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Supply chain contracts under demand and cost disruptions with asymmetric information

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ABSTRACT

We study the risk management strategies in supplier chain when the disruptions of demand and cost are the private information. We use linear contract menus to analyze the supply chain under demand and cost disruptions with asymmetric information. We derive out the optimal contract for the supplier and show the impact of asymmetric disruption information on the performance of the supplier, the retailer and the supply chain. Further, we find out that the effects of demand and cost disruption may interact with each other while the production plan does not change in some cases. The optimal production quantity with asymmetric information is not greater than that with symmetric information. The information value for all members is not monotone in all parameters. Each change will induce that the supplier revises his strategy when the supply chain members trade off the cost of deviation and asymmetric information.

1. Introduction

Today, firms are operating in a global environment. Both academicians and practitioners realize that the disruptions in supply chains become one of the most important supply chain risks (Chopra and Sodhi, 2004). As the economic integration and globalization is deepening, the unexpected changes of market demands and production costs are more common as never before. Therefore, suppliers may have to adjust the production plans before selling seasons. For example, economic policies adjustment, transportation delays or natural disasters can change the demand or cost of the products to some extent, which further influences the suppliers' original production plans. As a result, a significant negative impact on business performance may occur if disruption risk does not be managed properly. Usually, supply chains can hardly recover from these disruptions in a short period (Hendricks and Singhal, 2003, 2005a,b). In order to attain high level performance, the companies should ensure that their supply chains are robust enough to deal with the demand and supply uncertainties. Some new models have been set up to study how to handle the disruption risk in supply chains (Qi et al., 2004; Xu et al., 2006).

The existing models assume that supply chain partners have symmetric information so that supply chains can react to disruption risk in a coordinated way. However, the disruption information is more likely to be asymmetric between supply chain members in practice. Although some powerful manufacturers such as IBM and HP can get sales data from retailers so that they can design their production plans very well in their supply chains (Lee and Whang, 2000). In most situations, however, supply chain members cannot obtain precise demand information from the retailers. That is to say, the demand information is often known by retailers but not by manufacturers or wholesalers. In addition, global outsourcing has been very popular for original equipment manufacturers (OEMS), such as Nike and Dell. They can focus more on their core operation and exploit the economies of scale and flexibility in this way (Simchi-Levi et al., 2003). In this case, designing appropriate compensation plans for outsourcing products can be very challenging for OEMS, although the intense competition can help in disclosing the production cost. An important reason is that the production cost disruption may be their contract manufacturers' private information.

This paper investigates the interaction between disruption risk management and asymmetric information in a one-supplier and one-retailer supply chain. Our primary interest in this paper is to understand how disruption information asymmetry may affect supply chain players' behavior as well as the performance of the supply chain in this process. We try to shed light on the following three important questions: (i) How to revise the production plan when the demand and cost are disrupted simultaneously?

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(ii) How does the optimal production quantity change under disruption with information asymmetry? (iii) How does asymmetric disruption information influence the profit of the supply chain, the supplier and the retailer?

We use the principal-agent model and the linear price contracts to address above problems. The agent has full information about disruption and the principal does not know exactly the disruption information. The principal has monopoly power over the agent. The contracts are designed by the principal and offered to the agent as a take-it or leave-it offer. The agent accepts the contracts if and only if his expected profit/utility is greater than or equal to his reservation profit/utility. In the presence of asymmetric disruption information, we show how to optimize the production plan and the corresponding change of the channel members' profits.

In our model, the asymmetric information of demand and cost happens at the same time. That is to say, the supplier does not know the market demand while the retailer does not know the production cost exactly too. However, the supplier and the retailer make decision successively as the principal-agent model stated above. With private information of demand or cost, the principal makes decision before the agent, and the agent has the only right to choose to accept one of the contract menus or reject all of them. Thus the agent makes decision based on his reservation profit/utility instead of his profit. Therefore, the agent needs not to consider the principal's private information when he makes decision. That is to say, the private information of the principal can be seen as symmetric between them. So the information asymmetry of demand and cost does not appear in our model at the same time. If the principal and the agent make decision at the same time, they play the static game or the bargaining game. Our analysis does not include these two types of games.

The rest of the paper is organized as follows. Section 2 reviews related the literature. In Section 3, we present the optimal contracts when the supplier is the principal. Section 4 analyzes the impact of the information asymmetry of demand disruption on the channel, the supplier and the retailer. Section 5 investigates the case that the retailer is the principal. Section 6 provides conclusions.

2. Related literature

Since our work tries to understand the disruption management in the supply chain with information asymmetry, the early work related to ours includes the studies on screening model (Spence, 1974). An excellent survey of adverse selection and screening model can be found in Laffont and Martimort (2002). This paper focuses on how to distinguish the different types of agents and minimize the efficiency loss caused by asymmetric information through contract designing.

Our research is also related to incentive scheme derived from asymmetric information in supply chain management. Chen (2003) offers an excellent survey of the literature on information sharing in supply chains. Demand information is a kind of asymmetric information in supply chains that has been extensively studied in the literature. For instance, Cachon and Larivière (1999) discuss the allocation scheme when the supplier has limited capacity and the market demand is the retailers' private information. In another paper, Cachon and Larivière (2001) address incentive scheme which motivates supply chain partners to share forecasted demand information. Lau and Lau (2001) introduce a newsboy model to study how the manufacturer design contract scheme when the retailer has more information about market demand. Lau and Lau (2005) extend their model to linear demand function. Ha and Tong (2008) study the supply chain contracting under asymmetric demand information and supply chain competition. Asymmetric cost information is another kind of important information asymmetry in supply chains and has also received substantial attention (Corbett and de Groote, 2000; Corbett, 2001; Ha, 2001; Cachon and Zhang, 2006; Sucky, 2006). Corbett and Tang (2004) present how a supplier designs contracts so that a retailer has the incentive to disclose his private cost information. They provide a general framework to study the problem of screening in supply chains. All the above research does not incorporate disruption into their models. Yang et al. (2009) study risk management strategies of supply chains when the supplier's reliability is his own private information.

Disruption management in supply chain is the most closely related research to our work. Qi et al. (2004) examine the coordination scheme when supply chains experience demand disruption. Xu et al. (2006) study the supply chain coordination problem under the production cost disruption. Xiao et al. (2005) and Xiao and Yu (2006) extend the two models to the case with two competing retailers. Xiao et al. (2007) investigate the coordination mechanism when retailers compete with each other under the demand disruption.

There are several differences between our model and the above papers. First, they only consider one kind of disruptions in supply chains. We discuss the case in which demand and cost are disrupted simultaneously. Second, they assume that all the decision information between the supplier and the retailer is symmetric. We consider the asymmetric demand and cost chains. Third, they focus on the coordination problem between the supply chain partners. We study the incentive contracts that can improve the supply chain performance when the disruption information is asymmetric. Under our framework, the principal maximizes his and the supply chain profit at the same time.

3. Demand disruption with asymmetric information

In this section, we discuss optimal linear contracts in supply chains when demand and cost are disrupted simultaneously. In this case, the disruption information of both demand and cost are asymmetric. As mentioned early, however, the asymmetric cost disruption information has no effect in the model for the decision procedure. Before introducing our model, we summarize some basic and earlier conclusions without disruptions.

Consider a supply chain with one supplier and one retailer. The retailer purchases product from the supplier and then sells it on the market. The market demand d is linear in price p and has the expression $d=D-kp$, where D is the market scale and k is the price-sensitive coefficient. Suppose that the supplier's unit production cost is c, thus the supply chain profit is $\overline{f}^{sc}=(D-kp)(p-c)$ and it is maximized at $p^*=(D+kc)/2k$. Consequently, the retailer's optimal order quantity and the supplier's original production plan both are $Q^*=(D-kc)/2$ and the maximum profit of the supply chain is $\overline{f}^{sc}_{max}(Q^*)=(D-kc)^2/4k$.

In the rest of this paper, ΔD and Δc denote the demand and cost disruption, respectively. When disruptions occur, the optimal production quantity of the supply chain will change from Q^* to Q'. The deviation cost is λ_1 when $Q^*<Q'$ and λ_2 when $Q^*\geq Q'$. Further discussion of deviation cost and the original plan can be found in Qi et al. (2004).

As mentioned previously, asymmetric demand disruption information is very important in supply chain management. In this subsection, we assume the supplier is the principal and investigate the impact of asymmetric demand disruption information on the supplier's disruption management. Assume