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Game theoretic analysis of one manufacturer two retailer supply chain with customer market search

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ABSTRACT

It is common that when a stock out occurs at a retailer the customer may go to another retailer. This phenomenon is often referred to as the customer market search. This paper analyzes the one manufacturer two retailer supply chain while considering the customer market search behavior. Game theoretic models are built to investigate the implications of this phenomenon in scenarios where wholesale price is exogenous or endogenous. Conditions for the uniqueness of game equilibria are derived in each case. It shows that customer market search behavior leads to higher total order quantity of retailers and higher supply chain efficiency if the wholesale price is exogenous. In contrast, in the endogenous wholesale price scenario, customer market search behavior may decrease the total order quantity of retailers and result in lower supply chain efficiency because the manufacturer can gain much more profit by setting a higher wholesale price. We also study the impacts of the lost sales (brand loyalty) penalties which are incurred when customers' demand exceeds the retailers' (manufacturer's) inventory. It shows that the lost sales (brand loyalty) penalties have similar effects on the supply chain performance when the retailers compete. Numerical analysis illustrates the supply chain members' decisions and the supply chain performances of our models.

1. Introduction

Most customers are unwilling to wait. Corsten and Gruen (2003) hold a large-scale investigation into 71,000 customers of 20 countries. They find that when the stock out occurs at a retailer, 31% customers buy the product from another retailer, 26% customers buy another brand product, 19% customers buy a different size or type product with the same brand, 15% customers choose to delay their purchases and 9% customers give up their purchases. The phenomenon that when the stock out occurs at a retailer the customers go to another retailer is usually called the customer market search (Anupindi and Bassok, 1999; Dai et al., 2005). That is, the customers search the market for the products they wanted if their demand is unsatisfied.

Customer market search behavior aggravates competitions between the retailers. Each retailer does not wish to lose the local demand but do wish to fill the unsatisfied demand of the customers switched from other retailers. A solution that can be easily thought of to this problem for each retailer is to increase the inventory. If a retailer increases its inventory, then its stock out probability can be reduced. Moreover, a higher inventory position means the retailer can fill more demand from other retailers. This method is effective when we only consider the retailers' decisions. But if taking the upstream manufacturer's decisions into the model, the situations will be much more complicated and the conclusions may be doubtful, because the retailers' optimal decisions (on order quantity or inventory) are influenced by the wholesale price. If the wholesale price is endogenous, then the manufacturer may increase or decrease the wholesale price to affect the retailers' decisions with the purpose of maximizing its own profit. In this case, the retailers do not certainly tend to increase their inventories. As a result, the supply chain efficiency (can be defined as the ratio of total profits of the decentralized supply chain to profits of the centralized supply chain) may not be certainly increasing.

Previous studies on customer market search (Anupindi and Bassok, 1999; Dai et al., 2005) mainly focus on the competitions between downstream retailers. i.e., they assume the wholesale price is exogenous. In this paper, we consider both the downstream competition (between retailers) and the upstream–downstream competition (between manufacturer and retailer). We analyze a one manufacturer two retailer supply chain while considering the customer market search behavior. When a stock out occurs at one retailer, the customers go to the other retailer

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with a specific probability. Meanwhile, this retailer incurs a lost sales cost. If the customers switched to the other retailer still cannot be satisfied (stock out also occurs at the other retailer), then the manufacturer also incurs a brand loyalty loss cost.

We use game theoretic models (Cournot game model and Stackelberg game model) to analyze the supply chain in cases where the wholesale price is exogenous or endogenous. The conditions for the existence and uniqueness of game equilibria are derived. The major contributions of our research can be listed as the following:

- Customer market search behavior leads to higher total order quantity of retailers if wholesale price is exogenous. However, if wholesale price is endogenous, customer market search behavior may decrease the total order quantity of retailers. That is, if manufacturer's power is not strong, the retailers are likely to overstock in the supply chain when customers market search.
- If the wholesale price is exogenous, customer market search behavior compensates the double marginalization effect of the supply chain and increases the supply chain efficiency. But, if the wholesale price is endogenous, a higher customer market search probability may only benefit the manufacturer and result in lower supply chain efficiency.
- The lost sales penalty has similar effects to the customer market search behavior. The total order quantity of retailers is increasing in the lost sales penalty when the wholesale price is exogenous but is decreasing when wholesale price is endogenous and it is the same on the supply chain efficiency.

The rest of this paper is organized as follows. Section 2 reviews the literature. Section 3 describes the notations and the models of this paper. Section 4 studies the exogenous wholesale price case. Section 5 analyzes the endogenous wholesale price case. In Section 6, we provide a numerical analysis. We conclude in Section 7.

2. Literature review

As far as we know, papers that explicitly consider customer market search behavior in their models are Anupindi and Bassok (1999) and Dai et al. (2005). Anupindi and Bassok (1999) compare two systems: a system in which the retailer hold stocks separately and the other system in which the retailers cooperate to centralize sticks at a single location. They find that centralization of stocks may not always benefit the manufacturer and may even hurt the channel performance. Dai et al. (2005) extend the model to assume the manufacturer having infinite or finite capacities. They show that if total order quantity of the retailer does not exceed the manufacturer's capacities (infinite capacity case) then Nash Equilibrium is existent and unique between the retailers. Otherwise, Nash Equilibrium may not exist. For the latter case, they use a framework of Stackelberg game to analyze the retailer's optimal strategies. However, all these researches focus on the retailers' inventory problems. They did not take the manufacturer's decisions into their models. So, their conclusions may be established in the exogenous wholesale price case but may be doubtful in the endogenous wholesale price case because manufacturer's wholesale price decision may also affect the retailer's inventory decisions. In this paper, we analyze the implications of customer market search behavior in the cases where wholesale price is either exogenous or endogenous. In addition, we introduce the lost sales cost (at the retailer) and the brand loyalty loss cost (at the manufacturer) into our models and we also study their impacts on the supply chain performances.

Other highly related papers to our models are on the substitutable products. When a type of products is out of stock, the customer may also buy its substitutes. Hsieh and Wu (2009) and Edirisinghe et al. (2011) model two manufacturers selling substitutable products through a common retailer. Parlar (1988) uses the game theory to analyze inventory problems with two substitutable products having random demands. Mahajan and van Ryzin (2001) extend the model to n firms. They find that there is a bias toward overstocking caused by competition. Netessine and Rudi (2003) further show that although in most situations competition leads to overstocking, there are cases in which some of the retailers may under stock the product under competition. Netessine and Zhang (2005) study both positive (complementarity) and negative (substitutability) externalities in the inventory management. They find that under complementarity, retailers tend to under stock the product, thus aggravating the double marginalization effect of the supply chain, while it is opposite of what happens under substitutability. The substitutable products case is similar to the market search case because horizontal competitions are existent in both situations. But there are also significant differences between them. Substitutable products may be sold through a single retailer, while in the customer market search case there are two or more competing retailers. Besides, substitutable products may have different retail prices, while in market search case we usually consider a single type of products.

There are also some other papers that study the one manufacturer two retailer supply chain models (Ghiami and Williams, 2015; Rad et al., 2014). Xiao et al. (2007) investigate the coordination mechanism for a supply chain with one manufacturer and two competing retailers when the demands are disrupted. They study how the supply chain is coordinated, and how it differs from the original planned scheme. Yao et al. (2008) also study a supply chain comprising one manufacturer and two retailers. In their model, the two retailers compete on the retail price. By a numerical analysis, they show that the provision of revenue sharing in the contract can obtain better performance than a price-only contract. Xiao and Qi (2008) study the coordination of one manufacturer two retailer supply chain after the product cost of the manufacturer is disrupted. For the all-unit quantity and incremental quantity discount mechanisms, they derive the conditions under which the supply chain is coordinated and discuss how cost disruption affects the coordination mechanisms. Wang et al. (2011) study the cooperative advertising problems of a monopolistic manufacturer with competing duopolistic retailers. They reveal how cooperative advertising polices and profits of participants are affected by various competitive behaviors and then specify whether the partners have any incentives to transit to a different structure. These papers may be similar to our research in the supply chain structures. However, in our models, with customer market search, the retailers mainly compete in the inventory positions (i.e. the order quantities).

3. Model formulation

Consider a two echelon supply chain consisting of one manufacturer and two retailers. The manufacturer produces a single type of products with unit producing cost c and sells them to the two retailers with wholesale price w. The retailers sell the products to the customers with a common retail price p. Each retailer i ($i=1,2$) faces a random demand d_i (with the probability density function f_i and the cumulative distribution function F_i) from its local customers. For the retailer i, if the local demand exceeds its order quantity q_i, then the unsatisfied demand (d_i-q_i) may go to the other retailer (is referred to as the retailer j ($j=3-i$)) with a probability β_i. In this case, the retailer i incurs a unit lost sales cost b_i. If the unsatisfied demand switched to the retailer j still cannot be satisfied (when retailer j also does not have