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Coordination and price competition in a duopoly common retailer supply chain ☆

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ABSTRACT

This paper analyzes the coordination and competition issues in a two-stage supply-chain distribution system where two vendors compete to sell differentiated products through a common retailer in the same market. The demand of a product not only depends on its own price, but also on the price of the other. Mathematical models have been developed to analyze the coordination issues under three different contexts: (i) price competition without channel coordination; (ii) price competition with channel coordination; and (iii) global coordination. It has been shown that under certain conditions, price competition through the dynamic process of price adjustment reaches the Nash–Bertrand equilibrium. Conditions have been derived for the Nash–Bertrand equilibrium to be dynamically stable. Further, it has been shown that duopoly competition can make consumers better-off or worse-off depending on the degree of product differentiation and the type of the product; while coordination enhances overall supply-chain profitability. The model is illustrated with suitable numerical examples.

1. Introduction

The concept of integrating business activities beyond the organization's boundary has led to the development of the theory and practices of Supply Chain Management (SCM). Several strategies have been discussed in the literature to integrate the business processes and activities of the different members in a decentralized supply chain to ensure system-wide performance improvement in terms of cost, timely product-delivery and customer service. The system-wide performance improvement in the literature is referred to as supply chain (channel) coordination and it is concerned with the development and implementation of the strategies to look for global optima and bringing in transaction efficiency rather than local optima which often causes sub-optimal performance in a supply chain. Cachon (2003a) has provided an excellent review on supply chain coordination and contract. Other reviews, more specifically on '*buyer–vendor coordination*' in supply chain have been provided by Goyal and Gupta (1989), Benton and Park (1996), Munson and Rosenblatt (1998), Giannoccaro and Pontrandolfo (2004) and Sarmah et al. (2006).

From an operational perspective, researchers focus on coordination mechanisms that can align the objectives of individual supply chain members. Consider a prototype of two-echelon supply chain where a supplier sells a product/item to a group of buyers or retailers. The supplier may be a wholesaler/distributor who obtains his supply from an external source of supply or a manufacturer who produces the product internally under capacity limits. Demand generates only at the retailers, and each retailer replenishes its inventory from the supplier. Traditionally, production and inventory decisions are made locally at the site of activity. The supplier or a retailer adopts the deterministic EOQ policy or an installation policy to replenish its inventory. As these policies are results of local optimization, they typically do not optimize system performance. For example, order quantities that optimize individual performance are often not able to optimize system performance and this issue has long been realized. There is a vast literature on integrated game-theory based pricing policies that suppliers can use to entice buyers to increase their order quantities, so as to improve system profits. The mechanism is popularly known as 'Joint Economic Lot Size (JELS)' policy (Goyal, 1976; Dolan, 1987; Chen, Drezner, Ryan, & Simchi-Levi, 2000; Wang, 2005). But one critical finding from the existing body of literature is that in most of the coordination models, the buyers are assigned to the supplier(s) exogenously, i.e. products are considered independent. However, when there are many vendors in the market who can supply the similar type of the product to the buyers, there is a price-competition among the vendors. Under such scenario, development of coordination mechanism is an important area of study. With the existing literature, the issue is obviously no longer whether collaboration is beneficial rather, it is how to achieve such benefits under competition and this paper focuses to analyze such type of a coordination model.

In this paper, we have considered a two-stage supply-chain distribution system where two different vendors compete to sell differentiated products through a common retailer. The price of one

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product can affect the sales of a related product in two ways. Substitution effects describe the situation where a price increase in a product increases sales of other related products (e.g. if price of coffee goes higher, the demand for tea increases). Complementary effects describe the situation where a price increase in a product reduces sales of other related products (e.g. increase of fuel price reduces sales of automobiles). There are many substitutable products in different market place, for example, Pepsi and Coca-Cola in soft drink market, Sotheby's and Christie's in diamond auctions; Kodak and Fuji-film in motion picture film stock market; ABC, CBS, and NBC in US television (before FOX); GM, Ford and Chrysler in auto industry (before the 70s); etc. However, there are supply-chain distribution systems in which a single retailer stores differentiated products of an item sourced from two different sellers. For example, Wal-Mart sells substitute brands of detergents like, Unilever brands (Surf, Wisk) and P & G brands (Tide, Gain, Cheer). In most of the consumer goods market, retailers sell multiple (often highly substitutable) brands at the same location. This kind of channel structure represents numerous markets including those consisting of specialty stores (e.g. consumer electronics, sporting goods, automobile parts, etc.), department stores, supermarkets, etc.

The key features differentiating this paper from the existing related literature is that the formulations and equilibrium strategies of our models explicitly depend on the pricing policy of competing sellers. While modeling competition, we have considered the inherent dynamics associated with the process of price adjustment. Static modeling of general wholesale price competition can derive the equilibrium but the adjustment of wholesale prices to equilibrium does not occur instantaneously. Like most of the dynamic economic systems, the mechanism of dynamic adjustment is an iterative process converging to equilibrium over a period of time. This paper analyzes the stability of such equilibrium. By the term 'stability' we mean to say that whether the process of dynamic price adjustment will eventually converge to equilibrium over a period of time and there is no further divergence from that 'fixed' point. Conditions have been derived for the equilibrium to be dynamically stable.

Here, three different models have been developed to study three different scenarios. In the first model, both sellers compete each other by dynamically adjusting their wholesale prices in response to the other to maximize their individual profit till the game converges to equilibrium. In the second model, each seller coordinates with the retailer and then each integrated channel competes on choosing the product prices in response to the other channel to maximize the integrated profit. Further, we have developed a global coordination model where all the members collude to form unison. It has been shown that competition enhances supply-chain efficiency in terms of social welfare while coordination enhances overall supply-chain profitability. The model is illustrated with suitable numerical examples.

The paper is organized as follows. A brief review of literature is included in Section 2. The mathematical models are developed in Section 3. Suitable numerical illustrations have been carried out in Section 4. Finally, conclusions and some of the possible future research directions are included in Section 5.

2. Review of literature

From the perspective of economic theory, there are innumerable research papers on competition. Most of the papers deal with either quantity-competition or price-competition and their primary focus is on applying game-theory to derive equilibrium under varied assumptions. Many other papers further analyze the problem under dynamic differential game and investigate the stability of the equilibrium and the behavior of the system (Beavis & Dobbs, 1990). However, some papers are limited to assume a zero marginal production cost (Fishman, 1994) or simple linear variable cost which is not a very realistic assumption. Again considering marketing and operations management perspective, there are many papers on monopolistic and duopolistic competition. Moorthy (1988) has considered two identical firms competing on quality and price and analyzed the role of consumer preferences, firms' costs, and price competition in determining a firm's equilibrium product strategy. Rao (1991) has developed a modeling framework to derive the equilibrium in a duopoly market where the members compete on price and promotions. Yao and Liu (2005) have developed competitive equilibrium pricing policies under the Bertrand and the Stackelberg competition model between a mixed e-tail and retail distribution channel. The authors have shown that introduction of e-tail into a manufacturing distribution system not only generates competitive pricing and pay-offs, but also encourages cost effective retail services. They have also proposed a strategic approach for the manufacturer to add an e-tail channel. However, their model did not consider the coordination aspects inside the channel. Ha, Li, and Ng (2003) have considered a supply chain in which two suppliers compete for supply to a customer. The suppliers compete on price and delivery frequency in two three-stage non-cooperative games with different rights designated to the parties involved. They have shown that the customer is better-off under delivery competition, while the suppliers are better-off under price competition. However, the model did not consider any coordination aspects inside the channel and the demand was assumed to be price-independent.

The aspect of coordination and competition has received a considerable amount of attention from the researchers of both marketing and operations management. The models include whether to integrate or decentralize retail activities (Moorthy, 1988; McGuire and Staelin, 1983), setting transfer price schedule such as quantity discounts (Dolan, 1987; Lal & Staelin, 1984) or two-part tariffs (Ingene & Parry, 1995), achieving coordination among channel members via formal agreement or implicit understanding for maximum joint profit (Coughlan, 1985; Jeuland & Shugan, 1983), and analyzing channel efficiency and stability (McGuire & Staelin, 1983). However, the channel models that have been most widely used in these studies are the one in which each manufacturer distributes its product through exclusive dealers who do not carry competing brands (Choi, 1996). Most of these models are dyadic (i.e. single manufacturer and single retailer), except a few like Ingene and Parry (1995) who have studied a two-part tariff problem using a multiple retailer model with a single manufacturer. A model with multiple manufacturers and a single retailer has also been analyzed by Choi (1991) who focused on the effects of retailer power that stems from dealing multiple products.

Profit maximization models with uniform pricing and inventory policies for a single firm have been extensively studied under the assumption of stationary demands (Arcelus & Srinivasan, 1987), or under the assumption of dynamic and deterministic demands (Gaimon, 1988). There have been numerous studies investigating the optimal relations of production schedules, prices, and inventories. For example, Thomas (1974) has investigated the optimal relations of production quantities and prices under the assumption of stochastic demands. The traditional assumption of a single firm is replaced by a duopoly, and the optimal relations between production capacities and prices are studied by Gaimon (1989) under the framework of a differential game. Further, optimal pricing strategy under competition is examined and non-cooperative as well as cooperative equilibrium results have been studied by Dockner and Jorgensen (1984). Min (1992) has studied the profit maximizing Economic Order Quantity (EOQ) model to the case of a symmetric oligopoly consisting of sellers of a homogeneous product who compete with each other for the same potential buyers.