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Analysis of pricing decision for substitutable and complementary products with a common retailer

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ABSTRACT

In this paper, a competition of selling two substitutable products and one complementary product has been studied in two-echelon supply chain systems in which one of these three products is produced by one manufacturer separately, and all produced items are sold through a common retailer in the market. The demand of each product depends linearly on prices of these three products as per their nature. In this study, four different decision scenarios are developed mathematically under the game theory framework to maximize the profit function of each participant of the supply chain, and a number of pricing strategies are subsequently worked out for manufacturers and retailer. Finally, the model under different scenarios is illustrated with numerical data to study the feasibility of the model exploring the managerial insights, as well. Different marketing policies are predicted for maximum individual and system profits.

1. Introduction

The concept of integrating business activities beyond the boundary of markets has led to develop the theory of supply chain management. In recent decades, many powerful retailers have appeared in the world and in size and capacity, and they are often much larger than the manufacturers and usually retail multiple substitutable and/or complementary products. Additionally, many manufactures have increased product varieties by differentiating one or several attributes of the products, or manufacturers have produced negative cross elastic products to get full utility of other products in order to compete for market share and profit gain. Substitute products means that a consumer considers the product to be similar or comparable; for example, the consumer might compare one brand of smart phone with another, or may compare something slightly different, such as coffee and tea or a laptop and a desktop. The complementary product is a product with a negative cross elasticity on demand in contrast to a substitute product, such as toothpaste and toothbrush or a desktop and operating system. A consumer has to buy a complementary item to get full utility of the corresponding main item. This case has recently gained interest by the researchers. In this scenario, the firms supplying the products to the market are coupled in the sense that their demands are interrelated. One firm's marketing decision can affect the other firm's market performance, and vice versa. There is a large body of literature in the area of substitute products or complementary products for cooperative and non-cooperative markets. In this area, McGillivray and Silver [13] first derived the optimal policy for substitute products during stock-out. Huang et al. [7] developed an algorithm for multi-product competitive newsboy shortage problem and partial product substitution. Parlar [16] analysed the inventory problem with two substitutable products having random demands using game theory concepts, and concluded that the players always gain if they cooperate and maximize a joint objective function. Zhang et al. [25] developed a one-manufacturer and one-retailer supply chain model for deteriorating items with controllable deterioration rate and price-dependent demand. Pineyro and Viera [17] maximized re-manufactured quantities for an Economic Order Quantity (EOQ) problem with product returns allowing one-way substitution. Maiti and Maiti [12], Stavrulaki [19], and Krommyda et al. [9] presented inventory models for substitutable products, and the items were substituted based on their inventory levels.

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The most common assumption on the pricing/ordering decision process under game theory framework is that the manufacturer is a Stackelberg leader and the retailer is a Stackelberg follower in a two-echelon supply chain. McGuire and Staelin [14], and Gupta and Loulou [5] investigated the effect of product substitutability on non-cooperative distribution structures in a duopoly where each manufacturer distributes its goods through a single exclusive retailer. Choi's [3] model of product differentiation with two manufacturers selling to a common retailer showed that being a price leader is beneficial when demand is linear, but detrimental when demand is multiplicative. Tsay and Agrawal [20] studied a distribution system for a manufacturer and two retailers in which competition depends on price and service in a game theory framework. Lau and Lau [10] investigated a joint pricing model for a two-echelon system in the manufacturer-Stackelberg process, but in the absence of setup costs, they determined that under a downward-sloping price-versus-demand relationship, the manufacturer's profit is double that of the retailer's profit. Abad and Jaggi [1], and Ho et al. [6] formulated an integrated supplier–buyer inventory model with price sensitive demand, and where the supplier adopts a trade credit policy to determine the optimal pricing, shipment, and payment policy. Zhao et al. [26,27] formulated and analysed pricing strategies of substitute products in a supply chain with one manufacturer and two competitive retailers in crisp and fuzzy environments. Here, substitution was made based on retail prices of the products. Jiang et al. [8] considered information sharing of two firms that sell two substitute products under price competition, and showed that private signals are not perfectly correlated, and firms can benefit from sharing signals with each other. Zhang et al. [25] investigated the impact of consumer environmental awareness (CEA) on order quantities of one manufacturer and one retailer's supply chain with production capacity constraints, and showed that firms benefit from product customization and consumer segmentation based on CEA in the market. Li et al. [11] developed the joint ordering inventory games of multiple retailers who buy the same commodities from a supplier and are offered a permissible delay in payment. Their results showed that formation of a grand coalition of retailers is socially beneficial. Esmaeili et al. [4] proposed several cooperative and non-cooperative games for the seller–buyer coordination to optimize pricing and lot sizing decisions, while non-linearly demand depends on selling price and marketing expenditure. Raju and Roy [18] developed game theory models to understand how the intensity of competition affects the value of market information. They demonstrated that information is more beneficial in industries with fiercer competition, and has greater value for larger firms. Yue et al. [23] and Mukhopadhyay et al. [15] considered two separate firms for game theory models, which had private forecast information about market uncertainties and offered complementary goods. Yan and Bandyopadhyay [21] investigated the bundling of complementary products and showed that a firm can benefit from complementary bundling conditionally. Yan et al. [22] further investigated the strategic influence of product complementarity and advertising on the success of bundling products, and showed that when a firm sells bundled products, both the product complementarity and advertising have significantly impact the performance of bundled products. Yue et al. [23] showed that it is beneficial to share information in a Bertrand game, whereas Mukhopadhyay et al. [15] demonstrated that, in a Stackelberg game, information sharing could benefit the leader, but hurt the follower as well as the total profit. Bian et al. [2] found that information sharing significantly affects supply chain performance. If information is not shared correctly and accurately between manufacturers and retailers, it can make a firm's supply chain less reliable than that of the firm's competitors.

Thus, the applications of game theory to the supply chain, especially coordination, economic stability and the supply chain efficiency, have been discussed by a number of workers for either two substitutable products or two complementary products. This study investigates the cooperation and competition in a two-echelon supply-chain system where three manufacturers compete to sell two substitutable products and one complementary product using a common retailer in the market. The demands of the products generated by the consumers linearly depend on the prices of the products. Based on common sense, it has been seen that the market potentials (i.e., base demands) and manufacturing costs for different products are different. In this instance, one manufacturer separately manufactures one item. These concepts are introduced in the study of pricing strategies for four different marketing scenarios. We investigate the pricing strategies for different scenarios under asymmetric market potential and cost structure in the channel of the products both numerically and analytically. Additionally, we investigate the impact of price elasticity (i.e., price responses) in the pricing strategies of different scenarios, and explore the managerial insights. Finally, some discussions are drawn based on the numerical and analytical analyses.

Till now, no researcher has considered two substitute items and one complementary item in the supply chain of four members in the context of game theories. The above literature survey and new features of the present investigation are presented in Table 1.

Table 1
Research papers on substitute/complementary items.

Authors	No. of items	Nature of items	Substitute/complementary parameters	Solution method
McGillivray (1978)	2	Substitution during stock-out	Crisp	Traditional
Maity et al. (2009)	3	Complementary/substitute	Crisp	Pontryagin principle
Yan et al. (2011)	2	Price-dependent complementary	Crisp	Traditional
Stavrulaki (2011)	2	Stock-dependent substitution	Crisp	Traditional
Yan et al. (2014)	2	Price-dependent complementary	Crisp	Traditional
Krommyda et al. (2015)	2	Stock-dependent substitution	Crisp	Traditional
Choi et al. (1991)	2	Price-dependent substitution	Crisp	Game theory
Gupta et al. (1998)	2	Price-dependent substitution	Crisp	Game theory
Raju et al. (2000)	2	Price-dependent substitution	Crisp	Game theory
Yue et al. (2006)	2	Price-dependent complementary	Crisp	Game theory
Mukhopadhyay (2011)	2	Price-dependent complementary	Crisp	Game theory
Zhao et al. (2012)	2	Price-dependent substitution	Fuzzy	Game theory
Jiang et al. (2014)	2	Price-dependent substitution	Stochastic	Game theory
Zhao et al. (2014)	2	Price-dependent substitution	Crisp	Game theory
Bian et al. (2014)	1	Independent	Crisp	Game theory
Zhang et al. (2015)	2	Price, environmental quality dependent substitution	Crisp	Game theory
Present investigation	3	Price-dependent substitute and complementary	Crisp	Game theory

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