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Capacity planning and allocation with multi-channel distribution

Wenming Xie [a,b], Zhibin Jiang [a,b,*], Yingxue Zhao [c], Junjie Hong [c]

[a] Sino-US Global Logistics Institute, Shanghai Jiao Tong University, Shanghai, China
[b] Department of Industrial Engineering & Management, School of Mechanical Engineering, Shanghai Jiao Tong University, Shanghai, China
[c] School of International Trade and Economics, University of International Business and Economics, Beijing 100029, China

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ABSTRACT

In this paper, we study a multi-channel distribution system in which a manufacturer sells its product via an independent service provider and a direct selling market simultaneously. The manufacturer allocates its production capacity to the service provider, and then the service provider supplements some value-added services to the product to satisfy the demand of the downstream customers. We assume that the manufacturer's production capacity planning and allocation decisions are challenged by information asymmetry with the service provider and consider a two-stage model: at the first stage, the manufacturer determines the optimal production capacity based on the service provider's order reservation and the demand forecast in the direct selling market. At the second stage, the manufacturer allocates the production capacity, taking into account updated demand from the service provider and the direct selling market. In the paper, we propose several decision-making models and identify some structural properties for them. In addition, policies for production capacity allocation between the service provider and the direct selling market are developed with various different market scenarios. The numerical experiment results show that introducing direct selling market can significantly improve the system performance and the decision-making mechanism developed in the paper is feasible and effective for the system.

1. Introduction

Capacity planning is essentially important for effective strategic decision-making in various industries. The examples can be found in communication networks (Chang and Gavish, 1993; Ahlert et al., 2009), electric utilities (Murphy et al., 1987), automobile industries (Eppen et al., 1989), shipping industries (Wang and Yun, 2013; Hung and Chen, 2013), and in electronic goods and semiconductor industries (Chou et al., 2007; Chien et al., 2012). In all these applications, the manufacturing capacity building requires a commitment of substantial capital resource over a long period of time. Furthermore, multi-channel distribution and high uncertainty inherent in the long horizontal forecast for cost and demand make the problems concerning capacity planning and allocation extremely complex in supply chain management. One recent example that can be shared is the following practical case from the fastener manufacturing industry of China.

In the fastener manufacturing industry of China, there are more than 10,000 types of product, and each type has several different specifications. In general, each downstream customer needs hundreds types of fastener to meet the requirement of normal production. However, since each single manufacturer cannot meet all demands of a single customer, the downstream customers usually have to purchase the products from several manufacturers at the same time, which brings about very high procurement cost relative to the production cost. In order to change this operations deficiency, the manufacture sells the product to one distribution center, and then the distribution center distributes all required products to the customer with a customized manner, which helps the customer reduce purchasing and inventory costs. In this new operations pattern, the availability to all kinds of products and services in an integrated way allows the manufacturer and the distributor to form an alliance to create additional value sources and thus gain competitiveness. However, there are also some customers who do not need the distribution service from the distribution center, and for these customers they can buy the product directly from the manufacturer, which forms a direct selling market. Actually, such business mode has become an very popular practice in the manufacturing industries. Since the manufacturers can sell their products via a common service provider and a direct selling market simultaneously with such a business mode, the optimal decisions on production capacity planning and allocation needs a coordination between the demands from the service provider and the direct selling market, which arises some challenges for the manufacturer to well plan the production capacity and its allocation prior to receiving orders from the downstream partners.

* Corresponding author at: Department of Industrial Engineering & Logistics Management, School of Mechanical Engineering, Shanghai Jiao Tong University, 800 Dong Chuan, Shanghai 200240, China. Tel./fax: +86 21 34206065.
E-mail address: zbjiang@sjtu.edu.cn (Z. Jiang).

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With a purpose to resolve the issue mentioned above, this paper deals with capacity planning and allocation in a dual-channel supply chain, in which the manufacturer has production capacity, and the downstream service provider has marketing expertise and long-term relationships with the customers. The service provider provides additional services that may attract demands that are not directly accessible to manufacturers (Gupta, 2008). Information asymmetry problem, existing in the single channel supply chain, also exists in the multi-channel supply chain. That is, the service provider has some private information about the customers because it is closer to the downstream market than the manufacturer. Besides the service provider, the manufacturer can also sell the product via the direct selling market. The demand from the direct selling market fluctuates considerably with volatility risk. Therefore, the manufacturer will make the production capacity decision incorporating the demand information collected from both the service provider and the direct selling market. In order to build a better manufacturing capacity, the manufacturer wishes to share the service provider's private information as much as possible. However, the service provider usually has an incentive to inform the manufacturer of an exaggerated demand, so that it can better avoid capacity shortage in the expenditure of the manufacturer, which leads to bullwhip effect in the supply chain. As a result, the manufacturer often considers the demand information informed by the service provider incredible. Therefore, it is necessary for the manufacturer to develop an efficient decision-making mechanism by which to encourage the service provider to share truthful demand information with it, so that it can build an appropriate production capacity. After the manufacturing capacity is built and demand information is updated, the manufacturer will reconsider the manufacturing capacity allocation proportion between the service provider and the direct selling market. At this time point, the manufacturer will prefer satisfying the demand from the direct selling market to that from the service provider since the product price is generally higher in the direct selling channel than in the channel formed via the common distributor. Therefore, decision-making mechanism needs to be designed and policy for production capacity allocation between the direct selling market and the service provider needs to be developed, taking into account dynamic updation of the demand information, with the objective to minimize the losses resulted from information asymmetry and double marginalization effect in the decentralized supply chain.

In this paper, we propose a two-stage decision-making mechanism to address the above incentive problem with multi-channel distribution. The goal is to improve efficiency in production capacity planning and allocation, and at the same time achieve a coordinating assignment for the decision makers' incentives. In the paper, we propose a principal-agent model for the capacity planning and allocation problem. We develop an incentive scheme that can elicit truthful private information of the service provider and ensure an implementation of the optimal capacity planning that can maximize the manufacturer's expected profit. After demand information updating, the manufacturer will reallocate the production capacity between the service provider and the direct selling market. Since market demand is usually uncertain, the updated demand from the service provider is not necessarily equal to its reservation ordering quantity, and hence the manufacturer needs to make a proper decision on production capacity allocation between the service provider and the direct selling market on an ad hoc basis. The rest of the paper is organized as follows: Section 2 reviews the relevant literature. Section 3 describes the problem under study and formulates the model. Section 4 explores the optimal decisions for manufacturing capacity planning and its reallocation. Section 5 presents numerical examples, and Section 6 concludes with summary of the paper.

2. Literature review

The problems concerning capacity planning and allocation in the supply chain are challenging due to the long production lead-time and high demand uncertainty. In order to highlight our contribution, we first review the literature that addresses different aspects of the capacity planning and allocation. After that, we review the literature that is particularly related to our work.

Capacity management in the supply chain has been a major issue explored extensively in the literature (Van Mieghem, 2003). Some useful approaches can be found in the literature that addresses the participator's incentives in capacity management. For example, Mallik and Harker (1998) design a rewarding function which can provide the incentive for marketing managers to improve their forecast accuracy. Celikbas et al. (1999) develop a penalty function to coordinate demand forecasting and production planning. Porteus and Whang (1991) develop a transfer pricing scheme to coordinate capacity planning and allocation for different departments. Karabuk and Wu (2003) apply the approach utilized in Makowski and Mezzetti (1994) to achieve the first-best profit in a semiconductor capacity allocation problem. Although they also consider the issue of capacity contracting, they only discuss this problem in supply chains with one manufacturer and one supplier.

Another related research stream is the literature that addresses issues concerning multi-channel distribution. Simchi-Levi et al. (2004) provide a detailed review of this research stream. The problem explored most for this research stream is the mutual impacts of different channels. Chiang et al. (2003) study the issue of multi-channel design. They show that the manufacturer can gain a stable profit by introducing a direct selling channel. Yao and Liu (2003) study the customer diffusion between a direct selling channel and a traditional channel. They find that demands in both channels are stable under some conditions. Wallace et al. (2004) indicate that multiple complementary channels can provide a greater and deeper mix of customer service, and therefore enhancing the seller's overall value proposition.

In summary, there is a substantial literature exploring the issue of capacity planning and allocation in the supply chain. In most of these studies, an inherent assumption is that all input parameters in the decision models are available for decision maker. However, this assumption fails when the decision maker has some private information and are motivated to take advantage of it for local gains. Although there is some literature exploring the capacity planning and allocation problems with demand information asymmetry, seldom of them considers this issue with multi-channel distribution.

Hence, our paper contributes to the literature by the following two aspects: first, our paper develops a capacity reservation contract for the supply chain, taking into account multi-channel distribution and information asymmetry. The contract mechanism developed in our paper can minimize the losses resulted from information asymmetry and double marginalization effect. Second, our paper explores the capacity reallocation problem caused by the deviation between the forecasted demand and the realized demand for four different market scenarios. We also explore how to adjust the model parameters so as to reduce the deviation. The numerical experiments presented in the paper demonstrate that the results developed by us are effective in managing supply chains with multi-channel distribution.

3. Problem description

The manufacturer needs to make two decisions before demand is realized: capacity building and capacity allocation. The manufacturer