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# Equilibrium analysis of pricing competition and cooperation in supply chain with one common manufacturer and duopoly retailers

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ABSTRACT

This paper considers a pricing competition and cooperation problem in a two-echelon supply chain with one common manufacturer and duopoly retailers. Six decentralized game models are built to examine how pricing strategies (Bertrand and collusion) and power structures (manufacturer-dominant, retailers-dominant and non-dominant) affect supply chain members' performance. Specifically, without loss of generality, we rewrite our models as systems including only two parameters (retail substitutability and asymmetric parameter which represents the non-price difference between the two retailers) by standardizing prices and quantities. It is found that, regardless of the power structures, the two retailers' collusion behaviors will increase the sales prices and reduce the quantities of the product. The results demonstrate that whether the duopoly retailers benefit from their collusion behaviors depends on the power structures and the two parameters. We also state the conditions under which the manufacturer is better off giving up its power and making decision simultaneously with the two retailers even if it can move first. Some other managerial highlights are also presented in this paper.



## 1. Introduction

In this paper, we consider a pricing problem in supply chain with one common manufacturer (supplier or upstream member) who supplies an identical product to two retailers (distributors or downstream members). This type of supply chain with one upstream member and multiple downstream members is not uncommon in the real industrial world, e.g., smartphone producer usually distributes its products through both traditional and online channels. For convenience, we use “manufacturer” to represent the upstream firm and “retailer” to represent the downstream channel participant in the following discussion.

We assume that the manufacturer determines the wholesale prices and the two retailers choose their own sales prices and ordering quantities. Moreover, channel members' decision sequences are decided by the power structures of the supply chain. In some practical supply chains, the manufacturer often plays a more powerful role than the retailers (e.g., GM and Toyota are often much larger than their retailers). While in some other chains, the retailers, like Warmart and TESCO, are usually much bigger than most of the manufacturers and often hold the dominant power. There are also some chains in which, however, no absolute dominance exists and the members hold the same power. What impacts the power structures might have on the performance of the channel members and the whole supply chain? In addition, considering the fact that the two retailers compete directly in the same market, in what conditions will they choose to cooperate when making pricing decisions? What effects might the two retailers' various strategies (e.g., Bertrand or collusion) make on the wholesale prices and profit of the common manufacturer?

The main objective of this paper is to analyze the effects of various strategies (e.g., Bertrand or collusion) adopted by the duopoly retailers and different power structures on the optimal equilibria of the two-echelon supply chain. Our work mainly extends the work of Yang and Zhou (2006) and Wu et al. (2012). Firstly, Yang and Zhou (2006) considered a pricing problem in a two-echelon supply chain with a manufacturer who supplies a single product to two competing retailers. They assumed that the manufacturer acts as a Stackelberg leader, then they explored the effects of the retailers' various behaviors (Bertrand and collusion) on channel performance. However, they only considered the manufacturer dominant structure. After that, Wu et al. (2012) investigated the pricing decisions in a non-cooperative supply chain that consists of two retailers and one common supplier. They built six non-cooperative models where the two retailers play Stackelberg or Bertrand games under three possible power structures. The collusion behaviors of the channel members were not considered in their paper.

This paper extends the extant work by additionally considering

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**Table 1**
The models under different scenarios.

| Power structure | Strategy | |
|---|---|---|
| | Competition | Cooperation |
| Non-dominant | NN | NC |
| Manufacturer dominant | MSN | MSC |
| Retailers dominant | RSN | RSC |

the retailer-dominant and non-dominant power structures and collusion behaviors, respectively. Specially, we assume that the two retailers are totally separate and independent, and there is no dominant power between the two retailers. Namely, they are equal in the move advantage and take on simultaneous competition or collusion. We build six decentralized models shown in Table 1 to derive the equilibria under various scenarios.

A centralized model is also built to make comparisons of supply chains' performances under different power structures and channel members' different pricing strategies. Moreover, we assume that the consumers choose the purchase channels for items depending on the prices and their own preferences of the alternative retailers. We also explore how the non-price difference between the two retailers influences the equilibria prices and profits. The consumer preferences between the two retailers are usually based on some non-price factors, like location, service, brand and environment. Therefore, as most literature did, the differentiation of the consumers' preferences is represented by corresponding different market bases in linear demand functions. Specifically, without loss of generality, we rewrite our models as systems with only two parameters, retail substitutability parameter and non-price asymmetric parameter, which represents the non-price advantages or differences between the two retailers, by standardizing prices and quantities. The aim of rescaling the models is to enable the analytical comparison of equilibria from various models and to gain more managerial highlights without loss of generality.

We then analyze the behaviors from the equilibria derived from the above models. First, we show that the two retailers' collusion behaviors will increase the sales prices and reduce the quantities of the products regardless the power structures. Moreover, we state the conditions under which the dominant manufacturer is better off making decision simultaneously with the two retailers even if it can move first. Besides, the conditions under which the two retailers are better off choosing to cooperate in the pricing decisions are also presented. Some other managerial highlights are also presented in this paper.

The reminder of this paper is organized as follows: Some related researches on pricing competition in decentralized supply chain are presented in Section 2. Then we scale the demand functions and rewrite the profit functions of the channel members in Section 3. In Section 4, six decentralized game models are employed to formulate the pricing games under three possible power structures. After that, we analyze the effects of the different power structures, pricing strategies and some parameters on the performances of the supply chain members in Section 5. Finally, some conclusions and extensions of this paper are discussed in Section 6.

## 2. Literature review

Researches on vertical and horizontal pricing competition between two or more members in supply chains can be traced back to Jeuland and Shugan (1983). Since then, increasing literature has focused on this problem. The tendency of these researches is to apply game theory to deal with pricing competition under different power structures or different decision sequences. We detail

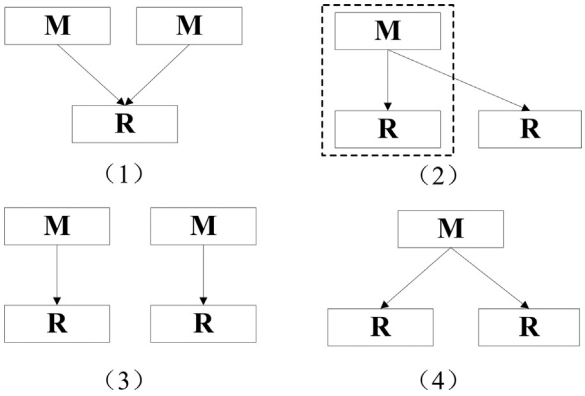


**Fig. 1.** The four channel structures.

the literature through four well-studied channel structures, shown in Fig. 1.

The first well-researched structure was initiated by Choi (1991), which studied the pricing competition problem in a two-echelon supply chain with two manufacturers and one common retailer. Recently, Sinha and Sarmah (2010) analyzed the coordination and pricing competition in this type of supply chain in different contexts. Zhao et al. (2012) explored the pricing competition problem under this structure in fuzzy environment. These researches with one common retailer usually focused on the effects of the power structures on the prices and profits. For instance, Zhao et al. (2014) and Wei and Zhao (2014) built several models to analyze the effects of the two manufacturers' various competitive strategies and different power structures on the optimal pricing decisions. Huang and Ke (2014) illustrated that consumers can enjoy lower prices when facing a powerful retailer, and the super retailer can make the supply chain more efficient.

Recently, more and more literature focuses on the pricing problem in supply chains with Structure 2. In this type of supply chain, a manufacturer sells its products through a hybrid channel structure: the direct channel (e-channel) where the manufacturer sells its own products to consumers directly and the indirect channel (off-line shop) where the intermediaries are employed. Webb (2002) found that the dual channels, especially the online channel, can potentially reduce costs and result in an increasing margin. Park and Keh (2003) compared the equilibrium under the hybrid channel with the equilibria under the single channels. Chiang et al. (2003) showed that when an online channel opens, both manufacturer and retailer can reap benefits even if no sales occur in the online channel. Dumrongsiri et al. (2008) studied the pricing equilibria of a dual-channel supply chain in which a manufacturer sells to a retailer as well as to consumers directly. They developed the conditions under which the manufacturer and the retailer share the market in equilibrium. Huang and Swaminathan (2009) concentrated on the optimal pricing strategies when a product is sold on two channels such as the Internet and a traditional channel and explored the behaviors (prices and profits) under different parameters and consumer preferences for the alternative channels. Additionally, Li et al. (2015) extended the hybrid channel structure by studying the manufacturers' introduction of direct channel in competitive supply chains. Recently, Ding et al. (2016) discussed various hierarchical pricing decision processes and operational strategies for the manufacturer when operating a dual-channel supply chain. Wang et al. (2016) studied a channel selection problem in dual-channel supply chain and explored the influence of operating costs in the e-channel on the manufacturer's structure strategies. Ma et al. (2016) derived the optimal online discount strategies for the manufacturer with consumer loss aversion in this channel structure.