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A Stackelberg model of pricing of complementary goods under information asymmetry

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ABSTRACT

We consider a duopoly market where two separate firms offer complementary goods in a leader–follower type move. Each firm has private forecast information about the uncertain market demand and decides whether to share it with the other firm. We show that information sharing would benefit the leader firm but hurt the follower firm as well as the total system if the follower firm shares information unconditionally. We then devise a "simple to implement" information sharing scheme under which both firms and the total system are better off. We also provide several interesting managerial insights and establish the robustness of the model in managing a supply chain through our analytical and simulation results.

1. Introduction

Information technology has significantly reshaped the way companies interact with suppliers and customers in the last two decades. One of its benefits is to allow firms to share the information, such as point-of-sale data, inventory, forecast data, and sales trends, quickly and inexpensively. The most celebrated implementation of information sharing is Wal-Mart's Retail Link program, which provides on-line summary of point-of-sales data to suppliers like Johnson and Johnson and Lever Brothers. Indeed, information sharing is the cornerstone of initiatives like quick response (QR), efficient consumer response (ECR), vendor-managed inventory (VMI), continuous replenishment program (CRP), and collaborative planning, forecasting and replenishment (CPFR). Major successes of such programs have been reported at companies like Campbell Soup and Barilla SpA (Lee et al., 2000).

These developments have motivated the academic community to explore the benefits of information sharing. Particularly, many recent papers study the effects of supply chain information sharing. This line of research falls into three streams: the impact of information sharing on inventory management in supply chains (e.g., Gavirneni et al., 1999; Lee et al., 2000; Yao et al., 2008; Mukhopadhyay and Ma, 2009; Aviv, 2001, 2002, etc.), the impact of information sharing on capacity (e.g., Cachon and Lariviere, 2001; Ozer and Wei, 2006; Taylor and Plambeck, 2007, etc.) as well as the impact of information sharing on pricing decisions in supply chains (e.g., Au et al., 2008; Wu and Cheng, 2008; Yao et al., 2005; Kurata and Yue, 2008; Li, 2002; Zhang, 2002, etc.). Benefits of information sharing include reduced operating costs and improved productivity, asset efficiency, higher revenues, and improved customer relationships.

Pricing game has been studied for decades. Several recent research papers discuss the pricing game under the new supply chain structures like dual-channel and outsourcing. Cai et al. (2009) evaluates the impact of price discount contracts and pricing schemes on the dual-channel supply chain competition. Chiu et al. (2009) uses game theory to study some strategic actions for retailers to fight a price war. Choi (2007) studies the pricing decisions for fashion retailers with multiple information updating. Wang et al. (2007) studies the manufacturer's optimal capacity decisions and the supplier's pricing strategies under complete, partial or no outsourcing scenario. Recently, a number of studies came out on asymmetric information and decision making under uncertainty. Corbett and de Groote (2000), Ha (2001), Gan et al. (2003), and Corbett et al. (2004), Mukhopadhyay et al. (2008) use revelation principle (Fudenberg and Tirole, 1991) to design contract under asymmetric information.

However, information sharing may lead to opportunistic and exploitative behavior in the supply chain (Zwass, 2006). In any information-sharing scenario, a critical question is how the receiving party uses the information, and whether and under

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what conditions information sharing is mutually beneficial. This paper contributes to the existing literature by addressing the pricing aspect of imperfect information sharing on demand forecast for firms producing complementary products.

The case of marketing substitutable products in a competitive setting has been extensively studied in the literature for a long time (e.g., Gal-Or, 1985; Vives, 1984, etc.). This is the traditional competition model where customers choose between the competing products depending on their preferences and the marketing strategy of the firms. The case of complementary products, on the other hand, arises when customers have to buy more than one product at the same time to get the full utility of the goods. This case has recently gained interest. 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, then, would affect the other firm's market performance and vice versa. In this paper, we consider a duopoly of complementary products marketed by different firms under the mode of a leader–follower move and with information asymmetry. We will present models for developing optimum pricing policies for two firms under various scenarios (i.e., non-information sharing, information sharing, and strategic alliance). The objective of this paper is to better understand how two firms with complementary demand should set prices when their pricing is based on forecasts.

Complementary products could be "perfect complement" when one good is consumed together with another good. A computer and an operating system, bed and mattress, baby bottle and nipple are good examples. Some complementary products are not perfect complement in that each product could be used separately, like a washer and a dryer. Sometimes, complementary products can also be classified as a base product and a complementary product. For example, an operating system (OS), like Windows, acts as base product, while application software, like Adobe, acts as complementary product. Other examples are cell phone and Bluetooth headset, and vehicle and GPS.

In the case of sequential entry, one good is bought after the other. The operating system provider moves first by announcing the price of the product, then the providers of complementary applications set their prices and make other marketing decisions. In such a scenario, since demands are interrelated, one firm has an obvious interest in learning the demand forecast of the other firm. Forecast accuracy is very critical for some industries, like fashion industry, computer industry, communication industry and others. Information sharing in these industries, therefore, would be very useful.

This paper considers two separate firms offering complementary goods to customers who have a need to buy both products and also to customers who have a need to buy only one product independently. We illustrate our model scenario with the example from the computer industry. Firm 1 develops and markets an operating system. Firm 2 then develops application programs (like word processors). A group of customers would buy both products. There also would be a group who would buy the operating system (Firm 1) but not the application program (Firm 2). Similarly, a third group would buy the application program (Firm 2) but not the operating system (Firm 1).

Nevertheless, the two firms' demands are linked by the demand of the common group who want to buy both products. Firm 1 would, therefore, be interested in the demand forecast information of Firm 2, who is under no obligation to share it. This gives rise to an information asymmetry. We will study three cases where the information is shared, where the information is not shared, and where the two firms form a strategic alliance. We first derive the equilibrium prices and profits under the three cases and study how the forecast precision would impact the firms' expected profit. We then investigate the impact of demand forecast sharing on the firms' performances.

The impact of forecast improvement/forecasting sharing on pricing has been studied in the marketing and economics literature. This literature typically considers the competition in a duopoly that uses different forecasts of the market demand. Closely related to our research, Raju and Roy (2000) analyze how firms selling the substitutable products use the forecast in their pricing decision in both the Stackelberg model and the Bertrand-Nash model (In this study, we extend Raju and Roy (2000) to address the forecast's impact on pricing for firms selling complementary products under the Stackelberg model). Roy (2000) studies channel pricing when there are two competing manufacturer-retailer channels with both channels facing stochastic downward-sloping (linear) demand functions. Vives (1984), Gal-Or (1985), Villas-Boas (1994), and Raith (1996) study whether a firm has incentive to share its private information horizontally with the competitors in an oligopolistic market. Researchers have also looked at how to combine information from different sources (Winkler, 1981; Blattberg and Hoch, 1990; Morrison and Schmittlein, 1991). Sarvary and Parker (1997) show that information from different sources could be substitutes or complements depending on characteristics such as variance and correlation. Our study complements this literature by explicitly characterizing the value of information sharing in complementary demand-related firms under a Stackelberg game mode and deriving a scheme under which the information can be shared. Yue et al. (2006) study a similar problem incorporating simultaneous move using Bertrand mode. One characteristics of our research is that we assume that both firms forecast their demands independently and one firm's forecast is not necessarily better than that of the other. The forecasts can be correlated, and their accuracies can be different, which is more realistic in practice.

In the next section, we introduce our notation and model. In Section 3, we first present the analytical results under three scenarios (non-information sharing, information sharing, and strategic alliance), and then analyze the value of information sharing. In Section 4, we present a simulation study. Section 5 concludes the paper.

2. The model framework

We consider a Stackelberg game where one firm acts as the leader and the other firm acts as a follower. Let Firms 1 and 2 be the suppliers of two functionally complementary products. We consider a single period model in our paper. We begin by dividing the market into three groups. Group 1 buys product 1 only. Group 2 buys both products 1 and 2, while Group 3 buys product 2 only. The price charged by Firm i for product i is p_i, i=1,2. We assume that there is no price discrimination among market groups. These prices are the decision variables for the two firms. In the model, we use linear demand functions as they are widely used in marketing and economics literature (e.g. McGuire and Staelin, 1983; Jeuland and Shugan, 1983; Vives, 1984; Gal-Or, 1985; Choi, 1991; Raju and Roy, 2000; Li, 2002; Zhang, 2002).

The demand of product 1 from Group 1 is given by

$$q_{1\_G1} = \alpha a - dp_1 \quad (1)$$

Similarly, demand for product 2 from Group 3 is

$$q_{2\_G3} = \beta a - ep_2 \quad (2)$$

Group 2 will demand both products. The respective demands for products 1 and 2 are

$$q_{1\_G2} = a - b_{11}p_1 - b_{12}p_2$$

$$q_{2\_G2} = a - b_{22}p_2 - b_{21}p_1 \quad (3)$$