Pricing and production decisions in a dual-channel supply chain when production costs are disrupted

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ABSTRACT

This paper studies a pricing and production problem in a dual-channel supply chain when production costs are disrupted. When a production cost disruption occurs, the original production plan which is designed based on the initially estimated production cost needs to be revised. It is necessary to explicitly consider possible related deviation costs caused by changes of the original production plan. We consider this problem in the centralized and decentralized dual-channel supply chain, respectively. The optimal prices and production quantity under production cost disruptions are derived. We find that the original production plan has some robustness with production cost disruptions. Only when the production cost disruption exceeds some thresholds will the decision-maker change the production quantity. The production cost disruption robustness region in the centralized dual-channel supply chain is the same as that in the decentralized dual-channel supply chain. In the centralized dual-channel supply chain, it is always beneficial for the central decision-maker to take timely response to the disruptions and utilize the revised strategy under production cost disruptions. In the decentralized dual-channel supply chain we characterize a threshold. If customers' preference for the direct channel is below the threshold, the optimal direct sale price equals the wholesale price; otherwise, the optimal direct sale price and wholesale price equals the optimal direct sale price and retail price in the centralized dual-channel supply chain. The manufacturer always gets better off if he takes timely response to the production cost disruptions, while the retailer gets better off only if the production cost disruption is negative and gets worse off otherwise.

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1. Introduction

Customers are becoming more and more accustomed to purchasing online in the passing decades. The rapid development of the Internet and emerging technology play a significant role in the development of this new business model. By means of an online channel, firms can deal with customers' orders, have control over the distribution and pricing of goods, have a greater understanding of customers' preference and be closer to customers (Mukhopadhyay et al., 2008). Many firms have engaged in online channels to reach customers who cannot be reached by the traditional retail channel. It is reported that about 42% of the top suppliers such as IBM, Nike, Pioneer Electronics, Estee Lauder, and Dell are selling to customers through an online channel (Chiang et al., 2003; Tsay and Agrawal, 2004). However, the introduction of the online direct channels has made the pricing and production decisions more complicated when facing unexpected risks or disruptions. On the one hand, the manufacturer's and the retailer's pricing strategies are

competitive to some extent; on the other hand, they have to respond to unexpected production risks such as machine breakdown and raw material shortage to maximize their individual profits. Generally, disruptive events in a supply chain will significantly affect the performance of the supply chain. It is reported that publicly trade firms experiencing disruptive events received negative stock market reactions with the magnitude of decline in market capitalization being as large as 10% (Hendricks and Singhal, 2003, 2005). Disruptive events have made companies realize the importance of disruption management.

The disruption management has gained much attention in the communities of academics and practitioners. Most literature is concerned with how to coordinate members' decisions to maximize the supply chain's profit in the traditional channel. Little attention has been paid to the disruption management in a dual-channel supply chain. In a dual-channel supply chain the interaction of member's pricing decisions and its impact on channel demands are even more complicated when there are possible disruptions. Once a disruption occurs, how the members should revise their decisions to maximize their individual profits is a problem worth of investigation. This paper considers the pricing and production decisions in a dual-channel supply chain consisting of one manufacturer and one retailer when the production cost experiences disruptions. The objective of this paper is not only to analyze how to revise the pricing and

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production quantity in response to production cost disruptions, but also to investigate whether the manufacturer who has access to the accurate production cost information is willing to take timely response to the disruptions and what the value of this reaction is.

This paper is closely related to disruption management. Qi et al. (2004) first introduced the idea of disruption management to supply chain management. In their paper, they considered two kinds of deviation costs. If the demand exceeds the original production quantity, underage cost may happen. Otherwise disposal cost may happen. Based on Qi et al. (2004), many researchers had extended disruption management in supply chain management in various scenarios. Yang et al. (2005) proposed a dynamic programming method for recovering a production plan after a disruption. Xu et al. (2006) discussed the supply coordination problem with production cost disruptions. Qi et al. (2006) investigated the disruption management in machine scheduling. Huang et al. (2006) investigated the coordination problem of a supply chain with exponential function under demand disruptions. Xiao and Yu (2006) developed an indirect evolutionary game model with two vertically integrated channels to study evolutionarily stable strategies of retailers in the quantity-setting duopoly situation. Xiao et al. (2005, 2007) and Xiao and Qi (2008) studied how to coordinate a supply chain with one manufacturer and two competing retailers by means of quantity discount schedule when demands are disrupted. Chen and Xiao (2009) studied how to coordinate the supply chain with a dominant retailer after demand is disrupted. Chen and Zhuang (2011) further considered the coordination model for a dominant retailer with constant demand-stimulating cost under demand disruptions. Lei et al. (2012) studied how to devise linear contract menus to coordinate the supply chain with asymmetric information under both demand and production cost disruptions. This paper is distinct from the disruption management literature above in two aspects. Firstly, the literature above considered a single channel and did not considered the disruption management in a dual-channel setting, with the only exception of Huang et al. (2012), which addressed the disruption management in a dual-channel supply chain under demand disruptions. However, in this paper we investigate the pricing and production quantity decisions in a dual-channel supply chain under production cost disruptions. Secondly, we examine the value of timely response to production cost disruptions in both centralized and decentralized dual-channel supply chain settings.

The research on dual-channel supply chain management had obtained much attention among the marketing and supply chain management researchers in recent years. For dual-channels, Chiang et al. (2003) studied a price-setting game between a manufacturer and a retailer in a dual-channel supply chain based on consumer choice model. Tsay and Agrawal (2004) used game theory to study the channel conflict and coordination between the manufacturer and the retailer in a dual-channel supply chain. Mukhopadhyay et al. (2006) proposed a way of alleviating the possibility of channel conflict when the retailer is allowed to add value to the product at a cost. Based on Chiang' work, Yan (2008) used a game theory approach to investigate the strategic role of profit sharing and found that both the manufacturer and the retailer will benefit from a dual-channel profit-sharing strategy. Cai et al. (2009) and Cai (2010) studied the influence of channel structures and pricing schemes on the dual-channel supply chain. Chen et al. (2008) investigated service competition in a dual-channel supply chain based on consumer channel choice behavior. Mukhopadhyay et al. (2008) investigated the optimal contract design problem in a mixed channels supply chain where the manufacturer had incomplete information about the retailer's cost of adding value. Zhang et al. (2012) studied the effect of product substitutability and relative channel status on pricing decisions under different power structures. However, the literature above all assumed that the production cost was given and known. Little attention has been paid to the issue of production

costs disruption management in a dual-channel supply chain. Usually, accurate production costs information cannot be obtained in advance if no mass production has been conducted before. As a result of long production lead time, manufacturers usually make the production plans according to the anticipated production costs. Many factors, such as increased labor cost, changed auxiliary material price, changed transportation cost, and interest rate fluctuation, will lead production cost to vary in practice. Once the real production cost is not equal to the original anticipated one, necessary adjustments have to be executed to mitigate the impact of production cost disruptions and achieve profit maximization.

The framework of this paper is most related to Qi et al. (2004), Xu et al. (2006) and Huang et al. (2012). We consider this problem in a two-period dual-channel supply chain. In the first period, a production plan is made based on the anticipated production cost. Raw material purchasing and preprocessing are conducted in this period. In the second period, the actual production cost is resolved, and a new production plan has to be made accordingly. Production cost variety will lead to selling price change, which will eventually lead to market demand change. Once the market demand changes, some related deviation costs will possibly occur. Especially, if the demand exceeds the original production quantity more raw materials will have to be purchased in the physical market at higher prices, while if the demand is less than the original production quantity the excessive materials will have to be disposed. Either of them will add deviation costs to the supply chain. We would like to know how the decision-maker should revise the original production plan in a dual-channel supply chain under production cost disruptions.

This paper contributes to the literature in two aspects. Firstly, this paper complements the disruption management in a dual-channel supply chain. As far as we know, the studies on supply chain disruption management usually consider the traditional retail channel, with the exception of Huang et al. (2012). This paper is distinct from Huang et al. (2012) in that we focus on production cost disruption management in a dual-channel supply chain, while they considered the demand disruption management in a dual-channel supply chain. As the impacts of demand disruption and production cost disruption on the optimal decisions are different, the main results of this paper are also different from theirs. As more and more manufacturers engage in dual channels and the environment in which the supply chain operates changes quickly, it is necessary to investigate how to respond to disruptions in a dual-channel supply chain. This paper studies how a dual-channel supply chain should revise its pricing and production quantity decisions to deal with production cost disruptions and derives the optimal pricing and production decisions. Secondly, this paper complements the dual-channel supply chain management by incorporating the disruption management. Most studies on dual-channel supply chain management focused on channel structure choice, channel conflict and coordination and joint decisions with other factors, such as retail service, cooperative advertising and lead time (Hua et al., 2010; Xie and Wei, 2009; Yan, 2008). Little attention has been paid to the issue that how a dual-channel supply chain should respond to disruptions caused by changing outside environment or inside operation. This paper contributes to this stream of literature by considering production cost disruptions in a dual-channel supply chain and derives optimal pricing decisions for the supply chain.

The remainder of this paper is organized as follows. The notations and the models are introduced in Section 2. In Section 3, we analyze the optimal pricing and production quantity decisions in the centralized and decentralized dual-channel supply chain without production cost disruptions as the baseline cases. Section 4 and Section 5 examine the optimal pricing and production quantity decisions in a centralized and decentralized dual-channel supply chain under production cost disruptions, respectively. Section 6 presents some numerical examples to illustrate the results. Section 7 summarizes the results and limitations and points out directions for future research.