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Coordination of a supply chain with one manufacturer and multiple competing retailers under simultaneous demand and cost disruptions

Erbao Cao [a,b,*], Can Wan [c], Mingyong Lai [a,b]

[a] College of Economics and Trade, Hunan University, Changsha 410079, China
[b] Hunan Province Key Laboratory of Logistics Information and Simulation Technology, Changsha 410079, China
[c] Department of Electrical Engineering, The Hong Kong Polytechnic University, Kowloon, Hong Kong

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ABSTRACT

This paper develops a coordination mechanism for a supply chain consisting of one manufacturer and n Cournot competing retailers when the production cost and demands are simultaneously disrupted. This differs from traditional supply chain coordination models under a static case and the case with only demand or cost disruption. The coordination mechanism with revenue sharing is considered, and the effects of production cost and demand disruptions on revenue sharing contract are discussed to investigate the optimal strategies of players with disruptions. The penalty cost is introduced explicitly to obtain the production deviation cost caused by the disruptions. In this study, it is obtained that the coordination contract considering the production deviation cost differs from that without disruption. Besides that, the disruptions may affect the order quantities, wholesale prices as well as revenue sharing contract. Then, the optimal strategies for different disruption levels under the centralized decision-making mode are proposed. Concerning the decentralized mode, the improved revenue sharing contract can be used to coordinate the decentralized decision-making supply chain effectively. Finally, the theoretical results are illustrated by conducting some numerical examples.

1. Introduction

With the development of technology and globalization of the economy, the ways that firms compete with each other have become competition in supply chains. Supply chain coordination has emerged as a focused opportunity in recent years. Generally, the conventional research on supply chain coordination focused on the decision making under normal environment, where the demand was deterministic and known, the manufacturer had perfect information about the market, and the operational costs could be excluded from the analysis. However, after the production and sell plan have been settled down, the environment is often disrupted by some unexpected haphazard events, such as terrorism, earthquake, SARS epidemic, financial crisis, labor strikes, raw material shortage, new tax or tariff policy, machine breakdown, and so on. The disruption caused by these unexpected haphazard events has made the members of supply chain aware of the need for active disruption management and focus on whether and how to promise the originally planned coordination scheme valid in the new disrupted environment.

Disruption events can affect the performance of a supply chain significantly. These disruptions may destroy facilities and cause that the supply chain cannot be coordinated any more. Therefore, it is meaningful to know how the supply chain can still be coordinated under different levels of disruptions. Handling unexpected disruptions in an efficient and effective way is becoming increasingly important to the success of supply chain management. While the conventional study on supply chain coordination management has developed a static coordination mechanism under a deterministic environment with a known market demand and production cost (Cachon, 2003). In contrast to many traditional studies on the design of supply chain coordination scheme, this paper will address another two aspects of the problem: how disruptions affect the coordination scheme and how to coordinate the supply chain after disruptions. In particular, this paper focuses on both production cost and demands disruptions simultaneously.

Generally speaking, production cost disruption is defined as the production cost changes from its estimated value used to design the original coordination scheme. Production cost disruption can occur in various forms at every stage of the production process with different consequences (Xu et al., 2006), for example, raw material prices and transportation costs change, certain equipments fail, and interest rates fluctuate. As such, different solutions are needed to deal with different situations. Practically,

* Corresponding author at: Hunan University College of Economics and Trade, Changsha 410079, China. Tel.: +86 731 8868 4825; fax: +86 731 8868 4825.
E-mail addresses: czp9491@163.com (E. Cao), can.wan@polyu.edu.hk (C. Wan), laimingyong@126.com (M. Lai).

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unexpected changes of the market demands are very common. For instance, the outbreak of earthquake may cause a large sudden demand for tent; the epidemic of mad cow disease reduces the demand for beef consumption; the execution of new environment legislations can affect the demand of some electrical and electronic products. These cost and demand disruptions have great influence on consumers, retailers, wholesalers, and manufacturers in the entire supply chain. Therefore, new models and effective coordination mechanisms for supply chain coordination are required to handle the disruptions.

In this paper, the production cost and demand disruptions are considered in a supply chain with a single manufacturer and n retailers competing in a Cournot market. The particular purpose of the study is to coordinate the disrupted supply chain, especially regarding how the supply chain can be coordinated under production cost and demand disruptions for the manufacturer; and the effects of the production cost and demand disruptions on supply chain coordination with revenue sharing between the manufacturer and the retailers will be investigated. To the best of our knowledge, such a case is considered the first time in this paper. The decision process is expressed as follows. First, the manufacturer makes an initial production plan before the selling season based on a market forecasting. When the selling season arrives, the real market demands and production cost may be found to be different from the forecasted one. Thus, the manufacturer has to adjust the production plan, which will usually cause deviation cost. Consequently, the manufacturer must decide how to adjust the production plan and how to design a new revenue sharing contract, by means of which the manufacturer can induce the retailers to order the proper quantity of products and maximize the profit of the whole supply chain system. So far, there is no research on coordination mechanism for supply chain that consists of a manufacture and n competing retailers in terms of dealing with the simultaneous cost and demands disruptions.

The rest of the paper is organized as follows. The related literature is reviewed in Section 2. Section 3 introduces the basic coordination model when n retailers competing in a Cournot market without any disruption. Section 4 studies the coordination of a centralized supply chain with revenue sharing contract in which the manufacturer bears the deviation cost when the demand for every retailer and production cost for manufacturer are disrupted simultaneously. In Section 5, the coordination of a decentralized supply chain with improved revenue sharing contract under both cost and demand disruptions is investigated in detail. The analytical results are illustrated by numerical examples in Section 6. Finally, this paper is summarized in Section 7.

2. State of the art in supply chain coordination and disruption management

In this paper, the study stems from the intersection of supply chain coordination and disruption management, and also touches upon two elements in supply chain management, namely revenue sharing contract and supply chain disruption management.

In recent years, the studies of supply chain management focus on how to design the coordination schemes. Since the revenue sharing contract is beneficial to a manufacture, revenue sharing contracts among supply chain participants have become popular (Cachon and Lariviere, 2005). Pasternack (1985) found that the right revenue sharing contract could coordinate two dyadic supply chains with stochastic demand. Dana and Spier (2001) adopted a revenue sharing contract to coordinate a supply chain in a basic supplier–retailer channel setting and to cope with the demand uncertainty and vertical control of competing firms. Cachon and Lariviere (2005) generalized the research achievements of Dana and Spier (2001) by studying the revenue-sharing contract applied in a two-echelon distribution channel with competing retailers. Cachon and Lariviere (2005) found that only a revenue sharing contract could coordinate the channel in an extended setting with stochastic and price-dependent market demand. Giannoccaro and Pontrandolfo (2004) introduced a revenue sharing contract to coordinate a three-stage supply chain. Gerchak and Wang (2004) studied a revenue sharing contract in assembly systems with stochastic demand. Wang et al. (2004) examined the channel performance of supply chain under consignment contract with revenue sharing, and found that both the overall channel performance and the performance of individual firms depended on demand price elasticity and the retailer's share of channel cost critically. Weng (2004) also considered the revenue sharing contract in a one-period supplier–buyer channel with uncertain and price-dependent market demand, and found that the loss of channel profit increased with demand price elasticity and decreased with the buyer's share of cost. Zou et al. (2004) proposed an analytical model to associate different processing times through strategic placement of safety stocks at each player's premise, and found that a revenue sharing contract could be used for channel coordination in a two-echelon decentralized system under uncertain market demand. Cachon (2003) summarized the supply chain coordination mechanisms and provided a detailed review.

Disruption management is a new and fledging field in the study of supply chain management. The main difference between the coordination under disruptions and the coordination under normal circumstances is that the sudden change of demand will lead to certain deviation cost which does not exist before. The deviation cost may be caused by the over-time production and the expedited delivery for an increased demand, or the extra inventory holding and possible disposal for a decreased demand. The deviation cost may be incurred to either the manufacturer or the retailers. To achieve an effective supply chain management scheme, the deviation cost should be appropriately taken into account. The concept of disruption management was firstly introduced by Clausen (2001), and applied successfully in the airline operations. Xiao and Yu (2006) investigated the impacts of supply chain disruptions on the evolution of retailers' behaviors in a certain supply chain, where retailers with bounded rationality addressed quantity completion in a duopoly market with homogeneous goods. All the above work assumed a centralized system without considering coordination schemes.

The earliest work on supply chain coordination for a demand disruption was completed by Qi et al. (2004). They introduced a quantity discount contract to coordinate a two-stage supply chain with one manufacturer and one retailer. Xu et al. (2006) studied the case with production cost disruption, and proposed a quantity discount contract to coordinate a supplier–retailer supply chain. Huang (2006) considered a novel exponential demand disruption, and applied an all-quantity discount policy to the coordination of a supply chain. Hou (2010) developed a buy-back contract between a buyer and a backup supplier when the buyer's main supplier encountered disruptions. Xiao and Qi (2008) applied a quantity discount contract to coordinating the supply chain with two Bertrand completing retailers when the production cost and market demand were both disrupted. Xiao et al. (2007) found that the linear quantity discount scheme could coordinate the supply chain with two competing retailers and the all-unit quantity discount scheme could coordinate the supply chain where the retailers were identical after the disruption of market demand. Lei et al. (2012) adopted linear wholesale price contract menus to analyze the supply chain under demand and cost disruptions with asymmetric information. Zhang (2012) found that the revenue