate a supply chain with competing retailers. A supply chain is coordinated when the players make the decisions that are optimal for the whole supply chain. In order to coordinate the supply chain, a Groves wholesale price contract is designed in our paper. From the perspective of structure, the contract involves revenue-sharing factors. The revenue-sharing scheme has received enormous attention in recent years. Moreover, the revenue sharing has become more prevalent than the wholesale price contract in the videocassette rental industry (Cachon & Lariviere, 2005). For example, Blockbuster, a chain of video rental stores, signed revenue-sharing contracts with several major studios, in which Blockbuster Video agreed to accept all titles under revenue-sharing terms, and it was reported that 90% of its revenue was derived from such contracts (Narayanan & Brem, 2002). In addition, according to the 2007s AffStat survey, about 80% of e-commerce websites used revenue-sharing to coordinate their affiliates. The website, such as YouTube, usually uses revenue-sharing with companies that advertise on its website. We investigate how to coordinate the supply chain by the Groves wholesale price involving revenue-sharing factors when considering both replenishment policies and the retail competition.

To be specific, this paper develops game models for the supply chain consisting of one supplier and competing retailers to study the optimal pricing decision and replenishment policy for each member. We focus on investigating the impacts of the different retail behaviors on the retail prices and replenishment policies. As a benchmark, we first study the centralized system, and find that each retailer makes more explicit plan on his own order policy and replenishment decision according to the actual supplier's order interval. We examine how retail competition affects the decision on pricing or order quantity in the decentralized system. Meanwhile, we also develop a comparative model that all retailers collude to price for maximizing their total profit, which is called as retail cooperation model in our paper. Through comparing these two models, we find that the retail competition can lead to the higher order quantities, while the retail cooperation without any incentive mechanism ultimately results in the low operating efficiency for each member as in the independent retail decision. Finally, in order to avoid the double marginalization effect and improve the channel performance, a special Groves wholesale price contract is designed to achieve the channel coordination.

## 2. Literature review

This paper is closely related to the replenishment policy, supply chain management with multiple retailers, supply chain game behaviors, and supply chain coordination.

### 2.1. The replenishment policy

Owing to the complexity and competition in the today's market, the demand of products has a high fluctuation, which brings a more severe problem at each stage of supply chain operation. That is, suppliers, manufacturers, warehouses, and retailers should decide the proper inventory levels to ensure some level of continuity of service with minimum amount of holding cost. The replenishment policy, also known as lot sizing in the most literature, is employed in a complex supply chain. The proper replenishment policy usually includes the decision of the replenishment quantity as well as the decision of the lead-time or replenishment interval. Usually, the change of replenishment lead-time could affect the manufacturer's logistics, inventory holding cost, service level, and shortage cost.

There exists the extensive survey of the literature about replenishment policy. For example, with assuming that the variance of the replenishment quantity at the retailer is larger than that of retail sales, Lee, So, and Tang (2000) show that the degree of variance amplification increases with the replenishment lead-time. Aviv (2003) proposes a heuristic replenishment policy of a convenient structure with assuming that a vector autoregressive time series has been described as a linear state space. Agrawal, Sengupta, and Shanker (2009) study the impact of information sharing and replenishment interval on bullwhip effect and on-hand inventory. For the inventory management of perishable products, Broekmeulen and van Donselaar (2009) develop a replenishment policy taking into account the age of inventories. Louly and Dolgui (2013) propose a replenishment model and the corresponding algorithms to minimize the sum of setup and holding costs under a service level constraint. Based on the existing studies on replenishment policy, we further consider the replenishment lead-time for the supply chain in the context of retail competition, and investigate how the replenishment policy affects the system's incentive mechanism.

### 2.2. Supply chain management with multiple retailers

For the supply chain with independent retailers, Boyaci and Gallego (2002) study the problem of coordinating pricing and replenishment policies in a supply chain consisting of a wholesaler, one or more geographically dispersed retailers. For the cases of competing retailers, Bernstein and Federgruen (2003) provide a nonlinear wholesale price contract to coordinate the channel. However, the supplier may gain a negative profit by using this contract, and it will result in the breakage of the supply chain. Furthermore, Ben-Daya, Hassini, Hariga, and AlDurgama (2013) model a consignment and vendor-managed inventory policy for the supply chain with a single vendor and multiple buyers, and find that it is more attractive to buyers when they have significant order costs and the vendor's unit ordering cost is not large. Similar studies can also be found in Chen and Zhuang (2011), Chiu, Choi, Hao, and Li (2015), Mateen, Chatterjee, and Mitra (2015) and Hafezalkotob (2015). Unlike the extant literature, we investigate how the different retail behaviors affect the decisions of replenishment and pricing decisions as well as the performance of each channel member. Through comparing two different retail behaviors, we find that the retail cooperation without binding agreements is not optimal for the independent profit-maximizing retailers even if the retail cooperation would benefit all the retailers.

This paper is closely related to Chen, Federgruen, and Zheng (2001a, 2001b) and Bernstein and Federgruen (2003). Chen et al. (2001a, 2001b) consider both the centralized and decentralized versions of our supply-chain model in the absence of the retail competition, while Bernstein and Federgruen (2003) extend to the case with competing retailers. However, they neither consider how retail behaviors including retail cooperation and retail competition affect the system's performance, nor investigate the stability problem of solutions. We show that the decentralized operation will inflate the holding costs at the retailer level. We design an incentive mechanism, i.e., the Groves wholesale price contract, to improve the performance of channel as well as each channel member when considering the different retail behaviors and replenishment decisions.