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Inventory competition in a multi channel distribution system: The Nash and Stackelberg game

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Abstract This paper investigates inventory management in a multi channel distribution system consisting of a manufacturer, with a single product, and an arbitrary number of retailers that face stochastic demand. Existence of the pure Nash equilibrium is proved and parameter restriction, which implies its uniqueness, is derived. Also, the Stackelberg game, where the manufacturer plays the role of leader is discussed. Under specified parameter restrictions which guarantee profitability, a sufficient condition for the uniqueness of the Stackelberg equilibrium is obtained. In addition, a comparison with a simultaneous move game is made. The results show that when whole prices are equal to production cost, the manufacturer carries more inventory than in the simultaneous move game.

1. Introduction

For any company with a product to sell, making that product available to intended customers can be a crucial strategic issue, as important as developing the product itself. While distribution strategy is a very traditional concern for many companies, it has recently come under intense scrutiny due to a number of major developments. First, the expanding role of the Internet in consumer and business procurement activity has created unprecedented opportunities for easy and vast access to customers. Furthermore, the economics of material delivery has been revolutionized by efficient and pervasive logistical networks deployed by third-party shipping powerhouses, such as Federal Express and United Parcel Services. As a result, many manufacturers are reconsidering whether they should rely on intermediaries, sell directly to end customers or even pursue both approaches in parallel [1].

The multi channel distribution system chooses the third approach for distribution of the products. It consists of a manufacturer and retailers, in which a manufacturer sells his/her products through independent retailers, as well as through his/her wholly-owned channel. Therefore, the manufacturer simultaneously acts as a supplier and competitor to the retailers.

This type of distribution allows firms to extend their market coverage by employing various distribution channels, because firms can target many different customer segments and reach new customer segments more efficiently. Moreover, the use of multi channel distribution enhances the ability to meet the needs of existing customers. Since purchase experiences vary among different channels, customers have different preferences with respect to purchase experiences. Price and non-price factors, such as location, product assortment and customer service, also influence customer channel choices. In addition, a more extensive market presence causes two things: increases customer awareness and establishes higher brand loyalty for existing, as well as future, products.

In a multi channel distribution system, the manufacturer and retailers present a substitutable product. Therefore, when a demand cannot be satisfied by each of them, because of stock out, the customer may go to other channels. So, the profit function of channels is influenced, not only by a personal order decision but also by the decisions of competitors. Thereby, a strategic interaction among the channel inventory decision is created, and game theory is applied to analyze it.

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In this paper, a game theory inventory management model for multi channel distribution, which consists of one manufacturer and an arbitrary number of retailers, is developed over an infinite horizon. Manufacturer and retailers face stochastic demand. They use a base stock policy to control inventory. We focus on equilibrium strategies of manufacturer and retailer channels, while players participate in the Nash and Stackelberg game. Also, a comparison between these equilibria is made.

The rest of the paper is organized as follows: Section 2 presents the literature review on inventory competition in supply chains. The main model is presented in Section 3. Section 4 discusses inventory management in a multi channel distribution in the two frameworks of the Nash and Stackelberg games, and Section 5 summarizes and concludes the paper.

2. Literature review

Inventory competition in a supply chain is originated from demand substitution. Parlar [2] develops a game theory model for single period inventory control of two substitutable products as a two person game. He proves the existence and uniqueness of the Nash solution. Wang and Parlar [3] extend Parlar's model [2] to a three person game and analyze it, both in non-cooperative and cooperative cases. In a non-cooperative scenario, they prove the existence of the Nash equilibrium. In a cooperative scenario, if side payments are not allowed, they prove that Nash strategies always exist in any case of cooperation, and if side payments are allowed, those conditions which imply the non-emptiness of the game core are investigated. Lippman and McCardle [4] extend Parlar's model [2] to an arbitrary number of retailers, whereas aggregate industry demand is allocated among firms by splitting rules. They examine the relationship between the Nash equilibrium inventory levels and the demand splitting rules, and provide conditions under which there is a unique equilibrium. Mahajan and van Ryzin [5] analyze an inventory management model consisting of N competing firms that provide substitutable goods. Demand is the stochastic sequence of heterogeneous customers who choose dynamically from the available goods. Existence of the Nash equilibrium is proven, and it is shown that under symmetric conditions (identical parameters), this equilibrium is unique. Anupindi et al. [6] develop a general framework for analysis of the inventory management of a decentralized distribution system. This framework entails N retailers who hold stocks locally or/and at one or more central warehouses. This consists of two stages. At the first stage, in order to satisfy local demand, inventory decisions are made. In the second stage, by giving inventory levels and realized demands, allocation of stock for satisfying residual demand is determined, as well as the financial decision of the allocation of revenue. At the first stage, sufficient conditions for the existence of the pure Nash equilibrium are derived. In the second stage, sufficient conditions for existence of the core for allocation decisions are investigated. Granot and Sošić [7] extend the model proposed by Anupindi et al. [6]. The difference between these two models is about the second stage; before shipment of residual supplies, each retailer decides how much of her residual supply she wishes to share with the other. Avşar and Baykal-Gürsoy [8] extend Parlar's model [2] into an infinite horizon and lost sale case. Under the discounted payoff criterion and with stationary base stock strategies for the inventory control system, the existence and uniqueness of the Nash equilibrium is proven. Netessine and Rudi [9] investigate inventory management of an arbitrary number of substitutable products under both centralized inventory management and competition. They show that in noncompetitive cases, the objective function is not necessarily a concave function. Also, a necessary optimality condition which may not be sufficient is obtained. For competitive cases, the existence of the Nash equilibrium is proven and conditions that imply uniqueness are obtained. Also, optimal conditions for the competitive case are obtained and compared with a non-competitive solution. Dai et al. [10] analyze inventory control decisions of two retailers in a distribution system that competes for both supply capacity and customers. The necessary and sufficient conditions for existence of a unique Nash equilibrium are derived. In case the Nash equilibrium does not exist, the concept of the Stackelberg game is used to develop optimal strategies for both the leader and the follower. Boyaci [11] presents an inventory management model in a multi channel distribution system over an infinite horizon, and proves the existence and uniqueness of the Nash equilibrium. Netessine et al. [12] present an inventory control model for two retailers in a multi period environment, wherein various customer responses to a retailer's backorder are considered. Serin [13], based on a newsvendor problem, discusses the Nash equilibrium and the Stackelberg equilibrium of two retailers, and presents conditions which imply that leader profit does not improve from a simultaneous game. They show that under appropriate conditions, the stationary base stock inventory policy is the Nash equilibrium of the game. Geng and Malik [14], based on a newsvendor problem, develop an inventory control model for multi channel distribution and propose a dynamic game, where the retailer is the Stackelberg leader and the manufacturer is the Stackelberg follower who has the authority to undercut retailer orders. Both capacitated and infinite capacity games are discussed and the equilibrium of the games is derived. Yao et al. [15] discuss three inventory strategies in a multi channel distribution system. These strategies are: (1) A centralized inventory strategy, (2) A Stackelberg inventory strategy, whereas the manufacturer plays a role as leader, and (3) A strategy where the manufacturer outsources to a third party logistics provider. They obtain and compare optimal inventory levels. Chiang [16] develops a Markov inventory management model for multi channel distribution, and discusses the Nash and Stackelberg games. Also, channel conflict induced by simultaneously vertical and horizontal competition is discussed. McGillivray and Silver [17], Parlar and Goyal [18], and Ernst and Kouvelis [19] discuss inventory competition in a single firm context. Also, Nie and Chen [20] explain a similar problem.

3. Modeling assumptions and notations

We consider a manufacturer who produces a single product at unit cost, $c \geq 0$. She/He distributes it through his/her wholly owned sales channel at price p_m and through an independent retailer, i, sales channel, $(i = 1, \ldots, n)$, at a wholesale price, w_{r_i}. The retailers will resell the product through their own channels at a price, p_{r_i}. All prices are exogenous. In order to avoid trivial solutions, it is assumed that:

$$c < w_{r_i} < p_{r_i} \quad (i = 1, \ldots, n) \quad \text{and} \quad c < p_m.$$

This set of assumptions guarantees that it is profitable to sell the product in all of the channels.

Each channel has a limited local monopoly as a result of some form of channel differentiation (in terms of location, brand name, prices, service and support provided, etc.). Therefore, the total market demand is shared between channels. Each