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Decision Support

Demand disruption and coordination of the supply chain with a dominant retailer

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ABSTRACT

This paper develops two coordination models of a supply chain consisting of one manufacturer, one dominant retailer and multiple fringe retailers to investigate how to coordinate the supply chain after demand disruption. We consider two coordination schedules, linear quantity discount schedule and Groves wholesale price schedule. We find that, under the linear quantity discount schedule, the manufacturer only needs to adjust the maximum variable wholesale price after demand disruption. For each case of the disrupted amount of demand, the higher the market share of the dominant retailer, the lower its average wholesale price and the subsidy will be under the linear quantity discount schedule, while the higher its fraction of the supply chain's profit will be under Groves wholesale price schedule. When the increased amount of demand is very large and production cost is sufficiently low, linear quantity discount schedule is better for the manufacturer. However, when the production cost is sufficiently large, Groves wholesale price schedule is always better. We also find that the disrupted amount of demand largely affects the allocation of the supply chain's profit.

1. Introduction

Supply chain coordination has been extensively studied in recent operations management literature. Generally, a supply chain is coordinated when the players, acting rationally, make the decisions that are optimal for the whole supply chain. Some coordination mechanisms, such as quantity discount schedule and revenue-sharing schedule, are used to regulate the relationship among the supply chain's members. Very often, schedules are designed for the static environment such as a known market demand, a distribution function in the stochastic environment. These schedules can be defined as static coordination mechanism. However, after the plan has been settled down, the environment is often disrupted by some unexpected events, such as machine breakdown, the raw material shortage, the SARS epidemic, and Hurricane Katrina. The disruptions have made companies aware of the need for active disruption management.

Disruptive events within a supply chain can significantly impact the performance of the supply chain's members. For example, publicly traded firms experiencing supply chain disruptions have reported negative stock market reactions to announcements of these disruptive events, with the magnitude of the decline in market capitalization being as large as 10% (Hendricks and Singhal, 2003, 2005). As a matter of fact, Ericsson reported a $400 million loss because it did not receive chip deliveries from the Philips plant in a timely manner. However, Nokia, a competitor of Ericsson, immediately sensed the disruption and responded aggressively. Nokia's share of the handset market increased from 27% to 30% because Nokia has taken better measures (Latour, 2001).

This paper considers coordination of a supply chain consisting of one manufacturer and one dominant retailer after demand disruption. In reality, there often is a dominant retailer competing with multiple fringe retailers, which can be described as the well-known dominant retailer model (Shepherd, 1997; Riordan, 1998). As Wal–Mart grew, for instance, the relationship between Wal–Mart and Tandy evolved into main partnerships. Wal–Mart's sale volume accounts for 39% of Tandy's in 2002 (Useem, 2003). The dominant retailer often is a price leader and a main or largest distributor of the supplier. Other fringe retailers are price followers and the market demand share of each retailer is very small (Weinstein, 2000). We assume that only the dominant retailer can provide the advertising service to promote sales.

In this paper, we define an operation without disruption as a *normal operation*, and the operation with disruption as an *irregular operation*. We explore the coordination contracts for the supply chain with demand-disruption, which differs from the case without disruption because we incorporate the deviation penalty into the utility functions. We consider two cases: deviation penalty is borne by the manufacturer, and shared by the manufacturer and the dominant retailer. For simplicity, we assume that the fringe retailers are identical and the changed amount of the demand is common knowledge to all players.

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Our paper complements the literature by investigating how to coordinate the supply chain with a dominant retailer and facing demand disruption under linear quantity discount schedule and Groves wholesale price schedule and analyzing how the choice of the two mechanisms depends on the production cost of the manufacturer and the disrupted amount of demand. The first coordination mechanism keeps some manufacturer–retailer relationships after demand disruption. That is, the manufacturer only needs to adjust the maximum variable wholesale price, while the discount slope and the subsidy rate are unchanged, comparing with those in normal operation. When the Groves wholesale price schedule is used, we find that the channel power, i.e., the profitability of the channel's player, shifts always from the manufacturer to the dominant retailer as the retailer becomes more dominant.

The rest of this paper is organized as follows: the related literature is reviewed in Section 2, and then the basic model and the basic centralized decision are presented in Section 3. Section 4 considers coordination mechanism under linear quantity discount schedule, where the manufacturer bears the (production) deviation cost. Section 5 studies the coordination mechanism under wholesale price schedule, where the manufacturer shares the deviation cost with the dominant retailer. These analytical results are illustrated by numerical examples in Section 6. Finally, in Section 7 we summarize the results and point out directions for future research.

2. Literature review

This paper is closely related to supply chain coordination management, demand-stimulating services and disruption management. In the decentralized decisions, the optimal supply chain profit is usually not achieved due to double marginalization (Spengler, 1950). Double marginalization means the fact that each player's relative cost structure is distorted when a transfer price is introduced within a supply chain. Designing coordination schedule has been an important issue aimed at reconciling conflicts and achieves a better coordination among players. Lariviere (1999), Tsay et al. (1998) and Cachon (2003) provided excellent introduction and summaries on coordination management. In the normal operation, our pricing schedule is closely related to Ingene and Parry (1995, 2000) and Xiao et al. (2007). Xiao et al. (2007) considered a linear quantity discount to coordinate the supply chain with one manufacturer and two competing retailers.

Another schedule presented in our paper is similar to the wholesale price schedule studied by Cachon and Lariviere (2005). They compared the wholesale price schedule with the revenue-sharing schedule, and found that the two schedules are equivalent for a simple supply chain. Boyaci and Gallego (2002) explored coordination issues in a supply chain with one wholesaler and multiple independent dispersed retailers and showed that the channel members would improve the channel and distribute the gains of coordination through bargaining, however, they have not provided a specific coordination mechanism. Chen (2001) provided a quantity discounts schedule to coordinate the supply chain with multiple independent retailers. Bernstein and Federgruen (2003) provided a nonlinear wholesale pricing schedule to coordinate the supply chain with competing retailers.

For the literature on demand-stimulating service, Tsay and Agrawal (2000) characterized the equilibrium behavior of oligopolies with two retailers competing in price and service level in a certain demand environment and showed that the wholesale price mechanisms could be used to coordinate the supply chain. Bernstein and Federgruen (2004) developed game models to study the price and service competition under demand uncertainty. Li et al. (2002) developed three strategic models for determining equilibrium marketing and investment effort levels for a simple supply chain and offered a formal normative approach for analyzing the traditional cooperative advertising program where the manufacturer is leader and the retailer is follower. Huang and Li (2001) presented the models where the manufacturer and the retailer simultaneously maximize their own profits with respect to any possible strategies set by the other member. Yue et al. (2006) studied the coordination of cooperative advertisement in a simple supply chain when the manufacturer offers price deductions to customers.

Our study complements Raju and Zhang (2005). Raju and Zhang (2005) considered the fixed constant cost of advertising service and provided the quantity discounts schedule and the two-part tariffs schedule, which can be used as channel coordination mechanisms. However, quantity discounts schedule and two-part tariff schedule are not equally effective from the manufacturer's perspective as a channel coordination mechanism, and the scale of the service investment plays an important role in the attitude of the manufacturer towards these coordination mechanisms. In our setting, the service investment cost is variable, and two coordination mechanisms, linear quantity-discount schedule and Groves wholesale price schedule, are investigated. The production cost and the possible demand disruption will affect the attitude of the manufacturer towards choosing coordination mechanism.

At the same time, our paper is closely related to disruption management. Generally, the system disruption will result in the deviation penalty for the production quantity change. It is difficult to quantify precisely the true (production) deviation costs incurred by supply chain disruption in the actual operation. A select few companies, however, have been able to quantify the impact of potential disruption. For example, one company surveyed by Rice and Caniato (2003) estimated that the daily cost impact of a disruption in its supply network to be in the neighborhood of \$50–\$100 million. The overview of general applications can be found in Yu and Qi (2004). Yang et al. (2005) proposed a dynamic programming method for the demand and cost disruption management of a firm.

Qi et al. (2004) introduced the idea of disruption management into supply chain management, specifically, into supply chain coordination management. Supply chain disruption management considering the deviation cost is relatively new. Qi et al. (2004) considered coordination problem of a simple supply chain after demand disruption. Xiao et al. (2005) extended the model into the supply chain with two competing retailers who have the options of investment on sales promotion, where the demand is the function of the promotion investment decisions. Xiao and Qi (2008) also studied the disruption management of the supply chain with two competing retailers, where the manufacturer faces a production cost disruption. Xiao and Qi (2008) investigated the two coordination mechanisms, all-unit quantity discount and incremental quantity discount. Usually, in order to simplify the models, the deviation cost is borne by the manufacturer. In some other cases, the deviation cost is borne by the retailers rather than the manufacturer (Xiao et al., 2007). However, in designing some schedules, the deviation cost can also be shared by the players, which will be considered in this paper.

3. The basic model

We consider a supply chain consisting of one manufacturer, one dominant retailer and N fringe retailers, $N \geqslant 2$. We assume that the dominant retailer, acting as a monopolist, has market power in the market, and only the dominant retailer can provide the demand-stimulating service, which goes beyond what the fringe retailers can do. For example, the dominant retailer can carry on some propagating advertisement to promote the product. At the same time,